Indian Research Journal of Extension Education

REVIEW ARTICLE

Disease Prevention in Human through Bioactive Medicinal Molecules of Vegetables : A Review

Shivraj Singh Panwar[1], Jitendra Kumar Chauhan[2], Kohima Noopur[3], Natasha Panwar[4], Kaushik Pradhan[5], Lalit Kumar[6] and Azad Singh Panwar[7]

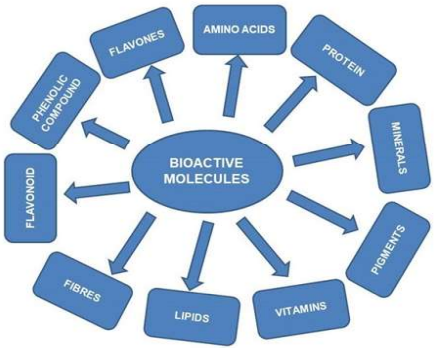
1. Medical Scholar. Emilio Aguinaldo College, Philippines, , 2. Prof., COF, CAU, Tripura, 3.Res. Scholar, Lady Hardinge Medical College, New Delhi, 4. Asst. Prof. Harvard University, Boston, USA,, 5. Prof, UBKV, Cooch Behar, WB, 6. Tech. Officer, Fertilizer Association of India, New Delhi,7.Dean, IIMT University, Meerut.

Corresponding author's e-mail: panwar7299@gmail.com

HIGHLIGHTS

- Vegetables are globally favoured for their high energy density, nutritional value and bioactive molecules.
- Bioactive compounds in vegetables offer health benefits beyond basic nutrition.
- Bioactive compounds in vegetables typically exhibit antioxidant, anticarcinogenic, anti-inflammatory, and antimicrobial properties.
- These compounds in vegetables contribute diverse health benefits through various biological effects.

GRAPHICAL ABSTRACT



ARTICLE INFO

Editor:
Dr. T. Rajula Shanthy

Key words:
Bioactive medicinal molecule, Nutraceutical, Vegetable, Health benefit

Received : 15.02.2024
Accepted : 28.03.2024
Online published : 01.04.2024

doi: 10.54986/irjee/2024/apr-jun/95-105

ABSTRACT

A vegetarian dietary preference highlights the significant role in human nutrition and overall health. They are the rich source of essential nutrients, vitamins, antioxidants, and bioactive compounds, which offer a multitude of health benefits. These bioactive compounds are particularly noteworthy for their potential to prevent chronic diseases, with a strong emphasis on conditions like cardiovascular disease and cancer. Brinjal (eggplant) contains chlorogenic acid and nasunin, which have demonstrated anti-carcinogenic, anti-obesity, and anti-diabetic properties. Lycopene, found in tomatoes, watermelons and carrots contributes to protection against cancer and enhances the immune system. Onions and garlic are rich in allicin, allyl propyl disulfide, and di-allyl disulfide, which not only help shield against certain cancers and heart disease but also boost immunity. Cruciferous vegetables are known for being a potent source of sulforaphane, which is renowned for its anti-cancer properties. Beans, on the other hand, are abundant in flavonoids (specifically isoflavones), which have the ability to lower cholesterol levels and mitigate the risk of cancer. Cucurbits, such as cucumbers and squash, contain cucurbitacin, which displays anti-inflammatory and cardiovascular effects. These bioactive compounds offer a wide range of health benefits, primarily due to their potent antioxidant properties and also play a significant role in protecting the body against diseases triggered by oxidative stress and can aid in the prevention of specific cardiovascular and neurodegenerative disorders, including high cholesterol levels, high blood pressure, Alzheimer's or Parkinson's diseases, type II diabetes, cancers, and urinary tract infections. It's important to note that the health benefits of these phenolic compounds are further accentuated by the fact that vegetables are typically low in calories while being high in vitamins and minerals. Their phytochemical-rich composition bestows them with medicinal value, making them invaluable contributors to human well-being. In conclusion, this paper emphasizes the essential role of these diverse bioactive compounds found in vegetables, highlighting their potential medicinal properties and advocating for the incorporation of more vegetables into the diet as a means of promoting overall health and preventing chronic diseases.

Green revolution in India during 1970's witnessed remarkable cereal production, bolstering national food security, however, its impact at the household level remained uncertain (Panwar *et al*., 2019). To address this, diversification with an emphasis on horticultural crops, particularly vegetables, and integration of livestock components was deemed necessary (Saxena *et al*., 2003 and Panwar *et al*., 2021), hence farm situation based farming system involving vegetables is the need of hour for nutritional security (Panwar, *et al.,* 2023). This transition from cereal-cereal cropping systems to vegetable-based cropping systems (Walia *et al*., 2022) represents a shift towards more sustainable and diversified agricultural approach aimed at improving livelihoods and food security at the grassroots level, while sustaining the gains of Green Revolution. India has achieved the status of the world's second-largest vegetable producer after China. Notably, India holds top position globally in the production of some vegetables such as okra, chilli, pepper, onion, and beans (Noopur *et al.,* 2023a). Vegetable cultivation in India occurs in various settings, including open fields on flat terrain, in high-moisture conditions on raised beds, and under protected environments such as polyhouse, aided by advanced agricultural technologies (Singh *et al*., 2017) and even in farming system mode. The adoption of modern technologies, particularly in protected cultivation, has enabled year-round production of high-quality vegetables for which quality seedlings production technology remained a pre-requisite at household levels or as agri-enterpreneure (Chauhan *et al.,* 2023a). However, this progress has also brought forth challenges, such as the emergence of nematode-related problems within polyhouse (Chikkeri *et al*. (2023a). This underscores the importance of careful management when implementing protected cultivation methods for vegetable production and in decision support and perception (Chauhan *et al*., 2003b).

India has achieved satisfactory level in vegetable production meeting dietary requirement (300 g/ capita/day). It is seen that 78% adults across world are not access to daily recommended diet (Hall *et al*., 2009) resulting in phytonutrient gap in their diet. Even than there is inadequate consumption leading to escalating burden of communicable and non-communicable diseases (GBD, 2019 and Iddir *et al.,* 2020. Beyond meeting recommended servings, embracing a wider assortment of fruit and vegetables has shown independent associations with reduced risks of conditions such as diabetes (Cooper *et al*., 2012), cancer (Buchner *et al*., 2010), mortality (Tao *et al*., 2020), and improved cognitive function (Ye *et al*., 2013). Particularly in during childhood, diversifying fruit and vegetable intake is crucial for fostering growth, development, and the establishment of lifelong healthy eating habits (Dalwood *et al*., 2020).

