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masteringhealth

Broccoli (*Brassica italica*)

Nutritional therapy

DESCRIPTION

In view of the fact that the oldest varieties of broccoli were cultivated as early as Roman times, broccoli is also referred to as the Italian brassica (*Brassica oleracea italica*). From its humble origins in Italy, this variety of cabbage started to spread far and wide on its path to conquering the world. Besides its delicious flavour, broccoli also courts scientific interest because, of all the cabbage varieties, it contains the highest concentrations of sulphurous compounds with a potent therapeutic effect: the glucosinolates, and in particular the derivative compounds (e.g. isothiocyanates, sulforaphane, indoles).

Broccoli (*Brassica oleracea italica*) is a member of the cabbage family (*Brassica oleracea*), which has been cultivated for at least 6000 years, probably the oldest form of vegetables grown by humankind. References to cabbage abound in the literature of the ancients and of the Middle Ages. The first varieties of broccoli probably had their origins in Ancient Rome, where the Romans were seeking a cabbage with eye-catching inflorescence. Broccoli as we now know it originally came from Italy, spreading throughout the rest of the world in the 19th and 20th centuries. The name stems from the Italian word “brocco”, meaning “shoot” (which in turn stems from the Latin “brachium”, meaning arm), and refers to the typical form of the flower heads, which are arranged in a tree-like structure on branches sprouting from a compact stalk.

The “Brassica” family includes all varieties of cabbage (mostly *Brassica oleracea* varieties), as well as such things as mustard, rapeseed, Chinese cabbage and turnips (see figure). Within these groups, broccoli proves to be the subject of most scientific attention.

BIOCHEMISTRY

Broccoli's effects on health are usually attributed to its high concentrations of glucosinolates, and especially the compounds derived from these. The glucosinolates are a family of organic sulphur compounds found in broccoli, the most important being the indoles and the isothiocyanates. Other varieties of Brassica also contain glucosinolates, though it is broccoli that has the highest concentrations (rendering it a good source of sulforaphane). The most important groups of compound produced by means of hydrolysis of glucosinolates are:

- **Isothiocyanates:** Isothiocyanates are sulphurous substances found primarily in the cabbage family. Sulforaphane in particular, which is a type of isothiocyanate found in broccoli, has been the subject of considerable scientific interest in recent years. In the plant itself, sulforaphane only occurs in compound form, as a constituent of sulforaphane glucosinolate (glucoraphanin). But even Brassica substances such as phenylmethyl isothiocyanate and allyl isothiocyanate are in the scientific spotlight. The seeds and sprouts are the richest in these substances. On average, sprouts contain concentrations of glucoraphanin twenty to fifty times [1] higher than are found in the mature broccoli plant, with concentrations being even higher in broccoli seeds. Huge variation can occur too, depending on growing method, time of harvest, soil composition/conditions, use of herbicides or pesticides. In a standardized preparation these concentrations are guaranteed to fall within a certain margin.
- **Indoles:** Indoles from Brassica varieties are also the subject of considerable interest. Just like the isothiocyanates, they belong to the group of indirect antioxidants, and encourage the production of detoxifying liver enzymes, implicating them in the elimination of harmful free radicals. Hydrolysis of glucobrassicin produces substances such as indole-3-carbinol (I3C), diindolylmethane (DIM, a dimer of I3C) and ascorbigen (I3C bonded with ascorbic acid).

In addition to these substances, broccoli is also rich in other bioactive substances that have therapeutic properties. Of all vegetables, those of the cabbage family probably contain the most variety in terms of phytochemical substances with therapeutic potential. A summary of the most important of these is given below:

- cabagin (S-methylmethionine, sometimes also referred to as vitamin U), a substance related to SAMe with an anti-inflammatory effect and a protective effect on the mucosae in the stomach and intestines.
- lutein and other carotenoids
- D-glucarate is important for glucuronidation, an important constituent in phase-2 detoxification.
- flavonoids, particularly quercetin and apigenin.
- selenium. Broccoli contains selenium in the form of methylated selenium compounds (e.g. Se-methylselenocysteine), which can readily be converted into the methylselenol [4].
- iron with a fairly high biological availability.
- zinc
- deacidifying minerals such as potassium and magnesium
- vitamin B6 and folic acid
- vitamins C, E and K
- protocatechuic acid
- chlorogenic acid
- carotenoids
- fibre

