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# Phytochemical and therapeutic potential of broccoli (*Brassica oleracea*): A review

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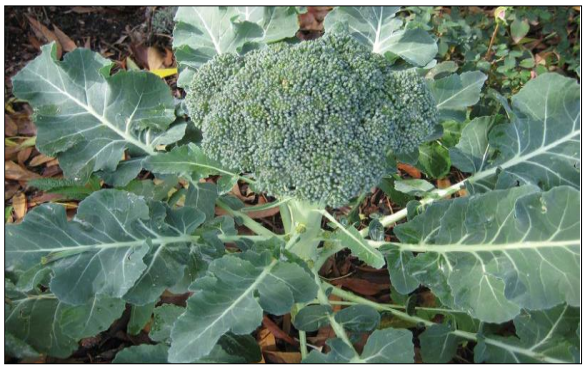
**Abstract**
Plants are a gift from nature to us that help us live healthy, disease-free lives and play a crucial role in protecting our well-being. The edible green plant known as broccoli or *Brassica oleracea* var. *Italica*, is a member of the Brassicaceae. It is thought that broccoli, *Brassica oleracea* var. *Italica*, is a nutritional hustler. Broccoli contains glucoraphin, sulforaphane, selenium and isothiocyanates. It is high in vitamin C and dietary fibre. Indole-3-carbinol can also be found in abundance in broccoli. Since they continue to possess a number of anti-cancer qualities and their benefits, these components found in broccoli are well recognized to be extremely popular. It is extensively utilised to treat different types of cancer as well as other neurological diseases. The phytochemical and medicinal potential of broccoli is covered the current review. The medicinal potential of broccoli has been discussed in relation to its use in the treatment of cancer, diabetes, and other major diseases. Brassinin, isothiocyanates, indole-3-carbinol and other phytochemicals similar to those found in broccoli have been shown to be very useful in the treatment of cancer. Glucosinolates, glucoraphin, and sulforaphane are a few more compounds that cause broccoli to produce more antioxidants activity. Broccoli sprouts contain sulforaphane, which has the potential to treat neurological conditions like Parkinson's and Alzheimer's disease. It is a good source of health promoting composite such Glucosinolates, flavonoids, hydroxycinnamic acid and vitamins according to a thorough review to the literature. Additionally, broccoli is a type of nutrient that has a vast range of beneficial effects, such as antioxidant, anti-cancer, hepatoprotective, anti-obesity, and anti-diabetic properties.

**Keywords:** Broccoli (*Brassica oleracea*), biological activities, phytochemistry

## Introduction
The main source of pharmaceuticals for the early discovery of medicines is plants. In developing nations, about 80% of the population are still depends on plant extracts material as a source of medications. The World Health Organization (WHO) is promoting the traditional use of herbal medicines for the treatment of various habitual illnesses in developing nations due to increases in the risk of chronic sickness globally (Vasanthi *et al*. 2012) [40]. Adding more cruciferous vegetables to one's diet has been recommended by the American Cancer Society (1984) and the National Research Council (1982). These vegetables include cabbage, broccoli, brussel sprouts, cauliflower, and kohlrabi. *Brassica oleracea* var. *Italica*, or broccoli, is a fast-growing annual plant that reaches heights of 60 to 90 cm and is a member of the Brassicaceae family. It originates from the eastern Mediterranean and Asia Minor, and in the 1700s, it was later brought to England and America Anonymous (2015) [2]. Due to difficulties in patenting genotypes with high attention to glucosinolates showing favourable effects in the treatment of cancer, broccoli has attracted interest (Wolf *et al*. 2014) [43]. The majority of broccoli portions that are consumed as food are its florets, which account for 30% of the entire plant. Because of this, only flour and fibre are made from broccoli by-products such leaves and stems (Ares *et al*. 2013) [3]. However, it is becoming increasingly recognized in the scientific community that these by-products are valuable sources of phytochemicals (Bertelli *et al*. 1998) [9]. Additionally, more than 72% of the world's broccoli production are cultivated in Jeju and made in Korea. In addition to being produced in vast amounts, byproducts like leaves and stems from broccoli are also consumed in large quantities. This has a detrimental effect on the environment around agriculture and the recovery of those byproducts for physiologically active compounds that help to lessen environmental issues and boost growers' profits (Borowski *et al*. 2008) [10]. Generally speaking, secondary metabolites with anti-microbial effects are known to be quite abundant in plants.

