



# Comprehensive appraisal concerning to potentially useful compounds occurring in Mustard Greens (leaves), seeds and oil: Evaluation of their nutritional benefits and toxicological perspective

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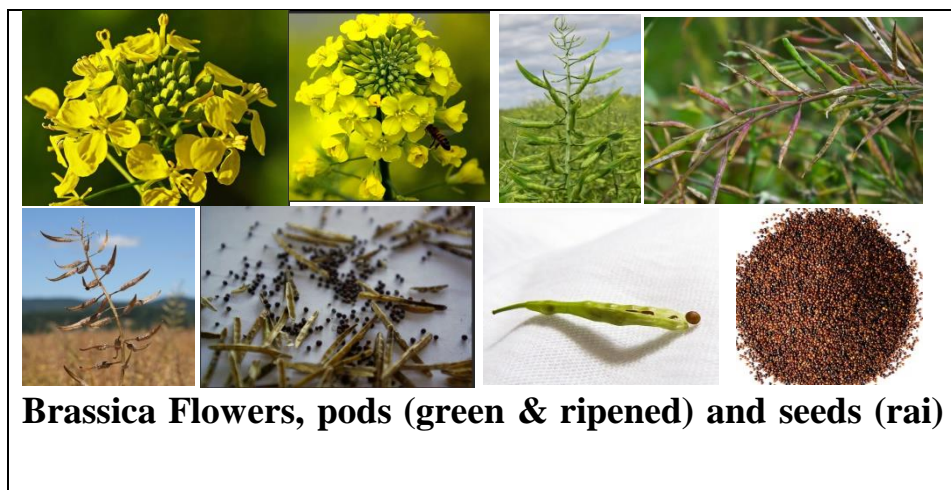
## Abstract

Mustard (*Brassica juncea*) is a cruciferous vegetable used as a food spice and folk medicine worldwide. Mustard contains numerous phytochemicals such as: vitamins, minerals, dietary fiber, S-containing compounds, glucosinolates (and their degradation products), polyphenols and volatile components (allyl isothiocyanate, 3-butyl isothiocyanate, etc.). While acidic compounds are mainly short-chain acids such as nonelic acid, sebacic acid, adipic acid, succinic acid, heptanoic acid, octanoic acid, phenylpropanoic acid, and benzenepropanoic acid. In addition, mustard may possess a plethora of pharmacological activities including anti-oxidation, anti-inflammation, and bacteriostatic and antiviral activity. Mustard has also been used to combat several illnesses such as cancer, obesity, depression, diabetes, and cataracts. The pleasant aroma of mustard comes from the balance of many volatile substances such as hydrocarbons, alcohols, aldehydes, ketones. As mustard plants contain several bioactive compounds, the purpose of this article is to present a comprehensive overview about potentially useful phytochemicals in the leaves, oil and toxicological aspects to evaluate possible risks to human health.

**Keywords:** Glucosinolates, allyl isothiocyanate, Alpha-linolenic acid, Bisphenol F, Erucic acid, Sinalbin

## Introduction

Mustard plants belong to the commonly known mustard family Brassicaceae and is distributed worldwide. Notable characteristics of this family are the four sepals in median position of the flowers followed by four alternating petals that are arranged in a cross form referring to the old family name Cruciferae. The most cultivated varieties within this family almost all belong to the six species *Brassica rapa*, *Brassica juncea*, *Brassica nigra*, *Brassica carinata*, *Brassica oleracea* and *Brassica napus* in which also two of three of the most important mustard species are included (*B. juncea* and *B. nigra*). [1-3] *Brassica juncea* L. is also known as Indian mustard or mustard greens or leaf mustard, is perennial herb, usually grown as annual or biennial mustard. *B. juncea* is an amphidiploid and second most important edible oilseed crop in India after groundnut and accounts for about 30% of the total oilseeds produced in the country. Mustard is widely cultivated as a vegetable but its seeds are also used in a variety of applications as food condiment and as ingredient in health and medicinal products. India has an abundant source of edible oils at home—mustard seed oil. The presence of organosulphur compounds is also a unique characteristic of this plant family. Mustard is a cheap and nutritious food that contains bioactive components such as glucosinolates and their degradation products and polyphenols (flavonoids and anthocyanins), as well as large amounts of dietary fiber, chlorophylls,  $\beta$ -carotene and ascorbic acid, minerals, and volatile components. Mustard is used as a spice because of its unique sharp hot pungent flavor.[4-7] Mustard also has a significant use in medicine and the leaves can be used as diuretic, stimulant, and expectorant in folk medicine. Specially, fermented mustard has been shown to exhibit various health benefits and disease prevention effects. Glucosinolate, the pungent principle in mustard oil, has antibacterial, anti-fungal and anti-carcinogenic properties, which account for many medicinal utilities of the oil. This plant is used to remove heavy metals from the soil in hazardous waste sites because it has a higher tolerance for these substances and stores the heavy metals in its cells. The plant is then harvested and disposed of properly. This method is easier and less expensive than traditional methods for the removal of heavy metals. It also prevents erosion of soil from these sites preventing further contamination. Currently, the use of the seeds of the mustard species *Sinapis alba* (white mustard or yellow mustard), *Brassica juncea* (brown mustard) and *Brassica nigra* (black mustard) in the food and beverage industry is immensely growing due to their nutritional and functional properties. The seeds serve as a source for a wide range of biologically active components including isothiocyanates that are responsible for the specific flavor of mustard, and tend to reveal conflicting results regarding possible health effects. Contemporary and forthcoming studies will undoubtedly focus on the health benefits of mustard plants and seeds whereas information on undesirable and antinutritional compounds in these products intended for human consumption will tend to fade into the background. Therefore, this article underscores and evaluates those compounds in mustard seeds potentially exerting undesired effects for human welfare. [8-11]