Glucoraphanin --> sulforaphane

There are two ways in which glucoraphanin can be converted to sulforaphane:

1. By means of the enzyme myrosinase (see figure), which is released in the event of bruising/damage to the plant and chewing. Myrosinase requires a moist environment in order to function.
2. By means of conversion in the gut flora. In excess of 80% of the glucoraphanin is converted to sulforaphane at a pH higher than 5. Consequently the acidic form of vitamin C (ascorbic acid) impedes sulforaphane formation. Vitamin C in the form of mineral ascorbates does not have this unwanted effect.

(GENTLE) STEAMING OR STIR-FRYING, NOT RAW

The glucoraphanin content (sulforaphane glucosinolates) in cooked broccoli can vary considerably, depending on cultivar, environmental influences and method of preparation, with a typical average being 30 mg of glucoraphanin per 300 mg of cooked broccoli.

The high temperatures to which the broccoli is subjected during the cooking process deactivate the myrosinase enzyme, as a result of which no sulforaphane is produced. Furthermore, most of the glucoraphanin dissolves in the cooking water (as do other glucosinolates), making it a very healthy base for things such as soup. In the case of steaming, the heating process is much more gradual and a much greater quantity of sulforaphane is formed in the broccoli (see figure). Moreover, steaming uses considerably less water, meaning most of the glucoraphanin remains in the broccoli. It is likely that stir-frying has a similar effect.

Frozen vegetables are blanched in order to deactivate the enzymes (which could cause spoilage), resulting in the deactivation of myrosinase as well.

However, the formation of sulforaphane and other isothiocyanates does not necessarily have to take place in the vegetable itself. The gut flora also contain enzymes capable of doing the same thing. After consuming glucoraphanin from broccoli, the gut flora convert the glucoraphanin into sulforaphane [6].

EFFECT

Sulforaphane is one of the most powerful detoxifying substances known to humankind and protects cells from various diseases, particularly those that have the capacity to cause irreversible damage to DNA. Consequently sulforaphane, and the group of isothiocyanates to which sulforaphane belongs, is the subject of considerable pharmaceutical interest and a variety of synthetic analogues have already been developed (inc. oxomate and isoselenocyanate [7]), with various others in the pipeline.

Sulforaphane increases the activity of phase-2 proteins and enzymes, one of the body's most important natural defence mechanisms.

- Induction of phase-2 detoxification: An important property of the Brassica family is the capacity to “switch on” genes that produce cellular enzymes required for optimum cell function. The most important of these are the genes for the three most important phase-2 detoxification enzymes: quinone reductase (QR), glutathione S-transferase (GST) and uridine diphospho--glucuronosyltransferase (UGT). These enzymes convert toxins into water-soluble substances that are readily excreted. Even in concentrations that occur in food, sulforaphane is a powerful modulator of these xenobiotic-metabolizing enzyme systems. It is possible that sulforaphane compensates for the body's inability to induce the right phase-2 enzymes itself. After all, the most significant effect of broccoli is one that occurs in people with a mutation (deactivation) of at least one of the following types of glutathione S-transferase: M1 type (GSTM1) or T1 type (GSTT1). In these people the isothiocyanates remain in the circulation, as a result of which other glutathione S-transferases become active[10].

- Indirect antioxidant: Induction of phase-2 proteins also encourages the removal of oxidants or impedes their formation. The result is a marked “multiplier effect”: one phase-2 protein inducer has the same effect as various typical antioxidant molecules, such as vitamin C and vitamin E. Free radicals which, as it happens, are for the most part activated in the phase-1 enzyme system, on which Brassica constituents also have an inhibitory effect.

Incidentally, broccoli is itself rich in antioxidants, such as carotenoids, flavonoids, vitamin C, isothiocyanates. Due to the presence of cysteine and methionine, it also encourages the production of glutathione, an important endogenous antioxidant [11].

