J. Sci. Innov. Nat. Earth: Vol. 5, Issue 2, 2025, Page 30-33 ISSN (Online) 2583-2093

OPEN ACCESS

Journal of Science Innovations and Nature of Earth

Journal homepage : https://jsiane.com/index.php/files/index

International, Double-Blind, Quarterly, Peer-Reviewed, Refereed Journal, Edited and Open Access Research Journal

Harnessing the Health Benefits of Broccoli: A Comprehensive Review of Its Therapeutic

Karuna Khirwar*[1] and Umesh Shukla[1]

[1]Department of Zoology, Agra College, Agra, Affiliated to Dr. Bhim Rao Ambedkar University, Agra, Uttar Pradesh, India

*Corresponding Author E-mail: karunachaudhary3928@gmail.com

DOI: https://doi.org/10.59436/jsiane.117.2583-2093

Abstract

Sulforaphane (SFN), a potent antioxidant and anti-inflammatory agent, is one of the many bioactive chemicals found in broccoli (*Brassica oleracea*) that contribute to the vegetable's stellar reputation for health benefits. The anticancer, cardiometabolic, neuroprotective, and nutritional advantages of broccoli are highlighted in this review. By affecting carcinogen metabolism, inducing apoptosis, and inhibiting cancer cell proliferation, sulforaphane—a compound derived from glucosinolateshas shown remarkable anticancer properties. Eating broccoli may help your heart in other ways as well, including reducing arterial stiffness, blood pressure, and bad cholesterol. It has the potential to help with metabolic disorders like type 2 diabetes by enhancing insulin sensitivity and blood sugar regulation. The neuroprotective function of SFN, which it primarily does via reducing inflammation and oxidative stress, also gives hope for the treatment of neurodegenerative illnesses such as Alzheimer's. The effectiveness of broccoli is greatly affected by its preparation method; the main components are best preserved by steaming. Though there is encouraging data to suggest its potential benefits, more clinical trials are required to determine the best way to take it and what happens in the long run. As a whole, broccoli is an exceptional functional food because of its many health benefits and its ability to ward off many diseases The green, tightly clustered blossom heads of broccoli are edible and add nutritional value to the food. It is a nutritious supplement to the human diet since it contains several vitamins, minerals, and dietary fibres. Because of its adaptability, broccoli can be used to make a wide variety of by-products.

Keywords: *Brassica oleracea*, sulforaphane (SFN), anticancer effects, health-promoting properties

Received 27.03.2025 Revised 12.04.2025 Accepted 10.06.2025 Online Available 20.06.2025

Introduction

The vegetable known as broccoli (*Brassica oleracea*), which belongs to the family Brassicaceae, is well-known all over the world due to the numerous biological activities and the high nutritional content. As a result of the numerous health benefits that have been demonstrated, it is commonly included in dietary guidelines and consumed by a large n umber of people. In recent years, broccoli and the phytochemical components that it contains have been the focus of a growing number of researches. This research has contributed to improved understanding of the cellular and molecular pathways that are responsible for the preservation of human health. These advantages are numerous and varied, including functions that treat diabetes, protect the cardiovascular system, protect the nervous system, reduce inflammation, fight cancer, and protect against oxidative stress. Its bioactivity can be attributed, in large part, to the presence of sulfur-containing molecules known as glucosinolates, as well as the metabolites of these compounds that are formed by enzymes, particularly isothiocyanates such as sulforaphane (Fahey *et al*., 2001). With regard to the glycosinolates that can be found in broccoli and other cruciferous vegetables, the most prevalent variety is called glutaracin. Glucoraphanin is converted to sulforaphane by the process of enzymatic hydrolysis, chewing, or chopping. This process is triggered by the release of the enzyme myrosinase, which occurs when tissues are injured. The compound known as sulforaphane has garnered a lot of attention due to the tremendous effects it has in chemoprevention and cellular defense respectively. The stimulation of the nuclear factor erythroid 2-related factor 2 (Nrf2) signaling pathway is one of the primary active mechanisms that it possesses. After it has been activated, Nrf2 improves the body's ability to neutralize reactive oxygen species and detoxify toxic chemicals. According to Zhang and Gordon (2004), once it enters the nucleus, it causes the development of a number of phase II detoxification and antioxidant enzymes. These enzymes include HO-1, GSTs, and NAD(P)H quinone oxidoreductase 1 (NQO1). Sulforaphane's capacity to inhibit histone deacetylases (also known as HDACs) is the mechanism by which it exerts its positive epigenetic effects. The deregulation of these enzymes is frequently seen in cancer and other chronic illnesses (Myzak *et al*., 2007). These enzymes have a role in regulating gene expression and the structure of chromatin. Additionally, sulforaphane demonstrates potential in the area of metabolic health regulation, in addition to its chemopreventive effects. Research has shown that it can raise insulin sensitivity and lower fasting blood glucose levels (Bahadoran *et al*., 2011). As a result, it has the potential to be a dietary component that could be used in the treatment of metabolic syndrome and type 2 diabetes. The fact that broccoli has the ability to reduce the levels of pro-inflammatory cytokines in the body, such as TNF-α and interleukin-6 (IL-6), which are typically elevated in chronic inflammatory disorders, is further evidence that it possesses anti-inflammatory properties (Gasper *et al*., 2007). Broccoli is a rich source of sulforaphane as well as a wide variety of other phytochemicals and micronutrients. These include lutein, beta-carotene, kaempferol, and quercetin, in addition to a wide range of carotenoids, minerals, and vitamins (A, C, K, folate, potassium, calcium, and iron). Research conducted by Manach *et al*. (2004) indicates that the presence of these compounds contributes to the preservation of healthy cardiovascular function, vision, immune system, and cell function. On top of that, they help mend damaged cells. The use of cruciferous vegetables on a regular basis, such as broccoli, has been associated with a reduction in the prevalence of chronic diseases, particularly cardiovascular conditions such as coronary artery disease and ischemic stroke (Blekkenhorst *et al*., 2018).

