Sarma and TR
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REVIEW

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Dietary phytonutrients in common green leafy vegetables and the significant role of processing techniques on spinach: a review

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Abstract

Leafy vegetables comprises of the majority of food intake around the world. A nuanced understanding of their phytonutrients, bioavailability and post-harvest processing will aid in understanding their utility in human health better. Plant foods have a variety of dietary phytonutrients beneficial to us. With a lot of diversity in the variety of these leafy vegetables, it is of utmost importance as consumers to understand their benefits, functional properties, post processing changes that occurs until it reaches us. Some of the most popular green leafy vegetables include spinach, cabbage, lettuce and mustard greens. In this review, we provide a summary of the phytonutrients in such leafy greens with a detailed description of its bioavailability of nutrients, role of bio fortification, changes during harvest and post-harvest processing. As a low calorie food item, green leafy vegetables are ideal candidates to add valuable nutrients into our daily diets, and spinach especially is known to have multiple therapeutic implications in human health. Post-harvest processing may include addition of nutrients, increasing bio availability of important constituents, assessing effect of fertilizers and growth promoting factors on their nutrient content. All of these parameters need to be studied in depth to improve their beneficial effect in human nutrition and diet.

Keywords Green leafy vegetable, Phytonutrients, Bioavailability, Processing techniques, Spinach

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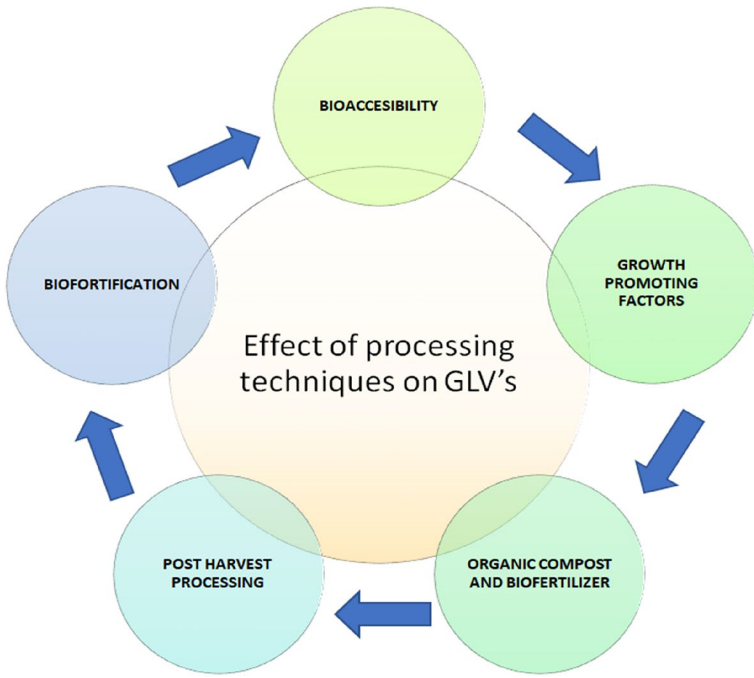
Graphical Abstract



Introduction

Green leafy vegetables encapsulate a broad term that covers a variety of plants including spinach, coriander, cabbage, lettuce, Swiss chard and kale, and is also an important part of the overall human diet (Farha et al. 2018). Among the regulatory bodies, FAO and WHO suggests consuming four to five servings of 80 to 100 g of green leafy vegetables daily (Mashitoa et al. 2021). Vegetables belong to a wide range of hues, shapes, textures and flavors for consumption. Health professionals strongly advise people to include leafy green vegetables in their diets because of their excellent nutritive value (Mohammed and Qoronfleh 2020). Leafy green vegetables, have the presence of substantial health-promoting benefits which are mainly due to their phytonutrients' and therapeutic qualities of different chemical components (Roberts and Moreau 2016). Most commonly consumed foods are low in micronutrients as a primary source of energy, which consequently results in starvation and malnutrition. Therefore, including more of green leafy vegetables and fruits as a source of vitamins and minerals in addition to commonly consumed foods is a better method to achieve a balanced diet (Sarker et al. 2020). It has been shown that regular consumption of important dietary phytochemicals lowers the prevalence of several infectious diseases and non communicable chronic disorders (Sivakumar et al. 2018). Due to larger amounts of bioactive components in them, even the intake of microgreens has increased in current times. The presence of vitamins, minerals, and antioxidants makes it important for human health (Mir SA et al. 2017). A number of scientific studies, both invitro and invivo, on GLVs have demonstrated significant health advantages, including antidiabetic effect, wound-healing, antibacterial properties, memory-enhancing capacity, antioxidant activity and neuroprotective effects (Chandrika and Prasad Kumarab 2015).

