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A Review of Nutritive Values of Green Leafy Vegetables in Human Diet

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SUMMARY

Vegetables play important role in nutritional as well as food security. Among various types of vegetables, green leafy vegetables are most commonly consumed in ancient Indian daily diet and predominantly considered as exceptional source for vitamins, minerals and phenolic compounds. Mineral nutrients like iron and calcium are high in leafy vegetables than staple food grains. Also, leafy vegetables are the only natural sources of folic acid, which are considerably high in leaves of Moringa oleifera plants as compared to other leafy and non-leafy vegetables. The importance of leafy vegetables in the developing countries has been recognized only now due to their nutritional and medicinal value. Green leafy vegetables occupy an important place among food crops as these provide adequate amounts of crude fiber, carotene, a precursor of vitamin A, vitamin C, riboflavin, folic acid and mineral salts like calcium, iron, phosphorus etc. They are also fair sources of proteins, containing about 2-7% and they are equal to legumes, soybeans or whole egg. They form cheap and best source of food. Green leafy vegetables are highly seasonal and are available in plenty at a particular season and can be easily cooked. However, edible green leafy vegetables appear to be underutilized throughout the world and, in some area, may even be diminished in use. Green leafy vegetables are rich source of a number of micronutrients and phytochemicals and it was the phytochemicals that appeared to provide much of the disease fighting power. In this context, this paper reviewed nutritional factors as well as importance of green leafy vegetables in human diet.

INTRODUCTION

Generally, vegetables are widely designated as "protective foods" in human diet due to their varied health benefits attributable to the richness in vitamins, essential fatty acids, minerals, amino acids and dietary fibre (Shukla *et al*., 2016) and various essential bioactive compounds (Da Silva and Imai S, 2017). These include health-promoting plant secondary metabolites composed of antioxidants and phenolic compounds. It is well acknowledged that to meet recommended daily allowance of nutrition, the World Health Organization (WHO) recommendation at least 400g of fruit and non-starchy vegetables (WHO, 2013) is used. The dietary guidelines for Americans recommend five servings of vegetables per day based on an intake of 2000 calories (HHS/USDA, 2015). It is also recommended that one of the five servings of vegetables should be green leafy vegetables. Nutritionists and dieticians are of the opinion that people should diversify their diets as no single vegetable meets all the nutritional requirements necessary for good health and wellbeing (Grusak and Della, 1999). Hence in today's agri-food systems, more emphasize is given to crop diversification with the intention of fulfilling human nutritional requirements, and to reduce the pressure on cereal production (Nath *et al*., 2004). Globally, crop diversity and nutritional value of vegetable crops are of special significance for improving food and nutrition security (Fresco and Baudoin, 2004). Plants are major sources of numerous bioactive compounds collectively termed as phytochemicals, which are reported to be key to good health (Da Silva and Imai S, 2017). Researchers have shown that the composition of phytochemicals is very distinctive and varies widely amongst plants (Dias, 2012). For instance, vegetables that belong to the *Alliaceae* family (e.g., onions, garlic, shallots, leek, Welsh onion and chives) are characterized by thiosulfides and flavonoids. Cruciferous vegetables that belong to the *Brassicaceae* family (e.g., cabbage, cauliflower, kale and broccoli) contain high sources of glucosinolates, and those that belong to *Cucurbitaceae* family (e.g., squash, pumpkin, cucumber, melon and bitter gourd) are rich in carotenoids and tocopherols (Da Silva and Imai S, 2017). However, the compositions of these phytochemicals have been documented to be affected by factors such as genotypic characteristics, climatic conditions, edaphic factors and management practices (Iheshiulo *et al*., 2017; Bian, *et al*., 2015; Odhav, *et al*., 2007 and Lee and Kader, 2000). For instance, it was shown that for the same plant species, the mineral nutrients content and total phenolic compounds and antioxidants can be altered by the application of different sources of nutrients (Iheshiulo *et al*., 2017; Bian, *et al*., 2015; Odhav, *et al*., 2007; Lee and Kader, 2000 and Zhang *et al*., 2017).