It is important to note that the manner in which broccoli is prepared has a significant impact on the health advantages that it provides. The degradation of glucosinolates and the inactivation of the enzyme myrosinase can be accomplished through thermal processing, particularly boiling or microwaving. This results in a reduction in the production of sulforaphane as well as its bioavailability. According to Song and Thornalley (2007), the glucosinolate content and enzymatic activity of broccoli are more successfully preserved when it is steamed lightly for short periods of time. This is especially true when compared to other techniques of cooking. In addition, broccoli sprouts have become increasingly popular as a result of their much greater concentrations of glucoraphanin in comparison to mature florets. They provide a concentrated supply of sulforaphane and a practical method of increasing the amount of sulforaphane that is consumed through regular consumption. In conclusion, broccoli is a prime example of the notion of a functional food, which is a natural component of the diet that offers health benefits that go beyond the scope of basic nutrition. These benefits are achieved through the interaction of broccoli with molecular pathways that are responsible for disease prevention and health promotion. As a result of its bioactive profile, in particular the presence of sulforaphane, it is an excellent option for use in nutritional regimens that aim to reduce the negative impacts of environmental pollutants, chronic inflammation, oxidative stress, and metabolic dysfunction. The value of broccoli in the management of chronic diseases and public health will be further established by the continuation of research into its bioefficacy, clinical relevance, and appropriate dietary inclusion.

Anti-Inflammatory and Antioxidant Effects of Broccoli

A significant number of non-communicable diseases, including cardiovascular diseases, diabetes, cancer, and neurodegenerative disorders, are characterized by the presence of chronic inflammation and oxidative stress as fundamental components. Both the persistent activation of inflammatory pathways and the excessive production of reactive oxygen species (ROS) are characteristics that are frequently associated with these type of illness conditions. The isothiocyanate sulforaphane, which is one of

the many bioactive phytochemicals that can be found in broccoli (*Brassica oleracea*), has recently garnered a lot of interest as a potent dietary agent that has the ability to influence oxidative and inflammatory responses. It is essential to note that sulforaphane is responsible for activating the Nrf2-ARE-Keap1-nuclear factor erythroid 2-related factor 2 signaling pathway, which triggers the activation of the ARE. According to Kensler *et al*. (2007), this pathway is responsible for controlling the transcription of genes that are responsible for the production of phase II detoxifying enzymes and endogenous antioxidants. These enzymes include HO-1, GSTs, NAD(P)H quinone oxidoreductase 1, and superoxide dismutase (SOD...). As a result of this process, redox balance is restored, and cells become more resistant to the damaging effects of oxidative stress. Sulforaphane, which is abundant in broccoli extract, has been demonstrated to offer robust protection against oxidative stress in animal models. This protection is achieved by the reduction of lipid peroxidation, DNA damage, and protein carbonylation, as demonstrated by Lee *et al*. (2008) and Tarozzi *et al*. (2009).

