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Chokkara Sri Lasya
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author
Chokkara Sri Lasya
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Spinach and its health benefits: A review

Chokkara Sri Lasya

Abstract
Natural plants and herbs are the natural medications practiced for centuries worldwide. Fruits and vegetables are rich source of vitamins and minerals that help strengthen the human immune system which in return and responsible for fighting against diseases. Such a plant with Vitamin and mineral rich vegetable, widely grown and consumed is spinach (*Spinacia oleracea* L.). Spinach is most widely used as food, consumed in various forms and with different combinations with different foods. Spinach is not only rich in vitamins and minerals content, they are also rich in phytochemicals, bioactive compounds and flavonoids. Spinaches bioactive compounds work against anti-cancer, anti-obesity, hypoglycemic, cancer, obesity and cardiovascular disease. Even though with such great benefits from spinach, the consumption of spinach worldwide is comparatively low. This review provides an overview on functional properties of spinach.

Keywords: Spinach (*Spinacia oleracea* L.), anti-obese, flavonoids, anti-cancer

1. Introduction
Spinach (*Spinacia oleracea* L.), a dark green leafy vegetable related to beets and chard, belongs to the Amaranthaceae family. (Gutierrez, R.M, *et al.*, 2019) [36]. *Spinacia oleracea* is commonly known as Spinach (English), Chhurika (Sanskrit), Palak (Hindi; Gujarati; and Marathi), Palakh (Kashmiri), Palang (Bangla), Pasalai (Tamil), and Mathrubhumi (Telugu) (Kirtikar KR, *et al.*, 2005) [46]. Spinach is arguably first or second most nutritious vegetable consumed in the United States (broccoli being the other). (Morelock, T. E, *et al.*, 2008) [70]. Spinach (*Spinacia oleracea* L.) is a cool-season annual vegetable that can be eaten raw, boiled, canned, frozen, in baked products, soups, and other dishes. (Ozkan, I. A, *et al.*, 2007) [76]. Vegetables play a significant role in Indian vegetarian diets. It has been shown that 95 percent of the total -carotene accessible in the country comes from fruits and vegetables, with green leafy vegetables (52 percent) and mangoes accounting for 90 percent of this total (38%) (Gopalan, C., 1992) [31]. Carotenoids (Vitamins) are abundant in green leafy vegetables, as are iron, calcium, ascorbic acid, riboflavin, folic acid, and a variety of other minerals (Devadas, R. P, *et al.*, 1980 and Prakash, D, *et al.*, 1991) [22, 85]. The human diet is primarily comprised of leafy vegetables. (Umar, S., *et al.*, 2007) [95, 96] This review gives an overview on the pharmaceutical benefits of spinach to human health.

2. Spinach origin
Spinach as assumed to be originated on Persia (Iran) (Ryder, E. J. (1979) [89]. Around 600 A.D., it was first recognized by the Chinese, who referred to it as Persia's herb. It was first cultivated by the Arabs in North Africa, and it arrived in northern Europe approximately 1100 A.D. via Spain, where the Moors introduced it. (Ryder, E. J. (1979) [89]. It was first recorded in Germany in 1280, and by 1500, it had become a widespread garden vegetable in England and France (Ryder, E. J. (1979) [89]. Early colonists carried it to North America, and by 1806 three varieties had been identified, with the first savoy variety being introduced in 1828 (Nonnicke, I.L. 1989).'Amsterdam Giant,' 'Bloomsdale,' 'Gaundry,' 'Victoria,' and 'Viroflay' were all introduced prior to 1885. 'Dark Green Bloomsdale,' 'Long Standing Bloomsdale,' 'Hollandia,' 'King of Denmark,' 'Juliana,' 'Nobel,' and 'Virginia Savoy' were all introduced between 1900 and 1925 (Nonnicke, I.L. 1989). 'Canner King,' 'Darkie,' 'Del Monte,' 'Domino,' 'Old Dominion,' 'Presto,' 'Viking,' 'Virginia Savoy Wilt Resistant,' 'Winter Giant,' and 'Winter King' were introduced between 1926 and 1950 (Magruder, R., 1938) [62].