- Anti-inflammatory (cardiovascular, joints). There is a good deal of evidence that sulforaphane impedes inflammatory processes. Sulforaphane probably has an effect on NF-kappa B as the central controller of inflammatory processes[12-13]. In addition, every inflammatory response involves excess production of free radicals, with this excess continuing throughout the inflammatory process. It is possible that intake of phase-2 protein inducers may counter this process. An animal study showed that sulforaphane countered age-related degenerative and inflammatory changes [14].
- Antibacterial and antifungal: Breakdown products of sulforaphane and other glucosinolates have a powerful inhibitory effect on *Helicobacter pylori*, a bacterium found in the stomach of many individuals [15]. The potential of Brassica constituent S-methylmethionine (cabagin) to protect against stomach ulcers was identified by Cheney, who called it vitamin U, as early as 1952 [16]. Nowadays a whole range of sulphurous constituents are proving to be responsible for this effect, and it turns out that the antibacterial and antifungal effect extends well beyond only *H. pylori* [17].
- Immunomodulation: Sulforaphane has an effect on the immune system, including by stimulating the cellular immune response, as well as interleukin-2 (IL-2) and interferon-gamma. At the same time, it inhibits the proinflammatory cytokines IL-1 beta, IL-6, TNF-alpha, and GM-CSF [18-19].
- Influence on oestrogen metabolism: Taking Brassica indole supplements, such as I3C and DIM, could have a beneficial effect on oestrogen metabolism [20]. Indications of this include improvements in hormone-related conditions, such as menopausal problems.

INDICATIONS

- **Inhibition of *Helicobacter pylori***: Inhibition of *Helicobacter pylori* on the part of broccoli constituents has been demonstrated in vitro on several occasions [15], though it has now been demonstrated in human studies as well [25-26].
- **Boosting immunity**: In mice, sulforaphane is capable of reversing the age-related deterioration of the immune system in a variety of respects and of restoring it to the level found in much younger mice [18-19] [27].
- **Protection from the sun**: It emerges that a cream made from young broccoli shoots protects the skin against the harmful effects of UV radiation. Sulforaphane incites skin cells to produce enzymes that protect the skin from within. The symptoms of burns turn out to be nigh on 40% less pronounced in people who have applied cream containing broccoli. Furthermore, this protection remains in effect for several days [28].
- **Cardiovascular health**: People who ate 100 grams of broccoli a day for a week showed a reduction in overall cholesterol levels

and an increase in HDL-cholesterol. There was even a reduction in the quantity of oxidative stress [29]. An animal study revealed that broccoli shoots were capable of increasing glutathione concentrations in the tissues of animals with hypertension. Administering supplements also lowered blood pressure and inflammatory biomarkers in the animal subjects. According to the authors of the study, phase-2 protein inducers have the capacity to reduce the risk of cardiovascular disorders, such as hypertension and atherosclerosis [30].

- **Prevention of cataracts:** Men who eat broccoli more than twice a week reduce their chances of developing cataracts by 23% in comparison with those who do not [31]. Preliminary treatment with sulforaphane allows for protection of retinal cells from chemical and photo-oxidative damage [32].
- **Degenerative disorders of the central nervous system:** Inflammation is an important factor in cognitive degeneration and related disorders. Induction of phase-2 enzymes by broccoli constituents impedes inflammation-related ageing of the central nervous system [14].

INTERACTIONS

Isothiocyanates are also referred to as goitrogenic compounds. Goitrogens are compounds that can inhibit the absorption of iodine by the thyroid gland and/or inhibit thyroid hormone production, which may cause enlargement of the thyroid (goitre) [33]. The enzymes required for the production of these are deactivated by the cooking process, even in the case of gentle steaming. Whether this is desirable is questionable, precisely because most of the health benefits are ascribed to sulforaphane and other isothiocyanates. It is even suggested that the goitrogenic effect is an important mechanism of action of the isothiocyanates. However, there is not a single reason to assume that consumption of (isothiocyanates from) Brassica varieties should have a negative effect on the thyroid in people who do not have a thyroid condition, particularly where iodine intake is sufficient [34-35]. Nevertheless, it could be advisable to be cautious about use of Brassica varieties in thyroid patients. Furthermore, it is not unreasonable to expect that, due to the effect of broccoli constituents on the cytochrome P-450 system (by means of which various medicines are metabolized), interactions could occur with these medicines.

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