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Phytonutrients and Nutraceuticals in Vegetables and Their Multi-dimensional Medicinal and Health Benefits for Humans and Their Companion Animals: A Review

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Abstract: At present, almost every third person in the society is under stress and having chronic disorders like diabetes, arthritis, allergy, cardiovascular disease, fatigue and even cancer. Recently, there is decline in the physical and mental capabilities along with the social values. So this certainly should raise the alarms as to why such deterioration is taking place in the society or what are the changes in the lifestyle that might have a role direct/indirect in evolution of such changes? Vegetable is an immense store of active chemical compounds and considered as the cheapest and most easily available sources of carbohydrate, fiber, proteins, vitamins, minerals and amino acids. The intake of green and leafy vegetables lowers the risk of chronic diseases, cardiovascular diseases, anemia, cancer, oxidative stress, diabetes, weight gain etc. In recent time, vegetables have also been identified as safe and economic expression system for producing the recombinant proteins including the vaccines against many infectious diseases like hepatitis B, malaria, rotavirus, HIV, *Helicobacter pylori*, pestedes petits ruminants etc. However, besides the beneficial effect, contaminated and raw vegetables harbors pesticide residues and many pathogenic microbes viz., norovirus, *Salmonella*, *E. coli*, *Shigella*, *Listeria monocytogens* and also prove to be an excellent source of disease outbreaks. The present review highlights the phytonutrients and nutraceuticals in fruits and vegetables; their medicinal and health benefits for humans and their domestic as well as companion animals along with their fruitful practical applications and perspectives like bioreactor for producing vaccine along with the methods that can increase their nutritional benefits.

Key words: Vegetables, vitamin, mineral, medicine, vaccine, bioreactor, pesticides residue

INTRODUCTION

In the stressful society of today, almost every third individual is suffering for the chronic health problems like diabetes, arthritis, allergy, cardiovascular disease, fatigue, chronic decrease in productivity and/or vigour and even cancer. The count of human and animal diseases is rising day by day. This certainly raises a question in the human mind that why such a huge emergence of diseases now? Medicos very easily answer the question that it is because of better diagnostics but it is an incomplete and debatable answer. Today, the physical and mental

capabilities are declining. Man is a social animal but even the social values are getting lost in the current scenario (Mahima *et al.*, 2012a). So this certainly should raise the alarms as to why such deterioration is taking place in the society or what are the changes in the lifestyle that might have a role direct/indirect in evolution of such changes? According to World Health Organization, the vegetables intake is less than 20-50%, which is below the recommended amount. This low intake of vegetables especially in developed nations of the world is because of the preference of the consumers for food which is convenient and not the vegetables' security. It has been

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Table 1: List of plant and their parts used

Buds, flower buds, leaves, shoots	Tubers, bulbs and other storage organs	Tubers, roots, rhizomes, bulbs and corms	Seeds
Lettuce	Carrot	Potato	Sweet corn
Asparagus	Cowpea	Water chestnut	Beans
Cabbage	Tomato	Sweet Potato	Peas
Broccoli	Cucumber	Carrot	
Green beans	Squash	Beet	
Gum acacia	Pumpkin	Radish	
Lichens	Okra	Turnip	
Capers	Avocado		
Globe artichokes			
Spinach			
Beet greens			
Chard			
Turnip			
Mustard greens			
Garlic			

found that more of processed than fresh vegetables are consumed in the United States (Rickman *et al.*, 2007). Compared to components that are isolated whole foods are found to be beneficial in a better way to human health in an ascending manner. Such foods have been found in supplements. There is outperforming of dietary supplements that are carotenoid in nature and are resistant to oxidation due to Low Density Lipoprotein (LDL); having lowered damage of deoxy ribonucleic acid (DNA) and in human volunteers induces greater activity of repairing (Southon, 2000). Addition of vitamins viz., A and C; E supplements to the diet of patients suffering from cancer affects negatively their radiotherapy as well as chemotherapy results (Seifried *et al.*, 2003). Resistance development in common pathogens of man and animals viz., *Salmonella*, *E. coli*, *Campylobacter*, *Arcobacter*, *Staphylococcus*, *Streptococcus*, *Klebsiella*, *Pseudomonas* and opportunistic pathogens like mycoplasmas towards the chemical compounds and drugs including antibiotics (Singh *et al.*, 2008, 2009; Kumar *et al.*, 2012a, 2013a, b; Dhama *et al.*, 2011, 2013a; Malik *et al.*, 2013; Anita *et al.*, 2013; Patyal *et al.*, 2011; Verma *et al.*, 2012; Rajagunalan *et al.*, 2012; Taddele *et al.*, 2012; Tiwari *et al.*, 2013a), antifungals, antivirals, people are now looking towards age old natural therapies viz., ayurvedic, herbal and traditional medicines with a great hope (Mahima *et al.*, 2012b; Tiwari *et al.*, 2013b; Dhama *et al.*, 2013b).

Fruits and vegetables have dietetic value, nutritive value and some may also have the medicinal value (Mahima *et al.*, 2012b, 2013a, b). The dietetic value is a prophylactic (preventive) or curative quality of certain foodstuffs and is natural. The main objective of the diet is the protection of the internal organs, first of those that participate directly or indirectly to digestion, of the blood-vascular system, etc. Fruits and vegetables have a natural dietetic importance because of their components

like vitamin and minerals, dietary fibers, amino acids, Polyunsaturated Fatty Acids (PUFA) antioxidants and even phytoncides (natural antibiotics) etc., (Chiu *et al.*, 2011; Esfahani *et al.*, 2011; Heim *et al.*, 2012). The plant world particularly the group ‘fruits and vegetables’ is an enormous store of active chemical compounds and considered as the cheapest and most easily available sources of carbohydrate, fiber, proteins, vitamins, minerals and amino acids (Ahmad *et al.*, 2008; Gibson *et al.*, 2012). The present review highlights the important phytonutrients and nutraceuticals in fruits and vegetables; their medicinal and health benefits for humans and their domestic as well as companion animals along with their fruitful practical applications and perspectives like bioreactor for producing vaccine along with the methods that can increase their nutritional benefits.

