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Mustard-based products

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Abstract
Mustard is a popular agronomic crop that is cultivated across the world mainly as an oilseed crop. Ancient Indian literature suggested the use of mustard for both culinary and medicinal purposes but today it is widely used for culinary purpose. The seeds and leaves can be used for consumption in raw, cooked and fermented forms. The whole seeds are used for seasoning curries and pickles while ground mustard is used as a condiment and forms a part of the fermentation substrate in hardaliye. Mustard oil is rich in essential unsaturated fatty acids and has a near optimal ratio of omega-6 and omega-3 fatty acids. Although oil is the primary product obtained from the crop, raw and fermented mustard leaves are recently gaining popularity in various diets for its numerous health benefits. The leaves are rich in antioxidant phenolic compounds and can be consumed raw in salads. Fermented mustard greens have been a part of traditional Asian cuisines for a long time. Suan-tsai, fu-tsai, dua muoi, kimchi and kombucha are all preparations in which mustard leaves are fermented by lactic acid bacteria. Mustard meal is the residue left after oil extraction which is a source of good quality protein and valuable antioxidant compounds which can be extracted and incorporated into commercial food products and supplements.

Keywords: Mustard seed, mustard greens, mustard meal, oil, fermented products

Introduction
Mustard is a common oilseed used widely across Asia and Europe. It is one of the oldest domesticated crops that was part of Roman specialty condiments (Thomas *et al.*, 2012) [28]. It is said to have originated in the northwestern region of India and then expanded eastward, eventually to China and Iran. The emergence of varieties is theorized to have occurred in China (Tian and Deng, 2020) [29]. Today, three major varieties of mustard are commercially in use – yellow mustard (*Sinapis alba)*, brown mustard (*Brassica juncea)* and black mustard (*Brassica nigra)*. Of these, *B. juncea* is the most popular variety grown in warm regions as it combines the high oil yielding property of *B. nigra* and rapid growth feature of *B. rapa*. Yellow mustard is commonly cultivated in western regions while brown and black mustard are grown in southwestern Asia and Mediterranean region. In terms of production, a 2009-10 statistic by the Ministry of Agriculture, Government of India showed that India stood third in mustard production after China and USA, with about 59.93 metric tonnes which account to 10.7% of total world production.
Although both mustard seeds and leaves have culinary and medicinal uses, it is used more as a culinary spice nowadays. Its medicinal use was listed first by Pythagoras who recommended it as an antidote for scorpion bites. Mustard seeds have marked stimulant, diuretic and laxative functions. It was used for treating skin diseases and infections from ancient times. The seeds are most popularly consumed for seasoning and tempering foods. Mustard leaves are popular in traditional Korean foods where it is used as an ingredient in *kimchi*. This review gives an overview of the various parts of mustard used in different traditional cuisines and its related health benefits.

Nutritional composition of mustard
Typical mustard seed is made up of 8% moisture, 28-36% protein and 28-32% fat (Charles, 2012; Ildikó *et al.*, 2006) [11, 16]. The compositions of the three major varieties of mustard are listed in table 1. It has a sulphur-rich amino acid composition and functional properties comparable to that of casein (Sehwag & Das, 2015) [26]. Among oilseeds, mustard seed has good fatty acid profile abundant with omega-6 and omega-3 fatty acids. The major antinutrient factor that limits the use of mustard meal is glucosinolates, although their hydrolytic product, allyl isothiocyanate, shows potential for use in functional foods owing to its anticarcinogenic and anti-microbial properties (Bhattacharya *et al.*, 2010) [6].

The major glucosinolate present in brown and black mustard is sinigrin while that in yellow mustard is sinalbin. Phenolic compounds impart bitter taste and characteristic pungency to mustard while carotenoids and phenolics together are responsible for the antioxidant properties of mustard. The use of mustard in as a spice, condiment, oilseed green vegetable and salad crop are mentioned in figure 1 and discussed in detail below.

