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MiniReview
Health promoting bioactive phytochemicals from *Brassica*

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Abstract: *Brassica* vegetables are a family of 6 agriculturally important species consumed in high quantities throughout the world. Cruciferous vegetables are a good source of many health promoting and potentially protective phytochemicals including folic acid, phenolics, carotenoids, selenium, glucosinolates and vitamin C. Incorporating these potent plant based compounds in a daily food is a safe, effective and inexpensive way to guard against many of today's most common and lethal cancers of which nearly 30-40% are directly linked to improper diet and related factors. The present paper reviews the available literature on bioactive compounds from edible crucifers, their health promoting beneficial effects and possible role in imparting defence against diseases especially cancer.

Keywords: Bio active compounds, structure, distribution, activity, *brassicaceae*, rapeseed, mustard

Introduction

Plant and animal foods, in addition to supplying essential nutrients for the mankind also possess a variety of bioactive substances like phenols, flavonoids, carotenes and organo sulphur compounds having anti proliferative activities (Plumb *et al*., 1997).

Nearly 30-40% of cancers are directly linked to improper diet and related factors (Czapski, 2009). Epidemiological studies indicated positive association between intake of fruits and vegetables and reduced mortality from common cancers, heart and other degenerative diseases (Art *et al*., 2005; Kaur *et al*., 2001; Scalbert *et al*., 2005; Vita, 2005). Cruciferous vegetables are a family of 6 agriculturally important species consumed in high quantities throughout the world (Fahey *et al*., 2001). *Brassica oleracea* is the main vegetable species of this family including kale, cabage, broccoli, Brussels sprouts, cauliflower whereas vegetable forms of *Brassica rapa* include turnip,Chinese cabbage and pak choi (Cartea *et al*., 2011). Cruciferous vegetables are a good source of many health promoting and potentially protective phytochemicals including folic acid, phenolics, carotenoids, selenium, glucosinolates and vitamin C (Howard *et al*., 1997; Femina *et al*., 1998; Kushad *et al*., 1999; Conaway *et al*., 2001; Fimognari *et al*., 2002) and offer powerful, broad-spectrum support for protecting against the ubiquitous cancer provoking agents encountered every day in our environment and have been reported to be associated with a lower incidence of certain cancers of lung, colon, breast, ovary and bladder (Higdon *et al*., 2007; Fowke 2007; Juge *et al*., 2007; Zhao *et al*., 2007). Mustard leaves have been reported to possess many bioactive substances and antioxidant properties (Kim *et al*., 2003). Mustard leaves extract has also been observed to control glucose metabolism and reduced lipid per oxidation as well as the level of oxygen radicals ameliorating the damage caused by oxidative stress (Yokozawa *et al*., 2003). Tiku *et al*., (2008) also recorded the protective effect of *Brassica campestris* leaves against *in vivo* chromosomal damage and oxidative stress induced by gamma radiation and genotoxic chemicals. Incorporating these potent plant based compounds in a daily food is a safe, effective and inexpensive way to guard against many of today's most common and lethal cancers. Earlier reviews appeared dealing with biocidal, bio herbicidal, anti oxidant, anti cancer activities of glucosinolates and their products from *Brassicaceae* (Rosa *et al*., 1997; Fahaey *et al*., 2001; Zukalova and Vasak 2002; Halkier and Gershenzon 2006; Vig *et al*., 2009). However, published information on other bioactive compounds from this family is very limited. The present paper reviews the available literature on bioactive compounds from edible crucifers, their health promoting beneficial effects and possible role in imparting defence against diseases especially cancer.