After harvest, the quality of edible products decreases depending on several factors, which includes temperature and the duration of storage involved. A study on rocket leaves indicated that easy to measure volatile organic compounds (VOCs) may offer helpful quality indicators, such as variations in isothiocyanates made from nutritionally significant glucosinolates. (Spadafora et al. 2016). As a novel strategy to effectively and efficiently manage and overcome post-harvest losses and alterations, many contemporary genetic techniques, such as genome editing, have evolved to a great extent. To address the problems associated with post-harvest storage quality; mutations can be efficiently introduced in many crops owing to modern genome editing techniques like ZFNs, TALENs, and CRISPR/Cas9 system (Kumari et al. 2022). Storage, processing and cooking affect the composition of phytochemicals like flavonoids, alkaloids, anthocyanins, carotenoids and saponins in a major way. The bio efficacy of these important phytochemicals is well established but the effects of postharvest handling practices have not been explored in depth. Factors that maintain and affect overall quality, the range of temperature, relative humidity, storage under controlled atmospheres (CA) or using modified atmosphere packaging (MAP) and processing are yet to be deciphered (Jones 2007). Therefore, the this review aims to summarize the extensive knowledge on various phytochemicals present in green leafy vegetables and the compositional changes they undergo due to various post-harvest constraints, the stability of these phytonutrients after processing techniques along with current challenges faced by scientists to reduce the deterioration level of these naturally occurring plant metabolites.

Major dietary phytonutrients present in green leafy vegetables

Since ancient times, green leafy vegetables have been utilized for their medicinal value and have been vital in maintaining our overall health. They are the most readily available sources of nutritional fiber, vital amino acids, vitamins, minerals, lipids, proteins and carbohydrates. The bioactive components can manage oxidative stress and age-related human diseases in addition to having a variety of health-beneficial actions, such as antioxidant and antibacterial activity to name a few (Bhat and Al-Daihan 2014). Phytonutrients have gained more popularity owing to greater consumer knowledge of natural and organic foods. They are prominent part in the food pyramid and an important component of the balanced diet that many dieticians and nutritionists recommend. Most importantly, leafy green vegetables are a perfect dietary source for weight management due to their low calorie content. Historically, many plant nutrients and health-improving substances were only determined after a lot of effort as it was difficult to validate their effects scientifically. In recent times, the application of chromatography, mass spectrometry, infrared spectrometry, and nuclear magnetic resonance have helped in the quantitative and qualitative measurements of many plant metabolites. About 50,000 plant metabolites have been identified, and it is anticipated that the total number will approach 200,000 in the near future. Most of them have functions which are yet to be ascertained (Hounsome et al. 2008). Even in several epidemiologic studies, it has been demonstrated that a diet high in fibre, fruits, and vegetables is linked to a lower risk of cancer and has been specially evident for different types of citrus fruits, carrots and leafy green vegetable (Frohlich et al. 1997). Many studies have been conducted in indigenous green leafy vegetables and phytochemical analysis reported. Green leafy vegetables *Cnidoscolus aconitifolius* and *Crotalaria longirostrata*, which are native to Mexico and Central America, along with *Solanum scabrum* and *Gynandropsis gynandra*, native to Africa, were studied and reported for their nutritional and phytochemical compositions. Numerous accessions of these green vegetables were examined for antioxidant activity, mineral and vitamin C content and the presence of phenolics and flavonoids. Elevated levels of important phytonutrients were reported (Jiménez-Aguilar and Grusak 2015). Another traditional green vegetable that is frequently being consumed is African nightshade (*Solanaceae* family). The phytochemicals and nutritional substances of this leafy vegetable are impacted by different agronomic practices and postharvest processing techniques (Sivakumar et al. 2020).