In the context of ensuring access to a nutritious diet rich in both macro and micronutrients, it becomes crucial to cultivate a diverse range of vegetables in the field as well as in kitchen gardens. Doing so not only enhances food and nutritional security at household level but also creates income and employment opportunities (Noopur *et al.,* 2021a) as well as health security. The production landscape has seen a significant shift from traditional farming practices to the adoption of advanced technologies, including the utilization of raised beds in maize-veggies based cropping systems, (Panwar *et al*., 2021b) and development as well as evaluation of varieties having more bio-molecule for enhancing health benefits. Participatory breeding helps in selecting the best genotypes or varieties suited for specific requirement (Noopur *et al.,* 2021b). This involvement not only empowers farmers but also fosters a sense of ownership and connection to the developed varieties and agricultural practices, promoting sustainable and successful farming outcomes and finally improving health through bio-active molecules which can be increased through improved decision support system (Chauhan *et al.,* 2023b).

Vegetables are often referred to as protective food due to their lower calories and high level of vitamins and minerals, besides additional health benefits due to the presence of bioactive compounds known as phytochemicals (Panwar *et al*., 2023).These phytochemicals encompass a range of substances including carotenoids, phytostanols, tocotrienols, organo sulphur compound and non-digestible carbohydrates like dietary fibre and pre-biotic which serve various roles, including acting as antioxidants, antibacterial agents and enzymes stimulators (Gupta *et al*., 2014). Fruits and vegetables owe their vibrant hues to naturally occurring and pigmented phytonutrients, which encompass various phytonutrient categories. For instance, red hues often indicate the presence of lycopene, while yellow is associated with alpha-

carotene, orange with beta-carotene, green with chlorophyll, purple and blue with anthocyanins, and white with flavones (Minich *et al*., 2019). These phytochemicals reported to promotes health, modulate immune system and play a preventive and curative role in various health conditions, including gastrointestinal disorders, cardiovascular disease, cancer, diabetes and other related chronic disorders. Among the vegetables, cruciferous vegetables, allium, tomatoes, cucurbits, carrots, okra, lettuce, sweet potato, yams, moringa, winged bean, basella and cluster bean are rich source of these bioactive compounds (Ahmad *et al*., 2020). These attributes open up new vistas in the use of plant-based products and introducing vegetables as future herbal medicine (Panwar *et al*., 2023). Unlike fruits, vegetables are low calories and fats but packed with essential vitamins and minerals. Green, yellow, and orange vegetables are particularly rich sources of calcium, magnesium, potassium, iron, beta-carotene, vitamin B-complex, vitamin C, vitamin A, and vitamin K. These vegetables are also house of numerous antioxidants, which play a crucial role in protecting the body from oxidative stress, diseases, and cancer, while simultaneously enhancing the body's immune system. Hence, vegetables are known as nutraceuticals is a sustainable alternative for prevention as well as control of disease as they have potential therapeutic nutritional effect. Therefore, for identification and evaluation purpose, vegetables need to be studied for their genotypic variability (Noopur *et al.,* 2019) resistance against stresses (Noopur *et al.,* 2022) followed by their seed production at large scale seed production to achieve food and nutritional security even at household level through addressing constraints in vegetable production (Noopur *et al.,* 2023b) and to have vegetable based agri-entrepreneurship (Chauhan *et al,* 2023c).

Adequate dietary fiber intake plays a pivotal role in safeguarding against various health conditions, including chronic constipation, haemorrhoids, colon-cancer by promoting optimal colon health, irritable bowel syndrome, and rectal fissures. Fiber helps in maintaining regular and healthy bowel movements, preventing constipation and the discomfort. A diet rich in fiber contributes significantly to overall gastrointestinal well-being and reduces the likelihood of these troublesome health concerns. Rothschild *et al.* (2018) study revealed that a diverse diet, encompassing a variety of fruits and vegetables rather than just their quantity, positively correlated with increased microbial diversity in the gut. This diversity was associated with changes in the relative abundance of key bacterial phyla, including an increase in Firmicutes and a decrease in Bacteroidetes. Furthermore, specific genera of gut bacteria responded differently to fruit and vegetable consumption. These findings underscore the significant role of dietary choices in shaping the gut microbiome composition, potentially impacting overall health including cancer.

Vegetables offer a promising strategy to delay or inhibit the pathogenesis of age-related diseases. A balanced and nutritional diet plays a crucial role in influencing aging and health improvement without adverse effects (Weindruch *et al.,* 1988). This has prompted an increased interest in understanding the positive correlation between aging and diet, leading consumers to seek more information about functional diets rich in antioxidants, such as those found in vegetables, fruits, and related products (Kaur *et al.,* 2001). The levels of bioactive compounds in crops are strongly influenced by factors such as the specific crop type, cultivar or genotype, agronomic practices, environmental conditions before harvest, and postharvest handling methods. Consumers are particularly intrigued by the bioactive compounds found in fruits and vegetables due to their potential health benefits, especially in addressing age-related and stress-related diseases.

*Nutraceuticals:*Nutraceutical is characterized as any substance present in food or constituting a part of a food item that imparts medicinal or health advantages, encompassing both the prevention and treatment of diseases. This term "nutraceutical" was coined in 1989 by Dr. Stephen De Felice, who served as the Chairman of the Foundation for Innovation in Medicine. Nutraceuticals are typically sold in the forms that are more medicinal than regular food products. These compounds have been demonstrated to have physiological benefits and may offer protection against chronic diseases (Gupta *et al.,* 2013). Vegetables are considered functional foods with nutraceutical properties because they are rich in minerals and nutrients that promote health. They are an essential part of the human diet and serve as a significant source of biologically active nutrients having nutritional and medicinal properties known as nutraceuticals.

Vegetables are a rich source of bioactive molecules

with proven antioxidant, anti-inflammatory, anticancer, and cardioprotective properties (Riaz *et al.*, 2021). For instance, flavonoids, commonly found in vegetables like onions, and kale have been associated with reduced risk of chronic diseases due to their potent antioxidant and anti-inflammatory effects (Ravishankar *et al.,* 2013). Similarly, carotenoids such as β-carotene, lutein, and zeaxanthin present in carrots, spinach, and tomatoes exhibit protective effects against age-related macular degeneration and certain cancers (Giovannucci, 2019).