There are numerous anti-microbial drugs that are used to treat a broad range of disorders caused by microorganisms which are produced from various traditional medicinal plants. The several orders of anti-microbial phytochemicals, such as alkaloids, flavonoids, tannins, polyphenols, and essential oils, are included in these groupings. Polypeptides and phenolics, according to (Samy and Gopal krishnakone 2010) [36]. Due to its antioxidant and anti-carcinogenic compounds, broccoli also has a number of health-promoting qualities. According to Mahn and Reyes (2012) [25], it is primarily made up of polyphenols, glucosinolates, sulforaphane, and selenium. Broccoli eating can lessen the prevalence of lifestyle diseases, which has become increasingly popular with consumers who are health conscious. Due to the presence of two different phytochemicals that support the body's defences against oxidative stress, broccoli has a strong antioxidant capacity (Atle and John 2006) [4]. Direct antioxidants, which participate in redox reactions and remove oxidation products directly. According to Cheung *et al*. (2009) [11], broccoli contains phenolic compounds, carotenoids, vitamin C, and vitamin E as its primary direct antioxidants. A variety of chemical compounds known as circular antioxidants, which can activate the cytoprotective Response to (Phase 2). Isothiocyanates (ITCs), the primary cyclic antioxidants in broccoli, are produced when endogenous myrosinase hydrolyzes glucosinolates. According to Atle and John (2006) [4], glucoraphanin is the most prevalent glucosinolate in broccoli and is also abundant in all cruciferous vegetables of the Brassica L. family, including cabbage, cauliflower, and other plants.

The juice from the leaves is used to reduce swelling in skin diseases, which is one of the primary phytotherapeutic uses of broccoli (Moreno, 2006) [8]. The current study's objective was to create a database for the phytochemical and therapeutic potential of broccoli (*Brassica oleracea*), which can be utilised to promote daily dietary consumption by examining diet-disease links. We emphasise the phytochemical composition, go over how it relates to pharmacological activity, and assess.



**Phytochemistry**

Glucosinolates, flavonoids, hydroxycinnamic acids, and other minor compounds are found in the broccoli inflorescence, which is a good source of substances that promote health (Vallejo *et al*. 2004). All Brassica plants almost exclusively generate glucosinolates, which have positive effects on insect and microbial defence. Various glucosinolates were identified in broccoli sprouts by means of liquid chromatography-mass spectrometry and liquid chromatography/tandem mass spectrometry such as glucoiberin, glucocheirolin, glucoraphanin, progoitrin, sinigrin, glucoalysin, gluconapin, glucoiberverin, 4-hydroxyglucobrassicin, glucoerucin, glucobrassicin, 4- methoxyglucobrassicin, gluconapoleiferin and Neoglucobrassicin Fig. 1 (Maldini *et al* 2012) [26].