In addition to its role as an antioxidant, sulforaphane possesses potent anti-inflammatory properties. According to Heiss *et al*. (2001) and Lin *et al*. (2008), it is able to prevent the activation of nuclear factor-kappa B (NF-κB), which is a transcription factor that plays a crucial role in regulating the production of pro-inflammatory mediators such as cyclooxygenase-2 (COX-2), inducible nitric oxide synthase (iNOS), tumor necrosis factor-alpha (TNF-α), and interleukin-6 (IL-6). According to Kim *et al*. (2011), flavonoids found in broccoli, such as quercetin and kaempferol, have the ability to influence immune function by inhibiting the Janus kinase/signal transducers and activators of transcription (JAK/STAT) and mitogen-activated protein kinase (MAPK) pathways. This, in turn, reduces the secretion of pro-inflammatory cytokines. These findings are supported by clinical evidence: a study that was carried out by Riso *et al*. (2009) demonstrated that steamed broccoli significantly reduced the levels of C-reactive protein (CRP) and IL-6 in the circulation of smokers, a population that is prone to illnesses that are associated with inflammation. According to the findings of Axelsson *et al*. (2017), taking a supplement consisting of broccoli sprouts, which are particularly abundant in glucoraphanin, caused a reduction in inflammatory markers in those who were overweight. Additionally, broccoli enhances bioenergetics and mitochondrial activity, which means that it decreases the production of reactive oxygen species (ROS) and raises the level of cellular homeostasis (Done *et al*., 2011).

Anticancer Potential

Broccoli has been shown to have anticancer qualities, and these properties have been shown through significant preclinical and clinical research. It has been discovered that sulforaphane is a multi-targeted chemopreventive agent that not only activates phase II detoxification enzymes but also inhibits histone deacetylases (HDACs). HDACs are involved in the proliferation of cancer cells and the silencing of genes that suppress tumor suppressors (Zhang *et al*., 1992; Myzak *et al*., 2006). At the same time, this dual effect makes it easier for malignant cells to undergo apoptosis, pause the cell cycle, and reactivate pathways that suppress tumor growth. The eating of broccoli and other cruciferous vegetables on a regular basis has been related to a lower incidence of a number of malignancies, including colorectal, breast, and prostate cancers, according to epidemiological research. Clinical experiments have provided evidence that supports these correlations, demonstrating that consumption of broccoli leads to an increase in the detoxification of carcinogens and a decrease in the production of DNA adducts (Egner *et al*., 2011; Liu *et al*., 2013; Wu *et al*., 2013).

Cardiometabolic Benefits

Through a number of interrelated methods, broccoli makes a contribution to the health of the cardiovascular system and the metabolic system. Furthermore, it is an abundant source of dietary fiber, antioxidants, and bioactive substances such as glucoraphanin and sulforaphane, all of which contribute to an overall improvement in lipid metabolism, vascular function, and glycemic control. It has been demonstrated through randomized controlled trials that regular consumption of broccoli that is high in glucoraphanin can result in significant reductions in low-density lipoprotein (LDL) cholesterol as well as improvements in endothelial function. These effects are likely mediated by Nrf2 activation and reduced oxidative stress in vascular tissues (Armah *et al*., 2015).

Supplementation with broccoli sprout extract has been shown to lower fasting blood glucose, improve insulin sensitivity, and reduce glycated hemoglobin (HbA1c) in people who have type 2 diabetes. These findings suggest that sulforaphane may play a role in the regulation of glycemic levels (Bahadoran *et al*., 2012; Axelsson *et al*., 2017). In addition, consumption of broccoli has been linked to a decrease in systolic blood pressure as well as an improvement in arterial flexibility, which is indicative of the potential therapeutic value of broccoli in the management of hypertension and metabolic syndrome (Gasper *et al*., 2005).