The increasingly popularity of Green leafy vegetables in the developing countries is mostly owing to its great nutritional value, widespread availability, and affordable price (Wijeyaratne and Kumari 2021). Hence, here we focus on some common leafy green vegetables and discuss their phytochemical composition (Fig. 1).

The leafy vegetable crop spinach (*Spinacia oleracea L.*) is commonly grown in and around the Mediterranean basin in open fields. It is a common element in many cultural dishes due to its great nutritional content and the presence of significant bioactive qualities in its leaves (Pereira et al. 2019). Most studies consider spinach (*Spinacia oleracea* L.) to be a functional food as it has higher phytochemical and bioactive compounds which promote positive aspects of human health. By secreting satiety hormones, phytonutrients present in it can scavenge reactive oxygen species and helps prevent oxidative damage, regulate gene expression in metabolism and proliferation, and decrease food intake. Properties such as anti-cancer, anti-obesity, hypoglycemic, and hypolipidemic effects of spinach are a result of these biological processes (Roberts and Moreau 2016). According to a study from Thailand, spinach comprises of a variety of micronutrients, that includes minerals and vitamins, which helps in preventing diseases caused by dietary deficiencies and preserve proper physiological function. Carotenoids, flavonoids, and phenolic compounds, which are the main phytochemicals, help prevent age-related diseases and chronic health issues (Jiraungkoorskul 2016). An Italian investigation revealed information demonstrating a complicated relationship between spinach plant growing circumstances and the modification of secondary metabolites content in spinach leaf juice, which led to various chemoprotective effects in colon cancer cells (Milano et al. 2019).

Another common vegetable crop is *Brassica oleracea,* and amongst different crops that are derived from it,

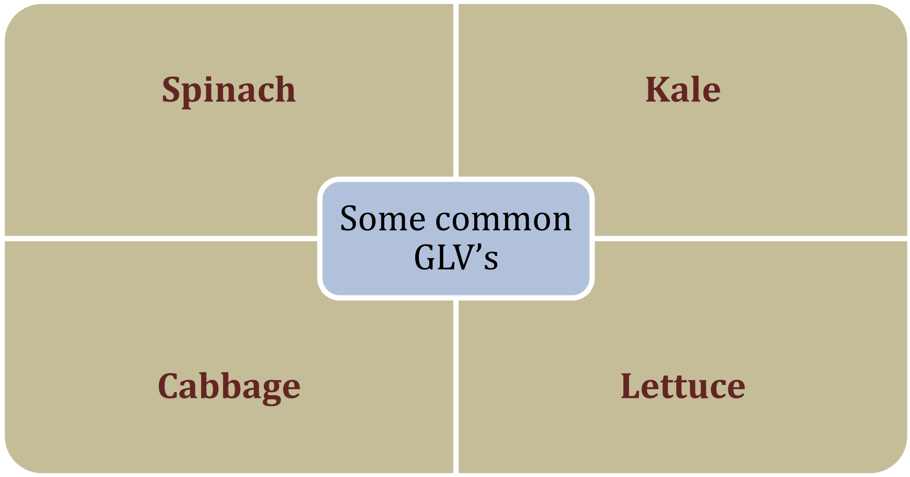


Fig. 1 Showing common green leafy vegetables

kale has been in the spotlight globally because of the number of health promoting compounds in it (Hahn et al., 2022). Chinese kale is consumed in China and South east Asia for its edible bolting stems, and the fragile rosette leaves are also commonly consumed as a green leafy vegetable. In various studies, it has been found to contain high nutritive value as it is a very good source of antioxidants, Vitamin C along with the presence of anti-carcinogenic compounds, phenolics and glucosinolates to name a few. It is crucial to research the bioactive chemical composition of Chinese kale and other significant green vegetables, since customers throughout the world place a premium on foods that promote health and take it into account when making purchases (Wang et al. 2017a, b). In a Saudi Arabian study, it was shown that there is little knowledge of kale and its health advantages there. All demographic groups need to be educated about the benefits of kale as a superfood (Alfawaz et al. 2022).