3. Spinach description
3.1 Scientific classification
Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Caryophyllidae
Order: Caryophyllales
Family: Chenopodiaceae
Genus: *Spinacia* L.
Species: *Spinacia oleracea* L.
(Plants.usda.gov. 2010)

3.2 Botanical Description
3.2.1 Leaves
Alternative leaf structure with the lower having a one very long petiole, variously lobed with lobes in acute triangle shape. The texture of leave is smooth on both the sides.

3.2.2 Stem
Straight up erected to a length height of 30-60 cm high, smooth texture and round diameter, piped, succulent stems, at some parts the tips are red in colour.

3.2.3 Male inflorescence
Flowers on long terminal glomerate spikes and shorter ones from the axial, very numerous, sessile, calyx 4-parted, stamen 4, anthers twin, very large, calyx 4-parted, stamen 4, anthers twin, very large.

3.2.4 Female inflorescence
Flowers are axillary, sessile, and densely packed. When the seed is ready, the calyx has two protruding horns on each side that grow into spines. In general, there are four white tapering styles. Capsules are one-celled, one-valved, armed, and capped with the little surviving calyx, which has two opposite short horns. (Kirtikar KR, *et al.*, 2005) [46].

3.3 Chemical composition
3.3.1 Flavonoids
Spinach (*Spinacia oleracea*) is known for its richness in flavonoids. Flavonoids have been linked to a lower risk of coronary heart disease (Hertog, M. G., *et al.*, 1995 and. Knekt, P., *et al.*, 1996) [38, 47], dementia (Commenges, D., *et al.*, 2000) [19], and several types of cancer, according to epidemiological studies (Neuhouser, M. L., 2004) [72]. One of the numerous aspects that determines the quality of vegetables is their flavonoid concentration. (Bergquist, S. Å., *et al.*, 2005) [8, 9]. Flavonoids content varies by genotype, environmental growing circumstances, growth stage, postharvest treatment, and storage state in vegetables and other plants. (Patil, B. S., *et al.*, 1995 and DuPont, M. S., *et al.*, 2000 and Howard, L. R., *et al.*, 2002) [82, 23, 40-41]. A wide range of flavonoids are present such as quercetin; myricetin; kaempferol [40]; apigenin; luteolin; patuletin; spinacetin; jaceidin; 4'-glucuronide; 5,3',4'-trihydroxy-3-methoxy-6:7-methylenedioxyflavone-4'- glucuronide; 5,4'-dihydroxy-3.3'-dimethoxy-6:7-methylene dioxyflavone-4'-glu-curonide (Ferreres, F, *et al.*, 1997) [27]; 5,4'-dihydroxi-3,3'- dimithoxi-6,7-methylene-dioxi- flavone (C18H14O8.); 3,5,7,3',4'pentahydroxi-6- methoxyflavone (Anonymous. The wealth of India. Vol 5 (R-Z) 2004).

3.3.2 Phenolic Compound
The polyphenols can be isolated from the plant and they are para-coumaric acid, ferulic acid, ortho- coumaric acid (Bunea, A., *et al.*, 2008) [2].

3.3.3 Carotenoids
Spinach may be a good source of carotenoids (yellow, orange, or red pigments) that are disguised by green chlorophyll. Carotenoids have been shown to be more stable during thermal processing than chlorophylls, despite being vulnerable to light oxidation (serving as effective antioxidants) (Bergquist, S. Å., *et al.*, 2006) [8, 9]. Spinach shows the presences of different carotenoids such as lutein 9'-(Z)-neoxanhin, β-carotene, and violaxanthin.

3.3.4 Vitamins
Spinach is also knowns for its high content of vitamins in them along with high concentration of folic and oxalic acid. Spinach shows high concentration of vitamin A, C, E, K.