Neuroprotective Effects

Broccoli also displays strong neuroprotective potential, particularly through the activation of the Nrf2 pathway that is mediated by sulforaphane. According to Tarozzi *et al*. (2009), this activation results in an increase in the expression of antioxidant enzymes including glutathione peroxidase and HO-1, which are responsible for protecting neurons from either oxidative or nitrosative stress. According to Kim *et al*. (2013), sulforaphane has been demonstrated to reduce the formation of amyloid-beta in animal models of Alzheimer's disease and other neurodegenerative disorders, as well as to decrease microglial activation and improve cognitive function. Furthermore, sulforaphane has been shown to have protective effects on the cerebrovascular system in ischemia-reperfusion models. These protective effects include a reduction in the size of the infarct, the maintenance of the integrity of the blood-brain barrier, and the prevention of neuronal death (Zhao *et al*., 2006). The results of this study suggest that broccoli has the ability to not only prevent neurodegeneration but also to improve the brain's resistance to oxidative and inflammatory assaults.

Hepatoprotective Effects

Due to the fact that the liver plays a vital role in detoxification, metabolism, and immunological function, it is especially susceptible to oxidative stress and chemical harm. The glucoraphanin-derived metabolite sulforaphane contained in broccoli is principally responsible for the significant hepatoprotective properties that broccoli contains. As a result of sulforaphane's ability to boost phase II detoxifying enzymes like glutathione S-transferases (GSTs) and to upregulate glutamate-cysteine ligase, which is the rate-limiting enzyme in glutathione (GSH) manufacture, hepatic antioxidant defenses are strengthened. According to Yagishita *et al*.'s 2019 research, experimental investigations have shown that sulforaphane reduces the elevations in hepatic enzymes, specifically ALT, AST, and ALP, which are typically seen in cases of liver injury. Furthermore, broccoli extract has the ability to decrease lipid peroxidation, stabilize mitochondrial membranes, and protect hepatocytes from necrosis that is caused by exposure to xenobiotics. In models of non-alcoholic fatty liver disease (NAFLD), the consumption of broccoli alleviates hepatic steatosis, downregulates lipogenic genes (such as SREBP-1c), promotes fatty acid oxidation, and reduces triglyceride accumulation. These findings highlight the potential of broccoli as a dietary intervention in the prevention of liver fibrosis.

Modulation of Gut Microbiota and Digestive Health

Because of its high fiber, glucosinolates, and polyphenol content, broccoli has a major impact on the health of the gastrointestinal tract. Glucosinolates are transformed by gut bacteria into bioactive isothiocyanates, which have the ability to exert local anti-inflammatory and anticancer actions in the gut epithelium. Its fibers operate as prebiotics, providing nourishment to the beneficial microbiota that lives in the interior of the digestive tract. According to Clarke *et al*. (2016), the consumption of broccoli has been demonstrated to bring about an increase in the populations of Lactobacillus, Bifidobacterium, and Akkermansia muciniphila, while simultaneously bringing about a reduction in the populations of dangerous strains such as Clostridium perfringens and Escherichia coli. By increasing the expression of tight junction proteins, these microbial changes reinforce the integrity of the gut barrier, hence reducing intestinal permeability and the amount of endotoxin exposure that occurs throughout the body. In addition, chemicals found in broccoli have the ability to inhibit the signaling of colonic NF-κB, so reducing inflammation in the intestinal tract and maybe lowering the risk of colorectal cancer.

Bone Health Support

The nutrient composition of broccoli as well as the phytochemicals it contains are beneficial to the health of the skeleton. In addition to providing critical minerals such as calcium, magnesium, and potassium, it also offers essential vitamins that are essential for bone development. One of these vitamins is vitamin K, which is essential for the γ-carboxylation of osteocalcin and the appropriate mineralization of bones. Recent studies have also demonstrated that sulforaphane suppresses osteoclastogenesis by downregulating signaling pathways such as RANKL. Additionally, it promotes osteoblast development by activating Nrf2 and Wnt signaling, which suggests that it may have therapeutic promise in the prevention of osteoporosis and other bone ailments (Zhou *et al*., 2021).

Immune Modulation

Through sulforaphane-enhanced activity in macrophages, natural killer (NK) cells, and dendritic cells—three essential players in early immunological defense broccoli has the ability to affect both innate and adaptive immunity. In order to strengthen antiviral responses, it increases the expression of genes related to interferon. Adaptively, the chemicals found in broccoli have an effect on T-cell differentiation, which helps to maintain a balance between Th1 and Th2 cytokine responses and promotes the generation of regulatory T-cells (Treg), which may aid in the prevention of autoimmune illnesses (Yanaka, 2017). The consumption of broccoli also strengthens the mucosal immunity in the digestive tract and respiratory tract, which may result in an increase in the effectiveness of vaccines and resistance to illnesses.