**Brassica Flowers, pods (green & ripened) and seeds (rai)**

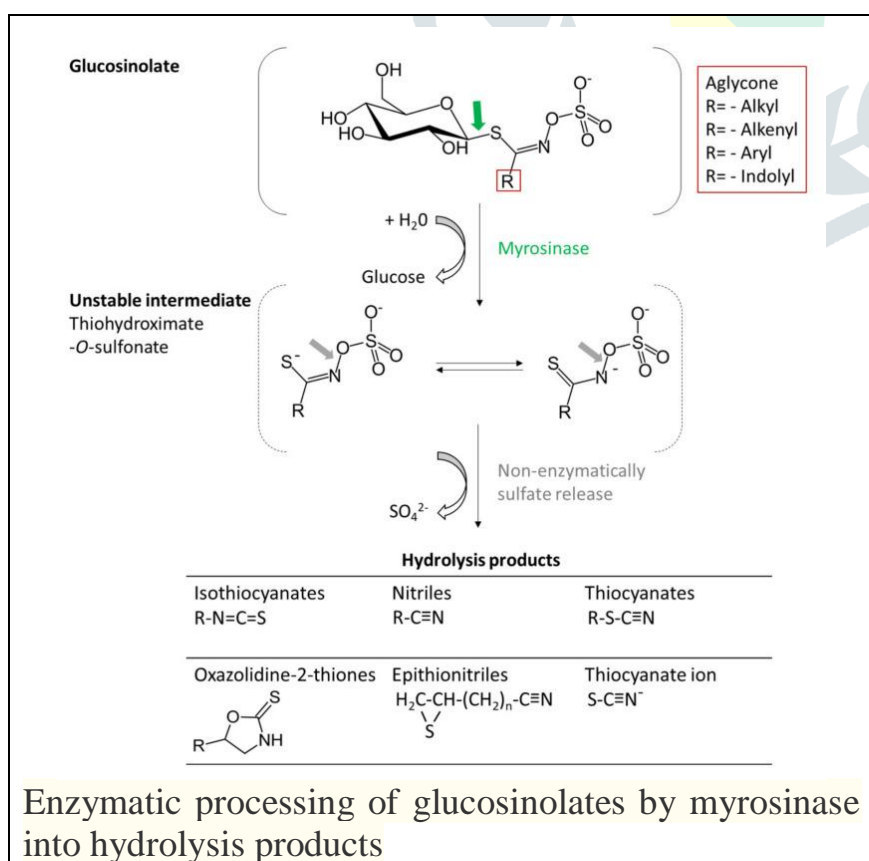


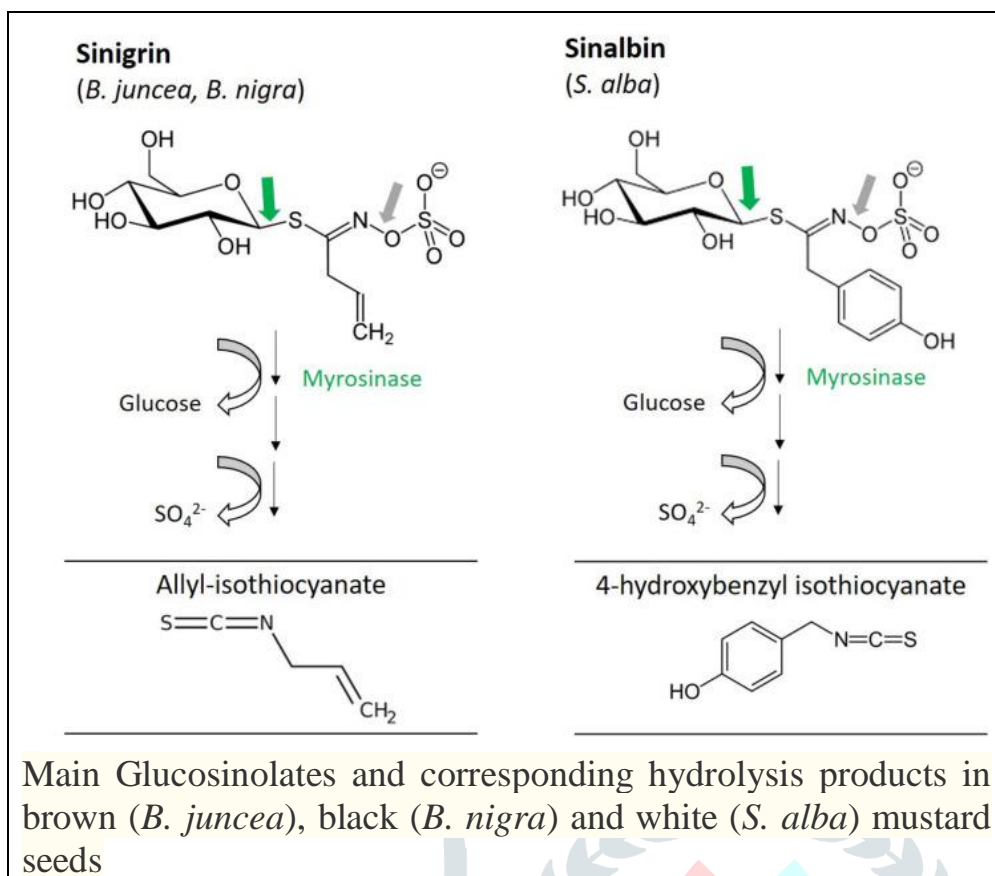
**Brassicca green and dried leaves**

## **Effects of food processing on nutritional components and bioactive components in mustard**

Mustard processing includes fermentation, storage, and a variety of cooking methods. The processing method had a great impact on the nutrient composition of mustard. Polyphenol content in Mustard tended to decrease during fermentation, along with a corresponding decrease in flavonoids. Glucosinolate content showed a trend of first decreasing and then increasing during the fermentation process. During the storage of mustard greens, the content of hydroxycinnamic acid showed a trend of increasing first and then decreasing. The effects of different cooking methods (cooked in a water bath, stove, and microwave oven) on the minerals (calcium, magnesium, potassium, sodium, iron, zinc, phosphorus, barium) in mustard leaves were evaluated. All cooking methods were 2.0 g sample, 50 ml water. The cooking times were 20 min for water bath and stove, 5 min for micro wave oven. Boiling cooking methods had the least impact on minerals, followed by stove, and microwave cooking had the greatest loss of minerals. [12-14] There are many chemical components in mustard, but few studies on the changes in components during processing and in those reports the degradation process and

mechanism of polyphenols, flavonoids, and glucosinolates are to be not mentioned. Glucosinolates when reach the colon, however might have a certain amount of the glucosinolates seem to be hydrolysed in the stomach or can be absorbed via passive transport or via diffusion in the small intestine. In the colon, several bacteria strains are able to hydrolyse glucosinolates to form isothiocyanates, amines or nitriles depending on the type of bacterial myrosinase-like activity. Usually, cooking reduces the concentration of glucosinolates, partly through thermal breakdown and partly to leaching of the intact glucosinolates and their derivatives into the cooking liquid. Besides, heat treatment inhibits the activity of myrosinase through denaturation of the enzyme. Therefore, the processing method can make a very large difference, both to the intake of glucosinolates, and to the bioavailability of their breakdown products. The pattern of intact glucosinolates and breakdown products upon heat treatment is influenced by the thermal stability of the corresponding molecules. For instance, indol glucosinolates—one of the best-known representatives is progoitrin—seem to be less stable than aliphatic ones such as sinigrin, which is the predominant glucosinolate in black and brown mustard seeds. However, sinigrin totally disappears upon boiling, while 5-vinyloxazolidine-2-thione (derived from progoitrin) and 3-methyl-sulphonylpropylisothiocyanate (derived from glucoiberin) may partly escape decomposition. [15-18] Comparison between different mustard seed preparations showed that the seed alone had higher sinigrin and lower content of the breakdown product isothiocyanate compared to mustard preparations, whereas the wholegrain-style mustard contained lower sinigrin and higher isothiocyanate levels. This suggests that during mustard preparation, the enzyme myrosinase can break down sinigrin in the presence of high salinity and acidity from added ingredients, such as salt or vinegar. Isothiocyanates are volatile and water-soluble. It can be expected that they largely disappear after processing steps using high temperatures and soaking in water, but those processes are commonly not included during mustard preparation. [19-21]





### Nutritional value of mustard greens

Mustard leaves contain many nutrients, including antioxidants, proteins, minerals, and vitamins.