3.3.5 Minerals
Along with high vitamin content in spinach they also come with a good amount of mineral composition. Zinc, calcium, potash, magnesium, manganese and phosphorous.
Spinach is a unique plant which can be eaten in various forms such as raw, in salads and raw smoothies or in cooked or semi-cooked forma like in soups, steamed or cooked in combination with other vegetables. Spinach possesses a high content of water, up to about 91.4% and possess a small quantity of protein (2.9%), with carbohydrates up to 3.6% and fats of 0.4%. lipids are majorly composed of mono- and poly-unsaturated fatty acids (alpha- linolenic acid, oleic acid, linoleic acid) and trace amounts of saturated fatty acids (e.g., capric acid, stearic acid, myristic acid). (Issa, A. Y., *et al.*, 2006 and Mattila, P., *et al.*, 2007) [43, 65]. A 100-g serving of spinach contains enough of vitamins to meet or exceed their RDA, including vitamin K (604%), vitamin A (188%), folate (49%), and vitamin C (47%) (US Department of Agriculture, Agricultural Research Service. (2011) [97].
A verity of factors affects the nutrient composition such as vitamins A, C, E, β-carotene, phylloquinone (K1), folate. (Lester, G. E., *et al.*, 2010 and Koh, E., *et al.*, 2012) [55, 49]. The mineral and vitamin composition in spinach varies from the season in which spinach was grown, like folate and tocopherol and minerals such as nitrogen, potassium, calcium, magnesium, copper, zinc, and manganese. Cooking effects the micronutrient composition in spinach too. For instance, the amount of folates decrease as spinach is boiled or steaming. (Delchier, N., *et al.*, 2012) [21].
Phytochemicals, like carotenoids and phenolic compounds, are non-essential nutrients found all through the plant kingdom, including a lot in spinach. Carotenoids are pigments found in nature that are part of photosynthetic light harvesting complexes (photosystem II), where they quench chloroplast triplet states, stabilise protein-lipid structures, scavenge reactive oxygen species (ROS), and dissipate excess radiant energy not needed for photosynthesis. (Yamaguchi, M. 2012) [103]. Spinach are rich sources of carotenoids, lutein (Chun, O. K., *et al.*, 2005) [17], which is considered to prevent age-related macular degeneration and cataracts. (Han, X., *et al.*, 2007 and Edenharder, R., *et al.*, 2001) [37, 25]. Spinach contains considerable amount of phenolic compound products of secondary metabolism (Edenharder, R., *et al.*, 2001) [25]. Phenolic compounds act as antioxidents, antimicrobials, anti-

viral and anti-fungal, (Thompson, L. U., *et al.*, 2006) [94], spinach also consist 0.8% gallic acid.

Polyphenols are categorised based on their chemical structures in to 4 categories: - phenolic acid, flavonoids, liganas and stilbenes. (Howard, L. R., *et al*, 2002 and Pandjaitan, N., *et al.*, 2005) [78] spinach contains high amount of 17 distinct flavonoids obtained from patuletin, spinacetin, spinatoside, jaceidin, and flavone. (Koh, E., *et al.*, 2012 and Citak, S., *et al.*, 2009 and Delchier, N., *et al.*, 2012) [18, 21, 49]. Phenolic 122 acids are divided into two classes; hydroxycinnamic acid (e.g., p-coumaric, ferulic) and hydroxybenzoic acid (e.g., p-hydroxybenzoic, vanillic acids). (Mattila, P., *et al.*, 2007 and Edenharder, R., *et al.*, 2001) [65, 25].

4. Traditional application of spinac

Sweet, cooling, carminative, laxative, alexipharmic herb; beneficial in blood and brain illnesses, asthma, leprosy, biliousness; induces "kapha" (Ayurveda). It's been used to treat urinary calculi in the past. It has been proven in studies to have hypoglycaemic effects. The leaves are antipyretic, diuretic, maturant, laxative, digestible, anthelmentic, and useful in urinary concretion, inflammation of the lungs and bowels, sore throat, pain in joints, thirst, lumbago, cold and sneezing, sore eye, ring worm scabies, leucoderma, soalding urine, arrest vomiting, biliousness, and flatulence. They've also been utilised to treat febrile illnesses. Fevers, leucorrhoea, urine discharges, lumbago, and brain and heart problems can all benefit from the seeds (Yunani). Seeds have laxative and cooling properties. They've been used to treat things like respiratory problems, liver inflammation, and jaundice. Urinary calculi are treated with the green herb (Patil, U. K., *et al.*, 2009 and Maeda, N., *et al.* 2008) [83].