Nutraceuticals from vegetables have gained attention as sustainable alternatives for preventing and controlling various diseases. They are considered safe and effective, offering both nutritional value and potential therapeutic effects as they are a rich source of bioactive molecules with proven antioxidant, anti-inflammatory, anticancer, and cardioprotective properties (Riaz *et al.,* 2021). For instance, flavonoids, commonly found in vegetables like onions, and kale have been associated with reduced risk of chronic diseases due to their potent antioxidant and anti-inflammatory effects (Ravishankar *et al*., 2013 and Noopur *et al*., 2022). Some well-known phyto-nutraceuticals include lycopene from tomatoes and carotenoids from carrots. Moreover, polyphenols found in vegetables like green tea, broccoli, and berries have garnered attention for their ability to modulate cellular signaling pathways involved in inflammation, oxidative stress, and carcinogenesis (Pandey and Rizvi, 2009). Glucosinolates, predominantly found in cruciferous vegetables such as broccoli, cabbage, and Brussels sprouts, are known for their chemo preventive properties against various types of cancer (Traka and Mithen, 2009). These compounds are known to contribute to disease prevention and reduce risk factors through their antioxidant properties. Nutraceuticals have emerged as effective and sustainable alternatives for the control and prevention of a wide range of diseases. In everyday life, nutraceuticals have gained significant attention due to their safety, efficiency, and their potential nutritional and therapeutic value. They are not only low in calories but also packed with vitamins, minerals, antioxidants, and phytochemicals. Vegetables play a crucial role in the human diet and serve as rich sources of biologically active compounds essential for human well-being. Phyto-nutraceuticals, such as lycopene from tomatoes, curcumin from turmeric, and carotenoids from carrots, have gained popularity for their health benefits. Lycopene content varies with the species and methods of cultivation, besides climatic variations (Chikkeri *et al.,* 2023b).

Table 1. Content of vegetables

Vegetables	Flavonoids Quercein Kampferol Myricetin Isorhamnetin	Flavones Apigenin Luteolin	Flavon-3-ols Catechins Epicathechins Thearubigins
Kidney Bean	*	-	*
Snap Bean	*	-	-
Beet	*	*	-
Broccoli	**	-	-
Broadbean	*	-	***
Cabbage	*	*	-
Cauliflower	*	-	-
Carrot	*	*	-
Celery	*	-	-
Cucumber	*	-	-
Kale	*	-	-
Leek	*	-	-
Lettuce	*	*	-
Onion, Yellow or white	***	-	-
Onion red	****	-	-
Spring onion	***	-	-
Pepper hot	***	*	-
Pepper sweet	*	*	-
Parsley	*	-	-
Pea, green	*	-	-
Potatoes	*	-	-
Radishes	*	-	-
Spinach	*	-	-
Tomatoes	*	-	-
Turnip green	**	-	-
Water spinach	*	*	-
Fennel leaves	****	*	-
Peppermint	-	***	-
Sweet potato leaves	***	*	–
Thyme	-	****	–

*= One content, **=Two contents, *** three contents and **** Four contents in food items.

Source: Haytowitz DB, et al Flavonoid content in vegetables https://www.ars.usda.gov>AICR03_VegFla

Flavonoids: Flavonoids, found in vegetables, are another group of active nutraceutical ingredients. They function as potent antioxidants and metal chelators. Furthermore, they have been recognized for their anti-inflammatory, antiallergic, hepatoprotective,

antithrombotic, antiviral, and anticarcinogenic properties. Some flavonoids have displayed antibacterial activity, with quercetin, in particular, being reported to possess antidiabetic properties. The potential of underutilized vegetables as nutraceuticals are also highlighted by Noopur (2015). The vast array of phytochemicals, including vitamins, flavonoids, terpenoids, carotenoids, phenolics, phytoestrogens, minerals, and antioxidants found in vegetables, are not only used as alternpotenative preservative agents in the food industry to control postharvest physiological disorders and microbial pathogen injuries but also have a growing interest in safeguarding human and animal health from fungal and bacterial diseases due to their lower or absence of toxicity. These natural compounds are becoming valuable candidates for both plant as well as health protection. Flavonoids are a diverse group of plant compounds with various subgroups. However, there are some updates and clarifications that can be made. The USDA Database for the Flavonoid Content of Selected Foods, which was released in 2003, contains information on the flavonoid content of various foods. The flavonoids are classified into several subclasses based on their chemical structure:

Flavonols: This subgroup includes quercetin, kaempferol, myricetin, and isorhamnetin which are widely found in vegetables. Excellent sources of these flavonols include onions, hot peppers, kale, broccoli, rutabagas, and spinach. Onions, lettuce, tomatoes, celery, hot peppers, spring onions, and broccoli are also significant contributors of flavonol compounds to the diet

Flavones: This subgroup includes apigenin and luteolin. Parsley and lettuce are notably rich in apigenin, a flavone. Other vegetable sources of apigenin include celery hearts and rutabagas. Thyme is exceptionally high in luteolin, another flavone. Luteolin also be found in beets, brussels sprouts, cabbage, and cauliflower. Major contributors of luteolin to the diet include celery, chili peppers, sweet peppers, lettuce, and spinach.

Flavanones: This subgroup includes hesperetin, naringenin, and eriodictyol. Vegetables do not typically provide flavanones, although eriodictyol is found in peppermint.

Flavan-3-ols: Legumes are unique among vegetables as they contain flavan-3-ol compounds such as catechins and epicatechins. This subgroup includes catechins, epicatechins, and other related compounds. The aflavins and arubigins are typically found in black tea and are more commonly associated with catechins that have undergone oxidation and polymerization during tea processing.

Anthocyanidins: This subgroup includes cyanidin, delphinidin, malvidin, pelargonidin, peonidin, and petunidin. Red potatoes and red onions are the only vegetables for which anthocyanidins have been reported.

It's worth noting that flavonoids are found in a wide range of foods, including fruits, vegetables, nuts, seeds, roots, and beverages like tea and wine. These compounds have various health benefits and are known for their antioxidant properties. However, the specific flavonoid content in foods can vary widely depending on factors such as the type of food, its ripeness, and how it's prepared. Additionally, scientific research on flavonoids and their potential health effects continues to evolve, so it's essential to stay updated with the latest findings in this field.

