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Nutritional components in green leafy vegetables: A review

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Abstract

Green leafy vegetables have generated interest worldwide as they exhibit multiple benefits for health of human beings. This paper reviews the literature on nutritional components in some important frequently green leafy vegetables. Green leafy vegetables are major components of a healthy diet, and their sufficient daily consumption could help prevent major diseases. These vegetables may help to meet daily requirements of these and other essential nutrients, especially in individuals with marginal nutritional status. Vegetables can form the cheapest and most readily available sources of important fibers, vitamins, minerals, essential amino acids and substances that help protect you from disease particularly. The type and composition of nutritional components vary among genera and species of different edible leafy vegetables plants. The aim is to evaluate the nutritional value of these plant species and their potential impact on the nutritional status. The low caloric value of leafy vegetables makes them ideal for weight management and these are a rich source of nutrients, high in dietary fiber, low in lipids, and rich in foliate, vitamin-C (ascorbic acid), vitamin-K (phyloquinone), magnesium, and potassium. 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 spinach, asparagus, lettuce, mustard green, colocasia green leaf and turnip green plants as compared to other leafy and non-leafy vegetables. The consumption, cultivation and possibly the commercialization of these leafy vegetables should therefore be promoted.

Keywords: nutritional components, green leafy vegetables, proteins, vitamins, minerals

Introduction

Green leafy vegetables occupy an important place among the food crops as these provide adequate amounts of many vitamins and minerals for humans. They are rich source of vitamins like beta-carotene, ascorbic acid, riboflavin, folic acid and minerals like calcium, iron, phosphorous etc. In nature, there are many underutilized greens of promising nutritive value, which can nourish the ever increasing human population. Green leafy vegetables are of importance to the nutrition of the populations especially in the developing countries. India being blessed with a variety of natural surroundings, varying climates and seasons, has a varied species of leafy vegetables. A large number of leaves from different sources such as perennial trees, aquatic plants and annuals are consumed. Some of the commonly consumed leafy vegetables are spinach (*Spinacia oleracea*), amaranth (*Amaranthus gangeticus*), fenugreek (*Trigonella foenum graecum*), drumstick (*Moringa oleifera*), cabbage (*Brassica oleracea* var. capitata), bathua (*Chenopodium album*), etc. These greens are inexpensive, high yielding, a part of the local diet and often easily available. Some of the greens are also used as leafy spices because of their flavour such as curry leaf (*Murraya koenigii*), coriander leaves (*Coriandrum sativum*), mint (*Mentha spicata*), bay leaf (*Laurus nobilis*), basil (*Ocimum basilicum*), etc. Normally, 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 fiber and various essential bioactive compounds. There is also growing ignorance among young people about the existence of these readily available nutritionally rich food plants^[35]. They are very important protective foods and useful for the maintenance of health and for prevention of various diseases^[12]. Apart from the variety which they add to the menu^[2, 7], they are valuable sources of nutrients especially in rural areas where they contributes substantially to minerals, vitamins, fibers, proteins and other nutrients which are usually in short supply in daily diets. Leafy vegetables have low energy densities thus recommended for weight management^[33]. Vitamins are important for human health and among the vitamins, vitamin C is an essential micronutrient required for normal metabolic functions of the body. Vitamin C plays an important role as a component of enzymes involved in the synthesis of collagens and carnitine. Vitamin C is the major water-soluble antioxidant in the human body.

Green leafy vegetables contains numerous minerals such as iron (Fe), calcium (Ca), phosphorus (P), Copper (Cu), Zinc (Zn), Sodium (Na) and chloride (Cl) which have vital for growth, metabolism etc (table-1). The predominant elements found in green leafy vegetables are iron (Fe), calcium (Ca), potassium (K), sodium (Na) etc. Dark lettuces are rich in vitamins A, C and K; eating them regularly will improve your eyesight, bone health and skin elasticity while helping your blood to clot normally. Spinach is one of the most nutritious foods available, as it is low in calories and high in vitamins; spinach is one of the most nutrient-dense foods in existence. It is packed with vitamins A and C, as well as foliate. Heat reduces the green's oxalate content, freeing up its dietary calcium [45], cooked spinach gives you more nutrition than raw, but is excellent eaten raw in salads. These include health-promoting plant secondary metabolites composed of antioxidants and phenolic compounds. WHO/FAO (2003) published a report recommends minimum of 400g of fruit and vegetables per day (excluding potatoes and other starchy tubers) for the prevention of chronic diseases such as heart disease, cancer, diabetes and obesity, as well as for the prevention and alleviation of several micronutrient deficiencies. 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. Spinach and other