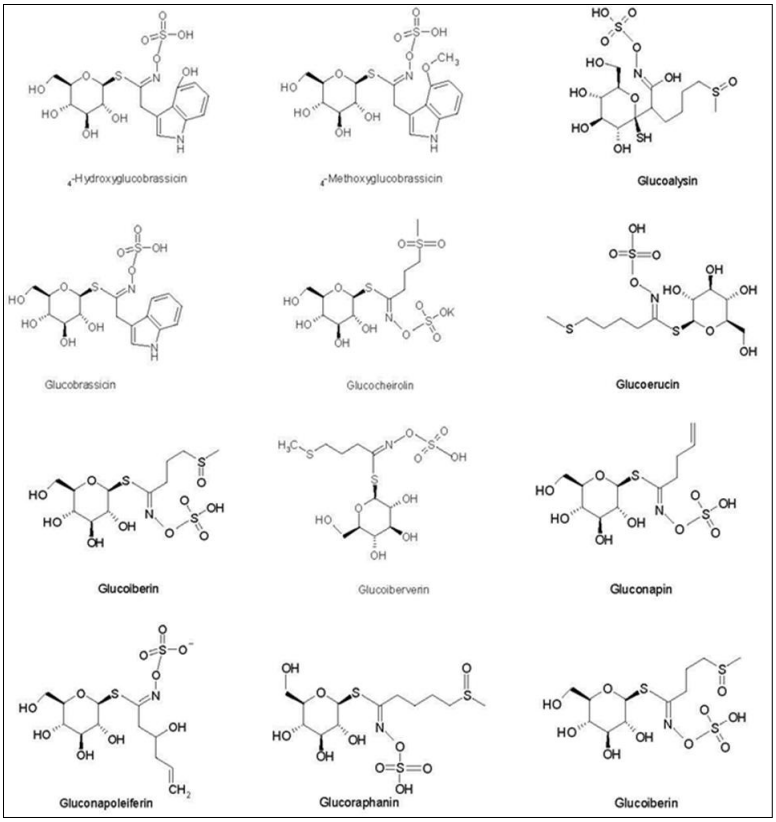



**Fig 1:** Structures of some glucosinolates present in broccoli

**Biological Activities**

Broccoli plays a major and a beneficial role in treating the cancer of various forms that occurs in different parts of the body and also effective in the treatment of various other diseases. Dietary use of broccoli has inspired the scientists to test for a vast range of biological activities including, antioxidant, anticancer, antimicrobial, cardio-protective, hepatoprotective, anti-obesity, antidiabetic, anti-inflammatory and immunomodulatory activities. Therefore, the pharmacological activities of broccoli are explained based on the diseased states.

**Anticancer Activity**

Uncontrolled cell division is the outcome of multiple processes that make up cancer. According to Gupta *et al* (2014) [18], isothiocyanates-the primary active ingredients of many cruciferous vegetables-suppress excrescence broadening by producing reactive oxygen species or by causing cycle arrest that results in apoptosis. According to Zhang *et al*. (2006) [44], indoles and isothiocyanates can prevent the growth of cancer in the bladder and breast among other organs in rats and mice. Numerous isothiocyanates, a well-known class of cancer chemopreventive chemicals, are abundant in broccoli sprouts. When the extracts are broadly distributed to the bladder epithelium through urine excretion, they limit the growth, multiplicity, and development of bladder cancer (Munday *et al*. 2008) [29]. When compared to regular broccoli sprouts, selenium-enriched broccoli sprouts are set effective and causes prostate cancer cells to die, slows the growth of new cells, and lowers the secretion of the prostate-specific antigen. For the treatment and prevention of prostate cancer, selenium-enriched broccoli sprouts are employed (Abdulah *et al*. 2009) [1]. Sulforaphane has proved effective in the chemotherapy of cancer combined with phytochemicals from broccoli, such as indole-3-carbinol and brassinin. In terms of safety, cost, and oral bioavailability, phytochemicals have a significant role to which helps in the prevention of cancer (Gullett *et al*. 2010) [17]. According to our theory, broccoli has an unparalleled anti-cancer impact.

**Anti-diabetic Activity**

One of the many vegetables commonly eaten in India that makes the claim to preserve anti-diabetic energy is broccoli. *Brassica oleracea* has demonstrated a positive impact on insulin response in both humans and experimental animals (Platel and Srinivasan 1997) [33]. Consuming broccoli sprouts may help type 2 diabetes people with IR. Eighty-one cases in a clinical investigation were used to demonstrate that consuming fresh broccoli sprouts [10 g/day] for four weeks causes a significant decrease in serum insulin attention and homoeostasis model assessment of the IR indicator. Flavonoids found in abundance in Brassica oleracea have anti-inflammatory and antioxidant properties that protect against diabetes. Flavonoids may contribute to a decreased risk of developing diabetes (Nettleton *et al* 2006) [30].

**Anti-oxidant Activity**

According to Riso *et al*. (2010) [34], eating broccoli is associated with an overall improvement in antioxidant status. Because glucosinolates are linked to antioxidant and anti-carcinogenic qualities, it is well recognized that their presence in broccoli plants represents a health benefit. One kind of Brassica sprouts, broccoli, is produced to determine the myrosinase activity and glucosinolate profile during sprouting. Another significant emulsifier found in broccoli sprouts is glutaraphin (Vale *et al*. 2015) [38]. Sulforaphane is employed as a beneficial antioxidant supplement. In addition to presenting anti-tumor action at the post-initiation phase, which suggests other roles in cancer prevention, it activates phase I and phase II enzymes to aid in carcinogenesis (Figueiredo *et al*. 2015) [14].

**Anti-obesity Activity**

Globally, the popularity of fitness is growing quickly and becoming a significant public health concern with significant social and economic implications. According to Williams *et al*. (2013) [42], advantageous phytochemicals are suitable to target several phases of the adipocyte's (fat cell) lifespan. Rats fed a high-fat diet which increase the weight and mesenteric adipose tissue weight, but after receiving ethanol and aqueous broccoli sprout extract, the weight gradually decreased to that of the rats fed a normal diet (Patel and Vimukta 2014) [32].