Glucosinolates

Structure and hydrolysis

Glucosinolates are sulphur containing secondary metabolites. The structure of the glucosinolates consists of a β-D glucose moiety linked to a sulphated thiohydroximate (Figure1). The moiety linked to thiohydroximate or side chain varies and resulting into about 130 different types of glucosinolates (Fabre *et al*., 2007). It could be aliphatic, aromatic or indolyl

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(Table 1).Desulphoglucosinolates, the penultimate compounds in the glucosinolates biosynthetic pathways are oximes having pka values about 9-12 (Jencks and Regenstein 1968; Underhill 1980). Due to low pka value of the sulphonic acid group, GSLs invariably occur in anionic form in nature (Larsen, 1981Prestera *et al*., 1996). Presence of glucose moiety and ionic forms makes glucosinolates hydrophilic and non-volatile compounds (Larsen, 1981).

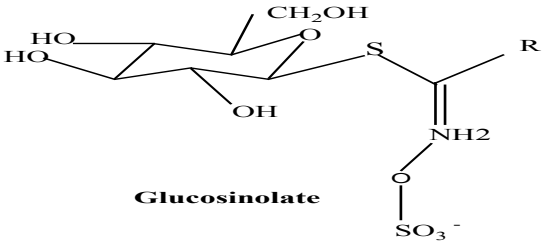
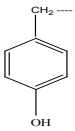
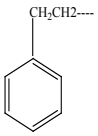
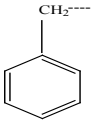
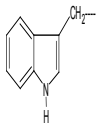
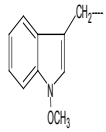
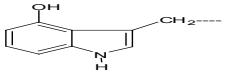
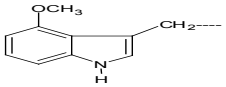


Figure 1. General structure of glucosinolate

Table1. Different types of glucosinolates occurring in family Brassicaceae (Hansen *et al*., 1995; Bellostas *et al*., 2007)

S. No.	Systematic name	Trivial name	R
	Aliphatic		
1	2-propenyl (allyl)	Sinigrin	CH_2=CH-CH_2
2	3-butenyl	Gluconapin	CH_2=CH-CH_2-CH_2
3	4-pentenyl	Glucobrassicanapin	CH_2=CH-CH_2-CH_2-CH_2
4	4-methylthiobutyl	Glucoerucin	(CH_3) S$(CH_2)_4$
5	3-methylsulphinyl propyl	Glucoiberin	$CH_3SO(CH_2)_3$
6	4-methylsulphinylbutyl	Glucoraphanin	$CH_3SO(CH_2)_4$
7	5-methylsulphinylipentyl	Glucoallysin	$(CH_3)SO(CH_2)_5$
8	3-methylthiopropyl	Glucoibervirin	$(CH_3)S(CH_2)_3$
II	**Hydroxy aliphatic**		
10	2-hydroxy-3-butenyl	Progoitrin	CH_2=CH-CHOH-CH_2
11	2-hydroxy-4-pentenyl	Napoleiferin	CH_2=CH-CH_2CHOH- CH_2
III	**Cyclic**		
12	4-hydroxy benzyl	Sinalbin	
13	Phenethyl	Gluconasturtiin	
14	Benzyl	Glucotropaeolin	
IV	**Heterocyclic**		
15	3-indolylmethyl	Glucobrassicin	
16	1-methoxy-3-indolylmethyl	Neoglucobrassicin	
17	4-hydroxy-3-indolyl methyl	4-hydroxy-glucobrassicin	
18	4-methoxy-3-indolyl methyl	4-Methoxy-glucobrassicin	

Glucosinolates are non-toxic *per se*. However, their hydrolytic bioactive products derived from cleavage by myrosinase (thioglucoside glucohydrolase; EC 3.2.3.1 (Fenewick, 1983), a medium molecular weight protein, co-existing in tissues of *Brassica* species forming an unstable aglcuone intermediate; the unstable aglucone then eliminates sulphate by Lossen rearrangement (Figure 2). Depending on factors such as pH, unstable intermediate spontaneously degrades to one of a number of products (Rouzaud *et al*., 2004; Ugolini *et al*., 2008]. Low pH tends to favour production of allylcyanide, however, under neutral and alkaline pH conditions allyl isothiocyanate is formed as predominant breakdown product of sinigrin (Uda *et al*., 1986). In presence of epithiospecifer protein, 1-cyano-2,-epithiopropane can also be formed (Cole, 1978). Epithionitriles and oxazoldine-2-thiones are formed from glucosinolates with a hydroxyl group at the 2-position of the side chain. Process of cooking vegetables destroys much of the naturally available myrosinase, however, glucosinolates can still be converted to isothiocyanates inside the body but much less efficiently than when myrosinase is available. The conversion can occur in the colon where native gut bacteria hydrolyze the glucosinolates (Getachum and Hung, 1999; Johanson, 2002).