Nutrition value per 100 g		
Principle	Value	Percentage of RDA
Fiber	03.20 grams	09.00 %
Carbohydrates	04.67 grams	03.60 %
Protein	2.860 grams	05.00 %
Total Fat	0.420 grams	02.00 %
Energy	27.00 K Cal	01.00 %
<b>Vitamins</b>		
Vitamin A	3024 IU	101.00 %
Vitamin E	0.00 milligrams	00.00 %
Vitamin C	70.00 milligrams	117.00 %
Vitamin K	257.50 ug	215.00 %
Pantothenic acid	0.210 milligrams	05.00 %
Thiamin	0.080 milligrams	07.00 %
Pyridoxine	0.180 milligrams	14.00 %

Folates	12.00 ug	03.00 %
Riboflavin	0.110 milligrams	08.00 %
Niacin	0.800 milligrams	05.00 %
<b>Electrolytes</b>		
Potassium	384.00 milligrams	08.00 %
Sodium	20.00 milligrams	01.30 %
<b>Minerals</b>		
Zinc	0.250 milligrams	02.00 %
Copper	0.165 ug	18.00 %
Phosphorus	08.00 milligrams	01.00 %
Iron	1.64 milligrams	20.00 %
Manganese	0.480 milligrams	21.00 %
Selenium	0.90 ug	01.50 %
Magnesium	32.00 milligrams	08.00 %
Calcium	115.00 milligrams	11.50 %
<b>Phyto-nutrients</b>		
Carotene- $\alpha$	0.00 ug	---
Crypto-xanthene- $\beta$	40.00 ug	---
Lutein-zeaxanthin	3730.00 ug	---
Carotene- $\beta$	1790.00 ug	---

### Phytopharmacotherapeutical aspects

Mustard greens contain typical nutrients that can be found in many fruits and vegetables, but these typical nutrients cause a massive positive change in the body by fighting certain diseases and keep it healthy and fit. Antioxidants present in mustard greens fight against free radicals that cause oxidative stress. Such oxidative stress leads to many unhealthy conditions and eventually a person to fatal diseases. Free radical is a dangerous process that harms the cells of the body and paves the way to diseases like cancer, cardiovascular disorders, and Alzheimer's disease. There are different types of mustard greens all over the world, and all of them contain a distinctive amount of antioxidants. Dark leafy mustard greens contain many antioxidants, including beta carotene, flavonoids, vitamin C, lutein, and vitamin E. Other varieties of mustard greens, including red varieties, are blessed with anthocyanins that decrease the chance of type 2 diabetes, cancer, and heart issues. Anthocyanins can be detected on fruits and plants as it is red or purplish dots on the surface of leaves or fruits. Eye health is totally dependent on two major components: zeaxanthin and lutein. There are certain functions of these two components regarding the eye. Zeaxanthin and lutein are the two antioxidant compounds that protect the eye from blue light and guard the retina against the process of oxidative stress. Consuming food that is high in antioxidants may lead to a reduced risk of macular degeneration. Mustard greens are a rich source of antioxidants that eventually help the health of an eye. Cooked or raw, mustard greens are the rich source of vitamin K in both forms. Vitamin K helps in thickening

the blood that proves to be important for bone and heart conditions. The deficiency of vitamin K brings in some serious health issues, including heart issues and weak bones (osteoporosis). Different studies also proved that the insufficient amount of vitamin K could damage brain cells and result in dementia, improper brain functioning, and Alzheimer's disease. To avoid such diseases, it is recommended that greens should be added to the daily meal. [22-25] To give boost to your immunity, it is necessary to inculcate mustard greens to your diet as they contain a large amount of vitamin C. Vitamin C is assumed to be the shield for the immune system. Deficiency of vitamin C may weaken immunity in the body, and as a result, the body becomes prone to illness and diseases. White blood cells in the body fight against different infections with the help of T cells. Vitamin A helps a lot in the growth and development of T cells. Mustard greens also contain vitamin A and consuming the right amount of these greens may protect the body from infections and diseases. Mustard greens also contain nutrients that are good for the heart. Fatal heart diseases can be controlled by taking the right amount of antioxidants, including beta carotene and flavonoid. A study proved that people who use more greens in their diet are less prone to dying from heart diseases. A proper digestion needs to bind bile acid that is protected by the nutrients present in mustard greens. This process lowers down the cholesterol in the body and eventually keeps the heart in good condition. It is suggested that mustard greens should be used in cooked form rather than in salad to avoid heart issues. Besides the above health benefits, mustard greens are also useful for cancer patients as mustard greens contain glucosinolates compounds that help DNA to fight against cancerous cells and prevent those cells from growing. Mustard greens are overall healthy and also reduce the chances of distinctive kinds of cancers. [26-28]