green leafy vegetables are rich sources of foliate along with other vegetables, fruit, Brewer's yeast, legumes, and especially liver^[31, 32]. 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^[3, 51]. Globally, crop diversity and nutritional value of vegetable crops are of special significance for improving food and nutrition security^[4, 32].

Fresh green vegetables are also good sources of folic acid, which is required for the multiplication and maturation of red cells^[18]. Cabbage is an excellent source of vitamin-C and vitamin-K, containing more than 20% of the daily value for each of these nutrients per serving^[5]. Cabbage is also a good source of dietary fiber, vitamin B-6 and folate, with no other nutrients having significant content per 100 gram serving. Dark green lettuces include romaine lettuce (*Lactuca sativa* L. var. longifolia), arugula or tara mira (*Eruca vesicaria*) and butter head lettuce (*Lactuca sativa* var. capitata). These nutrient dense leaves are crisp and slightly bitter, and most people use them to make raw salads^[5, 47]. Plants are major sources of numerous bioactive compounds collectively termed as phytochemicals, which are reported to be key to good health^[6, 15]. As such phytochemicals can be broadly classified as nutritional components (e.g., essential fatty acids, proteins, vitamins, minerals and phenolic compounds). Nowadays, underutilized foods are gaining importance as a means to increase the per capita availability of foods^[9, 16].

Table 1: Nutritional composition of some green leafy vegetables (per 100 g edible portion)

Vegetables	Macronutrients					Vitamins				Minerals		
	Energy	Moisture	Protein	Fat	Carbohydrate	Thiamine	Riboflavin	Niacin	Ascorbic	Calcium	Phosphorus	Iron
Spinach	26.0	92.1	2.0	0.7	2.90	30	260	500	28	73	21	1140
Coriander	44.0	86.3	3.3	0.6	6.3	50	60	800	135	184	71	1420
Mint leaves	48.0	84.9	4.8	0.6	5.8	50	260	1000	27	200	62	1560
Fenugreek	49.0	86.1	4.4	0.9	6.0	40	310	800	82	395	51	1930
Bathua	30.0	89.6	3.7	0.4	2.9	10	140	600	35	150	80	4200
Cabbage	27.0	91.9	1.8	0.1	4.6	60	90	400	124	39	44	800
Amaranth	45.0	85.7	4.0	0.5	6.1	30	30	1200	99.0	397	83	3490
Drumstick	38.0	75.9	6.7	1.7	4.1	60	50	800	52	440	70	850

Source: Gopalan *et al.*, (2004).

Nutritional components in green leafy vegetables

Dietary fiber

Green leafy vegetables have been traditionally recognized as good sources of dietary fiber^[39]. There are epidemiological evidences that show that dietary fiber is important in preventing several diseases, especially the fiber that is found in leafy vegetables such as celery, cabbage, spinach and lettuce that is characterized by high water content and a high percentage of fiber^[12]. Fibre has also been found to lower cholesterol levels by reducing the reabsorption of cholesterol produced by the body to help with the digestion of fat. Vegetables that belong to the cabbage family (cabbage, cauliflower, turnips and brussels sprouts) contain compounds that may be good at protecting against cancer. Vegetables that are high in fibre are spinach and cabbage^[36]. Literature information showed that Indian green leafy vegetables such as cabbage, spinach, fenugreek, coriander and basella are good sources of soluble dietary fiber content. Consumption of higher levels of vegetable fiber resulted keeps the digestive system healthy, helps healthy body weight and reduced risk of cardiovascular diseases and possibly, colon cancer^{[36],[25]}. It was more significant in resolving the problem of constipation, diabetes, diverticulitis and obesity^[44].