Another most significant vegetables produced worldwide is cabbage (*Brassica oleracea* L. var. capitata). Belonging to the family Cruciferae, it is shallow-rooted and said to have originated in Western Europe, is a cool-season crop grown due to its enormous leafy head. It has been studied and found that cabbage contributes to people's overall intake of phytonutrients (Singh et al. 2006). In another study, the antioxidant and neural protective properties of cabbages were examined. The protection of the neuronal cells was directly correleted with the phenolic content and the antioxidative capabilities of the cabbages. In addition, studies have shown that anthocyanins in cabbage also contributed significantly for the same activity (Heo and Lee 2006). Several epidemiological studies and interventional trials have shown cabbage to possess protective activities in lowering the risk of number of cancers as well as other chronic illnesses like diabetes, Alzheimer's, and cardiovascular disease. This is due to its nutrient-rich composition, which includes a variety of phytochemicals and antioxidants which includes carotenoids, glucosinolates, isothiocyanates and phenolic compounds (Moreb et al. 2020).

Lettuce is another famous green leafy vegetable present worldwide. Consumers can choose from different varieties of the lettuce group. In addition, the health advantages of bioactive substances like polyphenols, carotenoids, and chlorophyll are abundant in lettuce. It has 94–95% water content, is low in calories, and is high in water content. Because lettuce contains antioxidants, it has potential heart-protective, cancer-preventive, anti-diabetic, and anti-aging qualities (Shi et al. 2022). Another study produced and characterised mutants of lettuce's flavonoid biosynthesis that may be beneficial to health. The altered flavonoid profile has the potential to make lettuce even more nutrient-dense as a food (Gurdon et al. 2019).

Mustard is a *Brassica* vegetable that possesses multiple phytonutrients. Carotenoids found in mustard leaves also have additional potential health benefits, such as antioxidant properties. The most significant carotenoids found in mustard leaves, β -carotene, is thought to be highly effective for human health due to the presence of provitamin A and anticarcinogenic properties. It further suggested that mustard leaves have the presence of important phytochemicals, and their composition varies depending on their state of physiology and type of cultivar (Frazie et al. 2017). Another study found 209 phenolic components in red mustard greens, including anthocyanins, flavonol glycosides, and derivatives of hydroxycinnamic acid (Lin et al. 2011).

Processing techniques and their effect

Biofortification

Adding nutrients to plants is a process called 'biofortification' that raises the nutritional value of food. Green leafy plants that have been supplemented with Fe may improve the bioavailability of iron and offer an alternative to pharmaceutical treatments for people who experience iron deficiency anaemia around the world (Gautam et al. 2008). Iron fortified green leafy plants have the potential to increase bioavailable amount of this mineral and could be a complementary source with drugs for humans who suffer from iron deficiency anaemia worldwide (Khush et al. 2012). All necessary plant nutrients must be present in a nutrient solution, and nutrients must modify the solution's molecular make-up to meet the needs of the plants (Wang et al. 2017a, b). Studies have indicated that to increase the level of Fe and growth parameters in the edible tissues of various plants, including wheat, rice, chickpea, tomato and soybean, iron was added to the soil (Zhang et al. 2010). Similarly, foliar application helps to avoid chlorosis and promotes growth, but they are insufficient for fortifying plants with iron because of limitation in application doses that are to be used. The amount of Fe in spinach can be enhanced by adding higher doses of these mineral fertilizers to the hydroponic growth medium that already contains all the necessary plant nutrients. However, it is not clear which fertiliser dosage will increase the quantity of iron that spinach plant absorbs and the effect will be the same in other spinach cultivars (White & Broadley 2009).