PLANT WORLD-A RICH SOURCE OF VEGETABLES

The term ‘vegetable’ includes any edible part of a plant. Vegetables are those herbaceous plants whose part or parts are taken in the diet as supporting food and/or main dishes. They may be aromatic, bitter or tasteless. It is part of cultural heritage and they play important roles in the customs, traditions and food culture of household of India (Rahal and Kumar, 2009). Vegetables are the cheapest and available sources of carbohydrates, proteins, vitamins and minerals *ad libidum* (Prasad *et al.*, 2008; Lamprecht, 2012). Since centuries different parts of plants are edible (Table 1).

GREEN HERITAGE OF VEGETABLES

India is enriched with a variety of traditional vegetables and various types of vegetables are consumed

by the various ethnic groups for different reasons and purposes. If we look around, we find a lot of indigenous therapies, ethno medicines and traditions being practiced in different parts of the world. These practices vary among geographical regions as well as over generations. Human ancestry goes back to apes of Africa and then Asia. They ate an enormous range of plants-leaves, buds, flower buds, gums, tubers and even pollens. Little was known about their health benefits or toxicity. Today, the genetic manipulations have resulted in even more palatable and nutritious plants but the irony is 'we eat very few plants as our daily diet'.

Leafy vegetables are said to be an invaluable substitute for meat and therefore form integral part of daily diets of rural communities. The traditional leafy vegetables have a proven nutritive value in terms of having high carbohydrate, protein, vitamins and minerals in comparison to that of exotic vegetables. Many of vegetables like carrot, radish, tomato, onion, cabbage and cucumber are routinely used as salad. There is growing trend of taking micro greens (seedlings of edible vegetables and herbs) for the sake of flavors, colors and textures and served as garnish or salad (Xiao *et al.*, 2012). Studies showed that salad bar can be significant in promotion of the consumption of vegetables (Harris *et al.*, 2012). Consumption of green salad is helpful in reducing the risk of chronic and cardiovascular disease (Azadbakht *et al.*, 2012). Consumption of low energy soup or vegetables before meal can reduce the intake of more energy dense food in children (Spill *et al.*, 2011; Roe *et al.*, 2012); enhance satiety and control hunger and therefore helpful in managing weight (Ello-Martin *et al.*, 2005). Swiss chard (*Beta vulgaris* L.) and salad crop have been reported to be rich in vitamins and minerals (Logendra *et al.*, 2002). The vitamin and mineral contents of peas is helpful in preventing diseases due to Selenium or folate deficiency (Dahl *et al.*, 2012).

EFFECT OF ENVIRONMENT ON PLANT NUTRIENT CONTENTS

During the development stages, if a plant experiences certain stresses it starts to hold various phytochemicals as well as antioxidants at upper levels, wherein several secondary compounds are effective medicinally (Lila, 2006). On exposure to pests as well as other insults of the environment, the quality of organic vegetables may be lowered. It has been revealed that the quercetin content increases greatly due to organic management along with kaempferol level when the environmental stress is controlled (Bruulsema, 2002; Mitchell and Chassy, 2007).

PHYTONUTRIENTS AND NUTRACEUTICALS FROM FRUITS AND VEGETABLES

Nutrients are the food substances that ensure a normal deployment of the biological processes from the body of human and participate into the metabolic processes. The content of various nutrients is not as important as the quality, availability and ratio of the compounds. Many phytochemicals have been identified helping the body in maintenance of health and fighting various diseases. The term nutraceutical describes particular chemical compounds found in foods that may prevent disease development and phytochemical can underestimate the plant source of most of these protective compounds, whereas phytonutrient describes quasi-nutrient status of such compounds. The phytonutrients present in fruits and vegetables have been classified in the older times into vitamins, for example flavonoids were recognized as vitamin P, cabbage factors (glucosinolates and indoles) as vitamin U, ubiquinone as vitamin Q and Tocopherol as vitamin E. The description as Vitamin was removed for the other phytonutrients except tocopherol, due to be deficient in establishing specific deficiency symptoms.

The phytonutrients can be classified into various groups on the basis of alike protective functions as well as individual physical and chemical characteristics of the molecules. It is important to note that all classes of phytonutrients are required to be consumed for a sound and healthy body. Focusing nutraceuticals, there is greater potential for opportunities that are new, novel as well as exciting. Crops need to be selected with value addition for the growers and a demand for their transition to organic crop production (Greenleaf, 1999). The following is a list of important phytonutrients and their useful medicinal values.

Anthocyanidins: Anthocyanidins are a type of flavonoids, also known as flavonals, which provide cross-links that hook up and strengthen the intertwined collagen protein strands found in tissues, tendons, ligaments and bone matrix. These also act as free radical scavenger in tissue fluids (Jeong *et al.*, 2013). In human beings, risk of myocardial infarction is reduced by taking high amount of anthocyanins (Cassidy *et al.*, 2013).

Carotenoids: The carotenoid family consists of carotenes and xanthophylls. There are more than 600 naturally occurring carotenoids. The subclass terpenes comprises of bright red, orange and yellow pigments present in various vegetables viz., tomatoes, spinach, oranges, pink grapefruit and red palm oil. Carotenes are chemically

classified as 40-carbon tetraterpenes, missing the hydroxyl or keto groups (beta carotene), while xanthophylls include carotenoid alcohols and keto-carotenoids cryptoxanthin, canthaxanthin, zeaxanthin and astaxanthin.