### Chemical constituents in mustard

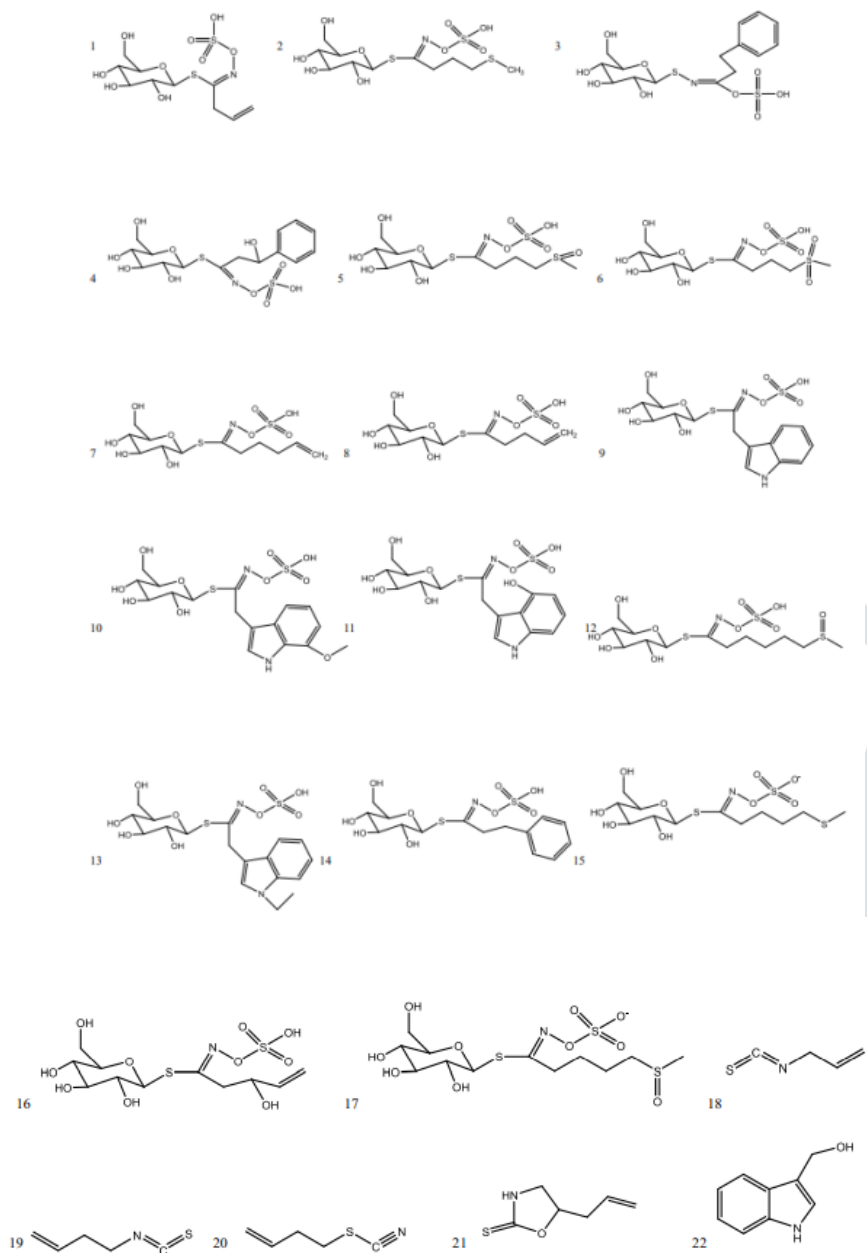
General nutrients Mustard leaves are rich in chlorophyll,  $\beta$ -carotene, ascorbic acid, potassium, calcium and other minerals. Mustard seeds contain protein, carbohydrates, dietary fiber and fat. In addition, they contain vitamins (such as vitamin C and K) and various trace minerals (such as Ca, Fe, Zn, Se, Cu, Mn, Mg) and electrolytes (Na and K), etc. As stated above the specific nutrients and their content in mustard vary with the variety, location, growing area, and processing method. There is insignificant difference in nutrient content between upper leaves and lower leaves of Mustard. The macro nutrient content of protein, carbohydrates and fat in the seeds are significantly higher than the rest of the plant, while the dietary fiber is lower than that of rest plant. Meanwhile, Indian mustard (*Brassica juncea* L.) is an oil-bearing mustard whose seeds are rich in protein and oil, and its prospects are promising. The content of total polyphenols in Mustard is generally calculated in the form of gallic acid or chlorogenic acid equivalent. It has been reported that the content of total phenolic compounds in Mustards ranges from  $3.26 \pm 0.25$  to  $404.33 \pm 2.52$  mg of gallic acid equivalent/g. Polyphenols such as sinapic acid, gallic acid, vanillic acid, caffeic acid, p-Coumaric acid, ferulic acid, p-Hydroxybenzaldehyde, vanillin, Epigallocatechin gallat, epicatechin gallat, rutin, naringin, proanthocyanidins, protocatechuic acid, p-hydroxybenzoic acid, catechin, chlorogenic acid have been detected in a variety of mustards. Sinapic acid is highest content in Mustard greens, followed by Chlorogenic acid. There was a significant difference in the polyphenol content in different parts of Mustard. In general, the polyphenol content in lateral buds was higher than that in other plant sections. The polyphenol content in other plant sections can be ordered as seed > leaf > root > stem. (In addition, studies have found that mustard is rich in flavonoids.

The content of flavonoids in Korean mustard (*Brassica juncea* var. *Gemmifera*) ranged from  $4.02 \pm 0.16$  to  $395.33 \pm 2.89$  mg quercetin equivalents/g, and the content of flavonoids in Chinese leaf mustard (*Brassica juncea* Coss) ranged from 56 to 2893  $\mu\text{g}$  kaempferol-3-O-hydroxyferuloyldiglucoside-7-O-glucoside equivalents/g. The content of flavonoids varied greatly with different mustard varieties and detection methods. 71 polyphenolic compounds have been identified in *Brassica* family vegetables, but there had been no comprehensive reports of polyphenol compounds in Mustard until now. Glucosinolates are a sulfur-containing secondary metabolite of plants. They consist of  $\beta$ -D-glucose, sulfonium sulfonate, and the side chain R of an amino acid. Depending on the difference in R, the glucosinolates are structurally classified into aliphatic glucosinolates, aromatic glucosinolates, and Indole glucosinolates. The biosynthesis of glucosinolates consists of three components: elongation of the amino acid side chain, formation of the core structure, and modification of the secondary side chain. Glucosinolates not only have a variety of biological activities, they are also important precursors for the formation of the flavor and smell of cruciferous vegetables. Glucosinolates are non-volatile flavor precursors of isothiocyanates, nitriles, and thiocyanates, which are sources of the spicy flavor of mustard. Glucoglucoside produce isothiocyanate degradation products with fresh, fragrant, or bitter and spicy flavors through three degradation pathways of enzymatic, thermal, and chemical degradation. Research on glucosinolates in Mustard was mainly concentrated in South Korea and India, particularly South Korea. It has been reported that the total glucosinolate content in Mustard was 13.0 mg/g. Sinigrin has been detected in all reported mustards, and its content was up to  $53.77 \pm 0.62$  mg/g. The content of sinigrin in Korean leaf mustard (*Brassica juncea* var. *Integrifolia*) accounted for 41.7% of the total glucosinolate content. It has been also reported that in fresh Mustard sinigrin accounted for more than 90% of the total glucosinolate content, after 3 day of fermentation the content of sinigrin was reduced by 95%, and the content of 4-methoxy glucobrassicin and neo glucobrassicin decreased to 80–90%. However, the glucosinolates in Potherb Mustard (*Brassica juncea*) were mainly gluconapin and progoitrin. Different plant organs/tissues showed significant differences in nutrient composition and content. It has been found that the content of aromatic glucosinolates in the skin of baby mustard (*Brassica juncea* var. *Gemmifera*) was higher than that of other edible parts. It was found that the content of sinigrin in Korean Dolsan Leaf mustard (*Brassica juncea*) was seeds > stems > roots > leaves. [20-40]