One of the most crucial nutrients for human health is selenium (Se). It contributes to both adult and infant hormone production and defense systems. In adults and neonates, Se is involved in defense mechanisms and helps in biosynthesis of hormones. Selenium is found to be responsible in membrane protection and has anticancerous properties (Germ et al. 2007). As a cofactor of glutathione peroxidase, Se protects tissues from oxidative tissue damage. It is also added to vegetables as a bio fortifier. Selenium treatments in some research studies have shown no impact on the yield (Malorgio et al. 2009).

A widespread issue observed in many nations is Zn deficiency in soils and plants. In a global soil survey research, 25 countries' worth of soil samples were examined, and 50% of them were found to be low in zinc (Sillanpaa 1990). An almost similar degree of deficiency has been reported in India. Coarse texture, high pH, calcareousness, and low organic carbon content of soil are the major contributing factors to the deficiency of Zn in soil. This insufficiency in the human population appears to be mostly caused by low dietary consumption (Alloway 2004).

The nutrients are considered to play a significant role in plant metabolism for growth. The plant productivity and quality are stimulated by the equilibrium between these nutrients. When one of them is present in excess or insufficient, this metabolism becomes disturbed, which lowers quality and yield of spinach. Several studies demonstrate that the presence of iron has significant impact on plant yield and a limiting factor for biomass production is the quality of iron (Datta et al. 2007). Excess iron competes with other cations for uptake of other macronutrients and micronutrients, it results in chelating Fe uptake and inhibiting it through competitive inhibition and removing it from the xylem. Fe and Mn compete for absorption, and have a synergistic relationship between them (Pirzad and Barin 2018).

Bioaccesibility

Bio accessibility is a predictor of bioavailability. Due to its linked results and less expensive analysis, it is frequently used compared to bioavailability to determine how much of the digesta is accessible to the enterocytes for absorption (Corte-Real et al. 2018).

The bioavailability of carotenoids and chlorophylls can be enhanced or suppressed by a variety of parameters like mineral content, lipid content, dietary matrix structure and particle size. One of the most favoured and nutrient rich green leafy vegetable is spinach, a well-known source of pro-vitamin A is carotenoids and chlorophylls (Van Loo-Bouwman et al. 2014). The changes in genetics, environment, and processing have been linked to bioactives. Beyond processing, the elements that impact a substance's bioavailability are nevertheless still poorly understood. Breeders are trying to increase the nutritional value of the material used in their programmes by adding substances that aids in better absorption of a target nutrient (Diepenbrock and Gore 2015). In another investigation a phenotypical surrogate for the bioavailability of phytochemicals from commercial cultivars and public germplasm repositories was employed (Gunaratna et al. 2019).

Dark green leafy vegetables make up the majority of the human diet's supplies of carotenoids. Dietary carotenoids are essential in prevention of chronic diseases like cancer, hip fractures, cardiovascular disease, and age-related function decline as shown by epidemiological studies (A. Aoki et al. 2016). Carotenoids cannot readily travel from plant tissues to the enterocyte absorption site due to their extreme hydrophobicity. Consequently, when green leafy vegetables are consumed, carotenoid bioavailability is both very low and unpredictable (J. L. Jeffery et al. 2012). To be soluble in the stomach lipid phase, carotenoids that are present in the food matrix must first be released from the plant tissue. In addition, by boosting the volume of their hydrophobic domains, lipid digestion products boost carotenoid solubilization inside mixed micelles. Consequently, lipids are crucial in influencing the bioaccessibility of carotenoids. Excipient foods were offered based on the impact of the food matrix effect on bioavailability as a technique to increase the bioavailability of nutraceuticals in the human diet. Because of varying sample processing methods and environmental conditions, chlorophyll content is typically more variable. Additionally, their capacity to control oxidative and inflammatory stress, non- pro vitamin A, carotenoids, chlorophylls, and their derivatives also have antimutagenic properties (McClements et al. 2015).