Vitamin A activity is only present in alpha, beta and epsilon carotene, out of these the beta carotene is the most active (Yoon *et al.*, 2012). The antioxidant activity of alpha carotene and epsilon carotene is 50-54 and 42-50%, respectively of the antioxidant activity of beta carotene. The alpha, beta, gamma, epsilon, lycopene and lutein carotenes have been found to provide protection against tumors of the lung, colorectal, breast, uterine and prostate (Yoon *et al.*, 2012). The overall protective effects of carotenes will be additive if taken together, since these are tissue-specific. The carotenes also augment immune response and can protect skin cells against UV radiation (Mahima *et al.*, 2013a). These also help liver in safely eliminating pollutants and toxins from the body. Xanthophylls help in the protection of vitamin A, E and various other carotenoids from oxidation. Xanthophylls especially canthaxanthin migrates to the skin and protects it from sunlight. The cryptoxanthin has been shown to protect vaginal, uterine and cervical tissues.

Catechins, gallic acids: The chemical structure of catechins is slightly different from other flavonoids but has the same chemoprotective activities. Green tea (*Camellia sinensis*) is rich in catechins (Scoparo *et al.*, 2012).

Flavonoids: Flavonoids constitute a subclass of phenols that improve the effects of ascorbate-vitamin C. The hesperidin found in citrus fruits, quercetin in grapefruit and rutin in buckwheat are some of the important flavonoids. These are beneficial in allergic conditions, inflammation, liver disorders, platelet aggregation, pathogens (bacteria and viruses), cancer and ulcers and acts as antioxidant. These inhibit a number of specific enzymes thereby help in preventing various diseases and maintenance of a healthy body. The flavonoids block the Angiotensin-converting Enzyme (ACE) that is responsible for raising blood pressure. The platelet stickiness and aggregation is prevented by blocking the cyclooxygenase enzyme that breaks down prostaglandins. Flavonoids are also helpful in protection of the vascular system (Van Dam *et al.*, 2013). The risk of estrogen-induced cancers in females can be reduced by flavonoids due to blocking of certain enzymes producing estrogen. Aldose-reductase can convert the galactose sugar into the potentially harmful form of galactitol. Flavonoids may

retard development of cataracts in individuals with inborn errors in sugar metabolism such as diabetes by blocking aldose-reductase (Van Dam *et al.*, 2013).

Glucosinolates: These are frequently present in the vegetables of *Cruciferi* family and set in motion the detoxification enzymes in liver, white blood cells and cytokines thereby helping in boosting immunity. The isothiocyanates, dithiolthiones and sulforaphane are the bio-transformation products of glucosinolates that are involved in blocking enzymes which are responsible for tumorous growth in liver, lung, breast and gastrointestinal tracts (esophagus, stomach and colon) (Baskar *et al.*, 2012).

Indoles: Indoles include phytonutrients that interact with vitamin C and their complexes bind with chemical carcinogens. These also help in activating the detoxification enzymes. The acid in stomach helps in the formation of bio-transformation products of indoles like the ascorbigen.

Isoflavones: This is a subclass of phenol found in beans and other legumes and its function is similar to flavonoids in effectively block enzymes promoting tumor growth, the important ones include genistein and daidzein which are found in soy products and the herb, *Pueraria lobata* (Kudzu) (Kaufman *et al.*, 1997). The incidence of breast, uterine and prostate cancers is rare in people who consume traditional diets rich in soy foods.

Isoprenoids: The isoprenoids neutralize free radicals by grabbing any free radicals attempting to attach lipid (fat) membranes passing them off to other antioxidants.

Limonoids: This is a subclass of terpenes that is found in citrus fruit, a peel that is specifically directed to protect lung tissue and prevent breast cancer that responds to oestrogen (Kim *et al.*, 2012; Sun *et al.*, 2013). The chemotherapeutic activity of limonoids may be due to induction of both Phase I and Phase II detoxification enzymes in the liver.

Lipoic acid and ubiquinone: Lipoic acid and ubiquinone (coenzyme Q) are antioxidants which can efficiently quench the hydroxyl radicals and are active on both lipids and tissue fluids and scavenges peroxy, ascorbyl and chromanoxyl radicals. It can protect both vitamin E and vitamin C, as can function in both lipid and water phases. They can also protect catalase and glutathione, thus helpful in liver detoxification activities.

Phytosterols: Phytosterols are present in green and yellow vegetables and their seeds. These can effectively compete with dietary cholesterol absorption through intestines and thus make easy the excretion of cholesterol from the body and therefore are helpful in alleviating the risk of cardiovascular diseases (Jones *et al.*, 1997; Awaisheh *et al.*, 2013). These have also been reported to be helpful in blocking the development of cancer in various organs especially colon, breast and prostate glands.

Phenols: Phenols are a large group of phytonutrients protecting the humans from various kinds of oxidative damages. Phenol gives the blue, blue-red and violet colorations to berries, grapes and purple eggplant. The red colour in bilberries is due to the presence of high phenolic anthocyanidins. The phenols block specific enzymes that cause inflammation and protect platelets from clumping most likely by modification of the prostaglandin pathways.

Terpenes: These form the largest classes of phytonutrients and are commonly present in green foods, soy products and grains. Carotenoid i.e., beta carotene is one of the most studied terpenes. The antioxidants property of the terpenes protects lipids, blood and other body fluids from attack by free radical oxygen.

Thiols: Thiols comprises of sulfur-containing phytonutrients present in garlic and cruciferous vegetables (cabbage, turnips and members of the mustard family). Allylic Sulfides subclass is abundantly found in garlic, onions, leeks, shallots and chives (Hofgen *et al.*, 2001) and are released when the plants are cut or smashed. These possess antimutagenic and anticarcinogenic properties as well as immune enhancing and cardiovascular protective properties (Vazquez-Prieto and Miatello, 2010). Garlic and onions activate liver detoxification enzyme systems and are also effective against tumors, bacteria, fungi, viruses, parasites, cholesterol and platelet/leukocyte adhesion factors.

Tocotrienols and tocopherols: Tocotrienols and tocopherols naturally occur in grains and palm oil. Tocotrienols can suppress breast cancer cell growth but not the tocopherols, which on the other hand show cholesterol lowering effects.