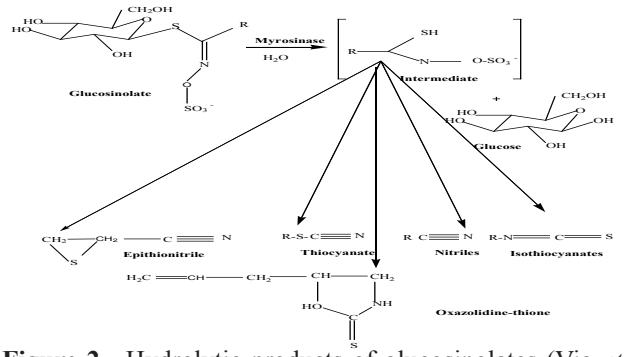


Figure 2. Hydrolytic products of glucosinolates (Vig *et al*., 2009)

Distribution

More than 100 glucosinolates have been identified from 16 plant families such as *Cruciferae* (syn. *Brassicaceae)*, *Bataceae, Bretschneideraceae, Pentadiplandraceae, Phytolaccaceae, Pittosporaceae, Resedaceae, Capparaceae, Moringaceae, Tropaeolaceae, Tovariaceae, Limnanthaceae, Caricaceae, Gyrotemonaceae, Salvadoraceae* and *Euphorbiaceae* (McGregor and Downey, 1975; Kjaer, 1980; Fahey *et al*., 2001; Fabre *et al*., 2007). They mainly occur in the *Brassicaceae*, which includes the crop plants such as rapeseed-mustard, cabbage, cauliflower, broccoli and Brussels sprouts (Table 2). They impart resistance/ tolerance to diseases and pests and accumulated in

the organs contributing to resistance/tolerance at a particular developmental stage (Brown *et al*., 2003; Grubb and Abel, 2006; Halkier and Gersherzon, 2006). Eight most significant glucosinolates have been identified so far from the Brassica genus. Ugolini *et al*., (2008) reported that sinigrin was the major component in Indian, Ethiopian and black mustard whereas glucosinalbin was the predominant glucosinolates in yellow mustard (Table 3). Aliphatic glucosinolates are mostly present in Brassica genus. Indole glucosinolates are in traces in Brassica species (Zukalova and Vasak, 2002). Indolyl glucosinolates are major glucosinolates in the vegetative parts of Brassica species but are reported to be lacking in seed (Bergmann, 1970; Josefsson 1970). Sinalbin also has been reported to occur only in trace amounts in the seed of *Brassica napus* (Kjaer, 1980). Quantitative and qualitative changes in glucosinolates in Brassica plants depend on variety, various plant parts, developmental stage, agronomic management and climatic conditions (Tiedink *et al*.,1988; Kushad *et al*.,1999; Vallejo *et al*., 2002, 2003; Borkowski *et al*., 2008).