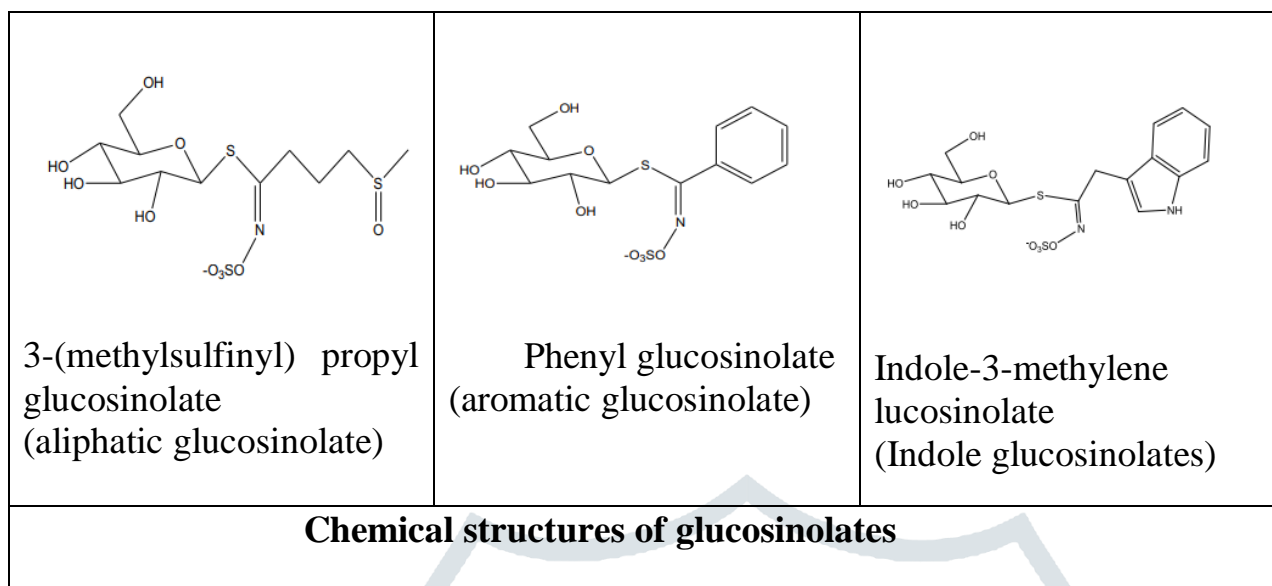


Mustard seeds are loaded with vitamins and minerals, phytochemicals, and other antioxidants. The seeds are available in different colors and have in-depth health and medicinal benefits and also used for cuisines and dishes since ancient times. Both its leaves and seeds are used and make your dishes more flavorful. Mustard seeds, also known as ‘Sarso’ or ‘Rai’ in Hindi. These seeds are important ingredients for various cuisines and dishes across the globe. Mustard seeds, which are available in white, brown and black varieties are full of health benefits and medicinal uses due to which, it is widely acclaimed as one of the world’s healthiest foods. Potential health benefits of mustard seeds: These seeds act as antioxidants because of the presence of carotene, lutein, Vitamin A, K & C, all of these help in slowing down aging. If mustard seeds are used along with aloe vera, it helps to hydrate your skin along with it also acts as a natural scrub to remove the dead skin if it is used with rose essential oil. The use of mustard seeds and its oil is beneficial in the case of hair growth, conditioning, and strengthening of hair. Massaging of the scalp with mustard oil is helpful in hair growth and its health. Since the seeds contain protein, calcium, vitamin A & E, omega-3, and omega-6 fatty acids, all these are good to make the hair stronger. Mustard seeds have a good amount of selenium and magnesium, which are effective for people who are suffering from rheumatic arthritis. Mustard seeds are having some phytochemicals such as glucosinolates and myrosinase, which are beneficial in the treatment and prevention of cancer. A study published in the Journal Human & Experimental Toxicology, wherein it has been shown that the seeds may have chemopreventive potential. Mustard seeds are having an adequate amount of dietary fibers, which are good for smooth digestion, metabolism, and prevention of constipation thus helpful in other digestive related issues. It also ensures easy bowel movement and enhances digestive power. There are numerous nutrients like copper, iron, magnesium, and selenium that are present in mustard seeds, which are important in reducing blood pressure. These are also good at giving relief from menopause. The regular use of mustard seeds is helpful for respiratory problems including asthma as it contains some important minerals like copper, magnesium, iron and selenium, which acts well against respiratory problems. The seeds have a suitable amount of magnesium, which is beneficial in case of migraine and headache. The optimal use of mustard oil helps to reduce bad cholesterol levels in the blood thus good for cardiovascular problems. Strengthens teeth and gums. Mustard seeds are packed with selenium, which makes bones stronger, and along with certain antioxidants it helps in relieving pain in the gum and teeth. [4,11,20-22]



## Chemical structures of glucosinolates and its degradation products in different mustards

Structuras químicas de los glucosinolatos y sus productos de degradación en diferentes mostazas. The name of glucosinolates and its degradation products: 1 Sinigrin, 2 Glucoiberverin, 3 Glucosturtiin, 4 Glucobarbarin, 5 Glucoiberin, 6 Glucocheirolin, 7 Glucobrassicinapin, 8 Gluconapin, 9 Glucobrassicin, 10 4-Methoxy glucobrassicin, 11 4-Hydroxy glucobrassicin, 12 Glucoalyssin, 13 Neo glucobrassicin, 14 Gluconasturtiin, 15 Glucoerucin, 16 Progoitrin, 17 Glucoraphanin, 18 allyl isothiocyanate, 19 3-Butenyl isothiocyanate, 20 3-butenyl thiocyanate, 21 oxazolidine thione, 22 indole-3-methanol



## Composition of Mustard oil

Mustard oil is the mixture of various acids like, linoleic acid and linolenic acid which have beneficial properties. Mustard essential oil is totally different from mustard oil, in terms of the process of extraction, chemical composition and medicinal properties.

Plant parts	Uses
leaves	Antiscorbutic, diuretic, stimulant and stomachic[4, 46], relieve headache (Burkill, 1966), Muscular and skeletal pains, diaphoretic. Liniment for rheumatic pain
seed	Antihelminthic, antidyenteric, diaphoretic, Fever and cold, for bladder inflammation or hemorrhage in china. Rubefacient and stimulant, tumors in China. In Korea, these are used for abscesses, colds, lumbago, rheumatism, and stomach disorders, Hypoglycemic, treatment of blisters in inflammatory neralgic affections and for Obstinate vomiting, antioxidant activity, seed paste is used in backache, arthritis, paralysis, stye, oedema of the lungs and liver
Powdered seed oil	Antibacterial activity, internally used for hiccup, augments the appetite. It relieves the phlegm in cough, Aphrodisiac, lubricant, hair oil, preservative, counterirritant, emetics in drunkenness and in poisoning, skin eruptions and ulcers (Perry, 1980), antimutagenic, colic, externally applied for arthritis, antiseptic and anti-inflammatory, seed oil, with salt is an effective gargle in dental infections and pyorrhea.
Seed residue	Cattle feed, fertilizer,
Other parts	Diuretic, for arthritis, footache, lumbago, and rheumatism (Duke and Wain 1981), its decoction is useful in amenorrhoea.
roots	A galactagogue in Africa
dried leaf and flower	A body odor repellent to mosquitoes, dengue fever
Total plant	In Java the plant is used as an antisyphilitic emmenagogue, Bronchitis, anorexia, dyspepsia, tumors, worm infestations and splenic disorders.