**Antimicrobial Activity**

Infectious diseases caused by bacteria, fungi, viruses, and parasites continue to represent a severe threat to public health despite recent advancements. Lethal drugs have advanced significantly, and their impact is large (Okeke *et al*. 2005) [31]. There is a lot of medication resistance. Antimicrobial peptides in food were examined by BenkoIseppon and colleagues in 2010 (Benko-Iseppon *et al*. 2010, 2011 and Carolling *et al*. 2013) [7]. The two kinds of ethyl acetate found in broccoli leaves are chloroform and ethyl acetate. Extracts from broccoli florets have been very effective for growing *B. subtilis* and *B. cereus*, respectively. Ethyl acetate is a kind of ethyl acetate that is effective in part against E. coli. Similarly, extracts of ethyl acetate and chloroform demonstrated strong anti-Candida albicans activity (Hashem *et al*. 2012) [20]. According to biological research, Klebsiella pneumoniae, Klebsiella sonnei, Klebsiella sonnei, Klebsiella staph, E. coli, and Saprophyticus were all found to be inhibited by a nanoparticle made from an aqueous extract of broccoli florets (Sibi *et al*. 2013) [37].

**Anti-inflammatory Activity**

A potential new treatment for rheumatoid arthritis is sulforaphane. Sulforaphane blocks the expression of matrix metalloproteinases (MMP-1, MMP-3), cyclooxygenase COX-2 mRNA and protein, as well as production of prostaglandin E2 (PGE2) brought on by interleukin-1 (IL-1) and rheumatoid arthritis synovial fibroblasts (RASFs). Additionally, sulforaphane prevents IL-1 from activating NF-kB and phosphorylating ERK-1/2, p-38, JNK, and JNK [46]. Finally, broccoli is regarded as a potent anti-inflammatory. Sulforaphane, which is present in broccoli sprout extract (BSE), has the potential to be utilized to reduce the inflammatory response in the nose. As a result, it is also valid for lessening how allergic illness and asthma are affected by particulate pollution (Heber *et al*. 2014) [21].

**Cardio-protective Activity**

The world is reportedly on the verge of a vascular typhoon of the burden of cardiovascular disease, according to the most recent epidemiological vaticinations. By 2020, it is expected that cardiovascular illnesses would be the major cause of disability and death worldwide. eating broccoli sprouts in

developing countries. Foods high in sulforphane have been shown to lessen oxidative stress. As a result, it both elevates and decreases blood pressure inflammation in SHR (suddenly hypertensive stroke-prone rats) and SHR (sudden hypertensive stroke-prone rats). A 12-case clinical investigation found that eating fresh broccoli sprouts [100 g/day] for a week lowers LDL, total cholesterol, and triglycerides. According to a recent study, consuming broccoli reduces the risk of coronary heart disease and stroke help shield against cancer. A decrease in mRNA and protein levels results from ischemic injury, whereas reperfusion damage results in cardiomyocyte death. Another study confirmed the anti-inflammatory benefits of broccoli. Treatment can reduce myocardial infarction and improve heart function. Acute myocardial infarction and reperfusion harm to cardiomyocytes. Through a number of mechanisms, including (a) inhibition of phase I enzymes and DNA adducts and activation of antioxidant enzymes, broccoli protects the heart. Antioxidant detoxifying enzyme, phase II; antioxidant detoxifying enzyme, phases III and IV; antioxidant detoxifying enzyme, function; (b) stimulation of cell cycle arrest; (c) prevention of angiogenesis; and, consequently, anti-inflammatory properties. (Vasanthi *et al*. 2012) [40] Said to be a potential functional food.

**Hepatoprotective Activity**

The doses of 150 and 300 mg/kg, broccoli extract considerably raised the conditions of NP-SH and lower MDA of liver tissue while dramatically decreasing the activity of serum enzymes, bilirubin, to generate significant hepatoprotection. The protective effect of broccoli against CCl 4 -induced hepatic damage in rats was also evident from histopathological examinations of the liver. Due to flavonoids and sulfurated composites, the obtained results imply that broccoli has hepatoprotective potential and may have implicit therapeutic value in the treatment of several liver illnesses (Hashem *et al*. 2013) [19].