Table 2. Distribution of Different types of glucosinolates in oilseed *Brassica* and related specie (Appelquivst 1972; Hansson *et al*., 2008 ; Ugolini *et al*., 2008)

Glucosinolates (common name)	*B. juncea*	*B. napus*	*B. campestris*	*S. alba*
Sinigrin	+			
Gluconapin	+	+	+	+
Glucobrassicanapin		+	+	
Glucoerucin			+	
Progoitrin		+	+	
Napoleiferin		+	+	
Glucoraphanin		+	+	
Glucoalyssin		+	+	
Glucoberteroin			+	
Gluconasturcin		+	+	
Glucosinalbin				+
4-hydroxy Glucobrassicin	+	+		
4-methoxy-3-indolyl methyl		+		

The pod wall has been identified as the main site of the glucosinolates synthesis (Lein, 1972). However, in species like *Tropaeolum majus* (garden nasturtium), leaves have been found to be the primary site of glucosinolates (glucotrapaeolin) synthesis (Lykkesfeldt and Moller, 1993). Synthesized glucosinolates are transported to different parts of the plant; however, nature of the transported forms is not clear. Identification of mechanism of transport could be useful to lower levels in specific tissues such as seed. Du *et al*., (1998) administered 14C tyrosine to developing seeds and siliquae walls of Sinapis alba and observed *de novo* synthesis of p-hydroxybenzylglucosinolate (sinalbin) in both and concluded that all the enzyme required for glucosinolate synthesis were present in seeds unlike the seeds of *B. napus*. Total glucosinolates in leaves of Indian mustard at 60 days after sowing ranged from 19.9-32.7 µ moles / g (Kumar *et al*., 2009).

Table 3. Major glucosinolates in oilseed Brassica and related species Ugolini *et al*., (2008)

Crop	Botanical name	Majorglucosinolates (%)
Indian mustard	*Brassica juncea*	Sinigrin (~90)
Karan rai (Ethiopian mustard)	*Brassica carinata*	Sinigrin (~97)
Black mustard	*Brassica nigra*	Sinigrin (~95)
Gobhi sarson	*Brassica napus*	Progoitrin (~70)
Taramira	*Eruca sativa*	Glucoerucin (~95)
Yellow / white mustard	*Sinapis alba*	Glucosinalbin (~100)
Cabbage	*Brassica oleracea*	Progoitrin

Activity

Glucosinolates and their derived products have been reported to have health beneficial effects by reducing the risk of certain cancers in humans (Zhang and Talay, 1994; Fahey *et al*., 2001; Shapiro *et al*., 2001; Mithen *et al*., 2003), while other GSLs are detrimental for human and animal consumption (Rosa *et al*., 1997). Epidemiological studies indicate that consumption of brassica vegetables is associated with a reduced incidence of cancers at a number of sites including the lung, stomach, colon and rectum (Conaway *et al*., 2001). Glucosinolates, the thioglucosides, present in brassica vegetables are thought to contribute to this phenomenon. Dietary glucosinolates have been reported to block formation of endogenous or exogenous carcinogens for preventing initiation of carcinogenesis (Vig *et al*., 2009).

Living organisms are continually exposed to a variety of naturally occurring chemicals. The ability of the carcinogens to exert their effects depends largely on the interaction between activating and deactivating enzymes. Imbalance, if any, will result in a change in the biological effect. Many compounds occurring naturally in the human diet moderate the biotransformation of several carcinogens, resulting in reduced tumour incidence (Wright, 1980). Glucosinolates and their hydrolytic products modulate the activity of xenobiotic metabolising phase I and II enzymes. Phase I enzymes generally increase the reactivity of lipophilic compounds. On the other hand, phase II enzymes increase the water solubility and facilitate removal of these metabolites from the body. For the protection of cell against DNA damage by carcinogens and reactive oxygen species, inhibition of phase I and induction of phase II enzymes are required. The genes for the phase II enzyme contain a specific sequence of DNA called antioxidant response element (ARE). Activities of

phase II enzyme have been reported to be enhanced by glucosinolates and their hydrolytic products (Holst and Williamson, 2004).

Isothiocyanates are an important group of breakdown products of glucosinolates and appear to act at a number of points in the tumour development by blocking the metabolism of carcinogenic compounds through biotransformation. They generally enhanced the activity of phase II enzymes and inhibited phase I enzymes (Tawfiq *et al*., 1995; Fahey *et al*., 1997; Smith *et al*., 1990; Conaway *et al*., 1996). Thus reduce the carcinogenic activity and enhance the detoxification and clearance of carcinogens. Further, they serve as suppressors during the promotion phase of neo-plastic process. Induction of apoptosis and action of signal transduction pathways within the cell activities of glucosinolates has also been reported (Smith *et al*., 2004).