Both of these oils are extracted from the seeds of mustard, which bears the scientific name Brassica Nigra (Black Mustard) or Brassica Hirta (White Mustard). Mustard oil is extracted at low pressure at low temperature. It contains 0.30-0.35% essential oil (Allyso-Thiocynate) which acts as preservative. Mustard and its oil have been used as a topical treatment for rheumatism and arthritis, as a foot bath for aching feet, and in the form of plasters over the back and chest to treat bronchitis and pneumonia. Mustard oil contains a high amount of selenium and magnesium, which gives it antiinflammatory properties. It also helps stimulating sweat glands

and helps lowering body temperature. In traditional medicines, it is used to relieve the pain associated with arthritis, muscle sprains and strains. Mustard is not just edible oil also an important medicine in the indigenous Ayurveda system of healthcare. It is used for therapeutic massages, muscular and joint problems. Oil with garlic and turmeric is used for rheumatism and joint pains. Mustard oil is also used as a mosquito repellent.

The main chemical component of mustard oil is allyl isothiocyanate, about 92% of oil. Mustard oil is hazardous oil because of its high content of allyl isothiocyanate. Mustard seeds contain numerous chemical constituents, including phytoalexins (sinalexin, sinalbins A and B), sterols and steryl esters (primarily sitosterol and campesterol), and flavonoids (eg, apigenin, chalcone). Crude mucilage from mustard contains 80% to 94% carbohydrates, 1.7% to 15% ash, and 2.2% to 4.4% protein. The flavour of mustard seeds derived from glucosinolates which are thiocyanate glycosides. Glucosinolates are nontoxic S-containing secondary metabolites. Sinalbin is responsible for the flavor of white mustard seed; sinigrin is responsible for the sharper taste associated with black and brown mustard seeds. The pungency is produced by glucosinolates, which are hydrolyzed by the enzyme myrosinase (a thioglucoside glucohydrolase) to flavor-active isothiocyanates (mustard oils). Glucosinolate in mustard oil has antibacterial, anti fungal and anti-carcinogenic properties, which account for many medicinal utilities of the oil. Mustard oil has 30% protein, calcium, phytins, phenolics and natural antioxidants. Brassica alba is white mustard, B. juncea is brown or Chinese mustard, and B. nigra is black, brown, or red mustard. The plant is grown both for mustard seed from which oil is extracted and for greens or animal feed. It was formerly used as an emetic, counter-irritant, and carminative.

### **Culinary uses**

In Indian cooking yellow and dark brown mustard seeds are more commonly used but black seeds contain a higher proportion of the volatile mustard oil and strongest flavor. The larger yellow variety, known as white mustard are much less pungent. Powdered mustard has no aroma when dry, but a hot flavor is released when it is mixed with water. In eastern part of India oil extracted from mustard seeds is used as cooking oil. The Bengalis and the Oriya community relishes their Fish and vegetables cooked in mustard oil only. It is also main ingredient of Kasundi a popular mustard sauce, which is used in sandwiches and burgers. In Northern part of India mustard leaves are eaten as Saag, popularly known as Punjabi Sarso da Saag. In Maharashtra, it is called as mohari, and is used frequently in Maharastrian recipes. The seeds can be put whole into very hot oil and popped. Raw food can be cooked in this flavored oil or it can be poured over some dishes just before serving. Mustard helps emulsify liquids use in salad dressing recipes to help blend oil and vinegar and add a spicy zip. Mustards seeds are a popular addition to dishes such as vegetable, beans, pastries and pickles. Mustard is also used as an ingredient in mayonnaise and barbecue sauce. It can also be used as a base for salad dressing when combined with vinegar and/or olive oil. Young tender leaves of mustard greens are used in salads or mixed with other salad greens. Older leaves with stems may be eaten fresh, canned or frozen, for potherbs, and to a limited extent in salads. Seed oil is used for cooking purpose. Oil contains 11% saturated and 89% unsaturated fatty acid. Again among unsaturated fatty acid 18% linoleic and 15% linolenic fatty acid. Mustard is used in Indian, French, German and Irish cuisines. Mustard is used in salad dressings, egg dishes, cheese dishes, pickles and vegetables. Mustard is rubbed over meat before roasting. It is also added to butter to give butter a pleasant

flavor. Cold-press and unrefined mustard oil is a good option for cooking purposes. One must remember its hot potency while cooking, so a person dominated by the Pitta energy, should not use it more frequently or should be cautious. A combination of Mustard and turmeric makes the potency hotter, and that combination should therefore be avoided unless recommended by your Ayurveda expert. The use of mustard oil for cooking is recommended for those who have elevated lipid levels, cardiac disorders, diabetes, skin diseases, skin infections, swellings and growths. [8,11,17]

### **Mustard Oil: Health Benefits, nutrition, uses and toxicological perspective**

Mustard oil is versatile and used in many parts of the world. It is popularly known as *Sarson ka Tel* in India and is a key ingredient found in every kitchen. Mustard oil has a strong flavour and enhances the taste of several dishes. Not only that, it also has numerous health benefits. It is also worth noting that mustard is good for diabetes, owing to its anti-inflammatory properties. So, it is considered as one of the ideal oils that can be used in recipes for diabetes. Mustard oil has about 60% monounsaturated fatty acids (MUFA) (42% erucic acid and 12% oleic acid); it has about 21% polyunsaturated fats (PUFA) (6% the omega-3 alpha-linolenic acid(ALA) and 15% omega-6 linoleic acid(LA)) and it has about 12% saturated fats. This optimum ratio of omega-3 and omega-6 fatty acids and low content of saturated fats makes mustard oil more beneficial and preferred over several other oils available in the market. Mustard oil is reddish-brown or amber in colour and is known for its strong smell and pungent sharp flavour. The pungency of mustard oil is due to the presence of allyl isothiocyanate. This fatty vegetable oil is obtained by pressing mustard seeds. Mustard oil is healthy edible oil it is low in Saturated fatty acid (SFA), high in MUFA and PUFA, especially alpha-linolenic acid and has a good LA: ALA ratio (6:5). Mustard oil is considered a healthy choice for patients with cardiovascular disorders. N6 (linolenic acid) and N3 (alpha-linolenic acid) are essential fatty acids that proved to be beneficial for the body. N6 PUFA lowers LDL cholesterol but can also decrease HDL, whereas N3 PUFA may lower triglycerides, blood pressure, inflammation and improve vascular function. Since ancient times, mustard oil is used to soothe colds, coughs and other respiratory illnesses and allergies. Inhaling steam containing mustard oil has shown to clear respiratory congestion. Also, a concoction made by heating mustard oil, few cloves of garlic and 1 teaspoon of ajwain, when massaged on our feet and chest provides relief from cold and cough. Mustard oil may also show positive effects in patients suffering from sinusitis. Glucosinolate, available in mustard oil which accounts for antibiotic, fungicidal and cancer prevention qualities, serves as a therapeutic for human health. It thus protects us from colorectal and gastrointestinal cancers. Allyl Isothiocyanate serves as an anti-fungal agent, which protects food from fungal growth and reduces infection. Mustard oil is a major source of all fats required by our body to perform diverse biological functions as components of plasma, cell lipids and cell membrane. Mustard oil reduces cholesterol and improves the membrane structure of red blood corpuscles (RBC). Mustard oil is a natural stimulant that is known to stimulate our sweat glands, thereby improving blood circulation throughout the body. It also helps to lower body temperature and remove toxins from the body. By increasing blood circulation in the entire body, also relieves and rejuvenates stressed and overworked muscles. A regular massage with mustard oil helps in relieving aching joints and muscles. Omega-3 fatty acids helps to ease stiffness and pain caused due to arthritis. The composition of mustard oil is based on our body requirement. This oil having <7% saturated fat, high amounts of monounsaturated fatty acids ranges from 3.6-32.2%. It also contains a considerable amount of linoleic (18:2) and linolenic