Bioavailability of bioactive molecules : Vegetables are integral components of the human diet, offering diverse nutrients based on their variety and category. Some foods are noteworthy for their carbohydrate content, such as potatoes, sweet potatoes, and pumpkins, while legumes serve as rich sources of proteins. Vegetables such as carrots, squash, sweet potatoes, peaches, and melons significantly contribute to vitamin A, while leafy vegetables provide vitamin B. Broccoli, brussels sprouts, cabbage, cauliflower are an excellent sources of vitamin C. These vegetables also provide dietary fiber, macro, and micro-minerals, along with various bioactive compounds (Thompson, 2010).

Nutritional and health benefits of traditional vegetables are continually expanding, prompting ongoing research aimed at creating new food products enriched with nutraceutical components (Rai *et al.,* 2012). This exploration underscores the significance of pinpointing particular plant substances vital for human nutrition. It also highlights the need for both conventional and molecular breeding techniques to cultivate varieties with enhanced nutritional qualities. Exposure to oxidative stress from industrial chemicals, air pollutants, ionizing radiation, or ultraviolet light can perturb the body's antioxidant system which may leads to oxidative damage to DNA and proteins responsible to initiate cancer and other degenerative diseases. The epidemiological studies suggest that certain foods, particularly cruciferous vegetables, rich in anticarcinogenic compounds like polyphenols and isothiocyanates, may have cancer-preventing effects.

Table 2. Important vegetables and their medicinal uses

Scientific Name	Bioactive compound	Medicinal Use
Leafy Vegetables		
Amaranthus Viridis (family- Amaranthaceae) Li et al.(2015)	Gallic acid, proto-catechuic acid, salicylic acids, chlorogenic acid, gentistic acid, 2,4-Dihydroxybenzoic acid, ferulic acid, quercetin, rutin, kaempferol-3-rutinoside and ellagic acid	Antidiabetic, Helminthic infection, anticancer and antimalarial. Decoction of the herb is used as mouth wash for toothache.
Celosia argentia L. (family- Amaranthaceae) Thorat, (2018)	Aphrodisiac, antipyretic, antispasmodic, anticancer, diuretic and antibacterial. Triterpenoids, flavonoids, alkaloids, saponins, steroids, and tannins	Immunological activity, cytoprotective, inflammation, antioxidant, haematological, anticancer, antimitotic activity, hepatoprotective, antimetastatic, antioxidant, antibacterial, antifungal, anti-diarrhead activity, gynaecologic disorders, anti-urolithiatic, anti-diabetes, immunomodulatory, growth activity anti-infection, anti-oxidant agent Leaves, seeds used in case of dysentery, Diarrhea, acute abdominal pains. Seeds used in various disorders of kidney
Colocassia esculanta (L) (family- Araceae) DOI: 10.52711/2321-5836.2023.000	Cyanidin-3-glucoside, pelargonidin-3-glucoside and cyanidin-3-rhamnoside	Nervine tonic, antioxidant, anti-inflammatory, anti-lipid peroxidative activity, hepatoprotective, antifungal, antidiabetic, anticancer and antimicrobial effects. Leaves, tubers are used as vegetables. Rich in proteins and minerals
Portulaca oleracea L. (Family- Portulacaceae) Chug et al. 2019	Vitamins, flavonoids, alkaloids, polysaccharides, omega-3 fatty acids (Especially alpha-linolenic and gammalinolenic acids), terpenoids, sterols, proteins and minerals and has also been reported as the super food for the future. Lutein,α-tocopherol, β-carotene, ascorbicacid and glutathione.	Leaves, stems It is good for painful or difficult urination. Sour, diuretic, cooling herb that lowers fever and clears toxins. The leaves are used for poulticing tumors, bed wounds, ulcers and edematous swellings, also for hemorrhage and leucorrhea. The seeds decoction is considered as excellent diuretic
Tamarindus indica L. (family- Papilionaceae) Zohrameena et al. (2017)	Cis-Vaccenic acid, trans-13-Octadecenoic acid, Oleic Acid, Octadecanoic acid, Octadecanoic acid, 2-(2-hydroxyethoxy) ethyl ester, Eicosanoic acid and Eicosane, 1-Iodo-2-methylundecane, 10-Methylnonadecane.	The decoction of leaves are given to children as an anthelmintic. The leaves and flowers are eaten as a vegetables. antibacterial, antifungal, hypoglycaemic, cholesterolemic, hypolipidemic, antioxidant, antihepatotoxic, anti-inflammatory, and antidiabetic
Cassia tora Linn (Family- Papilionaceae) Jain and Patil, 2010	Root- 1,3,5-trihydroxy-6-7-dimethoxy-2-methyl anthraquinone, and β-sitosterol. Seeds- neptho-Alph-pyrone-toralactune, chrysophanol, physcion, emodin, rubrofusarin, chrysophonic acids-9-anthrone. Leaves- emodine, tricontan-1-01, stigmasterol, β –sistosteral-β –D-glucoside, freindlen, palmitic, uridine, quercitrin and iso-quercitrin. Flower- Kaempferol and leucopelargonidin.	Leaves and seeds are also useful in treatment of leprosy, ringworm, flatulence, bronchitis, cough, dyspepsia and cardiac disorders. Decoction of the seeds is given in fever.
Root and tuber crops		
Radish https://www.mdpi.com/2072-6643/11/2/402	Pentyl hexyl, 4-methylpentyl isothiocyanate, dimethyl disulfide, methyl methanethiolsulfinate, and 1-methylthio-3-pentanone. indole-3-carbinol and 4-methylthio-3-butenyl-isothiocyanate.	Digestion, to lower blood sugar and blood pressure. antibacterial activity, including against Helicobacter pylori bacteria, which are linked to ulcers and stomach cancer
	Major fatty acids in seed lipids were erucic, oleic, linoleic, and linolenic acids. Major fatty acids in radish family lipids were linolenic acid (52–55%), followed by erucic acid (30–33%), and palmitic acid (20–22%)	
Carrot (Family- Apiaceae) doi: 10.4236/fns.2014.522227	Carotenoids and phenolics, α- and β-carotene and is a rich source of lutein, provitamin A and tocopherol.	Carrots are good for eyes, carotenoids, polyphenols and vitamins present in carrot act as antioxidants, anticarcinogens, and immunoenhancers. Anti-diabetic, cholesterol and cardiovascular disease lowering, anti-hypertensive, hepatoprotective, renoprotective, and wound healing benefits. Enhancement of immune system and decreased risk of degenerative diseases such as cancer, cardiovascular disease, age related mascular degeneration and cataract formation
Turnip (Family-Brassicaceae) https://www.medicalnewstoday.com/articles/284815	Peroxidase, kaempferol, phenolic compounds, sulforaphane, organic acids, vitamin K, glucosinolates. Peroxidase, kaempferol, phenolic compounds, Glucosinolates and isothiocyanates (mainly 2-phenylethyl, 4-pentenyl, and 3-butenyl derivatives)	Prevent all kinds of cancer, from breast to prostate. Eye health through antioxidant lutein. improve stomach and intestine conditions such as diarrhoea or constipation