5. Health benefits

5.1 Radiation protection against gamma rays

Vitamin E, C, selenium, phenolic compounds, carotenoids, flavanoids, and other plant-derived antioxidants are examples (Chandha, S. L., 1997) [15]. Increased intake of phyto-antioxidants, as a nutritional intervention, is thought to lessen the hazard of free radicals. Carotenoids are plant-derived compounds that protect plants from free radicals created during photosynthesis. One of the carotenoids, -carotene, is regarded to be beneficial to humans and other animals not just as a precursor to vitamin A but also as an efficient antioxidant. *Spinacia oleracea* L. is a rich source of carotenoids (lutein, β-carotene, zeaxanthin), p-Coumaric acid, ascorbic acid, proteins, vitamins and other substances.

In terms of lipid peroxidation (LPO) product and tissue glutathione levels, the protective effect of 1100 mg/kg/day of 50 percent methanolic extract of *Spinacia oleracea* L. (MESO) against radiation-induced oxidative stress was studied. With a source-to-surface distance of 77.5 cm, the animals were exposed to gamma radiation at a rate of 1.07 Gy/min. At 1, 3, 7, 15, and 30 days after exposure, the animals were autopsied. LPO levels increased up to day 15 in untreated irradiated mice and up to day 7 in MESO pre-treated irradiated mice after irradiation. At all intervals, LPO values were considerably lower in MESO pre-treated irradiation mice compared to respective untreated irradiated mice, but returned to normal by day 7. MESO was discovered to be able to reverse radiation-induced alterations in in malondialdehyde content and glutathione depletion in the liver. Swiss albino male mice were used in the tests, and they were given *Spinacia oleracea* leaves alcoholic extract (SE) once daily at a dose of 1100 mg/kg/day p.o. for 15 days. At a dose rate of 1.07 Gy/min, the animals are given a single dose of 5 Gy of gamma radiation. Mice were slaughtered at several postmortem intervals after exposure, including 1, 3, 7, 15, and 30 days. To calculate LPO, the brain was extracted and processed. Radiation caused a considerable increase in LPO readings, which could be reduced by supplementing SE before irradiation at all intervals investigated. The protection provided by SE in the LPO value of the brain in this study suggests that *Spinacia oleracea* may play a function as a radio protector to some extent if consumed regularly, which could be related to the synergistic action of antioxidant elements contained in spinach (Verma RK, *et al.*, 2003) [98].

5.2 Antioxidant Activity

Grossman reported the chemical proportion of natural antioxidant (NAO) components in *Spinacia oleracea* in 2001. The antioxidant activity in the spinach leaves was extracted with water, and the 20,000 g supernatant was extracted using a water: acetone (1:9) solution. The resultant 20,000 g supernatant was purified further using reverse phase HPLC and a C-8 semi-preparative column. The hydrophilic peaks were intense after elution with 0.1 percent TFA. Seven more hydrophobic peaks emerged after elution with acetonitrile in TFA. At 250 nm, all of the peaks were seen. When examined using three different assays, all of the fractions obtained demonstrated antioxidant activity. Four of the hydrophobic fractions were identified as glucuronic acid derivatives of flavonoids using 1H and 13C NMR spectroscopy, while three others were recognised as Trans and CIS isomers of p-coumaric acid and others as meso-tartarate derivatives of p-coumaric acid. The presence of flavonoids and p-coumaric acid derivatives as antioxidant components in the aqueous extract of spinach leaves was discovered for the first time in this study (Wang, Y, *et al.*, 2005) [99-100].

More research in humans is needed to see if the consumption of spinach NAO- or lutein-rich meals, which reduce inflammation in mice by modulating the NF-B pathway, is also useful clinically, especially in people with chronic inflammation or inflammation-related disorders (Roberts, J. L., *et al.*, 2016) [87].

