



Leafy Vegetables as Natural Sources of Minerals and Vitamins and Their Role in Human Health: A Review

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Abstract: This review aims to assess the nutritional composition and health-promoting effects of selected leafy green vegetables—celery, basil, arugula, garden cress, and radish—and their potential contribution to preventing chronic diseases. Recent scientific evidence (2020–2025) was analyzed from clinical, epidemiological, and biochemical studies highlighting the physiological effects of these vegetables. The review methodology focused on identifying bioactive compounds, including nitrates, flavonoids, vitamins, and minerals, and evaluating their effects on key health outcomes such as cardiovascular performance, metabolic regulation, and digestive function. Results indicate that regular consumption of nitrate-rich leafy vegetables significantly contributes to lowering blood pressure, improving vascular elasticity, and reducing oxidative stress. Bioactive components such as flavonoids and polyphenols enhance lipid metabolism, decrease LDL cholesterol, and support antioxidant defense systems. Furthermore, dietary fiber and phytochemicals from arugula, celery, and basil positively influence gut microbiota composition and intestinal health, while compounds in radish and garden cress demonstrate glucose-regulating and anti-inflammatory properties. Overall, incorporating a diverse range of leafy green vegetables into daily diets serves as an effective, low-cost nutritional strategy to improve cardiovascular, metabolic, and digestive health. The findings underscore the need for further controlled clinical trials to determine optimal intake levels, synergistic effects among different species, and precise biochemical pathways underlying these health benefits.

Keywords: Leafy Vegetables, Cardiovascular Health, Diabetes, Blood Pressure, Antioxidants

Introduction

Leafy vegetables are one of the most diverse plant groups in terms of nutritional content, containing high levels of vitamins (A, C, and K), essential minerals such as iron, calcium, and magnesium, as well as bioactive compounds such as flavonoids, carotenoids, and nitrates (Saini et al, 2022). Comparative analytical studies have shown that leafy vegetables are superior in nutritional density to starchy foods, making them a primary source of micronutrients essential for maintaining general health and preventing chronic diseases (Saini et al, 2022) (Kajszczak et al, 2024).

Recent epidemiological and clinical evidence suggests that leafy green vegetable consumption is associated with lower rates of cardiovascular disease and type 2 diabetes, partly due to its nitrate content, which is converted in the body to nitric oxide—a potent vasodilator that contributes to improved blood pressure and vascular elasticity (Bondonno et al, 2021) (Olas, 2024) (Tan et al, 2024). These findings also confirm that a diet rich in leafy green vegetables offers complementary protection against heart disease caused by chronic inflammation and oxidative stress.

On the other hand, recent studies have suggested that fat-soluble vitamins, particularly vitamin K₂, which is abundant in some leafy green vegetables, may play a direct role in supporting brain health by maintaining microvascular integrity and improving cognitive performance (Godos et al, 2024) (Roumeliotis et al, 2025). Meta-analyses have also found that low intake of this vitamin is associated with a slight decline in memory and learning in older adults, reinforcing the hypothesis of a link between vascular health and cognitive function.

On the metabolic side, clinical trials have shown that extracts of plants such as celery (*Apium graveolens*), radish (*Raphanus sativus*), and basil (*Ocimum basilicum*) have antioxidant and anti-inflammatory effects, in addition to significant improvements in metabolic markers such as glucose and triglycerides (Mohsenpour et al, 2023) (Kamelnia et al, 2023) (Kajszczak et al, 2024). Other meta-reviews indicate that a variety of leafy green vegetable consumption—not just quantity is associated with lower rates of cardiovascular and metabolic mortality (Nishi et al, 2023).

This recent evidence (2020–2025) shows that incorporating diverse leafy greens such as watercress, celery, radish, leeks, and basil into diets is an effective strategy to promote cardiovascular and metabolic health, with further longitudinal studies needed to determine the optimal dosages and precise biochemical mechanisms behind these benefits (Wen et al, 2025).

Accordingly, this review focuses on five major leafy green vegetables: arugula, celery, radish, leeks, and basil, with the aim of analyzing their biological components and understanding their positive role in promoting human health.

Methodology

This review was conducted based on an integrative analysis of recent scientific literature published between 2020 and 2025. The selection of studies focused on clinical trials, systematic reviews, and meta-analyses related to the nutritional and therapeutic effects of leafy green vegetables: arugula, celery, radish, leeks, and basil. The analysis was guided by contemporary nutritional theories emphasizing the role of bioactive plant compounds, such as nitrates, flavonoids, and polyphenols, in regulating cardiovascular, metabolic, and digestive health. These theoretical frameworks and previous studies formed the foundation for interpreting the evidence and identifying key health benefits of these vegetables.