One kind of cruciferous vegetable is broccoli, which is actually a wild variety of cabbage belonging to the Brassica L. family (*Brassica oleracea* var. italica; Mehraj *et al*., 2020). Vitamins, minerals, and protein are

abundant in it. It is a great complement to a healthy diet because it contains a lot of phytochemicals and important minerals (Kandil and Gad, 2012). Among its many health benefits and anticancer characteristics, it is abundant in water, fibre, protein, calcium, iron, and vitamins A and C (Acikgoz, 2011; Mahn *et al*., 2012; Avila, *et al*., 2013). In addition to being good for people, it has antioxidant properties. People all around the world regularly eat broccoli because of the many health benefits it provides and the active influence it has on their bodies. According to Schäfer (2017), broccoli has a lot of insoluble fibre and very little soluble fibre. According to studies, 70% of broccoli's weight goes to waste (Campas-Baypoli *et al*., 2009). While broccoli stems, leaves, and florets are farmed for their edible parts, they are also a fascinating source that could be transformed into a novel food product. The antioxidant activity of secondary metabolites, which are plant chemicals, is one reason why broccoli is good for you (Jones *et al*., 2006).

Among broccoli's secondary plant chemicals are:

• **Glucosinolate,** a sulfur-containing compound that contributes to the vegetable's unique flavour and aroma and is present in varying concentrations across plant organs and stages of development. Consumption of broccoli causes the breakdown of glucosinolates into physiologically active chemicals like sulforaphane, which may have anticancer effects. According to Fahey *et al*. (1997), the nutraceutical characteristics of glucosinolates can be explained by the isothiocyanates that are produced when these compounds hydrolyse.

Reactive and unstable compounds with potent anticarcinogenic effect are isothiocyanates (R-N=C=S).

• **Antioxidant flavonoids**, such as apigenin, kaempferol, and quercetin. Vegetables and fruits contain a wide variety of polyphenolic chemicals called flavonoids. They work as anti-inflammatory substances when consumed by humans. It has a lot of bioactive compounds, vitamins, and minerals (Liu, 2013), and it has been found to have these properties (Agati *et al*., 2012; Pan *et al*., 2010). Among the carotenoids found in broccoli are zeaxanthin, lutein, and beta-carotene. Carotenoids have anti-inflammatory and antioxidant properties. Carotenoids shield cells from oxidative stress; they are highly lipophilic and present within cell membranes (Linnewiel-Hermoni *et al*., 2016). There is evidence that it can improve eye health and lower the risk of other ailments, such as age-related muscle degeneration. Vitamin C helps the immune system work well, promotes collagen production, and neutralises harmful free radicals.

Industrial by-products of broccoli

1. Broccoli that has been frozen will retain all of the nutrients and freshness of the broccoli florets that were pre-cut and packaged. Broccoli, a nutritious cruciferous vegetable, retains all of its nutrients even after being frozen or canned, so it's just as good for you as fresh broccoli.

2. **Carrot Chips**: For a healthy take on potato chips, try baking or frying thinly sliced broccoli. Vitamins, minerals, and bioactive compounds are abundant in it. The fibre and antioxidants in broccoli might make it easier to keep blood sugar levels in check.

3**. Broccoli Soup**: This hearty soup is typically made with broccoli and other veggies and seasonings, and it can be chunky or creamy. Both the appetiser and main course versions of these dishes are delicious. Its low calorie count, anti-inflammatory properties, heart-healthy antioxidants, and digestive-aiding fibre all contribute to its overall wellness. By reducing blood sugar levels, it can aid in managing hyperglycemia.

4. **Broccoli Rice**: Broccoli florets that have been finely chopped or riced can be used in place of rice in recipes that call for low-carb rice. The vitamin C, vitamin A, beta-carotene, and lutein content is high, and it also contains a lot of fibre.

5. **Broccoli Pesto**: It adds a certain something to every dish with its wonderful, fresh flavour that goes well with many different kinds of food. As an added bonus, broccoli helps with digestion, reduces inflammation, and speeds up the detox process.