5.3 Anticancer Activity

With a projected 14 million new cancer diagnoses and 8.2 million cancer-related deaths in 2012, cancer is one of the main causes of mortality globally. According to current forecasts, the incidence rate of cancer would rise by 70% in the next two decades, underscoring the crucial need to develop safe and effective cancer prevention and treatment measures (World Health Organization. 2019). Vegetarian diets, particularly dark green vegetables, have been linked to a lower incidence of numerous malignancies. Consumption of spinach has been shown to protect against breast, colon, and esophageal cancers in epidemiological studies. Females who ate more raw spinach (>52 servings per year) had a 45 percent lower incidence of breast cancer in a case-control study with 6,888 cases and 9,428 controls (Longnecker, M. P., *et al.*, 1997) [59, 100]. Lutein, a type of carotenoid, has been linked to a lower risk of breast cancer (Freudenheim, J. L., *et al.*, 1996) [29].

In one study, the inhibition of calf DNA polymarases was examined using spinach ethanol extract (SE) and three fractions obtained by hydrophobic column chromatography (pol). The spinach glycoglycerolipid fraction dose-dependently decreased pol activity with an IC50 value of 43.0g/ml, but the fat-soluble fraction very mildly inhibited pol activity, while the water-soluble fraction had no impact. Although the ethanol extract from spinach includes pol inhibitory glycoglycerolipid, it had no effect on pol. This study found that oral administration of the spinach glycoglycerolipid fraction inhibited mammalian pol activity, human cultured cancer cell growth, and *in vivo* solid tumour proliferation. This fraction could aid in cancer prevention and serve as a functional meal with anticancer properties (Cartford, M. C., *et al.*, 2002) [14].

5.4 Sulphite oxidase activity

Sulphite metabolism in higher plants has received a lot of attention, especially in the context of SO2 fumigation. Sulphite oxidase activity is found in spinach chloroplasts, along with oxygen consumption and ferricyanide reduction. Non-ionic biological detergents solubilize this action, which is linked to thylakoids. Sulphite oxidase activity solubilized by Triton X-100 from spinach thylakoids had pH and temperature requirements that were compatible with those of an intrinsic membrane protein. This isolated activity was unaffected by radical scavengers (mannitol, mannose, and fructose) or catalase, and was only inhibited by superoxide dismutase at very high concentrations. Thus, the reported sulphite oxidation was done via a thylakoid membrane enzymic system with sulphite oxidase activity, rather of the photosynthetic electron transport system. Thylakoid sulphite oxidase kinetic characteristics were measured and compared to those of other sulphite oxidases (Bhatia, A. L., *et al.*, 2004) [11, 12].

5.5 Anthelmintic activity

The antihelmintic activity of crude extract of *Spinacia oleracea*Linn was studied by Dave *et al.* in 2009. Pheretimaposthumaas test worms were used to test two distinct extracts: fresh juice extract and methanolic extract. To evaluate the time of paralysis and death of worms, researchers used different quantities of fresh juice extract and methanolic extract of *Spinacia oleracea* Linn (MSO) at 10 mg/ml, 20 mg/ml, 30 mg/ml, 40 mg/ml, and 50 mg/ml. Both extracts had anthelmintic action *in vitro*. The standard reference was albendazole, while the control was saline water. According to the findings, fresh juice extract may have more strong anthelmintic effect than MSO (Patil, U. K., *et al.*, 2009) [83].

5.6 Anti-Inflammatory properties

Inflammation is a normal immunological reaction to injury or infection that, if left unchecked, can lead to significant chronic diseases including cancer, cardiovascular disease, and type 2 diabetes (Gregor, M. F., *et al*, 2011) [33]. Functional foods are appealing alternatives in the treatment and prevention of inflammation and inflammation-mediated diseases, as current pharmacological therapies for inflammation, while effective, are associated with adverse side effects (e.g., vomiting, nausea, constipation, dizziness), and thus are appealing alternatives in the treatment and prevention of inflammation and inflammation-mediated diseases. Several animal models have been used to test spinach's anti-inflammatory capabilities.

In terms of mechanism, spinach-derived NAO may provide protection via NF-B (Lin, Y. L., *et al.*, 1997) [56]. Cytosolic activation or DNA-binding activity is inhibited. Aromatic phenolics are a type of phenolic compound that has NAO's anti-inflammatory properties (including p-coumaric acid) are most likely due to these compounds (Bergman, M., *et al.*, 2001) [6, 7]. Evidence from animal and cell research indicates that lutein reduces the inflammatory response by inhibiting NF-B activation, and that eating lutein-rich foods like spinach could help to reduce inflammation.