Growth promoting factors

The rising interest in living a healthy lifestyle and safeguarding the environment is transforming agriculture and food consumption patterns. One example of good agricultural practise, which is necessary for fresh food, is the use of probiotic bacteria *Rhizobial* strain *PEPV40* to aid *Rhizobium laguerreae* in the growth of spinach plants (Saini et al. 2017). The synthesis of indole acetic acid, siderophores and phosphate solubilization are few of the processes that strive to promote plant growth in in-vitro condition. The outstanding plant probiotic *Rhizobium laguerreae* improves the quality and yield of spinach, which is widely consumed raw around the world. Hazardous bacteria may be present in fresh vegetables due to irrigation water, manure or compost used for fertilization of crops (Oyinlola et al. 2017).

Plant probiotic bacteria (PPB), which produce different substances including phytohormones siderophores, nitrogen fixation, phosphate solubilization, and other in-vitro plant growth promotion (PGP) mechanisms are examples of biofertilizers. Recent studies have shown that probiotic *Rhizobium* strains are involved in the production of cellulose and biofilms in the root colonisation process and it has been found to be a crucial step in enhancing plant growth (Flores-Félix et al. 2015). Moreover, relevant traits of bacteria aiding plant growth (Compant et al. 2010) include the capacity to move nutrients for plants, such as nitrogen or phosphate, and the creation of many metabolites essential for plant growth, such as siderophores and indole acetic acid. Consequently, the strain PEPV40 may be a bacterium that promotes plant growth, although this property needs to be verified in plant assays. The PEPV40 inoculation promotes the development of edible branches of spinach plants' at both the juvenile and adult growth phases. Rhizobium does not produce nitrogen for free, together these data implies that rhizobia, which raise the N content of legumes via symbiotic nitrogen fixation (García-Fraile et al. 2012) for encouragement of plant growth, which promotes the intake of soil nutrients.

The manipulation of spectral light composition has been successfully used to enhance plant growth (Ilić and Fallik 2017) and it is also being employed in horticulture to increase crop output and quality. This is due to variety of alterations to primary and secondary plant metabolism (Paradiso and Proietti 2022). The spectral quality was altered using a variety of techniques, including photo-selective nets, films, colored shade nets and artificial illumination systems (Zhang, et al. 2022). Plant photosynthesis and carbon uptake have been reported to be influenced by light quality (LQ) and different wavelengths. Red and blue light are primarily used by plants for photosynthetic purposes. Blue light impacts stomatal opening, photosynthesis, pigment synthesis, biomass production, and photomorphogenesis through the light receptors (i.e., cryptochromes and phototropins) (Izzo, et al. 2020). Red light is known to regulate the development of the photosynthetic machinery, the growth of the stem and petiole, and the reproductive system. Green light significantly affects photosynthesis in the parenchymal cells' inner layers (Smith et al. 2017) where it is more effective than red and blue light in controlling leaf photosynthesis. In comparison to red-blue light, *Bidens pilosa L.* plants produce more photosynthetically active molecules. These findings suggest that photosynthesis in plants is constrained by an insufficient lighting environment. Crop output is pushed by both favorable soil environment and lack of heavy growth conditions. This aspect is important because some phytohormones are essential in regulation of photosynthesis (Müller and Munné-Bosch 2021).