Sweet potato https://www.medicalnewstoday.com/articles/281438	Phenolics, flavonoids, carotenoids, vitamin C, alkaloids, saponins, and tannin. In orange fleshed varieties, α-carotene, β-carotene, β-5 cryptoxanthin. vitamin C, chlorogenic acid, caffeic acid, quercetin, and rutin	Anti-cancer, antidiabetic, and anti-inflammatory activities.
Potato https://www.researchgate.net/	Anthocyanins, glycoalkaloids, phenolic compounds, and flavonoids	Aids in heart, muscles, and nervous system. Antioxidant, anticancer, antiallergy, antibacterial, anti-inflammatory, antiobesity, anti-ulcer activity
Tomato Collins et al. (2022)	Phenolic acids and flavonoids, lycopene, α, and β carotene, ascorbic acid and vitamin A and tomatine.	Anticancer properties of lycopene in relation to its anti-angiogenic properties, Reduction in insulin-like growth factor Modulation of cellular pathways that lead to cancer
Brinjal Naeem et al., (2019)	Niacin, thiamin, vitamin C, riboflavin, choline, vitamin B6, vitamin A, folate, vitamin K, beta-carotene and vitamin E.Phenolic acids, butylated hydroxytoluene and butylated hydroxyanisole, lutein anthocyanin.	Reduces the risk of various types of cancer, protects against cardiovascular diseases, and prevents acute respiratory infections, anemia, atherosclerosis, and fatty degeneration. Chlorogenic acid (5-O-caffeoyl-quinic acid; CGA) a compound found in fruit skin (Prohens et al., 2013) which work as an anti-obesity, anti-inflammatory, anti-diabetic agent and also have cardio-protective fun
Capasicum Kalaiyarasi et al., (2021)	Phytochemicals such as carotenoids (lutein, β-carotene, β-cryptoxanthin, zeaxanthin, violaxanthin, and capsanthin), capsaicinoids (capsaicin, dihydrocapsaicin, nordihydro capsaicin, homocapsaicin, homodihydrocapsaicin, and nonivamide), and flavonoids (quercetin, luteolin, kaempferol, catechin, epicatechin, rutin, apigenin, myricetin, and cyanidin	Cancer, rheumatoid arthritis, bronchitis, macular degeneration, anemia, osteoporosis, coronary heart disease, diabetes, obesity, hypertension, sinus infection, migraine, neurological disorders, menopause problems, and digestive complications

Verhoeven *et al.* (1996) claimed inverse associations between crucifer intake and the incidence of various cancers, including skin, pancreas, lung, prostate, bladder, stomach, colon, and thyroid cancers. Case-control studies have noted inverse associations between the risk of cancer and the intake of specific vegetables like broccoli, cauliflower, Brussels sprouts, or cabbage. While another study indicated that higher myricetin intake (from berries) was associated with a lowered risk of prostate cancer, while higher quercetin intake (from apples and onions) was associated with a lowered risk of breast cancer. Soybean consumption has been linked to a reduced risk of prostate and breast cancer in Japanese men and women, attributed to isoflavone genistein's estrogen-antagonistic properties.

Intake of cruciferous vegetables like broccoli, cauliflower, brussels sprouts, and cabbage has been associated with reduced cancer risk (Keck and Finley, 2004). They stated that tomato and tomato products are under investigation for their potential role in cancer chemoprevention, especially in prostate cancer (Giovannucci *et al.,* 2002). Tea, rich in polyphenolic catechins, exhibits chemo preventive effects against various cancers due to its antioxidant properties. Turmeric, a well-documented spice, demonstrates chemo preventive effects against skin, oral, esophageal, liver, and colon cancers, containing phenolic acids and flavonoids, such as caffeic acid and quercetin, which inhibit carcinogen activation and induce carcinogen deactivation enzymes.

Awakening the potential : In an age where health is becoming an increasingly valued commodity, the importance of nutrition cannot be overstated. As science delves deeper into the intricate relationship between diet and well-being, the spotlight is turning toward vegetables as powerhouses of bioactive molecules essential for human health (Panwar *et al*., 2023c). However, despite their immense nutritional value, vegetables often find themselves sidelined on the plate in favor of less wholesome options. Thus, there arises a critical need to create awareness in the public sphere, advocating for the production to make them cheaper (Kumar *et al*., 2017) and consumption of vegetables rich in bioactive compounds. Here the role of agri-entrepreneurship of women cannot be ignored (Chauhan and Saikia , 2022) as they are the seed of agriculture development (Chauhan, 2015) including their marketing behaviours (Marbaniang *et al*., 2020)

The journey to popularize vegetables begins with education. Many individuals are unaware of the vast array of bioactive molecules present in vegetables and their profound impact on human health (Bhullar and Bhullar, 2019). By disseminating knowledge through various channels such as educational campaigns,

workshops, and informational pamphlets, we can empower individuals to make informed dietary choices. Highlighting the benefits of specific vegetables and their bioactive components, such as antioxidants, vitamins, and phytochemicals, can serve as a catalyst for change (Mennella *et al*., 2019). Furthermore, it is imperative to address the misconceptions surrounding vegetables. For some, the perception of vegetables as bland or unappealing may deter consumption. However, by showcasing innovative recipes and cooking techniques that enhance flavour and texture, we can transform vegetables into delectable culinary delights (Lakkakula *et al*., 2019). Collaborating with chefs, nutritionists, and food bloggers can provide a platform to share enticing vegetable-based recipes and inspire individuals to incorporate more greens into their meals.