5.7 Anti-obesity Properties

Despite the many initiatives obesity has been a major public health issue worldwide. An estimated 300 million adults are obese worldwide (Hill, J. O., *et al.*, 2003 and Ogden, C. L., *et al.* 2014) [39, 74]. To control the epidemic the medical community had suggested a few lifestyle changes such as diet and exercise. The use of nutraceuticals to decrease the caloric intake by repressing the orexigenic signals thereby inducing a feeling of fullness after meals, is also gathering interest. A thylakoid rich spinach extract has been observed to induce satiety in human and animal test subjects (Albertsson, P. Å., *et al.*, 2007 and Köhnke, R. *et al.*, 2009 and C. Montelius, *et al.*, 2013) [13, 1, 50-51]. A 100 grams sample of spinach thylakoid contains 23.5 g of protein, 11.9 g of fat, 41.7 g of carbohydrate, 3.5 g of salt, 3000 mg of chlorophyll, 27.9 mg of lutein, 730 µg of zeaxanthin, 4760 µg of β-carotene, 21 µg of vitamin A, 1313 µg of vitamin K, 6.07 mg of vitamin E and 166 µg of folic acid. In a 13day study, rats fed with a high fat diet, supplemented with thylakoids showed lower consumption of food and reduced body weights. A longer 100 day study showed a significant body fat and body weight reduction of almost 33% and 27% compared to the control group (Köhnke, R., *et al.*, 2009) [50-51]. Thylakoids are thought to slow down the digestion process and absorption of fats at a reduced speed by interacting with the lipase/colipase complex (Maljaars, J., *et al.*, 2007) [63].

Kohnke *et al.* demonstrated a similar effect in humans, the experiments proved a dose dependent increase in cholecystokinin (a gut derived satiety hormone) 6 hours after meals. The increase in CCK was likely in response to the thylakoid (Köhnke, R., *et al.*, 2009) [50]. Separate studies have shown a significant increase in the level of glucagon-like peptide-1(GLP-1) (an endocrine-derived satiety hormone) and an adipose derived satiety hormone (Köhnke, R., *et al.*, 2009 and Albertsson, P. Å., *et al.*, 2007) [1, 50]. It also showed a significant reduction in a stomach-derived hunger hormone, serum ghrelin in a thylakoid rich diet (Hill, J. O., *et al.*, 2003) [39]. These experiments report a decrease in feeling of hunger post meal, fewer thoughts of food and a reduced urge to eat in healthy overweight subjects (Köhnke, R., *et al.*, 2009) [50]. However, it is to be noted that thylakoids had no effect on the urge to consume high carbohydrate foods or salt (. Montelius, C., *et al.*, 2014). It is also important to note that the satiety effect of thylakoids is not as pronounced in large, double blind, placebo-controlled randomized tests (Rebello, C. J., *et al.*, 2015) [86].

There is evidence suggesting supplementing the diet with spinach-derived thylakoids to be useful in controlling interim hunger, calorie intake, and weight gain in healthy individuals through the modulation of CCK, GLP-1, and ghrelin secretions, but the relevance of these effects in longer clinical trials, focusing on the obese, is still a matter of further investigation.

5.8 Hypoglycemic activity

Hypoglycemia is a risk factor for type-2 diabetes and elevated blood glucose levels (Hypoglycemia), which is actually quite prevalent worldwide. Therefore, there is a need to find a therapeutic way to control glycemia and reduced insulin sensitivity (Beltrán-Sánchez, H., *et al.*, 2013) [5]. The insulin-like and insulin-sensitizing effects of spinach extracts have been demonstrated in cell culture experiments. Park *et al.* (Park, J. H., *et al.*, 2012) [81] looked studied how fresh spinach, whether juiced or extracted with ethanol, affected the differentiation of 3T3-L1 pre-adipocytes.

From various vast research, Thylakoids may help manage postprandial glycemia and insulinemia by interfering with glucose absorption and lowering insulin secretion, according to studies, however the effects may be transient.