Benzyl-p-hydroxybenzyl- and 2-hydroxy but-3-enyl glucosinolates have been reported to induce mammalian phase 2 enzymes of detoxification (Tawfiq *et al*., 1995; Fahey *et al*., 1997; Smith *et al*., 1990). Sulforaphane (Figure 3), enzymatic degradation product of glucosinolate glucoraphenin, activated gene expression, thereby, helping to clear carcinogenic substances from the body. Sulforaphane (SFN) also increased levels of mammalian phase 2 enzymes through antioxidant response element (ARE) mediated transcriptional activation (Zhang *et al*., 1992, 1994; Talalay and Zhang 1996; Talalay *et al*., 1995; Fimognari *et al*., 2002; Hwang and Jeffery 2005; Khor *et al*., 2006). SFN supported a healthy immune system by significantly enhancing the production of chemicals involved in immune response (Thejass and Kuttan, 2006). In a study in which animals were genetically bred to develop intestinal polyups, a condition that led tumour formation, group of animals that were fed sulphoraphane had higher rates of apoptosis (cell suicide) and smaller tumour growing more slowly than animals not receiving sulphoraphane (Wang *et al*., 2004).

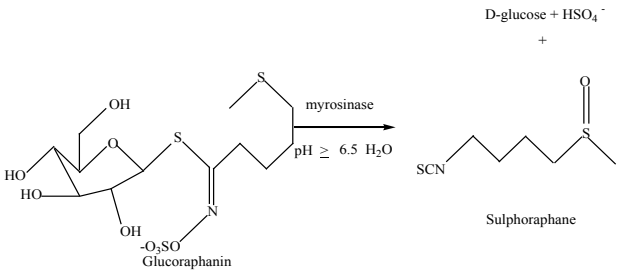


Figure 3. Sulphoraphane from enzymatic hydrolysis of glucoraphanin (Fimognari *et al*., 2002)

Watercress and broccoli are reported to be rich sources of phenethyl isothiocyanate (PEITC) which may block the cytochrome P450 mediated metabolic activation of the common nitrosoamine to its potent carcinogenic forms (Palaniswamy *et al*., 2003). Extracts of watercress and broccoli suppressed metalloproteinase-9, an enzyme closely associated with invasive potential of breast cancer (Conaway *et al*., 1996). It also suppressed production of pro-inflammatory compounds such as nitric oxide (NO) and prostaglandins (Ribnicky *et al*., 2001). PEITC also Inhibited induction of lung and oesophagus cancer in both rat and mouse tumour (Morse *et al*., 1993; Stoner and Morse, 1996; Hecht, 1996; Stoner *et al*., 1999).

Indole-3-carbinol (I3C) is produced from indole-3-glucosinolates like glucobrassicin through hydrolysis (Figure 4). Under acidic conditions indole-3-carbinol (I3C) and elemental sulphur are formed. Anti carcinogenic, antioxidant and anti-atherogenic activities of Indole-3-carbinol have been reported (Jongen, 1996). Further, indole-3-carbinol modulates the activities of both phase I and II enzymes. It suppressed cancer growth and induced programmed cell deaths in tumours of breast, prostate, leukaemia, cervix and colon because of its ability to favourably influence the human body's balance of estrogens (Aggarwal and Ichikawa, 2005; Ashok *et al*., 2001; 2002; Yuan *et al*., 1999). I3C also inhibited cancer cell growth by interfering the production of proteins involved in abnormal cellular reproduction and by promoting the production of tumour suppressor proteins (Firestone *et al*., 2003; Sarkar *et al*., 2003; Aggarwal and Ichikawa, 2005). I3C has also been reported to prevent cancer by interfering with angiogenesis, process of formation of new blood vessels that tumour require for their survival and spread (Wu *et al*., 2005). 3-3'-diindolyl methane (DIM), a condensation product of I3C enhanced beneficial effects of I3C by influencing the expression of genes involved in carcinogenesis, cell survival and physiological behaviour (Li *et al*., 2005; Pappa *et al*., 2007; Pledgie-Tracy *et al*., 2007).