The challenges such as variability in bioactive content, bioavailability, and consumer acceptance remain pertinent in the field of vegetable nutraceuticals. Standardization of extraction methods, optimization of processing techniques, and targeted delivery systems are areas that warrant further research to maximize the efficacy of vegetable-derived nutraceuticals (Figueira *et al*., 2017). In addition to education and culinary creativity, accessibility plays a pivotal role in popularizing vegetables. For many communities, limited access to fresh produce remains a barrier to adopting a vegetable-rich diet. Initiatives such as community gardens, farmers' markets, and subsidized vegetable programs can bridge this gap, making nutritious options readily available to all socio-economic strata (Gallaher *et al*., 2018). Furthermore, advocating for policy changes to incentivize vegetable production and distribution can create a more conducive environment for widespread adoption.

Harnessing the power of social media and digital platforms is another potent tool in the arsenal of vegetable advocacy. Through engaging content such as cooking tutorials, nutritional infographics, and success stories of individuals who have embraced vegetable-centric diets, we can cultivate a vibrant online community passionate about health and wellness (Khan *et al.,* 2020). Encouraging user-generated content and fostering online support networks can further amplify the message and foster a sense of collective empowerment. Lastly, collaboration is key to effecting lasting change. By forging partnerships with healthcare professionals, educational institutions, governmental agencies, and non-profit organizations, we can leverage collective expertise and resources to amplify the reach of our advocacy efforts (Story *et al*., 2020). By uniting under a common goal of promoting vegetable consumption for improved health outcomes, we can sow the seeds of change and cultivate a healthier, more vibrant future for generations to come.

CONCLUSION

Vegetables are fundamental in disease prevention due to their rich nutrient profile. They also provide health benefits, encompassing lowered blood pressure, reduced risks of heart disease, stroke, and certain cancers, while also decreasing the likelihood of eye and digestive issues. Their positive impact on blood sugar levels assists in regulating appetite. Non-starchy vegetables, especially green leafy types, aid in weight management by eating their low glycemic loads, which deter blood sugar spikes known to induce hunger. The incorporation of a diverse range of vegetables into daily meals is pivotal. This not only fosters overall health but also sustains weight maintenance through their multifaceted nutritional advantages. Nutrients like potassium aid in blood pressure regulation, and dietary fiber in various vegetables improves bowel health, lowers cholesterol, manages blood glucose levels, and facilitates the absorption of minerals and phytochemicals. By increasing vegetable intake, individuals can reduce saturated and trans fats while maintaining a healthy diet overall. Since each vegetable contains a unique combination of vitamins, minerals, dietary fiber, and phytochemicals, diversifying vegetable choices is essential to harness the full spectrum of health benefits, and the availability of a wide variety of vegetables year-round, combined with increased income and awareness, enables consumers to incorporate these health-promoting phytonutrients into their diets

Packed with essential vitamins, antioxidants, fiber, and phytochemicals, they contribute significantly to various aspects of health. The potassium, magnesium, and antioxidant content aids in reducing blood pressure, cholesterol levels, and the risk of heart disease and stroke. Additionally, vegetables, particularly cruciferous ones, contain compounds that may lower cancer risk. Their fiber content supports digestive health, while carotenoid-rich options benefit eye health and antioxidants bolster the immune system. With their low-calorie, high-fiber nature, vegetables

also play a role in weight management and blood sugar control, making them indispensable for overall well-being and disease prevention. Creating awareness to popularize vegetables rich in bioactive molecules is a multifaceted endeavor that requires concerted efforts on various fronts. Through education, culinary innovation, accessibility, digital engagement, and collaboration, we can empower individuals to embrace vegetable-centric diets and reap the myriad health benefits they offer. Together, let us embark on this journey towards a greener, healthier tomorrow.

Funding: There is no funding for this research work.

Declaration of competing interest: Authors have no competing interests

Data availability: Data would be made available on request

Acknowledgment: Authors are thankful for the senior and colleague for their time to time critical inputs, suggestions.

Author contribution: The first, fourth and seventh authors collated and analysed the data. The second, third and fifth author conceptualized, operationalized the data, While Sixth authors collected the relevant literature.

REFERENCES

Ahmad, N.; Ahmad, A.; Malik, K.H.; Malik, G.; Ahmad, S.W.; Rather, A.M. and Magary, M. (2020). Nutraceutical and bioactive healthy compounds in vegetable crops. *Int. J. chem. Studies*. **8**(4): 3078-3086.

Bhullar, K.S.; and Bhullar, R.P. (2019). Potential of bioactive compounds from plants in modulation of aryl hydrocarbon receptor signaling. *Biomolecules*, **9**(8):285.

Buchner, F.L.; Bueno-de-Mesquita, H.B.; Ros, M.M.; Overwad, K.; Dahm, C.C.; Hansen, L. and Tjonneland, A.; Clavel-Chapelon, F.; Boutron-Ruault, M.C.; and Touillaud, M. (2010). Variety in fruit and vegetable consumption and the risk of lung cancer in the European prospective investigation into cancer and nutrition. *Cancer Epidemiol. Biomark. Prev*., **19** : 2278–2286

Chauhan, J.K. and Saikia, P. (2022). Effect of entrepreneurship on women entrepreneurs. *Indian Res. J. Ext. Edu,* **22** (1):155-159

Chauhan, J.K.; Noopur, K.; Panwar, S.S., and Kumar, L. (2023a). Vegetable nursery: A village based agri-entrepreneurship. In proceedings of International conference "Rural Transformation and Sustainable Agri-Food System through Community based Organization (CBO) Oriented Extension Strategy" held at Jaipur 18-20 Dec, 2023,

Chauhan, J.K.; Noopur, K.; Panwar, S.S., and Kumar, L. (2023c). Village based Agri-entrepreneurship in vegetable nursery. In proceedings of International conference "Rural Transformation and Sustainable Agri-Food System through Community based Organization (CBO) Oriented Extension Strategy" held at Jaipur 18-20 Dec, 2023.

Chauhan, J.K.; Noopur, K.; Panwar, S.S.; and Panwar, A.S. (2023b). Improvement in decision support and attitude of farmers through information and communication technology and skill improvement for enhanced production. In proceedings of International conference "Rural Transformation and Sustainable Agri-Food System through Community based Organization (CBO) Oriented Extension Strategy" held at Jaipur 18-20 Dec, 2023.

Chikkeri, S.S.; Kranti, K.V.V.S.; Salalia, R.; Kumar, S.; Samnorta, R.K.; Noopur, K. and Diksha L. (2023a). Emerging nematode problem in protected cultivation in Jammu. *Ind. J. Hill Farming,* **36** (1):72-74.