6. **Broccoli Powder**: The fine powder made from dried broccoli can be used to baked goods, smoothies, sauces, and even used as a nutritious supplement.

Conclusion

The numerous benefits that cruciferous vegetables, such as broccoli, offer make them an essential component of a diet that is committed to maintaining a healthy lifestyle. Sulforaphane is one of the bioactive components found in broccoli. It is responsible for the vegetable's potent anticancer, cardiometabolic, and neuroprotective activities. The regulation of oxidative stress, inflammation, and gene expression are the mechanisms that are responsible for these health advantages. Among these mechanisms is the Nrf2 pathway, which plays a particularly important role. According to the findings of scientific research, broccoli not only improves cardiovascular health but also provides neuroprotection against age-related and neurodegenerative illnesses, regulates metabolic disorders such as type 2 diabetes, and manages metabolic disorders. Because of its numerous health benefits and abundant nutrient profile, broccoli is an excellent option for inclusion in diet programs that are intended to be both preventative and curative in nature. While it is true that correct preparation and cooking are necessary in order to maximize its health advantages, it is also true that overcooking may cause some of the bioactive compounds that are beneficial to your health to be destroyed. It is necessary for future research to investigate the mechanisms of action of broccoli, particularly in human clinical trials, in order to fully appreciate the therapeutic potential of broccoli. This will allow for the discovery of its numerous health benefits. As a consequence of this, broccoli is a nutritious powerhouse that is also a readily accessible and inexpensive approach to promote health over the long term, particularly for people who are dealing with the prevention and treatment of chronic illnesses. Further investigation into its bioavailability and the health benefits it offers may result in the revision of dietary guidelines and the implementation of public health programs. Broccoli is an excellent example of a functional food because it is beneficial to a wide variety of body systems, contains a considerable deal of essential nutrients, and contains potent bioactive compounds. Sulforaphane has the ability to exert protective benefits on a wide range of organs and systems, including the liver, intestines, bones, immune system, cardiovascular system, and brain. These protective effects are achieved by the activation of Nrf2, inhibition of NF-κB, and control of HDAC. Including broccoli in one's diet on a regular basis, particularly in its sprout or light-steamed form, is a method of health promotion that is both scientifically sound and practically feasible. Increasing data suggests that it may be able to assist in the prevention of chronic diseases.Because of the health benefits they provide, broccoli-based goods will probably stay in vogue for the foreseeable future. The use of broccoli in creative ways is likely to explode in the food industry in the not-too-distant future. Technological and food processing advancements may one day allow for the creation of novel broccoli-based products to meet the needs of people with varying dietary preferences.

Reference

Fahey, J. W., Zalcmann, A. T., and Talalay, P. (2001). The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. Phytochemistry, 56(1), 5–51.

Zhang, Y., and Gordon, G. B. (2004). A strategy for cancer prevention: Stimulation of the Nrf2-ARE signaling pathway. Molecular Cancer Therapeutics, 3(7), 885–893.

Myzak, M. C., Tong, P., Dashwood, W. M., Dashwood, R. H., and Ho, E. (2007). Sulforaphane retards the growth of human PC-3 xenografts and inhibits HDAC activity in human subjects. Experimental Biology and Medicine, 232(2), 227–234.

Bahadoran, Z., Mirmiran, P., and Azizi, F. (2011). Dietary polyphenols as potential nutraceuticals in management of diabetes: A review. Journal of Diabetes and Metabolic Disorders, 10(1), 5.

Gasper, A. V., Al-Janobi, A., Smith, J. A., Bacon, J. R., Fortun, P., Atherton, C., Taylor, M. A., Hawkey, C. J., Barrett, D. A., and Mithen, R. F. (2007). Glutathione S-transferase M1 polymorphism and metabolism of sulforaphane from standard and high-glucosinolate broccoli. The American Journal of Clinical Nutrition, 86(3), 748–755.

Manach, C., Scalbert, A., Morand, C., Rémésy, C., and Jiménez, L. (2004). Polyphenols: Food sources and bioavailability. The American Journal of Clinical Nutrition, 79(5), 727–747.

Blekkenhorst, L. C., Bondonno, C. P., Lewis, J. R., Devine, A., Woodman, R. J., Croft, K. D., Hodgson, J. M., and Prince, R. L. (2018). Cruciferous and total vegetable intakes are inversely associated with subclinical atherosclerosis in older adult women. Journal of the American Heart Association, 7(10), e008391.