MEDICINAL PROPERTIES

One of the more unique things about vegetables is the belief that some vegetables act as medicines and are

reserved for the sick and convalescence individuals because of their multi-dimensional medicinal properties. Nearly half the medicines being used today are of herbal origin and a quarter contains plant extracts or active chemicals taken directly from various plants (Ahmad *et al.*, 2006). Many more have yet to be discovered as well as recorded and researched. Only a few thousand have been studied so far, carrot being a wonderful example. Carrot is a common vegetable that finds its way to the dining table in the salad as well as cooked greens. As a fruit, it is an excellent promoter of reproductive potential of man and animals but its seeds have proven anti-fertility role. The beta carotene and other carotenoids in carrot also provide protection against the oxidant induced changes in lipid peroxidation, deoxy glucose transport, LDH release and amino acid and also protect the skin from damaging effects of sunlight (Stahl and Sies, 2012).

The medicinal value is subordinated to the nutraceutical value and some foodstuffs may have medicinal properties and can be administered as a therapeutic agent. The knowledge about the healing features of fruits and vegetables has been well preserved in the form of ethno-botanical tradition of the folk and ancient heritage of medicine in all the countries. Some of our vegetables had originally been used as medicinal plants, the difference between these two types are very vague. The same compounds as are present in medicinal plants may equally be found in vegetables. Some vegetable foods have been recognized as natural medicines; in particular some vegetables and legumes have been used as traditional medicines in China for many years. Adherence to vegetables particularly green and leafy vegetables, tomatoes etc., and legumes (including soybean, peanut etc.) has been found to be inversely associated with the chances of anaemia (Pamgrahi and Sahoo, 2011) and type 2 diabetes (T2D) in a large Chinese population (Villegas *et al.*, 2008a, b). Folate present in fresh leafy green vegetables is helpful in reducing the risk of chronic diseases that include: megaloblastic anemia; neural tube defects, cardiovascular disease and cancers (Esfahani *et al.*, 2011; Shohag *et al.*, 2012).

The medicinal uses of various common vegetables range from burn ointments to diuretics. Parts of vegetables may be used to produce drugs, or may be effective dietetic food. The lycopene present in tomato when present in the bloodstream has been shown to protect against oxidation of low density lipoproteins and thus reduces the incidence of arterial disease. Epidemiological studies have also shown tomato consumption to reduce the risk of prostate cancer. The

seeds of the carrot are reported to possess emmenagogue and abortifacient properties and are also used in uterine pain. Seeds of the pea (*Pisum sativum* L.) are reported to possess antifertility and abortifacient actions (Vohra *et al.*, 1973). Oil obtained from pea seeds have been found to elicit contraceptive action in albino rats. The active ingredient is m-xylohydroquinone; a single dose of 1 mg caused abortion, reabsorption, or still births in mice and rats. *Foeniculum* seeds are effective against hernias and hydrocele when used with other salts or ingredients. Radish and green chillies, a common constituent of salad, are good potentiators of uterine involution.

Vegetables can provide phytonutrients as well as nutritional components, such as vitamins, minerals and fiber (Mattoo *et al.*, 2007; Orech *et al.*, 2007; Murphy *et al.*, 2012; Bumgarner *et al.*, 2012). Some of dark green leafy vegetables like arugula, broccoli, spinach, kale and cabbage; dandelion greens; swiss chard and watercress etc., provide a variety of nutrients like vitamin A and B complex, vitamin E, major minerals (calcium and phosphorous) and trace minerals (manganese and potassium) etc. Root vegetables like beets are rich in vitamin B complex, vitamin C, manganese, magnesium, iron, copper and phosphorus. A close relative of Indian drumstick, *Moringa stenopetala* has highly nutritious leaves, edible flowers, edible pods, antibiotic properties in seeds and the bark is used as a hot condiment with one of the highest calcium levels and highest vitamin C levels. *Young plantain* leaves, consumed raw in salad in Asia, are rich source in vitamin B1 and riboflavin. *Plantain* are rich in various glycosides like aucubin, ascorbic acid, apigenin, baicalein, benzoic and chlorogenic acid; citric and ferulic acid; oleanolic and salicylic acid and ursolic acid, which are all having tremendous medicinal activities viz., antimicrobial, anti-inflammatory, antitusive, cardiac stimulant, diuretic, laxative, antitussive, antiseptic, poultice, refrigerant and vermifuge. The use of these drugs for the treatment of respiratory problems (asthma, bronchitis and emphysema), bladder disorders, pyrexia, cardio-vascular disorders (hypertension), rheumatism and blood sugar control has been scientifically proven. It also causes a natural aversion to tobacco and is currently being used in preventing smoking.

Vegetables are an amazing source of antioxidants (Kiefer *et al.*, 2004; Odukoya *et al.*, 2007; Thompson *et al.*, 2010) and vitamins (β -carotene, vitamins C and E) (Esfahani *et al.*, 2011; Mahima *et al.*, 2011). Pumpkin, tomato, carrot, garlic, clove; the list is everlasting. Vegetables like carrots, pumpkins, acorn squash butternut squash, Hubbard squash and sweet potatoes, also known as orange vegetables, are a rich source of carotenoids, which act are known antioxidants. Due to presence of

antioxidants, higher intake of green leafy vegetables and cruciferous vegetables reduces homocysteine and markers of oxidative stress (Singh *et al.*, 2009; Esfahani *et al.*, 2011) thus leading to lower risk of bladder cancer (Michaud *et al.*, 1999), non-Hodgkin's lymphoma (NHL) and particularly follicular lymphoma (Thompson *et al.*, 2010; Chiu *et al.*, 2011). Increased consumption of vegetables has also been found to improve the Pneumovax II vaccination antibody response in older people, leading to improved immunity (Gibson *et al.*, 2012). Garlic clove is also well recognized for protection against bowel cancer. These antioxidants are also helpful in combating the oxidative stress induced by the environmental pollutants such as heavy metals and pesticides (Singh *et al.*, 2007; Kumar *et al.*, 2012b).