acids (18:3). The optimum range of omega-3 and omega-6 fatty acids and vitamin E provides the required nutritive value and boosts our immune system. The amount of vitamin E in the alpha-tocopherol present in mustard oil has beneficial effects to control diabetic hazards. Mustard oil is extremely useful and can be consumed by people who are underweight. It makes you want to eat more by pumping your stomach and facilitates the secretion of gastric juices and bile which is known to create the feeling of hunger. Research suggests that mustard oil may also help in slowing down the growth and spread of certain types of cancer cells in your body. Trans fat is the major cause of insulin failure and high oxidation of fat. The absence of trans fat in mustard oil thus helps maintain insulin levels, which in turn regulates our blood sugar levels. Massage in infancy with mustard oil improves growth and post-massage sleep. Massage with mustard oil improves the weight, length and midarm and midleg circumferences as compared to infants without massage. Mustard oil helps strengthen your gums and makes it easier to remove the plaque. Plaque is generally formed due to bacteria that are surrounded by fatty membranes. Swishing mustard oil in our mouth can help loosen the fat-soluble bacteria and further avoid gum bleeding. Mustard oil contains alpha fatty acids that keep our hair hydrated, lively and help them to grow faster. Mustard oil is also a rich source of antioxidants, minerals like iron, calcium and magnesium and vitamins like A, D, E and K, all of which are important for hair growth. The anti-fungal properties of mustard oil also prevent the development of fungus and dandruff in our scalp. Mustard oil is rich in vitamin B complex, vitamin A, vitamin E, calcium, protein and omega 3 fatty acids. This reduces fine lines and wrinkles. It also helps to remove tan from the skin. Mustard oil also works wonders if you have chapped lips. The anti-bacterial and anti-fungal properties of this oil prevent the development of acne and keep our skin clean and glowy. The pungent and strong smell of mustard oil makes it a natural mosquito repellent. Rub a few drops of mustard oil on the skin and drive mosquitoes away. Mustard oil can be used for cooking and frying food. In this way, it boosts immunity and is good for our heart and diabetics. It acts as a preservative when added to pickles and chutneys. To clear our respiratory system from congestion, inhale steam containing mustard oil. Consuming a teaspoon of mustard oil and honey helps in various respiratory problems. Using mustard oil for oil pulling kills bacteria and prevents bleeding of gums. Rubbing a paste of mustard oil, turmeric and salt on our teeth and gums; makes them healthy. A mixture of mustard oil and coconut oil can be used to massage our entire body. Mustard oil contains Erucic acid. As per research in the United States, Erucic acid has toxic effects on the heart at high enough doses. Consumption of mustard oil is thereby banned in the USA. Long-term topical application of mustard oil can have harmful effects on the skin. It can even cause minor to major skin blisters. Excessive consumption of mustard oil can cause rhinitis in which the mucous membrane tends to get inflamed. Pregnant women should avoid the consumption of mustard oil as it contains a few chemical compounds that are harmful to them as well as the growing foetus. [12,15,21,23-26]

## Discussion and Conclusion

All parts of the mustard plant are edible, including the seeds, leaves, and flowers; it is in the same genus as cabbage and turnips and is an annual plant. *Brassica nigra* is the plant that produces black mustard seeds. It is native to North Africa and parts of Europe and Asia; black mustard seeds are still very popular in the Middle East and Asia Minor where they originated. The seeds are removed from their seed coats and are very small. They can be ground into a spice or used

whole, often added to hot oil to bring out the flavor. Brown mustard seeds come from the *Brassica juncea* plant. It is also often called Chinese mustard or Indian mustard. There are different varieties of brown mustard seeds, ranging from those with a dark brown seed coat to others that are dark yellow. Yellow mustard comes from the seeds of the white mustard plant, *Sinapis alba*. While it is in the Brassicaceae family, it is not as closely related to the other two types of mustard as they are to each other. The white mustard plant bears light tan seeds that are a little larger than brown mustard seeds. These end up as the bright yellow mustard due to the addition of turmeric or dye. Black mustard seeds are the most pungent of the three but are also the least common. Brown mustard seeds are less spicy than black and spicier than white mustard seeds, as can be seen in most types of brown mustard condiments. White mustard seeds are milder than brown or black mustard seeds, but they still contain pungent flavor producers, especially sinalbin. Their heat stays mainly on the tongue rather than traveling up the nose, as it does with brown and black seeds. The heat is also shorter-lived than those varieties. Black mustard seeds are a common ingredient in Indian cooking. They are often kept whole and fried (or toasted) before adding to a dish or including in a stir-fry along with other aromatic ingredients. White mustard seeds can be toasted to add to dishes or used for pickling. Mustard seeds can be ground to make homemade mustard condiments. However, there are some dishes, particularly in Indian cuisine, that use the black mustard seeds for spice and texture. The seeds are sauteed in oil until they pop and cooked along with the other ingredients. Brown and white mustard seeds are not only made into mustard but also incorporated into pickling spice. Rajika is pungent and bitter in taste, pungent in the post digestive effect and has hot potency. It alleviates vata and kapha doshas. It possesses light and sharp attributes. It is emetic, digestant, anti-inflammatory and irritant in properties. It is used in the diseases like abdominal pain, anorexia, worms, and diseases of the spleen, tumours and wounds. It is commonly known as Rai, /Indian mustard. Mustard contains vitamins, minerals, dietary fiber, chlorophylls, glucosinolates and their degradation products, polyphenols and volatile components, and other phytochemical components. The content and type are affected by variety, growth environment, extraction technology, and food processing. Mustard has various biological activities such as anti-cancer, antioxidation, anti-inflammatory, antibacterial, anti-virus, antiobesity, anti-depression, prevention, and treatment of diabetes and cataracts. Mustard is rich in glucosinolates, polyphenols, and other bioactive components. Although a lot of research has been carried out on its qualitative determination, there is still no exact content and structure of glucosinolates and polyphenols among mustards. Sulforaphane, benzyl isothiocyanate, indole-3-carbinol phenethyl allyl isothiocyanate have all had outstanding anti-inflammatory effects. Although mustard is rich in these isothiocyanates. Typically it is black mustard or black mustard greens (*Brassica nigra*) that are used for ailments ranging from the common cold to rheumatism and osteoarthritis. Black mustard seed is sometimes also taken as a diuretic, an appetite stimulant, or to induce vomiting. However, there is not enough scientific evidence to support the use of mustard greens for these uses. Mustard leaves are commonly consumed in Asia and Africa and have been linked to a host of potential health benefits. According to the existing literature, mustard extract possess anti-inflammatory, antioxidant, antidepressant, antimutative, and antibacterial properties. Additionally, Mustard extract have been shown to inhibit angiotensin-converting enzymes, lower plasma cholesterol levels, increase high-density lipoprotein cholesterol levels, and provide renal ischemic protection. Finally, mustard extract has been linked to reduced cancer risk in several cancer types including: colon cancer, lung cancer,