It is worth noting that while there are many groups of chemical compounds that have health benefits, others can be very toxic and fatal to humans when consumed. As such phytochemicals can be broadly classified as nutritional (e.g., essential fatty acids, proteins, vitamins, minerals and phenolic compounds) and anti-nutritional

(e.g., oxalates, tannins, nitrate) chemical compounds (Uusiku, *et al*., 2010). It is important for consumers and researchers to understand the importance of these chemicals and their impacts on human health and available methods for their assessments. This paper aims at reviewing the common phytochemicals in green leafy vegetables grown in various geographic locations of the world. The health-promoting phytochemicals will be referred to as nutritional factors and the health-inhibiting or toxic phytochemicals will be referred to as anti-nutritional factors. The importance of these phytochemicals will be highlighted to reflect their beneficial or toxicity and/or inhibitory effects on human health and wellbeing. Additionally, a brief description will be made on methods for determining the compositions of these phytochemicals in green leafy vegetables.

Nutritional factors in green leafy vegetables

Proteins:

Proteins are large and complex molecules composed of various compositions of amino acids. Proteins play critical roles in cellular functions, structure and regulations of metabolic activities in all living organisms. Hence, proteins have primary importance in the daily diets of consumers. Green leafy vegetables are the richest and cheapest sources of proteins. This is because of their ability to synthesize and accumulative amino acids with the help of abundant source of sunlight, water, oxygen and nitrogen which is readily available in the atmosphere (Aletor *et al*., 2002). About 50% of total leaf cell protein is dominated by ribulose-1,5-bisphosphate carboxylase/oxygenase (RUBISCO), which can be found in leaf chloroplasts. It plays a vital role in the fixation of atmospheric carbon during photosynthesis (Kawashima and Wildman, 1970). RUBISCO is a similar protein found in all green leafy vegetables with few changes in amino acid groups from species to species. Recent evidence showed that green leafy vegetables such as spinach *(Spinacia oleracea)*, broccoli *(Brassica oleracea var. Italic)* and duckweed *(Lemna perpusilla)* provide all the essential amino acids that meet the FAO nutrition standards (Edelman and Colt, 2016). Evidence showed that apart from lower methionine content, cassava *(Manihot esculenta)* leaves consumed as green leafy vegetable has amino acids profile comparable with pulse and dairy products (Fasuyi, 2005). It has been found that some of the African leafy vegetables such as green leaves of septic weed (*Senna occidentalis*) and cassava both have 7 g protein/100 g of fresh weight. This is higher than that of exotic leafy vegetables such as *Brassica oleracea* Capitate with a protein content of 1 g/100 g of fresh weight (Uusiku, *et al*., 2010). However, protein content in African leafy vegetables cannot be compared with legume proteins such as white lupines *(Lupinus albus)*, which has 11.5 g protein/100g of fresh weight (Kalogeropoulos *et al*., 2010). The amount of protein content in leafy vegetables can vary with farming practices and prevailing environmental conditions (Odhav *et al*., 2007). Bioavailability of protein in leafy vegetables is typically influenced by thermal processing, which inactivates heat-labile anti-nutritional factors such as protease inhibitors, lectins, thiaminases and goitrogens but enhances digestibility of proteins and starch (Gibson *et al*., 2006). Total protein is determined by evaluating total N using the Kjedahl method and multiplying the N value by 6.25 as described by Association of the Official Analytical Chemists (AOAC report. 1990).

Dietary fibre:

Dietary fibre is the constituent of plant cell wall (MacDougall, 1995). Dietary fibre is classified as soluble dietary fibre (SDF) and insoluble dietary fibre (IDF), which is collectively termed as total dietary fibre (TDF). Green leafy vegetables have been traditionally recognized as good sources of dietary fibre (Gopalan *et al*., 2000). Literature information showed that Indian Green leafy vegetables such as basella *(Basella rubra)*, fenugreek *(Trigonella foenum graecum)*, hibiscus *(Hibiscus cannabinus)*, coriander *(Coriandrum sativum)*, cabbage *(Brassica oleracea)* and spinach *(Spinacia oleracea)* are good sources of soluble dietary fibre content. Consumption of higher levels of vegetable fibre resulted in reduced risk of cardiovascular diseases and possibly, colon cancer (Jenkins *et al*., 2001). It was more significant in resolving the problem of constipation, diabetes, diverticulosis and obesity (National Research council report, 1989; Roberfroid, 1993 and Spiller, 2001). The amount of total dietary fibre in green leafy vegetables can vary with different plant variety of the same species, agro-climatic conditions, stages of maturity and type and rate of fertilizer applications. Estimation of DF in GLV can be performed by using lyophilized powder and its fractions by enzymatic or gravimetric methods of AOAC.