Out of more than 600 carotenoids present in plants, only few like alphacarotene, betacarotene, lycopene, zeaxanthine, lutein and betacryptoxanthine are utilized by human beings. The high level of α -carotene, β -carotene, lutein, zeaxanthin, lycopene and total carotenoids in blood circulation is helpful in reduced risk of breast cancer in women (Eliassen *et al.*, 2012). Phytoene and phytofluene, precursors of higher unsaturated carotenoids are responsible for photoprotective effects (Stahl and Sies, 2012). A USDA study also detected compromised immune function in otherwise healthy females fed on low carotene diet. Green leafy vegetables are rich in iron content required for synthesis of haemoglobin, hence suggested in iron deficiency anaemia. Various minerals including the trace minerals are also co-enzymes in certain biochemical reactions in the body (Mahima *et al.*, 2012c), which adds to the importance of leafy vegetables in metabolic reactions.

The fiber content of vegetables provides a bulk in the diet. This helps to reduce the intake of starchy foods, enhances gastrointestinal function, prevents constipation and may thus reduce the incidence of metabolic diseases like maturity onset, diabetes mellitus and hypercholesterolemia. The fibre cleanses the gut by removing the various carcinogens from the body and prevents the absorption of excess cholesterol. It also prevents the intake of excess starchy food and therefore protect against metabolic disorders (hypercholesterolemia and diabetes mellitus). Fibre from the seed coat and the cell walls of the cotyledon of peas is beneficial for gastrointestinal function and health (Dahl *et al.*, 2012).

Some vegetables are also potent antibiotics, antihypertensive and blood building agents and also improve fertility in females when eaten in soups. The phytochemical contents of the leafy vegetables provide nutritive supplements for food and also improve the health status of its consumers due to the existence of several compounds fundamental for good health.

Phytochemicals like polyphenolics and saponins present in coloured seed coat of peas have potent antioxidant and anticarcinogenic properties (Dahl *et al.*, 2012). Polyphenols play critical role in prevention of various diseases including of cardiovascular, neurodegenerative disorders, diabetes mellitus, osteoporosis and even cancer (Hafidh *et al.*, 2009; Mudgal *et al.*, 2010), hepatic damage (Salawu and Akindahunsi, 2006), inhibit angiogenesis (Sahib *et al.*, 2010) and obesity (El-Shebini *et al.*, 2007). It is well known and proven fact that certain foods possess potential to effectively prevent many diseases as universal medicines. For example, the Mediterranean diet is lowers the risks of coronary heart disease, cancer and cognitive impairment. Consumption of green tea is beneficial for preventing cancer and Alzheimer's disease (AD) (Chen and Zhang, 2007). Green and yellow vegetables decreases the risk of chronic disease and inhibits the development of atherosclerosis (Wolfenden *et al.*, 2012). Therefore, it may lead to a reduction in the risk of coronary heart disease (Samman *et al.*, 2003; Adams *et al.*, 2006; Esfahani *et al.*, 2011), diabetes (Imai *et al.*, 2012), stroke, markers of inflammation and oxidative stress (Holt *et al.*, 2009) viz., serum homocysteine and markers of protein, lipid and DNA oxidation (Esfahani *et al.*, 2011). Such consumptions could also mitigate contaminant exposure and/or their adverse health effects (Gagne *et al.*, 2013). The presence of mucilage in some vegetables makes their soups more tasty and palatable.

Vegetables help in retaining stronger bones by decreasing the amount of calcium excreted in the urine. They also act as an alkaline buffer neutralizing acids produced when non-vegetarian diet is consumed. Major mineral components of the leaves include calcium (1.22-4.13 mg 100 g⁻¹), potassium (0.08-6.10 mg 100 g⁻¹), sodium (0.03-6.84 mg 100 g⁻¹) and iron (0.01-0.12 mg 100 g⁻¹). Calcium is a major component giving strong bones, muscle contraction and relaxation, synaptic transmission, blood clotting and absorption of Vitamin especially B₁₂. The relatively high content of calcium in *Gryllotalpa africana* (4.13 mg 100 g⁻¹), *T. triangulare* (7.44 mg 100 g⁻¹), potassium and magnesium are known to decrease blood pressure. Potassium plays a crucial role in skeletal muscle contraction and transmission of nerve impulses. Therefore, the persons having the soft bone are usually advised to have the vegetables rich in calcium and potassium.

Phytoconstituents of vegetables are also very effective stimulants for the nervous system of the body. The bitter leaf contains an alkaloid, vernomine, which is capable of reducing headaches associated with hypertension (Ayitey-Smith, 1989). Broccoli is as excellent source of sulphoraphane, which has a powerful

anticancerous effect. Spinach retards central nervous system and cognitive behavioral deficits. *Ocimum* species are rich in alkaloids that are useful in cold, cough, chronic catarrh and migraine. The medicinal importance of tannins, saponins and inulins which are components of traditional herbal preparations are highly useful in managing various common ailments. Lesser medication and more natural foods need to be have a priority place in our life but to get maximum health benefits sufficient knowledge and understanding a necessity. The demarcation between nutritious/medicinal vegetables and toxic vegetables is very thin. The most commonly consumed tuber, potato (*Solanum tuberosum*), also contains a toxin, solanine which is destroyed by heat.

VEGETABLES HAVING HERBAL POTENTIAL AND PERSPECTIVES

Raw potatoes are very useful in gastrointestinal problems like dyspeptia and its topical application is helpful in pain or for softening furuncles (Vlachojannis *et al.*, 2010). *Bidens biternata*, a leafy vegetable for the Paniya and Kattunaayika tribes in Kerala (India) is helpful to cure hepatitis, cold, cough, dysentery, etc (Sukumaran *et al.*, 2012). The ginger and garlic possess antioxidant, anticancerous and antioxidant properties (Tilak *et al.*, 2005; Park *et al.*, 2012; Dhama *et al.*, 2013c). Due to presence of allicin in garlic, it is beneficial for the treating plasmodium infection (Feng *et al.*, 2012). The ginger and onion posses therapeutic applications against bacterial infections particularly due to gram positive bacteria (Alzorekya and Nakahara, 2003). Onion is helpful in lowering the lipid level in body and inhibits the oxidation of low density lipoproteins (Ahmed and Bassuony, 2009). Sitaphal (*Annona squamosa*) helps in wound healing and boosting immunity (Mahima *et al.*, 2013b). Besides this, intake of fruits and vegetables reduces the risk of chronic diseases like breast cancer, diabetes mediated retinopathy and carotedi artery disease (Sun *et al.*, 2012). Methanolic extract of coriander is reported to be antibacterial (Wong and Kitts, 2006). Flavonoids present in fruit and vegetables can prevent colorectal neoplasm (Jin *et al.*, 2012).