**Health Benefit of Broccoli**

**Effect of cooking method**

Processes including blanching, heating, and slicing broccoli have an impact on the quantity of glucosinolates, sulforaphane, polyphenols, and antioxidant activity. The steamed *Brassica oleracea* Anti-carcinogenic flavonoids' (through glucosinolates) capabilities should be improved upon by antioxidant flavonoids' (by phenols and flavonoids). Due to its anti-carcinogenic properties, cooking broccoli boiling at temperatures under 100 $^{0}$C is a recommended choice after cutting or slicing it. These issues seem to be According to Mahn and Reyes (2012) [25], processing broccoli as a functional food looks to promise increased dietary health-promoting rates. Due to the significantly increased extractability and higher antioxidant content of brume-treated broccoli, phenols and flavonoids were more readily absorbed into the body. These substances enhance health-promoting rates in living organisms (Roy *et al*. 2009; Gliszczynska-Swiglo *et al*. 2006) [35, 16]. In Traditional and microwave cooking methods significantly reduced the amount of polyphenols in broccoli as compared to raw broccoli (Jones *et al*. 2006) [24]. According to Zhang and Hamauzu (2004) [45] and Cieslik *et al*. (2007) [12], cooking food at temperatures between 50°F and 60°F (90 °C and 950 °C) has an impact on the glucosinolate concentration of broccoli. Active isothiocyanates include, for instance, anti-carcinogenic isothiocyanates. Sulforaphane has been related to broccoli's increased potential as a functional food (Jeffery *et al* 2003) [22].

**1. Effect of cooking on glucosinolates**

It was measured how much glucosinolate each individual broccoli floret contained when it was prepared using various methods. The most prevalent aliphatic glucosinolates in broccoli were glucoraphanin and glucoiberin, whereas the most prevalent indole glucosinolates were glucobrassicin and neoglucobrassicin. Total aliphatic glucosinolates were decreased in stir-fried, stir-fried/boiled, microwaved, and boiled broccoli by 55 percent, 54 percent, 60 percent, and 41 percent, respectively (P0.05). However, the total aliphatic glucosinolate concentration of steamed broccoli barely changed. Each number is the mean plus a standard deviation of replicate samples. Values without a common letter are substantially different at P0.05.

**2. Effect of cooking on isothiocyanates**

Investigated in terms of ITC content were isothiocyanates according to the presence of their parents glucoraphanin, glucoiberin, and GLS, as well as the presence of sulforaphane (SFN) in broccolini samples and the presence of iberin (IB) in kale samples. Similarly, both ITC were chosen because human cell lines have shown evidence of their anti-inflammatory and anticancer properties. Our research showed that after cooking, ITC concentration significantly decreased, with boiling causing the greatest losses. SFN was present in raw broccolini samples at a concentration of 2.4 mg 100 g1 F.W., however after steaming (20%), stir-frying (36%), and boiling (88%), this concentration decreased. After cooking, broccolini (a kailan-hybrid broccoli) suffered enormous losses of SFN (>99 percent), potentially as a result of various processing techniques and analytical methods strategies (Wagner *et al*. 2013) [41]. These findings are intriguing because no other writers had previously described them. Jones *et al*. (2010) [2] similarly reported SFN levels in broccoli florets after cooking, with the likelihood that losses of this ITC after steaming, microwaving, and boiling ranging from 20 to 50%. These contents were lower than those established in the current investigation after steaming and stir-frying additional researchers examined the impact of boiling on additional Brassica spp., including broccoli heads and Brussels sprouts (Jones *et al*. 2010, Ciska *et al*. 2015) [23, 13], and found no SFN. This idea highlighted broccoli as a type that requires additional research to determine the effects of processing on its composition and potential health effects. Effect of cooking on sulforaphane (Galgano *et al*. 2007; Bayat Mokhatari *et al*. 2018) [15, 6].

**Conclusion**

The gift of nature to humanity is plants. They are regarded as the most significant suppliers of human food and medicine. A revolution in understanding of nutritious plants and remedies has occurred. For health improvement, prevention of disease, and the treatment of various afflictions, there are now strong recommendations for the consumption of natural factory food and the use of nutritional supplements. In several nations, broccoli is frequently employed in industrial food production. It is clear from this study that numerous research have been conducted utilising a variety of methods, and they have

produced good results in terms of how well they operate in various fields, particularly in the treatment of cancer. Therefore, it has been demonstrated that the many phytochemicals or composites found in broccoli lessen the risks of various serious illnesses, such as diabetes, cancer, and neurological disorders.

**Future Prospects**

A promising medication for prostate cancer chemoprevention is broccoli-derived SFN, according to consistent bench study findings. Future research in this area should focus on lengthy clinical trials that are conducted over a long period of time. Intense work should be put into developing a therapeutic index and a standard dosage for sulforaphane use in clinical settings.

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