Chikkeri, S.S.; Kumar, S.; Samnotra, R.K.; Loona, D. and Noopur, K. (2023b). Evaluation of tomato (*Sonalum lycopersicon* L.) genotypes for growth, yield attributes and yields under subtropical region of Jammu. *J. Pharm. Innov.,* **12**(6):3036-3038.

Cooper, A.J.; Sharp, S.J.; Lentjes, M.A.; Luben, R.N.; Khaw, K.T.; Wareham, N.J., and Forouhi, N.G. (2012). A prospective study of the association between quantity and variety of fruit and vegetable intake and incident type 2 diabetes. *Diabetes Care*, **35** :1293–1300.

Dalwood, P.; Marshall, S.; Burrows, T.L.; McIntosh, A.; Collins, C.E. (2020). Diet quality indices and their associations with health-related outcomes in children and adolescents: An updated systematic review. *Nutr. J.*, **19** : 118.

Gallaher, C.M.; Gallaher, D. D., and Marshall, M. (2018). The impact of urban community gardening on health, well-being, and social capital. Landscape and Urban Planning, **170** : 1-10.

GBD (2019). Diet Collaborations. Health effects of dietary risks in 195 countries, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet*, **393** : 1958–1972.

Giovannucci, E.; Rimm, E.B.; Liu, Y.; Stampfer, M.J. and Willett, W.C. (2002). A prospective study of tomato products, lycopene, and prostate cancer risk. *Natl. Cancer Inst.* **94**: 391-98.

Gupta, C.; Prakash, D. (2014). Phytonutrients as therapeutic agents. *J. Complement. Integr. Med*., 11, 151–169. [CrossRef]

Gupta, S.K.; Yadav, S.K. and Patil, M.S.M. (2013). A bright

scop and opportunity of Indian Healthcare market. *Int. J. Res. & dev. In Phar. and Life Sci,.* **3**(2) : 478-481.

Hall, J.N.; Moore, S.; Harper, S.B.; Lynch, and J.W. Global. (2009). Variability in fruit and vegetable consumption. *Am. J. Prev. Med*., **36**, 402–409.

Iddir, M.; Brito, A.; Dingeo, G.; Sosa Fernandez Del Campo, S.; Samouda, H.; La Frano, M.R. and Bohn, T. (2020). Strengthening the immune system and reducing inflammation and oxidative stresses through diet and nutrition: Considerations during the COVID-19 crisis. *Nutrients*, **12** :1562.

Kaur, C.and Kapoor, H.C. (2001). Antioxidants in fruits and vegetables–the millennium's health. *Int. J. Food Sci. Techno*. **36** : 703–725. [Google Scholar]

Keck, A.S., and Finley, J.W. (2004) Cruciferous vegetables: cancer protective mechanisms of glucosinolate hydrolysis products and selenium. *Integr Cancer Ther*. **3** : 5-12.

Khan, A.; Manzoor, S., and Ramachandran, S. (2020). Role of social media in nutritional awareness and adherence to dietary recommendations: A systematic literature review. *Clinical Nutrition ESPEN*, **40** : 39-47.

Kumar, S.; Singh, R.; Rao, D. and Chauhan, J. (2017). Information needs of Indian farmers: an elixir for connect and disconnect of agriculture *Indian Res. J. Ext. Edu,* **18** (1):37-44

Lakkakula, A. P.; Zanovec, M.; Silverman, L.; Murphy, E., and Tuuri, G. (2019). Interventions promoting vegetable consumption among preschoolers: A systematic review. *Public Health Nutrition*, **22**(2): 299-314.

Marbaniang, E.K.; Pasweth., D. and Chauhan, J.K. (2020). Marketing behaviour of tomato growers in West Khasi Hills district of Meghalaya Women: seeds of change in agriculture. *Indian Res. J. Ext. Edu,* **20** (2&3) : 22-26

Mennella, J.A.; Trabulsi, J.C., and Papas, M.A. (2019). The role of vegetable and fruit consumption in the prevention of obesity in early childhood. Advances in Nutrition, **10** (suppl_1), S31-S43.

Minich, D.M. (2019). A Review of the science of colourful, plant-based food and practical strategies for “eating the rainbow”. *J. Nutr. Metab*. 2019, 2019, 2125070.

Noopur, K. (2015). Underutilised crops of North East: Potential conventional foods of the future. In Proc. National seminar on seminar on Sustaining Hill Agriculture in changing Climate, held during 5-7 Dec at Agartala, pp 41.

Noopur, K.; Ansari, M.A. and Panwar, A.S. (2021a). Self-reliant in year-round vegetable production and consumption through Kitchen garden model in Indo Gangetic Plains: *Ind. J. Agri. Sci.,* **91**(12): 1773-7.

Noopur, K.; Babu, S. and Somasundaram, E. (2021b). On-farm assessment of French bean (*Phaseolus vulgaris* L.) cultivars for seed production in the Nilgiri hills. *Ind. J. Hill. Farm*. **34** (1):158-161.

Noopur, K.; Chauhan, J.K.; Kumar, L.; Chandegara, A.K., and Panwar, S.S. (2023a). Vegetables for food and nutritional security. *Indian Res. J. Ext. Edu.,* **23** (4):21-27.

Noopur, K.; Chauhan, J.K.; Walia, S.S.; Verma, M.R.; Urseen Dhar; Chaudhary, S. and Chikkeri, S.S. (2023b). Constraints in vegetable production in India: A Review. *Indian Res. J. Ext. Edu.,* **23** (3) :14-19.

Noopur, K.; Jawaharlal, M. and Praneetha, S., Kashyap, P. and Somasundaram, E. (2019). Genetic variability and character association studies in French bean (*Phaseolus vulagris*) in the Nilgiri Hills of Tamil Nadu. *Ind. J. Agri. Sci*. **89**(12): 2009-13.

Noopur, K., Samnotra, R.K. and Kumar, S. (2022). Screening of okra (*Ablemoschus esculentus* (L) Moench) genotypes for resistance to yellow vein mosaic under agro-climatic conditions of Jammu. *Ind. J. Hills. Far*. **35**(1): 47-49.

Pandey, K.B. and Rizvi, S.I. (2009). Plant polyphenols as dietary antioxidants in human health and disease. *Oxid Med Cell Longev*, **2**(5):270-8. doi: 10.4161/oxim.2.5.9498. PMID: 20716914; PMCID: PMC2835915.