VEGETABLES AS ETHNOVETERINARY MEDICINES (EVM)

The medicinal role of vegetables in veterinary health has been proven in many studies (Kumar and Rahal, 2000; Rahal, 2006; Ahmad *et al.*, 2006). Garlic and onion are commonly used for the treatment of food poisoning, bloat, stomach-ache, Foot-and-mouth Disease (FMD), skin

infections and hypersensitivities, arthritis, internal parasites and rheumatism. The extract of onion is useful in eye infections. Onion roots are used to facilitate expulsion of the placenta and inhalation of an essential oil from fresh bulb provides relief from cold etc. Coriander is helpful in preventing tympany, food poisoning, diarrhea, constipation, indigestion and dyspepsia (Wangensteen *et al.*, 2004). Fennel (*Foeniculum vulgare* saunf) besides serving as antifatulent also serves as an estrus inducer.

ENRICHING HUMAN BODY WITH TRACE MINERALS WITH ADDITION OF FUNGI TO VEGETABLES

The addition of endomycorrhizal fungi in vegetables under certain conditions help in increasing the uptake of trace elements. Such fungi include: *Glomus mossae*; *Glomus calendonium*; spores of E3 as well as mycelium that have been tested on various vegetables. Such vegetables include carrots and onions; parsnips and potatoes. For treatment of plants, mycorrhizal inoculum is used singly or in combination with rock phosphate; Nitrate-potash-and Phosphorus (NPK) fertilizer; or ashes from wood; or can be placed in control group. There is lower uptake of trace elements when plants are given only alone among the tree fertilizers. It has been seen that on application of mycorrhizal inoculum there is increase in content of trace elements. When the rock phosphate or NPK fertilizers are used however in combination with the inoculum there is either lower uptake of trace elements (except phosphorus) or there is colonization of mycorrhiza. There is also increase in the uptake of trace elements on application of both ashes of wood as well as the inoculums (Ward *et al.*, 2001).

RECENT TRENDS FOR EXPLORING MULTI-DIMENSIONAL USAGES OF VEGETABLES

Recently, the search for effective methods involving organic production of the vegetables having higher and valuable nutritive value (overall) is of high interest. Investigations have been carried out on the nutrient value of food that are produced organically as well as conventionally but there are lack in consistency of results (Worthington, 1999; Bourn and Prescott, 2002; Mitchell and Chassy, 2007; Safefood Consulting Inc., 2007). The differences in vitamin C as well as riboflavin and beta-carotene between few green vegetables (Chinese mustard; Chinese kale; lettuce; spinach and swamp cabbage) grown in this way have been examined. The level of all the three nutrients have been found higher only in the swamp cabbage among the food that is organically produced than that produced conventionally.

Higher levels of nutrients are usually contained in foods which are produced organically, however the environmental as well as post-harvest factors may influence the production if controlled poorly (Ismail and Fun, 2003). The overuse of pesticides and herbicides inhibits the ability of plants to uptake as well as accumulate phytochemicals. Synthetic fertilizers however, do not contain various nutrients that are important for plants and may alter soil properties resulting into inhibition of the uptake of various phytochemicals. These crucial issues need to be considered for successful organic production systems to grow and produce better vegetables (Halweil, 2007).

More recently, various plants have been identified as safe and economic expression systems for producing the recombinant proteins viz., hormones, cytokines, monoclonal antibodies, bulk enzymes and vaccines (Tacket, 2009; Huy *et al.*, 2011; Dhama *et al.*, 2013d). Transgenic tomatoes lines have been developed containing the multiepitope antigenic gene of *Toxoplasma gondii* (Tg-MAG) which produces tomatoes containing Tg-MAG recombinant protein with good immune activity (Zhou *et al.*, 2008). The edible plant parts can be used as oral vaccine or some of the desired antigen can be purified from the plants and be used by alternative routes (Dhama *et al.*, 2013d). Various plant species including cowpea, lettuce, maize, lupin, spinach, tobacco, potato (Thanavala and Lugade, 2010), corn, pea, carrot (Zhang *et al.*, 2010) and tomato (Salyaev *et al.*, 2009; Soria-Guerra *et al.*, 2011) etc., have been used with different rate of success to express the candidate vaccine for Human Immunodeficiency Virus (HIV) (Horn *et al.*, 2003), malaria, Norwalk virus, rotavirus, measles, anthrax and human papillomavirus (Giorgi *et al.*, 2010) and Peste des petits ruminants (PPR) (Khandelwal *et al.*, 2011). Mucosal vaccines against HIV, hepatitis B (Thanavala and Lugade, 2010), tuberculosis and Newcastle disease virus (NDV), diphtheria, whooping cough, tetanus, *Helicobacter pylori*, *Escherichia coli*, norovirus etc., have been developed using transgenic plants as bioreactors (Streatfield, 2006; Gomez *et al.*, 2008; Tacket, 2007, 2009; Matsui *et al.*, 2009; Shchelkunov and Shchelkunova, 2010; Salyaev *et al.*, 2010; Zhang *et al.*, 2010; Soria-Guerra *et al.*, 2011; Mathew *et al.*, 2011; Yang *et al.*, 2011; Dhama *et al.*, 2013d). Apart from these beneficial applications, transgenic lettuce can be used for expressing cholera toxin B subunit gene (CTB) fusion protein against porcine epidemic diarrhea virus infection (Huy *et al.*, 2011); protein F1-V from *Yersinia pestis* to provide immunity against plague (Rosales-Mendoza *et al.*, 2010); transgenic potato for vaccine production against porcine reproductive and respiratory syndrome virus (Chen and Liu, 2011).