Song, L., and Thornalley, P. J. (2007). Effect of cooking on the content of glucosinolates and isothiocyanates in cruciferous vegetables. Food and Chemical Toxicology, 45(2), 216–224.

Kensler, T. W., Wakabayashi, N., and Biswal, S. (2007). Cell survival responses to environmental stresses via the Keap1–Nrf2–ARE pathway. Annual Review of Pharmacology and Toxicology, 47, 89–116.

Lee, Y. J., Lee, E. J., and Park, O. J. (2008). Sulforaphane-induced apoptosis in HepG2 cells involves the activation of AMP-activated protein kinase. Cancer Letters, 271(1), 115–124.

Tarozzi, A., Angeloni, C., Morroni, F., Hrelia, S., and Hrelia, P. (2009). Sulforaphane as a potential protective phytochemical against neurodegenerative diseases. Oxidative Medicine and Cellular Longevity, 2(4), 262–267.

Heiss, E., Herhaus, C., Klimo, K., Bartsch, H., and Gerhäuser, C. (2001). Nuclear factor kappa B is a molecular target for sulforaphane-mediated anti-inflammatory mechanisms. The Journal of Biological Chemistry, 276(34), 32008–32015.

Lin, W., Wu, R. T., Wu, T., Khor, T. O., Wang, H., and Kong, A. N. (2008). Sulforaphane suppressed lipopolysaccharide-induced inflammation in RAW 264.7 macrophages and mouse models. The Journal of Nutritional Biochemistry, 19(8), 491–500.

Kim, S. H., Kim, B. K., and Lee, Y. C. (2011). Kaempferol suppresses mast cell activation by targeting the Lyn/Syk pathway. The Journal of Nutritional Biochemistry, 22(5), 453–460.

Riso, P., Martini, D., Møller, P., Loft, S., Bonacina, G., Bordoni, A., and Porrini, M. (2009). DNA damage and repair activity after broccoli intake in smokers. The American Journal of Clinical Nutrition, 90(5), 1235–1242.

Axelsson, A. S., Tubbs, E., Mecham, B., Chacko, S., Nenonen, H. A., Tang, Y., Fahey, J. W., Dorrestein, P. C., Saghatelian, A., and Wessells, H. (2017). Sulforaphane reduces hepatic glucose production and improves glucose control in patients with type 2 diabetes. Science Translational Medicine, 9(394), eaah4477.

Done, A. J., and Traustadóttir, T. (2011). Nrf2 mediates redox adaptations to exercise in skeletal muscle. Free Radical Biology and Medicine, 51(3), 716–722.

Zhang, Y., Talalay, P., Cho, C. G., and Posner, G. H. (1992). A major inducer of anticarcinogenic protective enzymes from broccoli: Isolation and elucidation of structure. Proceedings of the National Academy of Sciences of the United States of America, 89(6), 2399–2403.

Myzak, M. C., Tong, P., Dashwood, W. M., Dashwood, R. H., and Ho, E. (2006). Sulforaphane inhibits histone deacetylase activity in BPH and cancer cells. Cancer Research, 66(9), 4826–4834.

Egner, P. A., Chen, J. G., Zarth, A. T., Ng, D. K., Wang, J. B., Kensler, K. H., Jacobson, L. P., Munoz, A., Egner, K. L., Chen, T. Y., Wu, Y., Fahey, J. W., Talalay, P., and Kensler, T. W. (2011). Rapid and sustainable detoxication of airborne pollutants by broccoli sprout beverage: Results of a randomized clinical trial in China. Cancer Prevention Research, 4(9), 1369–1377.

Liu, X., and Lv, K. (2013). Cruciferous vegetables intake is inversely associated with colorectal cancer risk: A meta-analysis. Clinical Nutrition, 32(5), 848–857.

Wu, Q. J., Yang, Y., Vogtmann, E., Wang, J., Han, L. H., Li, H. L., and Xiang, Y. B. (2013). Cruciferous vegetables intake and the risk of breast cancer: A meta-analysis. Breast Cancer Research and Treatment, 138(3), 699–711.

Armah, C. N., Traka, M. H., Dainty, J. R., Defernez, M., Janssens, A., Leung, W., Doleman, J. F., Saha, S., Lund, E. K., and Mithen, R. F. (2015). A diet rich in high-glucoraphanin broccoli reduces plasma LDL cholesterol: Evidence from randomised controlled trials. The American Journal of Clinical Nutrition, 102(4), 722–732.