Organic compost and biofertilizer

Compost is advantageous on soil fertility, soil functionality, and soil microbial community. They are all related to the cycling of carbon (C) and nitrogen (N) during solarization, for the spinach crop's growth and harvest. Microbial activity and soil fertility were both increased by CAS. After a week the soil was covered with plastic the activity of the functional genes increased by removal of the plastic. On spinach, numerous illnesses have been recorded. Many of them are caused by *Fusarium oxysporum* (McDonald et al. 2021), *Alternaria spp*. (Kipkogei et al. 2019), *Stemphylium botryosum* (Koike et al. 2001), *Pythium ultimum* (Magnée et al. 2022) and*Olpidium spp* that indirectly affect spinach as they are carriers of viruses (Gratsia et al. 2012). Consequently, to create a high-quality product, an integrated disease management approach is frequently required (Correll et al. 1994). In order to trap solar radiation, build up heat and to retain moisture in the soil, a clear plastic film is placed over the soil during solarization, which is a chemical-free method of controlling weeds and pathogens (Kanaan et al. 2018). This alters the soil's microbial ecology and generates a biological vacuum that lowers the number of soil pathogens. Due to the buildup of bio pesticide compounds, volatile substances like alcohols, aldehydes, sulphides, and isothiocyanates caused by the decomposition of organic matter results in the production of CO_2, water, and heat (Fernández-Bayo et al. 2019). The emergence of soil structure, the decomposition of organic matter, the elimination of toxins, the cycling of nutrients and the management of soil pathogens all depend on microorganisms. (Cuartero et al. 2022). The addition of compost and solarization should alter the microbial composition of the soil (Simmons et al. 2013). It has also been observed that thermo-tolerant bacteria survived during solarization and contribute to disease resistance (Kanaan et al. 2017). Furthermore, *Firmicutes* and *Geobacillus* were capable of degrading the lignocellulose of the various compost source materials. Composting has the potential to alter soil microbial populations that are closely tied to the carbon (C) and nitrogen (N) cycle through changes in the physicochemical parameters of the soil when composting and solarization are combined (Yanardag et al. 2017).

Most green leafy vegetables, including spinach, comprises of vitamins, proteins, fats, carbohydrates and minerals. Calcium, iron and phosphorous are predominantly found in spinach (Santoso, 2023). Fertilization can encourage the development of spinach, since they can produce quicker, more usable, and simpler harvests right now and the community relies on inorganic fertilisers. NPK fertilizer is the most popular type of chemical fertilisers. When inorganic fertilizers are applied concurrently, over a prolonged period of time in large quantities they have detrimental effects on the environment, soil's structure and soil fertility (Mulyani 2014). To reduce the negative effects of excessive application of inorganic fertilizers, these forms of fertilizers should be used in conjunction with organic fertilizers. Vermicomposting is one of the biodegradable fertilizers that can be applied when growing plants. It can assist in supplying nutrients to vegetation. It has the nutrients that plants require to hold water, balance the pH of the soil, has a high concentration of macro and microelements that are environmental friendly and effective for plant development (Palungkun 2010). Vermicomposting is described as having a beneficial effect on plants has it includes the ability to fertilize and loosen the soil so that it becomes suitable for use as planting medium and can stimulate root, stem, leaf development, flower growth, fasten the process of harvesting and also increase plant productivity (Manahan 2016).

Due to many crop species having high nitrogen demands with growth cycles, shallow root systems and nitrate leaching occurs during the production of vegetables (Tei et al. 2020). There is a high necessity of adequate level of soil mineral nitrogen in the root zone to meet market demand for the quantity and quality of the produce (D'Haene et al. 2018). Total nitrogen supply in spinach growing is normally divided into a basic fertiliser application at sowing and top dressing before intensive nitrogen uptake starts (Schenk et al., 1996). In order to maintain fields more easily and grow crops despite changeable weather, spinach is typically grown on sandy soil. For crops like spinach, harvesting is quickly finished to prevent bolting and flowering, which would degrade the quality of the product (Grevsen & Kaack 1997). However, the N availability should be matched to the real uptake of the spinach crop by dividing N supply into several applications in order to decrease Nitrogen minimum residue at harvest and flatten NO_3 peaks after fertilization (Massa et al. 2018). However, if N is added during the plant development stage, there is a chance of nitrogen deficit, which could have a detrimental effect on the growth and quality of spinach (Biemond et al. 1996). Additionally, NO3-based fertilisers are used in conjunction with sufficient irrigation to guarantee adequate N availability in the root zone (Quemada et al. 2013). Foliar fertilisation results in greater N uptake efficiency compared to fertilisers applied to the soil for nutrient uptake (Krishnasree et al. 2021). Results of a greenhouse fertilization trial shows that even tiny amounts of aerially applied urea or ammonium (NH_{4+}) may encourage growth and green coloration of spinach leaves (Borowski and Michałek 2008). Reducing the overall amount of fertilizer applied has been suggested as a way to reduce the risk of NO_3 leaching in field-grown vegetable crops. After a few days, above-ground biomass production is hindered if there is inadequate N available at the base, and deficiency indicators like yellowing on older leaves are noticeable (D'Haene et al. 2018).