Genetic engineering has the capacity to significantly increase the phytonutrients in plants and thus reducing the risk of chronic disease (Martin, 2012). Transplastomic tomatoes have been developed, which contain high carotenoid, a potent antioxidant and provide precursor of vitamin A (Mattoo *et al.*, 2007; Apel and Bock, 2009; Fraser *et al.*, 2009). The unique purple (Pr) gene mutation in cauliflower (*Brassica oleracea* var botrytis) formed a new variety with enhanced properties of promotion of health and visual appeal (Chiu *et al.*, 2010). Scientists are also attempting to use the genetic and molecular approaches for increasing the levels of tocopherols in potato (*Solanum tuberosum*) tubers through metabolic engineering tools and techniques (Crowell *et al.*, 2008).

PRECAUTIONARY MEASURES, CARE AND KITCHEN HYGIENE PRACTICES DURING USAGES OF VEGETABLES

Vegetables may also be the source of many disease outbreaks for example of norovirus by unhygienic practices of kitchen personnels (Baert *et al.*, 2011; Schmid *et al.*, 2011), *Salmonella*, Shiga toxin-producing *E. coli* O: 157 (Berger *et al.*, 2010) by consuming contaminated leafy vegetables, radish sprouts and pre-packaged spinach. Diarrheic *E. coli* including enterotoxigenic (ETEC), enteropathogenic (EPEC), enteroinvasive (EIEC), enteroaggregative (EAEC), diffuse adherent (DAEC) and Shiga toxin-producing (STEC); *E. coli* (Castro-Rosas *et al.*, 2012); *Vibrio parahaemolyticus* (Tunung *et al.*, 2010); *Salmonella* (Singh *et al.*, 2005), *Shigella* and *Listeria monocytogenes* (Guchi and Ashenafi, 2010; Franz *et al.*, 2010; Santana *et al.*, 2012), intestinal helminthes like *Trichuris trichiura* (Huat *et al.*, 2012). They may act as source of protozoa too, which include: *Giardia* and *Cryptosporidium* (Amoros *et al.*, 2010) commonly present on ready to eat (RTE) vegetables particularly when the vegetables were grown in untreated sewage water.

Various chemicals like pesticides; insecticides; herbicides and fungicides used during the production of vegetables may play an important role in survival and growth of microbes viz., *Pseudomonas*, *Salmonella*, *E. coli* and other coliforms on vegetables and affect their shelf-life and public health safety (Ng *et al.*, 2005). Since raw Ready to Eat (RTE) vegetables cannot be heated, therefore it is recommended that these should be washed thoroughly and treated with food grade chemicals to reduce the microbial load on them (Guchi and Ashenafi, 2010). Salad dressing with spinach leaves mixed with

vinegar and oil is helpful in reducing the bacterial load (Faith *et al.*, 2012). So, there is a great need of effective intervention strategies for control of infectious organisms in the vegetables (Dhama *et al.*, 2013a). Through washing followed by boiling and/or cooking processes is also quite effective in reducing the pesticides and insecticides residues (Kaur *et al.*, 2011).

Indiscriminate use of pesticides, insecticides or other synthetic compounds leads to contamination of water and food sources including vegetables (Kumar *et al.*, 2008). Various vegetables like beans, brinjal, tomato, carrot, cabbage, okra, spinach, green beans, green chilli, crucifers and cucurbits have been reported to be containing the harmful insecticides like, chlorpyrifos, cypermethrin, decamethrin, organophosphates, pyrethroids, imidacloprid, beta-cyfluthrin, bifenthrin, fenvalerate, α -cypermethrin and λ -cyhalothrin (Arora, 2009; Kaur *et al.*, 2011; Gowda and Somashekar, 2012; Banerjee *et al.*, 2012; Bouri *et al.*, 2012; Zhang *et al.*, 2012b). Thus there is increasing trend for the use of biological control agents such as *B. thuringiensis*, a gram positive soil bacterium (Bt) as effective biopesticides (Kumar *et al.*, 2008), commonly used in vegetables crop like Indian mustard (*Brassica juncea*) (Cao *et al.*, 2008) and brinjal (Kumar *et al.*, 2011). Vegetables with pest repellent properties are also being attempted for example transgenic Chinese cabbage expressing the potato proteinase inhibitor II gene (pinII) has the ability to repel pests (Zhang *et al.*, 2012a).

READY-TO-EAT PRODUCTS AND HEALTH HAZARDS

Now-a-days, there is an increase in trend of packaged or canned food, fast food or processed food consumption due to socioeconomic changes in the life. But the consumption of these foods is not always safe for the health. The dietary pattern (consuming red or processed food) of western culture may increase the development of colo-rectal cancer (Yusof *et al.*, 2012). Packaged/canned food are generally recognized as safe food but canned vegetables and fruits and their juices, canned hot dog chili sauce etc are very common cause of botulism outbreaks, which is a serious public health concern and cause of high case mortality round the globe (Date *et al.*, 2011; Juliao *et al.*, 2013). In a study, fast food consumption may lead to more chances of asthma, rhinoconjunctivitis and aczema (Ellwood *et al.*, 2013). Deep fried food can increase the risk of prostate cancer (Stott-Miller *et al.*, 2013). Ready-to-eat foods viz., packaged salads, sandwiches, hamburger, pre-cut

packaged lettuce are also potent source of various pathogens like *Salmonella typhimurium*, *Listeria*, verotoxic *E. coli* etc (Hanning *et al.*, 2008; Signorini and Frizzo, 2009; Little *et al.*, 2010; Taban and Halkman, 2011; Boxall *et al.*, 2011). In Japan, consumption of pickles named 'Wafu-Kimuchi' a Japanese style pickle was the source of outbreak of enterohemorrhagic *E. coli* O157:H7 (Ozeki *et al.*, 2003). In the era of one health, one medicine, all precautionary measures need to be adapted along with following appropriate prevention and control measures for checking pathogens transmitted to animals and humans from contaminated vegetables (Dhama *et al.*, 2013e, f).