Vitamins

Like other leafy green vegetables, spinach contains a wealth of nutrients. Each half-cup of boiled spinach provides 573mcg of vitamin A, which is 229% of the daily value (DV). Some research indicates that spinach can lower blood pressure and improve heart health. Fresh, young, leaves contain more vitamin C than mature plants. The green outer leaves of lettuce and cabbage are rich in vitamin, than white inner leaves. Thinner and greater leaves are more nutritious and usually have lower calories. Carotenoids, like beta-carotene, are found in plant foods and have to be converted by the body into vitamin A^[49]. Green leafy vegetables are abundant sources for beta-carotene. In leaves, vitamin-A is present in the form of provitamin-A carotenoids such as beta-carotene (ca. 25-30%), alpha-carotene, beta-cryptoxanthin, gamma-carotene and non-provitamin A carotenoids lutein (ca. 45%), violaxanthin (ca. 15%) and neoxanthin (ca. 15%),^[40] the content of vitamin-A is expressed in retinol equivalents (RE) with one (1) RE being equivalent to 6µg of beta-carotene and 12µg of the other pro vitamin carotenoids. Processing techniques such as cooking, boiling, and steaming have significant influence on availability of carotenoids content in green leafy vegetables^[40]. A study conducted on 30 commonly used green leafy vegetables for

nutritional purposes confirm the presence of good amount of lutein [37] and richness in various vitamins. For instance, any species of Amaranths are excellent source of vitamin-C [26]. Moreover, comparisons can be made on vitamins distribution among seeds and leafy plants.

For instance, data obtained from USDA national nutrient database [50, 52], clearly shows that vitamin A and K1 (Phylloquinone) in leafy vegetables are exceptionally high for kale and spinach than the cereals and pulses. Vitamin-E in duck weed (45.7mg/100g) is high among many common leafy vegetables and seeds. Folate is a water-soluble compound, which belongs to vitamin-B (B-9) group. Deficiency of folic acid has severe metabolic and clinical consequences. Plants are the major source of foliates for humans especially, green leafy vegetables [31]. 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 [30]. High-performance liquid chromatography i.e. HPLC-DAD-MS/MS based method developed by Santos *et al.* [46] allows a simple and sequential extraction and monitoring of several free forms of water soluble vitamins (vitamins B-1, B-2, B-3, B-5, B-6, B-9 and C) and fat-soluble vitamins (pro-vitamin-A and vitamin-E) present in raw green leafy vegetables (Table-2).

Table 2: Vitamins composition for some green leafy vegetables

Vitamins concentrations	Leaf	
	Kale	Spinach
Vitamin A, IU	130,000	85,500
Vitamin-B1, mg	0.9	0.9
Vitamin-B2, mg	0.9	1.8
Vitamin-B5, mg	0.9	0.9
Vitamin-B6, mg	2.5	1.8
Vitamin-C, mg	1014	256
Vitamin-E, mg	9.3	18.2
Vitamin-K1, mg	6900	4400

Source: (Edelman and Colt, 2016) [9]

Proteins:

Green leafy vegetables are the richest and cheapest sources of proteins. Protein nutritional quality is determined by the proportions of essential amino acids, which cannot be synthesized by humans and hence must be provided in the diet. If only one of these amino acids is limiting, the others will be broken down and excreted, resulting in poor growth of livestock and humans and loss of nitrogen in the diet. Ten amino acids are strictly essential: lysine, isoleucine, leucine, phenylalanine, tyrosine, threonine, tryptophan, valine, histidine and methionine, all of which are present in *C. album* [21]. Green matter of *C. album* is a valuable high-protein product [27], which is another argument in favour of cultivation of this species. 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. 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. Protein nutritional quality is determined by the

proportions of essential amino acids, which cannot be synthesized by humans and hence must be provided in the diet [1]. If only one of these amino acids is limiting, the others will be broken down and excreted, resulting in poor growth of livestock and humans and loss of nitrogen in the diet. Proteins are large and complex molecules composed of various compositions of amino acids. 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 [28]. 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 [9]. 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 [14]. It has been found that some of the leafy vegetables such as green leaves of septic weed (*Senna occidentalis*) and cassava (*Manihot esculenta*) both have 7g protein/100g of fresh weight. This is higher than that of exotic leafy vegetables such as cabbage (*Brassica oleracea Capitata*) with a protein content of 1 g/100 g of fresh weight [50]. The amount of protein content in leafy vegetables can vary with farming practices and prevailing environmental conditions [34].