The importance of leafy vegetables as a natural source of support for human health

Leafy vegetables are a mainstay of a healthy diet, as they contain an abundance of vitamins and minerals essential for the body's vital functions. Varieties such as arugula, celery, radish, leeks, and basil are rich plant sources of bioactive compounds that contribute to enhancing natural immunity, stimulating the digestive system, and supporting detoxification processes. The antioxidants in them combat free radicals, reducing the risk of chronic diseases associated with oxidative stress and enhancing overall vitality. Maintaining a regular intake of these vegetables is an essential step towards achieving a sustainable health balance and optimal quality of life. Accordingly, this study focuses on five main types of leafy vegetables arugula, celery, radish, leeks, and basil to review their nutritional values, active components, and positive role in supporting human health, as illustrated in Figure (1).



Figure 1. The group of leafy vegetables that the study focused on and their positive role in promoting human health

1. Effect of Leafy Green Vegetables on Digestive System Health

Leafy green vegetables play a vital role in maintaining the integrity and functionality of the human digestive system through multiple biological pathways. These vegetables are rich in dietary fiber, polyphenols, flavonoids, and nitrates, which collectively support gut microbiota diversity, intestinal barrier protection, and gastrointestinal motility. Recent systematic reviews have demonstrated that the intake of leafy greens significantly enhances the composition and metabolic activity of gut microbiota, promoting the production of beneficial short-chain fatty acids (SCFAs), such as butyrate, which strengthen the intestinal mucosa and reduce inflammation (Fu et al, 2022). Similarly, a human-based multi-omics study reported that spinach supplementation reshaped gut microbiota composition and improved intestinal metabolic pathways associated with anti-inflammatory responses (Chen et al, 2021).

Clinical intervention studies between 2020 and 2024 have provided additional evidence of the protective role of green leafy vegetables against colorectal and gastrointestinal diseases. Frugé et al. (2021) demonstrated that participants consuming high

quantities of leafy greens exhibited reduced oxidative DNA damage, a biomarker linked to colorectal cancer risk. Moreover, recent mechanistic analyses have shown that the soluble fibers in celery promote prebiotic effects, stimulating beneficial bacterial growth, although excessive fiber–flavonoid interaction may attenuate anti-inflammatory potential (Wang et al, 2023). The functional components in leeks, particularly sulfur-containing compounds, have also been found to modulate digestive enzymes and inhibit pathogenic bacterial adhesion to intestinal walls, supporting gut homeostasis (Xie et al, 2023).

From a broader nutritional perspective, dietary fiber from leafy greens such as watercress and celery increases stool bulk, accelerates intestinal transit time, and decreases the risk of constipation and diverticular disease (Calatayud et al, 2021) (Ma et al, 2021). Furthermore, basil and cress species contain active phytochemicals (e.g., eugenol, glucosinolates) that possess antimicrobial and anti-inflammatory properties, which can mitigate gastrointestinal infections and intestinal inflammation (Vazifeh et al, 2022). These findings are consistent with recent evidence emphasizing the synergistic interaction between dietary fibers and bioactive compounds in modulating gut microbial ecology and improving digestive efficiency (Gill et al, 2022).

In summary, converging research from 2020 to 2025 confirms that regular consumption of leafy green vegetables — including arugula, celery, radish, leeks, basil, and cress — contributes to maintaining digestive system health by enhancing microbial diversity, fortifying mucosal immunity, and reducing oxidative and inflammatory stress in intestinal tissues. However, future randomized clinical trials are needed to determine optimal intake levels, preparation methods, and the long-term impact of specific leafy greens on human gastrointestinal health.

2. Effect of Leafy Green Vegetables on Human Blood Pressure

Leafy green vegetables play a critical role in regulating vascular tone and maintaining normal blood pressure, primarily due to their high nitrate content and abundance of antioxidant compounds such as flavonoids and carotenoids. When dietary nitrate from leafy vegetables (e.g., spinach, arugula, celery, and lettuce) enters the body, it undergoes bioconversion through the nitrate–nitrite–nitric oxide (NO) pathway, leading to vasodilation and improved endothelial function. Clinical and experimental trials have consistently shown that nitrate-rich vegetable intake can cause moderate but significant reductions in systolic and diastolic blood pressure, especially among individuals with mild hypertension (van der Avoort et al, 2020) (Sundqvist et al, 2020) (Siervo et al, 2020).