5.9 Lipid-Lowering Properties

Fasting blood triglyceride levels exceeding 150 mg/dL (> 1.69 mM) are clinically characterised as hypertriglyceridemia, and are a significant risk factor for pancreatitis, liver disease, and cardiovascular disease (Park, J. H., *et al.*, 2012) [81]. Hypertriglyceridemia is common in industrialised countries such as the United Kingdom (27.5%), 100 France (27%), (Laforest, L., *et al.*, 2009) [54] South Korea (25%), (Yuan, C., *et al.*, 2015) [104] and the United States (24%), but it is also a public health concern in low- and middle-income countries like India (47 percent) (Bhardwaj, S., *et al.*, 2011) [10].Treatments for hypertriglyceridemia include weight loss and exercise, dietary supplementation with fish oil or niacin, and pharmacological intervention. Spinach thylakoids and phytochemicals, in particular, may provide an alternative to these tactics.

Blood lipids have been demonstrated to be reduced by thylakoid membranes extracted from spinach leaves. When compared to subjects who did not consume spinach thylakoids, men and women who consumed a meal containing 50 g thylakoids had considerably reduced serum free fatty acids postprandially (ca. –25%) (Köhnke, R., *et al.*, 2009) [50]. Sprague-Dawley rats and apoE-deficient mice showed similar results, with thylakoid-enriched high-fat diets considerably lowering blood triglycerides (–39% (Albertsson, P. Å., *et al.* 2007) [1]; ca. –25% (Köhnke, R., *et al.*, 2009) [50] and free fatty acids (ca. –15% (Köhnke, R., *et al.*, 2009) [50]. In a rodent investigation, alloxan-induced type-1 diabetic Wistar rats were given a daily dose of 70 percent ethanolic spinach extract (100 mg/kg body weight, oral) to see if they might lower their cholesterol levels. When compared to control diabetic rats, the rats fed with spinach extract had a 62.3 percent reduction in serum triglycerides (Sharma, T., *et al.*, 2014) [90]. In diabetic rats, spinach extract reduced plasma triglycerides to the levels seen in non-diabetic animals (83 mg/dL) (Sharma, T., *et al.*, 2014) [90]. Sprague-Dawley rats fed a high fat-cholesterol diet (9.5 percent fat) supplemented with 5% freeze-dried spinach powder for 6 weeks were used to test the effects of whole spinach supplementation on serum lipids. The spinach group had an 11% lower serum triglyceride level than the control group, but the difference was not statistically significance (Ko, S. H., *et al.* 2014) [48].

Although animal studies have shown the ability of spinach-derived thylakoids and phytochemicals to decrease blood triglycerides, there has yet to be proof of efficacy in people. One-time supplementation with thylakoids (5 g) had no effect on serum free fatty acids (Rebello, C. J., *et al.*, 2015) [86] or triglycerides in people. (Montelius, C., *et al.*, 2014 and Rebello, C. J., *et al.*, 2015) [13, 86]. Similarly, in healthy weight or obese patients who took a fat-rich meal, ingestion of cooked spinach (75 g spinach/meal) had no effect on postprandial blood triglycerides (25 g butter and 170 g white bread) (Maruyama, C., *et al.*, 2013). However, no research has compared the effects of boiling spinach vs. raw spinach on blood triglycerides after a meal. It's likely that boiling changed the amount and/or activity of the lipid-lowering chemicals in the leaves because boiling changes the constitution of spinach. The effects of spinach and its contents on blood lipids should be investigated further due to a lack of data.

6. Conclusion

Spinach (*Spinacia oleracea*L.), a plant with the richness in several vitamins and minerals is a very beneficial plant to the health of humans. Increasing exposure to the phytochemicals and bioactives discussed herein by include spinach in regular meals and salads, or by partially swapping spinach for lettuce, would likely result in good health consequences. Human and animal research have also shown that spinach-derived chemicals can help with obesity, hyperglycemia, and hypertriglyceridemia, all of which are symptoms of the metabolic syndrome. The leaves of spinach are used in various pharmacological activities such as, anti-cancer properties, anti-inflammatory properties, anti-obesity properties etc. various phytochemicals such as flavonoids, carotenoids and phenolic groups have been noticed in high amounts. Active research for further health benefits on spinach is carried on.

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