Minerals

This group includes spinach, lettuce, curly lettuce, chard, chicory etc. these are important minerals (iron and calcium), Vitamins (A, B-2, & C) and fiber sources. This serving also provides 17% of the DV for iron and 20% of the DV for magnesium. Magnesium plays a role in over 300 processes in the human body. Vitamin K-1 (phyloquinone), present in green, leafy vegetables and some other plant sources. The zinc content of *C. album* compares favourably to most values for green leafy vegetables reported in the literature [22]. Zinc is involved in normal functioning of immune system. Shahi (1977) conducted field studies for 2 years which revealed that *C. album* contained very high degree of N, P, K, Ca, Mg, Fe and Mn. Its nutrient content declined with advancement in age of the plant. Guerrero and Isasa (1997) reported high mineral contents than in other green leafy vegetables.

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 [4]. 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 anemia [17]. Zinc deficiency is results in impaired gastro intestinal and immune functions [33, 49]. A comparative mineral profile for seeds and green leaves are presented in Table-2. 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). Minerals have greater stability during food processing as compared to vitamins and proteins [30].

Table 3: Minerals composition of some green leafy vegetables (mg per 100 g)

Minerals	Green Leafy Vegetables	
	Kale	Spinach
Magnesium	265	827
Phosphorus	519	513
Potassium	2769	5840
Calcium	846	1036
Sodium	214	827
Iron	8.3	28.4
Zinc	-	3.2

Source: (Edelman and Colt, 2016).

Essential fatty acids

Omega-3 is an important nutrient, which is not produced by our body and that is why we need to take it orally. It is an extremely beneficial compound as it offers multiple health benefits. Some health benefits are: it reduces the risk of heart disease, improves brain function, improves memory, regulates blood pressure and control diabetes [8, 20]. 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 [22], alpha-linolenic acid, the precursor of omega-3 fatty acid has been found in green leafy vegetables with beneficial effects on health. It is known that essential fatty acids help to control various chronic diseases [42]. Evidence shows that omega-3 fatty acids is relatively high in wild plants than in cultivated vegetables [19, 20]. The same study also reported the presence of alpha-linolenic acid in other leafy green vegetables such as 1.7 mg/g in spinach, 1.1mg/g in mustard greens, 0.7 mg/g in red leaf lettuce and 0.6 mg/g in butter crunch lettuce [22]. Fatty acids in leaves can be determined by gas chromatography [47]. Spinach helps to improve the brain function, memory, lower the risk of heart problems, regulates blood pressure and boosts our energy. Spinach is also rich in Omega-3 fatty acid. 100 g of spinach contains 370 mgs of omega-3.

Conclusion

Green leafy vegetables provide vital nutrients required for human health and wellbeing. Being rich in essential micronutrients the green leafy vegetables can be utilized for the purpose of enrichment of nutritional deficient products. These include dietary fiber, vitamins, essential fatty acids, minerals and amino acids etc. In rural areas, traditional leafy vegetables play important role as nutritional source, and it is available round the year. It also has significant socioeconomic benefits. Green leafy vegetables are usually considered as the cheapest source of food for vitamins and micronutrients supplementation to conflict nutrients deficiencies. It is also used as herbal and medicinal plants in various cultural and traditional settings for many different ailments. 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. Research is also needed to explore different varieties and possibility of adopting agronomic practices in green leafy vegetables and enhance their nutritive value. The Thermal processing of leafy vegetables through boiling, cooking and blanching before consumption help in reducing the level of anti-nutrients. The results suggest that the vegetables if consumed in sufficient amount would contribute greatly towards meeting the nutritional requirement for normal growth and also could provide adequate protection against

diseases emerging from malnutrition. The present study has shown that the leafy vegetables have high content of moisture. The low fat content of all green leafy vegetables is in agreement with the general observation that leafy vegetables are low in lipids. The results suggest that the vegetables if consumed in sufficient amount would contribute greatly towards meeting the nutritional requirement for normal growth and also could provide adequate protection against diseases arising from malnutrition.

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