A large population-based study from Denmark further confirmed that habitual consumption of nitrate-containing vegetables was inversely associated with long-term cardiovascular disease incidence and blood pressure progression (Bondonno et al, 2021). Subsequent randomized controlled trials and meta-analyses reinforced these findings: beetroot juice or leafy vegetable interventions lowered blood pressure by 3–5 mmHg on average, which, at the population level, translates to a substantial reduction in cardiovascular risk (Benjamim et al, 2022) (Bahadoran et al, 2022). A mechanistic overview suggested that the antihypertensive effect of vegetable-derived nitrate is enhanced when

combined with diets rich in polyphenols and low in sodium, as these compounds improve nitric oxide bioavailability and vascular reactivity (Bryan et al, 2023) (Zhang et al, 2023).

Recent reviews between 2023 and 2024 have emphasized the role of dietary patterns containing leafy vegetables as a non-pharmacological adjunct for hypertension control. A comprehensive review by Tan et al. (2024) concluded that a daily intake of approximately 300–400 mg of dietary nitrate from green vegetables may achieve clinically meaningful blood pressure reduction without adverse effects. Moreover, meta-analyses conducted in 2024 highlighted that the blood pressure–lowering response varies across individuals depending on gut microbiome composition, baseline nitrate status, and genetic polymorphisms affecting nitric oxide metabolism (Bowles, 2024) (Clifford et al, 2024). In 2025, a GRADE-assessed systematic review of 67 randomized controlled trials demonstrated a clear dose–response relationship between nitrate intake from vegetables and reductions in blood pressure and vascular stiffness, confirming earlier experimental results (Norouzzadeh et al, 2025).

Collectively, evidence from 2020 to 2025 supports the inclusion of leafy green vegetables as a dietary strategy to modulate vascular health and blood pressure regulation. The magnitude of the antihypertensive effect depends on the nitrate concentration of specific vegetables, their preparation (raw vs. cooked), and the overall diet quality. Nevertheless, consistent findings across multiple populations reinforce the clinical relevance of promoting leafy green vegetable consumption as a simple, low-cost, and natural approach to cardiovascular risk reduction.

3. Effect of Leafy Vegetables on Cholesterol Levels in Humans

Leafy vegetables are a key dietary component of plant-based diets that contribute to improved cardiovascular health by modulating blood cholesterol levels. They contain dietary fiber, polyphenols, flavonoids, and bioavailable nitrates, which collectively reduce fat absorption and improve lipid metabolism. Studies have shown that including leafy vegetables in plant-based dietary patterns leads to lower total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C), key markers associated with heart disease risk (Carson et al, 2020) (Koch et al, 2023). Recent clinical trials and systematic reviews show that diets rich in leafy vegetables are associated with moderate reductions in cholesterol levels and improved blood lipid profiles compared to traditional diets rich in saturated fats (Bhandari et al, 2022) (Devirgiliis et al, 2024).

At the individual species level, arugula has been shown to be rich in nitrates and antioxidants such as flavonoids. Experimental studies have suggested that these compounds contribute to reducing cholesterol absorption and improving metabolic balance, but direct clinical evidence in humans is still limited (Hekmatshoar et al, 2022). Leek, a member of the garlic and onion family, has been described as containing organosulfur compounds that help reduce lipids and improve fatty liver markers. A recent review indicated that regular consumption of leeks reduces lipid accumulation and enhances the activity of antioxidant enzymes (Xie et al, 2023). Regarding celery, a randomized, double-blind clinical trial in diabetic patients showed that consuming celery

powder for 12 weeks resulted in a slight reduction in total cholesterol and an improvement in some metabolic markers (Mohsenpour et al, 2023).

In contrast, comprehensive scientific reviews have shown that basil, a member of the Lamiaceae family, contains phenolic compounds and antioxidants capable of lowering cholesterol and triglycerides. This is supported by a recent meta-analytic review confirming that plants from this family can significantly improve LDL and HDL levels (Hassanpour et al, 2024). Recent evidence also suggests that garden cress has antioxidant and lipid-modifying effects in animal models, supporting its potential use as an adjunct to improving cholesterol levels in diets (Hekmatshoar et al, 2022). Overall, recent reviews confirm that the cholesterol-lowering effect is associated with the diversity of leafy green vegetable sources and their consistent consumption within a comprehensive, fiber-rich diet, and that the interaction between the bioactive compounds in watercress, leeks, celery, basil, and garden cress may produce a synergistic effect that enhances cholesterol reduction and the prevention of lipid metabolism disorders (Devirgiliis et al, 2024) (Norouzzadeh et al, 2025).

4. Effect of leafy vegetables on diabetes

In recent years (2020-2025), several small studies and reviews have emerged highlighting the potential impact of consuming leafy vegetables in the diet of people with type 2 diabetes or those at risk for developing it. For example, a prospective analysis from an Australian cohort (AusDiab) showed that higher vegetable intake, particularly green leafy vegetables, was associated with lower post-load glucose, improved markers of β -cell function and serum insulin levels, and a reduced risk of diabetes over a 12-year follow-up. However, the study did not examine the effects of specific leafy vegetables such as celery or basil alone (Pokharel et al, 2024).