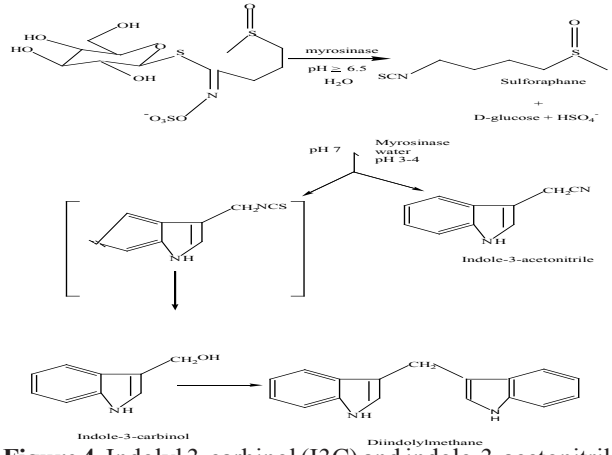


Figure 4. Indolyl 3-carbinol (I3C) and indole-3-acetonitrile from hydrolysis of indolyl glucosinolate (Jongen 1996)

Phenolic compounds

Structure

Phenolic compounds are secondary metabolites and exist widely in plants.The predominant phenolics present in rapeseed-mustard are phenolic acids and condensed tannins. Phenolic acid present in the free, esterified and insoluble forms are derivatives of benzoic acid and cinnamic acids (Figures 5 a, b). Sinapine, choline ester of sinapic acid being the most abundant followed by sinapoyl glucose making up to 1-2% of the seed dry matter (Kozlowska *et al*., 1990; Shahidi and Naczk, 1992) and markedly influenced by abiotic factors like soil and climate. The presence of sinapines, viz., sinapoycholine (sinapine), feruloylcholine, isoferuloylcholine, coumaroylcholine, 4-hydroxybenzoyl choline and 3,4- dimethoxybenzoyl choline has been reported in rapeseed (Larsen *et al*., 1983). Sinapoyl glucose is precursor of sinapine and other minor sinapate esters. Sinapic acid is derived from hydrolysis of sinapine. It constitutes 71-75 % of the total free phenolic acids.

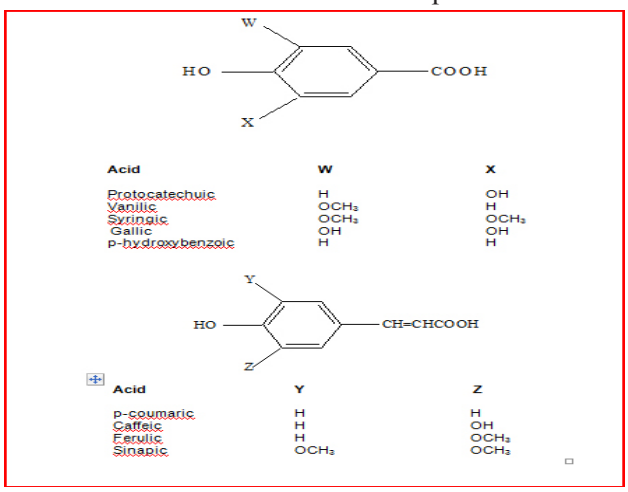


Figure 5a. Structures of phenolic acids found in rapeseed (Naczk *et al*., 1998)