Panwar, A.S.; Babu, S.; Noopur, K.; Tahsildar, M.; Kumar, S. and Singh, S. (2019). Vertical cropping to enhance productivity and profitability of dry terraces in North Eastern Indian Himalayas. *Ind. J. Agri. Sci*., **12**: 2020-2024.

Panwar, A.S., Babu, S., Chauhan, J.K.; Panwar, S.S. and Noopur, K., (2023c). Farming situation based farming system for livelihood security in Meghalaya. In proceedings of International conference “Rural Transformation and Sustainable Agri-Food System through Community based Organization (CBO) Oriented Extension Strategy” held at Jaipur 1-20 Dec, 2023, pp

Panwar, A.S.; Babu, S.; Noopur, K. and Kumar, S. (2021a). Maize (Zea-mays)- based cropping system on raised beds influenced the productivity, soil quality and profitability in North-Eastern. Indian J. of .Agron. **66**(3): 333-338.

Panwar, A.S.; Ravisankar, N.; Singh, R.; Prusty, A.K.; Shamim, M.; Ansari, M.A. and Noopur, K. (2021a). Potential integrated farming system modules for

divers' ecosystems of India. *Indian. J. Agron*., **66** (5th IAC Special issue): S15-S32.

Panwar, A.S.; Subash Babu.; Chauhan, J.K.; Panwar, S.S. and Noopur, K. (2023). Farming situation-based farming system for livelihood security of tribal farmers in Meghalaya. In proceedings of International conference "Rural Transformation and Sustainable Agri-Food System through Community based Organization (CBO) Oriented Extension Strategy" held at Jaipur 1-20 Dec, 2023, pp

Panwar, S.S.; Natasha Panwar; Chauhan, J.K., and Kohima Noopur (2023). Bioactive medicinal molecule from vegetable for disease prevention in Human. In proceedings of International conference "Rural Transformation and Sustainable Agri-Food System through Community based Organization (CBO) Oriented Extension Strategy" held at Jaipur 1-20 Dec, 2023, pp

Rai, S.K.; Arora, N.; Pandey, N.; Meena, R.P.; Shah, K. and Rai, S.P. (2012). Nutraceutical enriched vegetables: molecular approach for crop improvement. *Int. J Phar. and Bio. Sci.,* **392** : 0975-6299.

Ravishankar, D.; Rajora, A.K.; Greco, F. and Osborn, H.M. (2013). Flavonoids as prospective compounds for anti-cancer therapy. *Int J Biochem Cell Biol.*, **45**(12):2821-31. doi: 10.1016/j.biocel.2013.10.004. Epub 2013 Oct 12. PMID: 24128857.

Riaz, A.; Rasul, A.; Hussain, G.; Zahoor, M.K.; Jabeen, F.; Subhani, Z.; Younis, T.; Ali, M.; Sarfraz, I. and Selamoglu, Z. and Astragalin (2018). A bioactive phytochemical with potential therapeutic activities. *Adv Pharmacol Sci*.; 9794625. doi: 10.1155/2018/9794625. PMID: 29853868; PMCID: PMC5954929.

Rothschild, D.; Weissbrod, O.; Barken, E.; Kurilshikov, A.; Korem, T.; Zeevi, D.; Costea, A.; Godneva, I.N. and Kalka, N. (2018). Environment dominates over host genetics in shaping human gut microbiota. *Nature*, **555**: 210-15

Saxena, D.C.; Singh, N.P.; Satpathy, K.K., Panwar, A.S. and Singh, J.L. (2003). Sustainable farming system for hill agriculture. In Approaches for increasing agricultural productivity in hill and mountain eco-system. (Eds) B.P. Bhatt, K.M. Bujarbaruah, Y.P. Sharma and Patiram. ICAR Research Complex for NEH Region, Barapani, Meghalaya, PP 73-86.

Singh, A.K.; Sabir, N. and Noopur, K. (2017). Horticulture based plasticulture cum covered cultivation for livelihood security. *Ind. Horti.*, **62**(5):68–74.

Sobral, F.; Sampaio, A.; Falcão, S.; Queiroz, M.J., Calhelha, R.C.; Vilas-Boas, M. and Ferreira I.C. (2016). Chemical characterization, antioxidant, anti-inflammatory and cytotoxic properties of bee venom collected in Northeast Portugal. *Food Chem Toxicol*, **94**:172-7. doi: 10.1016/j.fct.2016.06.008. Epub 2016 Jun 8. PMID: 27288930.

Story, M. T., and Neumark-Sztainer, D.R. (2020). A perspective on policy approaches to nutrition and physical activity interventions for adolescents. J. *Adolescent Health*, **66**(6), S6-S14

Tao, L.; Xie, Z., and Huang, T. (2020). Dietary diversity and all-cause mortality among Chinese adults aged 65 or older: A community-based cohort study. *Asia Pac. J.Clin. Nutr*. **29** :152–160.

Thompson, H.J. (2010). Vegetable and fruit intake and the development of cancer: a brief review and analysis. In: Watson RR, Preedy VR, editors. Bioactive foods in promoting health. London: Academic Press; : 19-36

Traka, M. and Mithen, R. (2009). Glucosinolates, isothiocyanates and human health. *Phytochem. Reviews*, **8**(1), 269-282.

Verhoeven, D.T.; Goldbohm, R.A.; Van Poppel, G.; Verhagen, H. Anf Van den Brandt, P.A. (1996). *Cancer Epi. Bio. Prev.,* **5**: 733-48.

Walia, S.S.; Babu, S.; Gill, R.S.; Kaur, T.; Noopur, K.; Panwar, A.S.; Yadav, D.K.; Ansari, M.A.; Ravishankar, N.; Kumar, S.; Karmjeet, K. and M.H. Ansari. (2022). Designing resource-efficient and environmentally safe cropping systems for sustainable energy use and economic returns in Indo-Gangetic Plains, India. *Sustainability,* **14** :14636. https://doi.org/10.3390/su142114636

Weindruch, R. and Walford, R.L. (1988). Retardation of aging and disease by dietary restriction; CC Thomas: Springfield, IL, USA, pp. 339–397.

Ye, X.; Bhupathiraju, S.N., and Tucker, K.L. (2013). Variety in fruit and vegetable intake and cognitive function in middle-aged and older Puerto Rican adults. *Br. J.Nutr*., **109**: 503–510.

• • • • •