Post harvest

When spinach leaves are washed, ascorbate loss is more likely to occur. Mechanical stress appears as oxidative stress and results in the oxidation of ascorbate would appear to be the main cause of the ascorbate loss. In the end, this causes oxalate an anti nutrient to rise. These findings have commercial significance since altering washing practises may increase the amount of ascorbate retained during postharvest storage. Oxalate can serve as an antinutrient by insolubilizing calcium, which may result in calcium shortage and the development of kidney stones (Franceschi and Nakata 2005). Oxalate is known to accumulate in spinach leaves (Yang and Loewus 1975). Crops could become more nutrient-dense and possibly more resilient to oxidative stress, if the ascorbate content of food were to be increased (Hancock and Viola 2005). Despite the ease with which ascorbate may be chemically created and then added to food there is a general movement away from artificial food additives, which is opening up a market for naturally ascorbate-enriched crops. Crop plants may produce more ascorbate if their biosynthesis is increased and their degradation is reduced. The study focused on treating young salad leaves after harvest as a potential area where ascorbate loss could be minimized and also looks into the ascorbate breakdown routes when processing and storing post-harvest (Dewhirst et al. 2017).

Because of the yields obtained are more efficient and sensible use of the soil remaining nutrients after the main crop is harvested, growing spinach as a subcrop in the fall has significant economic and agro-ecological implications. (Mitova et al. 2005).

1. The variation with the effect of mineral fertilisation produces the maximum yield of spinach.
2. The nitrogen, chlorophyll and nitrate contents of plants cultivated with mineral fertiliser are higher.
3. When spinach is grown following a prior harvest that received manure fertiliser, the dry matter content and total sugars are at their maximum level.

In polymeric film packets, fresh produce is packaged using modified atmosphere packaging (MAP) technique to alter the O_2 and CO_2 levels in the environment around the container. The shelf life of fresh produced during storage is believed to be effectively maintained by the MAP technology (Sandhya 2010). Based on its effectiveness and particular impact on slowing the metabolism process of the produce (Church & Parsons 1995) indicated that the mixture of oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2) is widely utilized in operating the MAP technology during storage has it impact on slowing the metabolism process of the produce. Baby spinach's reduced respiration rate, weight loss, and antioxidant loss while being stored in low O_2 concentrations are indicators of the impact of CA on its postharvest quality and shelf life.

Conclusion

Natural, organic plant based food is the need of the hour. Their consumption and general knowledge on the phytonutrients is increasing amongst the general public. Apart from being low in calorie value, green leafy vegetables have immense therapeutic potential. Further processing with bio fortification with iron, selenium etc. and increasing their bio availability have made them a potential source of natural therapeutics in daily diet. Climate, geography, harvesting techniques, post-harvest processing all play a major role in quality control of GLV's. One needs to acknowledge the fact that various biotic and abiotic factors play an important role in quality assessment and nutrient uptake. Creating awareness and improving the techniques can have a major beneficial impact on human health. Common leafy greens like spinach, kale, cabbage, lettuce are found worldwide but handled differently across the globe during harvest and post-harvest time. As a result, the phytonutrient availability and benefits differ from place to place. Understanding the mechanism by which maximum benefit can be yielded off these phytonutrients is of immense importance and can help combat many illnesses across the globe. Given that spinach is one of the most consumed green leafy crops, knowing how different processing methods affect yield quality and post-harvest losses can be beneficial globally.

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Authors' contributions
US proposed the idea for the literature review and performed the literature search and drafted the manuscript. TR has contributed in the literature search and drafting process of the review work as well. Both have critically revised the work.

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The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

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The authors declare that they have no conflict of interest.

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