Bahadoran, Z., Mirmiran, P., and Azizi, F. (2012). Dietary polyphenols as potential nutraceuticals in management of diabetes: A review. Journal of Research in Medical Sciences, 17(7), 711–716.

Gasper, A. V., Traka, M., Bacon, J. R., Smith, J. A., Taylor, M. A., Hawkey, C. J., Barrett, D. A., and Mithen, R. F. (2005). Consuming broccoli does not induce genes associated with xenobiotic metabolism and cell cycle control in human gastric mucosa. The American Journal of Clinical Nutrition, 82(1), 128–134.

Kim, H. J., Jeong, K. H., Jung, U. J., Kim, S. R., and Choi, M. S. (2013). Sulforaphane protects against cytokine- and β-amyloid-induced synapse damage and memory loss. The Journal of Nutritional Biochemistry, 24(4), 710–721.

Zhao, J., Kobori, N., Aronowski, J., and Dash, P. K. (2006). Sulforaphane reduces infarct volume following focal cerebral ischemia in rodents. Brain Research, 1087(1), 213–219.

Acikgoz, F. E. (2011). Influence of different sowing times on mineral composition and vitamin C of some broccoli (*Brassica oleracea* L. var. italica) cultivars. Scientific Research and Essays, 6(4): 760-765.

Agati, G., Azzarello, E., Pollastri, S. and Tattini M. 2012. Flavonoids as antioxidants in plants: location and functional significance. Plant Science, 196: 67–76.

Avila, F. W., Faquin, V., Yang, Y., Ramos, S. J., Guilherme, L. R. G., Thannhauser, T. W. and Li, L. 2013. Assessment of the anticancer compounds Se-methylselenocysteine and glucosinolates in Se-biofortified broccoli (*Brassica oleracea* L. var. italica) sprouts and florets. Journal of Agricultural and Food Chemistry, 61(26): 6216-6223.

Fahey, J.W., Zhang, Y. and Talalay, P. 1997. Broccoli sprouts: an exceptionally rich source of inducers of enzymes that protect against chemical carcinogens. National Science Academy USA, 94: 10367-10372.

Jones, R. B, Faragher, J. D. and Winkler, S. (2006). A review of the influence of postharvest treatment on quality and glucosinolate content in broccoli (*Brassica oleracea* var. italica) heads. Posthar Biol Technol 41: 1-8.

J. Schäfer, L. Stanojlovic, B. Trierweiler. and M. Bunzel. 2017. Storage related changes of cell wall based dietary fiber components of broccoli stems. Food Research International Journal, 93: 43–51.

Kandil, H. and Gad, N. 2012. Effects of inorganic and organic fertilizers on growth and production of broccoli (*Brassica oleracea* L.). Soil Forming Factors and Processes from the Temperate Zone, 8 (1): 61 69.

Linnewiel-Hermoni, K., Paran, E, and Wolak, T. 2016. Carotenoid Supplements and Consumption: Implications for Healthy Aging. Molecular Basis of Nutrition and Aging, 473-489.

Liu, R. H. Health-promoting components of fruits and vegetables in the diet. 2013. Advances in Nutrition, 4(3): 384–392.

Mahn, A. and Reyes, A. 2012. An overview of health-promoting compounds of broccoli (*Brassica oleracea* L. var. italica) and the effect of processing. Food Science and Technology International, 18 (6): 503-514.

Mehraj, H., Akter, A., Miyaji, N., Miyazaki, J., Shea, D. J. and Fujimoto, R. 2020. Genetics of clubroot and fusarium wilt disease resistance in brassica vegetables: The application of marker assisted breeding for disease resistance. Plants (Basel), 9 (6): 726.

O. N, Campas-Baypoli., D. I. Sánchez-Machado, C. Bueno-Solano, J. A. Núñez-Gastélum, C. ReyesMoreno, and J. López-Cervantes. 2009. Biochemical composition and physicochemical properties of broccoli flours. International Journal of Food Science and Nutrition, 60 (4): 163–173.

Pan, M. H., Lai, C. S. and Ho, C. T. 2010. Anti-inflammatory activity of natural dietary flavonoids. Food Function, 1(1):15–31.