Table 1: Proximate composition of *Brassica juncea*, *Brassica nigra* and *Sinapis alba* seeds

Components	Moisture (%)	Protein (%)	Lipid (%)	Fibre (%)	Ash (%)	Reference
Brown mustard (*Brassica juncea)*	7.89	18.68	13.88	5.69	4.25	Adegbeye *et al.* (2019) [1]
Black mustard (*Brassica nigra*)	4.16	24.7	30.3	0.3	5.14	Danlami *et al.* (2016) [15]
Yellow mustard (*Sinapis alba*)		37.5	26.4	22.2	5.4	Slominski *et al.* (1999) [27]

Whole mustard seeds

Brown mustard has a pungent taste and finds limited use in Western recipes while yellow mustard has a hot principle but is minimally used in Asian households. The seeds of brown mustard are popped in oil and used for tempering and seasoning Indian curries, chutneys, meat and pickles. Various famous spice blends are prepared from ground and compounded mustard seeds, the most popular being the classic French Dijon mustard, which is used in salad dressings, mayonnaise and as dip with steak and grilled or roasted rabbit meat. It is made by crushing brown mustard seeds soaked in vinegar and ground with wine, salt and spices (Charles, 2012) [11]. Black mustard is the primary ingredient of Bordeaux mustard prepared by blending *B. nigra* seeds and unfermented wine. American ballpark-style mustard and English mustard use yellow mustard seeds for its hot principle and turmeric for colouring (Thomas *et al.*, 2012) [28].

Mustard oil

Mustard oil is a dark yellow coloured oil due to high carotenoid content and changes during processing. It can be extracted by solvent extraction which yields less pungent oil due to inactivation of myrosinase enzyme, mechanical pressing or cold pressing which results in dark coloured oil due to enzymatic degradation of glucosinolates (Sehwag & Das, 2015) [26]. A recent national survey revealed that mustard oil is the most widely used edible oil in India (51%) and its consumption was inversely related to obesity in population (Chhajed *et al.*, 2021) [13]. The Food Safety and Standards Authority of India (FSSAI) regulations on mustard oil specifies an iodine value of 96-112 and saponification value of 168-177. It is composed of 10-16% saturated fatty acids, 58-71% monounsaturated fatty acids (of which a large portion is erucic acid) and 22-27% polyunsaturated fatty acids. It is a rich source of oleic acid (7-16%), linoleic acid (11-17%) and α-linolenic acid (7-11%) and contains small amounts of palmitic, stearic, arachidic, eicosanoic, behenic and lignoceric acid (Mishra & Manchanda, 2012; Chakraborty *et al.*, 2018) [21, 9]. Mustard oil has an omega 6: omega 3 ratio of 1.2:1, which falls nearest to the optimal ratio recommended by WHO. The phytosterol concentration – brassicasterol, campesterol and β-sitosterol- in mustard oil is also one of the highest when compared to common edible oils. The essential oil content as allyl isothiocyanate ranges from 0.12-0.33% (Chakraborty *et al.*, 2018) [9]. It has been found to positively impact cardiovascular health and acts as a lipid-lowering agent. The oil can be used for frying as it has high smoke point and good heat and oxidative stability due to the presence of natural antioxidants. and it can reduce chances of cardiac problems by 70% (Mishra & Manchanda, 2012) [21]. In addition to this, mustard oil also has antimicrobial and anticarcinogenic properties, all of which makes it a great alternative to various refined oils (Kaur *et al.*, 2019) [17]. The presence of a very long-chain fatty acid, erucic acid, is a source of concern in mustard oil as it is reported to cause myocardial lipidosis in rats. To remedy this, a low erucic acid variety called Pusa Mustard-30 containing less than 2% erucic acid was developed by the Indian Agricultural Research Institute, New Delhi (Yadava *et al.*, 2014) [32].

Mustard greens

Mustard greens refer to leaves of the mustard plant. The flavour of mustard greens varies depending on the growing region and variety that is cultivated. Chinese mustard, for example, has a strong bitter taste when compared to other varieties. In India, mustard greens are consumed more in the North-eastern region where it is fermented and added in many traditional dishes. Mustard greens can be consumed both raw and pickled and goes well with sweet vegetables like carrot, sweet potato, and corn. It is a low-calorie, fibre-rich leafy vegetable that is a part of many modern weight loss diets. Additionally, it contains fat-soluble vitamins A and K as well as ascorbic acid and minerals like iron and calcium. The demand for mustard greens in increasing among the health-conscious population due to its many health benefits. In Ayurveda, mustard leaves are cited to cleanse cranial cavity and improve digestion (Manohar *et al.*, 2009) [19]. Its other reported benefits include cholesterol-lowering activity (Chaiyasut *et al.*, 2018) [7], maintenance of cardiovascular health and supporting good eyesight owing to lutein and zeaxanthin content (Meena *et al.*, 2022) [20].