Also, a comprehensive systematic review titled "Association between leafy vegetable consumption and incidence of metabolic syndrome and its symptoms" concluded that some randomized trials showed a reduction in fasting and postprandial glucose, while others showed no effect, indicating inconsistent results and the need for more standardized human trials (Muriuki et al, 2025).

A pilot clinical trial (RCT) supplementing the diet with celery powder (750 mg daily for 12 weeks) in individuals with type 2 diabetes showed a reduction in body fat but no significant differences in HbA1c or fasting glucose compared to a placebo. (Mohsenpour et al, 2023)

A recent laboratory study of red radish leaves demonstrated inhibitory abilities for α -amylase and α -glucosidase enzymes, as well as resistance to oxidation and glucose binding, supporting the hypothesis that radish leaves may delay glucose absorption and reduce post-meal spikes. However, the study was not clinical (Kajszczak et al, 2024).

Overall, the evidence from 2020-2025 supports a positive trend for leafy green vegetable consumption to improve some parameters of diabetes control. However, the effect on indicators such as HbA1c and fasting glucose remains inconsistent across all studies. Larger human studies, with specific doses, longer follow-up, and separation between specific leafy green vegetables, which may differ in their nutritional content and active compounds, are needed.

5. Effect of leafy vegetables on heart disease

In a summary of evidence published between 2020 and 2025, reviews, observational studies, and trials have shown that consumption of leafy green vegetables is associated with consistent but varying strength cardiovascular benefits across studies. A large systematic review and meta-analysis demonstrated that various vegetable sources contribute to a reduced risk of cardiovascular events, with stronger evidence for leafy green vegetables for a reduced incidence of coronary heart disease (Zurbau et al, 2020). Cohort studies and subsequent meta-analyses supported an inverse association between fruit and vegetable intake—especially leafy green vegetables—and a reduction in cardiovascular mortality and events (Wang et al, 2021). A comprehensive analysis of lutein and leafy green vegetables also indicated an association between intake and multiple health indicators, including a reduced risk of cardiovascular disease, in an expanded meta-analysis of previous studies (Li et al, 2021). A subsequent larger systematic review confirmed the observational cohort findings and demonstrated that a small daily dose of nitrate-rich vegetables may be sufficient to improve important intermediate indicators such as lower blood pressure and improved endothelial function, partly explaining the long-term benefit (Stanaway et al, 2022) (Tan et al, 2024). Subsequent specialized systematic reviews on fruit and vegetable diversity have supported the idea that increased diversity and quantity are associated with lower overall mortality and some cardiovascular outcomes, although evidence for a clear, independent effect of diversity on all cardiovascular outcomes remains limited and requires further longitudinal studies (Nishi et al, 2023). The most recent comprehensive literature analysis from 2019–2024 highlighted the consistent trends supporting a protective effect of vegetables (particularly leafy greens) on cardiovascular outcomes, with a call for further long-term randomized human trials to determine optimal doses/varieties and understand the biochemical mechanisms (Chan et al., 2025). In summary, human evidence from 2020–2025 supports a protective role for leafy green vegetables on cardiovascular health by improving intermediate factors (blood pressure, endothelial function, plaque characteristics) and reducing the risk of cardiovascular disease. However, the degree of effect and the differentiation between different leafy green vegetables (e.g., spinach, lettuce, arugula, celery) require larger, well-designed experimental studies.

Conclusion

This review concludes that leafy green vegetables particularly celery, garden cress, basil, arugula, and leeks—are essential dietary components that significantly contribute to maintaining human health. Their high content of fiber, antioxidants, and nitrates supports cardiovascular function, regulates blood glucose, and improves digestive efficiency. Regular inclusion of these vegetables in daily meals can help prevent major chronic diseases such as heart disease, diabetes, hypertension, and hypercholesterolemia. Promoting their consumption offers a natural, low-cost strategy for improving public health. Further clinical studies are recommended to determine optimal intake levels and specific bioactive mechanisms.

Future research should focus on long-term, well-controlled clinical trials to determine optimal intake levels and bioavailability of nutrients from different leafy greens and to elucidate the synergistic effects among their bioactive compounds. Molecular and nutrigenomic studies are recommended to understand individual variability in health responses. Practically, public health strategies should promote the regular consumption of diverse leafy vegetables as part of a balanced diet to enhance cardiovascular and metabolic well-being, especially in communities with limited access to fresh produce.

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