CONTROLLED ABIOTIC STRESSES AS A TOOL FOR ENHANCING NUTRACEUTICAL CONTENT AND ADDING-VALUE TO FRESH FRUITS AND VEGETABLES

The fresh fruit and vegetable industry is an important contributor to the world economy. The global market for nutraceuticals and functional foods is expanding at an exponential rate. Products containing nutraceuticals contributed an estimated value of \$65 billion (Lachance, 2002). Many nutraceuticals (vitamin C, E, carotenoids etc) are antioxidants and have preventive roles against certain cancers and cardiovascular diseases (Scheerens, 2001). There is a need to enhance the health benefit properties of fresh produce which in turn will add value and create new opportunities for producers and processors by reaching the health-oriented markets. This goal can be achieved by providing technologies that can ensure the delivery of high quality products with high quantities of the desired nutraceuticals.

Certain abiotic stress treatments, like temperature, UV light, wounding, phytohormones, altered gas composition, heat shock and water stress etc., will influence the secondary metabolism of fresh produce and augment the synthesis of phytochemicals with nutraceutical activity or lessen the synthesis of undesirable compounds. Abiotic stresses affect the biosynthesis of the three principal groups of secondary metabolites viz., terpenes, phenolics and nitrogen-containing compounds. Phytochemical accumulation or losses also gets affected by inducing an increase or reduction in key enzyme activities of secondary metabolic pathways (Dixon and Paiva, 1995). The fresh produce industry must explore the usefulness of controlled stresses to enhance the health benefit properties of fresh-cut or whole fresh produce. Similarly, the food processing and dietary supplement industries can also utilize it to obtain healthier processed products or boost nutraceutical yields.

Preharvest abiotic stresses have been used to enhance the quality and yield of products in the field (Kalt *et al.*, 2001). Exposure to higher light intensity or those with less frequent irrigation has been found to augment vitamin C production (Lee and Kader, 2000). An increase in pungency levels is seen in water-stressed pepper fruits (Estrada *et al.*, 1999). Postharvest abiotic stresses may affect the levels of secondary metabolites in plant tissues. The ripening and temperature affect anthocyanin accumulation and its content in certain fruits (blackberries, apples and strawberries) and in colored potatoes during cold storage (Lewis *et al.*, 1999). Wounding helped in increasing the anthocyanins and phenolic acids in red pigmented lettuce (Ferrerres *et al.*, 1997) and phenolic compounds in carrots (Babic *et al.*, 1993a, b). Phytohormones, such as ethylene induce phenolic compounds in carrots (Lafuente *et al.*, 1996). Light stimulate the accumulation of chlorogenic acid in potato tubers (Percival and Baird, 2000), anthocyanin in red cabbage (Craker and Wetherbee, 1972) and apples (Dong *et al.*, 1995) and quercetin in apples (Reay, 1999).

The genetic potential of vegetables and fruits can be boosted to yield products with potent health benefit properties by using stresses to induce accumulation of targeted phytochemicals. Controlled postharvest abiotic stresses have useful applications in terms of increasing nutraceutical levels fruits and vegetables. The UV irradiation enriched the resveratrol content in red table and wine grapes (Cantos *et al.*, 2000). Post-harvest abiotic stresses such as methyl jasmonate increased the anthocyanin content in purple fleshed potatoes (Reyes *et al.*, 2001) and differentially potentiated phenolic compounds, avoiding the accumulation of isocoumarin phytoalexins in purple carrots (Heredia *et al.*, 2001). Antioxidant property of lettuce was found to be increased by wounding (Kang and Saltveit, 2002).

The abiotic stresses are not always beneficial as phytochemical loss or production of undesirable compounds has been reported after some stress treatments. Anthocyanin loss due to the effect of carbon dioxide in stored pomegranate arils (Holcroft *et al.*, 1998) and strawberries (Gil *et al.*, 1997) and chlorophyll loss in broccoli due to temperature (Toivonen and Sweeney, 1998) has been well documented. Heat treatments may reduce anthocyanin accumulation in strawberries during storage and phenolic synthesis in lettuce (Loaiza-Velarde and Saltveit, 2001). Water stress may induce ascorbic acid loss in strawberries (Nunes *et al.*, 1998) and leafy greens (Lazan *et al.*, 1987). Induction of the bitter compounds, isocoumarin, in carrots (Lafuente *et al.*, 1996) and xanthotoxin in parsnips (Shattuck *et al.*, 1988) by the action of ethylene has been observed.

CONCLUSION AND FUTURE PROSPECTS

Vegetables are routinely used in day today life as a compulsory ingredient of food. Their use in strengthening current community-based health services due to multifactorial usages and potential. They are designated as healthy foods of the millennium or Nutraceutical foods of the century. The current information on the nutritive and medicinal value of leafy vegetables is only the tip of the iceberg. In most cases, this knowledge is not well documented and disseminated, however, what so ever has been explored that is sufficient enough to understand the potential of vegetables in the form of household country medicine and betterment of humanity without much difficulties and cost. Still there is a long way to go as only a small part of natural medicinal components of vegetables has been documented in established medicinal databases. It is not only expected but also the need of time that with the progress of medicinal chemistry and pharmacology, more and more medicinal components should be identified from foods. Moreover, nowadays health professionals are aiming to the concept of “food sovereignty” means the most of vegetables the person eats are also grown by them. A better understanding of fruits and vegetables along with their perspectives including of microbiological, pharmaceutical, environmental, processing and food handling factors is the need of the hour. All of these facilitate in development of methods, technologies and policies aimed at reducing the risk of contamination of fresh produce and sustaining there potent nutraceuticals, medicinal and pharmacological values. Moreover, the used of plants including vegetables as bioreactors for the production of recombinant proteins such as enzymes and vaccine should also be explored to their full potential for safeguarding health of humans and their companion animals.

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