Fermented products

Fermented mustard products have been used for consumption since ancient times in Asian countries. Suan-tsai is a popular fermented traditional food in Taiwan and northeastern part of India. Mustard after harvesting is dried in the sun and layered alternately with 13% salt, covered with a sheet with heavy stones placed on top and allowed to ferment by lactic acid bacteria for 3-6 months. It is not only used as food but also for seasoning main dishes. The high salt concentration only allows growth of desirable salt-tolerant lactic acid bacteria *Pediococcus pentosaceus* and *Tetragenococcus halophilus* (Chen *et al.*, 2006) [12]. Fu-tsai is a derivative of suan-tsai in which partially fermented mustard leaves are taken from the bucket, rinsed with clean water, dried in the sun for 24-48 hours and then again fermented for a minimum of 48 hours in 12% salt solution. The brine is allowed to leave from the container by being turned upside down with a plastic sheet covered on top (Chao *et al.*, 2009) [10]. Zhacai is traditional Chinese pickled mustard tuber (*B. juncea*) which is spontaneously fermented by halophilic and lactic acid bacteria. It is one of the oldest and most widely consumed dry-salted pickles in the world and is prepared by dry salting (12-14%) tuber mustard in layers (Zhang *et al.*, 2021) [33].

Vietnamese "dua muoi" is fermented mustard greens mixed with onions in sugar and salt brine. It is fermented by *Lactobacillus fermentum, L. pentosus* and *L. plantarum* along with other minor lactic acid bacteria (Nguyen *et al.*, 2013) [24]. Mustard leaf kimchi is touted as a functional food due to its anti-inflammatory properties that work by suppressing the mRNA expression of pro-inflammatory agents and mediators like TNF-α, IL-6, and IL-1β, in mice. This anti-inflammatory property is attributed to the presence of high content of phenolic compounds, mainly quercetin (Le *et al.*, 2020). African mustard (*Brassica tournefortii*) leaves can be used for kombucha fermentation which increased total phenolic content and enhanced the otherwise low bioactivity value of the leaves (Rahmani *et al.*, 2019) [25]. Traditional Turkish beverage 'hardaliye' is a grape juice-based fermented beverage originally made in the Thrace region of Turkiye, produced with addition of ground mustard seeds and lactic acid bacteria as starter culture (Coskun, 2017) [14]. Black mustard is added mainly for its characteristic taste and aroma contributed by allyl isothiocyanate after hydrolysis of glucosinolates by myrosinase enzyme. A clinical trial conducted by Amoutzopoulos *et al.* (2013) [5] found that it reduced lipid peroxidation products, namely dien conjugate and malonaldehyde and thus established its high antioxidant activity.

Mustard meal

Mustard meal is the waste or residue that remains after oil extraction, which is commonly used as fodder due to high content of antinutrients like phytic acid and glucosinolates as well as its bitter and pungent taste. It is a source of abundant good quality protein and fibre as well as natural antioxidants like sinapic acid, glucosinolate hydrolytic products, and phenolic acids like flavonoids and p-hydroxybenzoic acid. Products have been formulated in which components extracted from it have been incorporated in varying concentrations to enrich and fortify existing products. Chakraborty *et al.* (2021) [8] prepared functionally improved breadsticks by incorporating brown mustard meal concentrates which revealed that substitution of wheat flour at 5-15% improved fibre both protein and fibre content. The breadsticks also showed increased phenolic content when 15% mustard meal concentrate was incorporated and corresponding increase in antioxidant activity was also recorded. However, there was significant difference in the porosity and flavour of fortified breadsticks which could be reduced by extrusion cooking. 15% incorporation of mustard flour in biscuit dough resulted in 2.5 times increase in its protein content with no undesirable distinct changes in textural characteristics. The fortified biscuits exhibited increased breaking strength at 20% mustard flour concentration and little difference in dough characteristics (Tyagi *et al.*, 2007) [31]. The possibility of enriching processed meat products with plant-based protein was explored by Alekseev *et al.* (2021) [3] and Ammar (2012) [4] with the use of mustard flour (powdered seed cake) in sausages and beef burger patties respectively. Its substitution up to 7% garnered good overall acceptability in terms of sensory parameters and enhanced protein content and reduced total fat content of sausages while higher concentrations of mustard flour gave pungent taste and darker colour to the product and were not preferred by sensory panelists. Defatted mustard flour incorporated into beef burger patties improved its functional properties like water retention capacity and emulsifying ability due to the presence of low molecular weight proteins and justified its use as a meat binder. The activity of mustard as an antimicrobial agent due to allyl isothiocyanate is well-recognized and this property has been exploited to increase shelf-life of perishable products. Torrijos *et al.* (2019) [30] developed a bioactive sauce in active packaging using oriental mustard flour which helped to reduce population of ochratoxin-producing fungi in pita bread and increased its shelf life upto two days. They observed no ochratoxin production when 50 mg/g of mustard flour was incorporated into the sauce. Similarly, studies have reported use of mustard flour as an antibacterial agent in ground beef (Nadarajah *et al.*, 2005) [22] and antifungal fumigant for almond storage (Nazareth *et al.*, 2021) [23].