Vitamins:

Green leafy vegetables are abundant sources for β-carotene. In leaves, vitamin A is present in the form of provitamin A carotenoids such as β-carotene (ca. 25-30%), α-carotene, γ-carotene, β-cryptoxanthin and non-provitamin A carotenoids lutein (ca. 45%), violaxanthin (ca. 15%) and neoxanthin (ca. 15%) reported by Britton, 1996, the content of vitamin A is expressed in retinol equivalents (RE) with one (1) RE being equivalent to 6 µg of β-carotene and 12µg of the other pro vitamin carotenoids. The recommended daily allowance (RDA) for vitamin A is also expressed in RE but recently, the U.S. Institute of Medicine has replaced RE with the term ‘‘retinol activity equivalent’’ (RAE; IOM, 2001). The Institute of Medicine dietary reference intake recommended 900 and 700 µg RAE of vitamin A for an adult male and female, respectively (Trumbo *et al*., 2001) Increasing the consumption of green leafy vegetables that are widely available in developing countries help in combating prevailing vitamin A deficiency in regions where pharmaceutical supplements and vitamin A fortified foods are limited (Baudoin and Louise 2002). Processing techniques such as cooking, boiling, and steaming have significant influence on availability of carotenoids in green leafy vegetables (Cheynier, 2005). A study conducted on 30 commonly used green leafy vegetables for nutritional purposes confirm the presence of good amount of lutein (Raju *et al*., 2007) and richness in various vitamins. For instance, any species of Amaranths are excellent source of vitamin C (Jiménez and Grusak 2017) Furthermore, comparisons can be made on vitamins distribution among seeds and leafy plants. For instance, data obtained from USDA national nutrient database ((Edelman and Colt, 2016) clearly shows that vitamin A and K1 (Phylloquinone) in leafy vegetables are exceptionally high for kale and spinach than the cereals and pulses. In addition, cereals and pulses are devoid of vitamin C whereas, leafy vegetables are the potential sources of vitamin C with good amount in kale (1014mg/100g). Vitamin E in duck weed (45.7mg/100g) is high among many common leafy vegetables and seeds. However, vitamin B5 in cereals and pulses are higher than spinach and kale but not in duck weed (2.1mg/100g). Foliate is a water-soluble compound, which belongs to vitamin B group. Deficiency of folic acid has severe metabolic and clinical consequences. Plants are the major source of foliates for humans especially, green leafy vegetables. (Castorena *et al*., 2014) Cereal grains and tuber based staple diet are very low in foliate, which can be improved by the addition of green leafy vegetables. Leaves of colocasia *(Colocasia esculenta)* are used as an excellent source of foliate in the Indian diet. However, it is noticed that about 50% or more of foliate in food is found to be destroyed during cooking. This is mainly attributed to prolonged heating of vegetables in a large volume of water. Hence, it is advisable to consume the water used during the cooking of vegetables (FAO report, 2001). A research study reported that5-formyl-5,6,7,8-tetrahydrofolic acid (502.1µg per 100g dry weight) and 5,6,7,8-tetrahydrofolic acid (223.9µg/100g dry weight) are the dominant forms of foliate present in *Moringa oleifera*. *Moringais* known to be a significant source of foliate with higher bioavailability compared to other vegetables (Saini *et al*., 2016). High-performance liquid chromatography i.e., HPLC–DAD–MS/MS based method developed by (Santos *et al*., 2012) allows a simple and sequential extraction and monitoring of several free forms of water-soluble vitamins (vitamins C, B1, B2, B3, B5, B6 and B9) and fat-soluble vitamins (pro-vitamin A and vitamin E) present in raw green leafy vegetables.