gastric cancer, and breast cancer. Mustard greens are incredibly nutritious plants with many vitamins, especially vitamin A and vitamin C. The presence of vitamin A makes this plant a particularly good antioxidant and helps in reducing the spread pace of cancer. While vitamin C makes this plant exceptionally good for the immune system. They are amazingly good for the health of the vision, heart, and digestive system. Mustards greens have a spicy taste that makes them taste enhancers in different salads, casseroles, and soups. Besides these benefits, if they are consumed in huge quantities, they cause many allergies and heart problems. Mustard oil is specifically contraindicated for enema. Mustard oil is an effective antifungal, anti-parasitic, antibacterial, disinfecting and antimicrobial oil that protects the skin against infections, prevents wounds from getting septic and heals minor skin problems like cuts, athlete's foot, ringworm, insect bites, small lacerations, abrasions etc. Mustard oil is extremely good for hair. Applying mustard oil on your scalp can vitalize your hair follicles and can correct pigmentation problems, this way it can help maintaining natural dark hairs for long. The essential fatty acids like linoleic acid (an omega-6 fatty acid), and certain other components present in this oil, make it an effective natural remedy for treating hair loss due to fungal infections, premature greying, dull and lifeless hair. Potentially undesirable or toxic compounds, such as bisphenol F, erucic acid or allergens, may also occur in the seeds and in mustard products intended for human consumption. Characteristic of the white mustard seeds is the glucosinolate sinalbin, which is enzymatically hydrolysed to 4-hydroxybenzyl isothiocyanate contributing significantly to the irritating odour and the sharp flavour of the mustard. However, white mustard is milder in taste than other mustard species. The seeds are often used for pickling gherkins or mixed pickles or making sausages. *Brassica nigra* (L.) W.D.J. Koch (black mustard, syn.: *S. nigra*, *B. sinapioides*) is widely cultivated for its blackish brown-red seeds which are slightly bitter and more pungent than the seeds of the white (*S. alba*) or brown (*B. juncea*) mustard. Sinigrin is the major glucosinolate in the seeds of black mustard and can be hydrolysed to allyl-isothiocyanate (AITC) giving the characteristic of a pungent irritating odour. Black mustard is commonly used as spice, potherb and as source of oil. Likewise, the plant plays an important role in traditional medicine since eternal times, either used internally or externally. Among the different mustard varieties, the traditional Dijon mustard originated in the city of Dijon in France, is very popular and made from black or brown mustard seeds blended with wine (vinegar) and/or verjuice and seasonings. If vinegar is added to a ground mixture of seeds of black and white mustard a milder blend is produced (e.g., German mustard). The most important constituent in brown mustard is the natural glucosinolate sinigrin which on hydrolysis yields up to 1.4% allyl-isothiocyanate, known as volatile oil responsible for the pungent taste of brown mustard. *B. juncea* is also used as fodder and in traditional medicine, e.g., as diuretic or stimulant. Mustard plants, especially the seeds, are used as or in food in many different forms and due to different functional properties. Processed foods are often mixed with natural mustard seeds, such as in pickled gherkins or small white onions. Mustard is also used as an ingredient in many ready-cooked dishes like crackers, appetizers, various flours and dehydrated products for soups. Moreover, various spicy sauces, vinaigrettes and mayonnaises often contain mustard condiment. To put it briefly, the seeds of mustard plants are characterized by various nutritional and functional properties and the use in the food and beverage industry is constantly growing. Due to its different functional and technological properties, mustard is gradually utilized in a wide-range by the food and beverage industry as well as in the cosmetic and pharmaceutical industry. Moreover, the use of mustard plants has gained increasing interest for several non-



food uses. For instance, seed meal of yellow mustard (*S. alba*) was shown to be efficient in controlling weeds, and oriental mustard (*B. juncea*) seed meal has been used as a broad-spectrum pesticide to control nematodes, insects, and fungi. Consumption of mustard seeds, either whole or after preparation, may lead to the intake of intact glucosinolates as well as their different breakdown products. One has to note, that the pungent taste of different prepared mustard samples strongly depends on levels of allyl-isothiocyanates. The concentration of glucosinolates and their breakdown products in mustard plants, especially in the seeds, is largely dependent on the activity of myrosinase or related bacterial enzymes or further chemical transformation prior to consumption. In case of mustard as food one has to distinguish between the intake of whole not-processed seeds as seasoning in several dishes, and processed seeds, for example as mustard flour made from ground, peeled and non-degreased seeds or as oil made by pressing the seeds. Prepared mustard is mostly composed of a mixture of ground mustard seed and/or mustard flour and/or mustard cake. In general, glucosinolates are relatively stable in the seeds until cell damage results in chemical degradation involving myrosinase-catalysed hydrolysis. Thermal treatment leads to inactivation of myrosinase via denaturation and preserve most of the glucosinolates. Optimum temperature of myrosinase activity of mustard seeds from *S. alba* was at 60 °C, however the activity decreased when the temperature of the experimental system was higher and was influenced by several other factors such as pH or presence of ascorbic acid. Mustard seeds are widely used in foods due to its sensory attributes, nutritional values, and its numerous functional properties. The intake of mustard products and foods formulated with mustard is expected to rise in future and may contribute considerably to the exposure to several biologically active compounds that were objects of this work. Mustard products and their seeds are consumed in very small quantities primarily explainable by the characteristic hot and pungent flavour. Adverse effects of bioactive compounds such as erucic acid or glucosinolates breakdown products have been mainly observed in in vitro or in vivo animal studies rather than in humans and especially when the compounds were administered in concentrated or isolated form, and given in high doses. When consumed in average amounts typically found in a normal diet, it can be expected, that the intake of mustard seeds or products made thereof do not pose a direct health risk, except for consumers allergic to mustard proteins. However, it cannot be excluded that high intake levels of mustard seeds or products made thereof, such as mustard seed oil, cause health problems. Nowadays, research is basically focusing on the potential beneficial effects of the multifunctional mustard plant and its ingredients, however reliable data on potentially toxic compounds and possible health risks should likewise be considered.

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