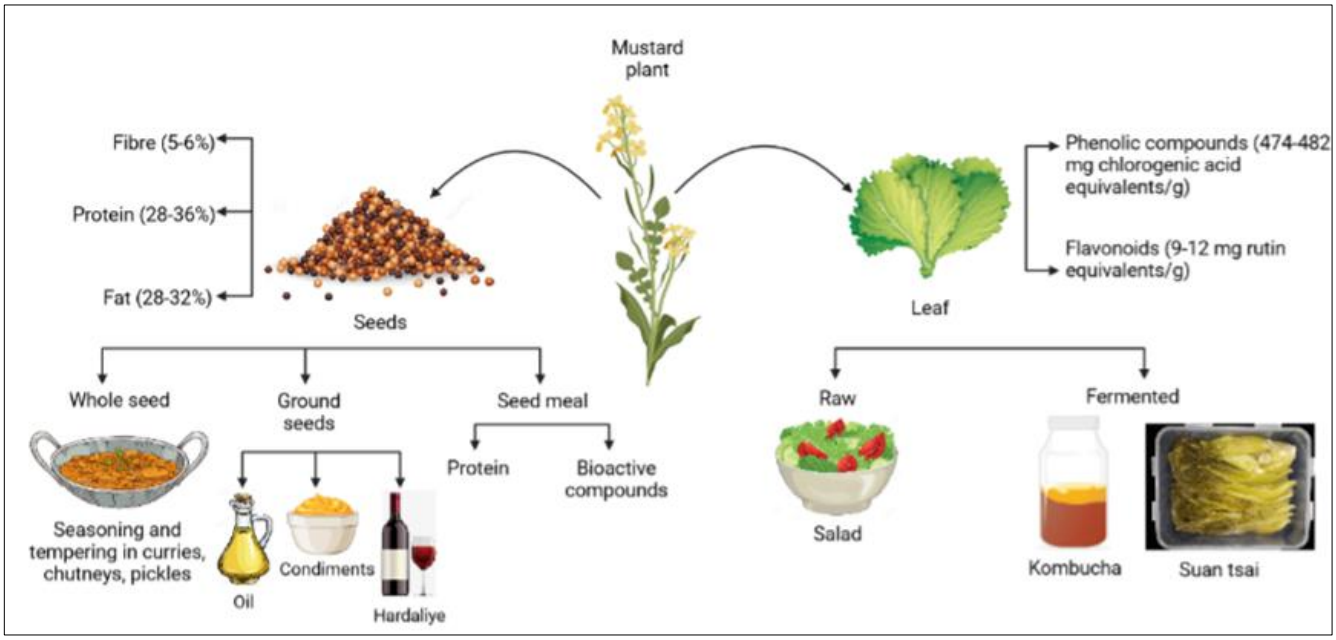

Fig 1: Mustard-based products

Conclusion

Different parts of the mustard plant can be used in various ways and each part possesses specific bioactive properties. Mustard seeds have nearly equal concentration of lipids and

protein but merely the oil is extracted, and the proteinaceous cake is fed to ruminants due to high content of antinutrient factors like glucosinolates, phytic acid and polyphenols. Research carried out on the meal has facilitated the extraction of protein and bioactive compounds like allyl isothiocyanate from this waste after elimination of toxic factors. As people incline towards choosing healthier lifestyles, mustard leaves are also finding use in diets through salads and pickles. This complete use of mustard promotes sustainability in agriculture and opens new possibilities for its incorporation into foods as a low-cost source of protein and phenolic compounds.

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