Minerals:

WHO (1996) stated that the “overall malnutrition must no longer be considered without reference to micronutrient status, as the two are inextricably linked. Attempting to improve protein-energy status without addressing micronutrient deficiencies will not result in optimal growth and function” reported by Baudoin and Louise 2002. Metal ions are important to the normal functioning and wellbeing of humankind as they serve as cofactors in enzymatic reactions, and maintain protein structures. Iron deficiency in women and children lead to the development of anaemia (Galloway, 2003). Zinc deficiency results in impaired gastrointestinal and immune functions (Welch, 1993). The data shows that green leafy vegetables are good sources of mineral nutrients. For instance, spinach has highest amount of calcium (1036mg/100g), magnesium (827mg/100g), iron (28.4mg/100g) and sodium (827mg/100g) whereas duck weed is high in zinc (15mg/100g). However, soy seed also has considerable amount of calcium (195mg/100g), iron (6mg/100g), magnesium (407mg/100g), phosphorus (469mg/100g) and potassium (2387mg/100g), sodium (12.3mg/100g) and zinc (3.7mg/100g) when compared to all the seeds but comparatively higher in the leafy vegetables. The absorption of mineral nutrients is adversely

affected by the presence of inhibitors like oxalate and phytates and many other anti-nutritional factors (Kumari *et al*., 2004). Minerals have greater stability during food processing as compared to vitamins and proteins (Kala and Prakash 2004). But mineral profiles in green leafy vegetables are highly dependent on application of external synthetic fertilizer or organic soil amendments. Minerals in leafy vegetables can be determined by atomic absorption spectrophotometry (AAS) method (AOAC, 2005) inductively coupled plasma optical emission spectroscopy (ICP-OES).

Essential fatty acids:

Omega-3 fatty acids are important for normal growth and development, and play vital role in the prevention and treatment of coronary artery diseases, hypertension, diabetes, arthritis, cancer and other inflammatory and autoimmune disorders (Hamazaki and Okuyama 2001). α-linolenic acid, the precursor of omega-3 fatty acid has been found in green leafy vegetables with beneficial effects on health (Simopoulos, 2002). Also reported that essential fatty acids help to control various chronic diseases. Evidence shows that omega-3 fatty acids is relatively high in wild plants than in cultivated vegetables. For instance, the US Department of Agriculture (USDA) and other studies have reported that purslane *(Portulaca oleracea)*, a wild plant and weed in most cases, is a good non-aquatic source of α-linolenic acid with 4 mg/g fresh weight. The same study also reported the presence of α-linolenic acid in other leafy green vegetables such as 1.7 mg/gin spinach, 1.1mg/g in mustard greens, 0.7 mg/g in red leaf lettuce and 0.6 mg/g in butter crunch lettuce (Simopoulos, 2002). Fatty acids in leaves can be determined by gas chromatography reported by Shukla *et al*., 2016.

CONCLUSION

Green leafy vegetables provide vital nutrients required for human health and wellbeing. These include amino acids, vitamins, essential fatty acids, minerals and dietary fibre. It also has significant socioeconomic benefits. For instance, farmers in the tropics and subtropics, mostly women, grow and harvest green leafy vegetables to supplement household income. In rural areas, traditional leafy vegetables play important role as nutritional source, and it is available all-year. Green leafy vegetables are usually considered as the cheapest source of food for vitamins and micronutrients supplementation to combat nutrients deficiencies. It is also used as herbal and medicinal plants in various cultural and traditional settings for many different ailments. The presence of anti-nutritional factors such as nitrates, oxalates, phytates, cyanogenic glycosides and tannins in green leafy vegetables can affect micronutrients absorption and thus, make the latter unavailable. Thermal processing of leafy vegetables through boiling, cooking and blanching before consumption help in reducing the level of anti-nutrients. There is a scope for research to identify and explore the potential of edible leaves of indigenous and under-exploited plants for use as food and medicine, and inclusion in mainstream agri-food systems. Poverty is a major problem in our country for which many are unable to get required amount of nutrient in their daily diet. However, this can be rectified by the various underexploited leafy vegetables such as available locally in rural-tribal areas of India. India is blessed with many such type of leafy vegetable which need to be exploited commercially. The growth habits of most of these crops are of short duration which hardly requires 3-4 months to obtain the herbage yield. Also these are good source of various phytochemicals such as phenolic acids, flavonoids, tannins, saponins which help in building antioxidant properties in our body to fight against several diseases like chronic diseases, diabetes, etc. Many can be processed and stored for future use. So, focus need to be concerned towards their commercial cultivation and improvement for nutritional security

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