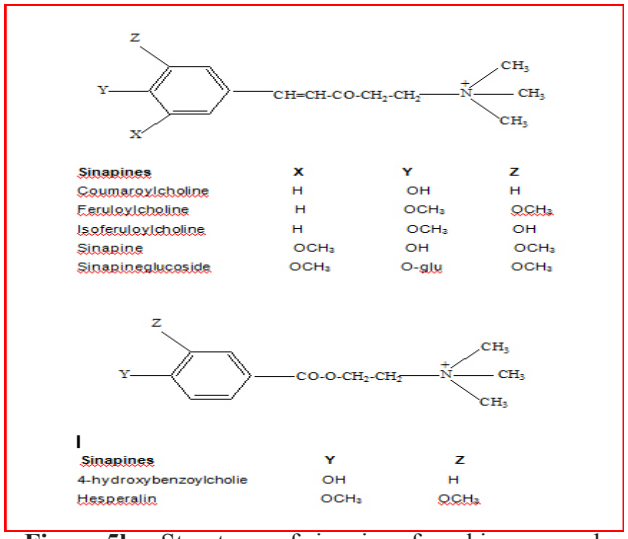


Figure 5b. Structures of sinapines found in rapeseed (Naczk *et al*., 1998)

Distribution

Sinapic acid is widely distributed in plants of *Brassicaceae* like *B. juncea* and *Lepidium sativum* (Andreasen *et al*., 2002; Lu *et al*., 2001; Chalas 2001). A number of phenolic choline esters, known as sinapines have also been reported. Rapeseed-mustard has been reported to contain more phenolic compounds than other oilseeds (Nowak *et al*., 1992). Kumar *et al*., (2009) reported significant varietal differences for total phenols (4.3-8.3 ppm gallic acid equivalent) and in vitro antioxidant activity in Indian mustard. In vitro antioxidant was positively correlated with total phenols and flavonoids content.

Activity

Phenolics play an important role as defence compounds, however, their exact contribution is still not very clear (Puupponen-pimia *et al*., 2005). Presence of sinapine and related phenolic compounds such as sinapic acid has been of concern to the oilseeds breeders and processors as they impart bitter taste, astringency and dark colour to repressed-mustard products (Sosulski, 1979; Ismail *et al*., 1981; Blair and Reicnert, 1984; Sosulski and Dabrowski, 1984). These compounds also have anti oxidant activity depending on the type of phenolics-etherified, glycosylated and non-glycosylated (Andreasen *et al*., 2001; Lu *et al*., 2001; Chalas, 2001; Robbins 2003)

Flavonoids

Structure

Flavonoids are a group of poly phenolic compounds. Natural flavonoids usually occur as glycosides-glucose, rhamnose, rhamno glucosides and can be divided into subclasses according to the structure of C6-C3-C6 flavone skeleton. Kaempferol, quercetin, Isorhamnetin are aglucones. Rutin flavonol glycoside-C27 H30 O16 (quercetin-3-B-rutinoside) has been identified in the seeds of *B. campestris* .

Distribution

Flavonoids are present in most plant tissues and often in vacuoles (Croteau *et al*., 2002).The flavonoid composition of different edible Brassica species pak choi (*Brassica campestris*), broccoli (*Brassica oleracea*), cauliflower (*Brassica oleracea*), turnip tops (*Brassica rapa*) and tronchuda cabbage (*Brassica oleracea*) have been reported (Llorach *et al*., 2003; Vallejo *et al*., 2004; Romani *et al*., 2006; Ferreres *et al*., 2005; Rochfort *et al*., 2006; Harbaum *et al*., 2007; Ferreres *et al*., 2008). Derivatives of flavonols kampferol and quercetin are the main flavonoids reported from brassica vegetables;

however, isorhamnetin and myricetin are less common. Flavonic glycoside has been detected in seeds of rapeseed cultivars (Durkee and Harborne, 1973). Flavonoids ranged from 0.8-2.3 ppm (quercetin equivalent) in 60 days old leaves of Indian mustard (Kumar *et al*., 2009).

Activity

Bioactive properties such as free radical scavenging, inhibition of hydrolytic and oxidative enzymes, anti-inflammatory (Frankel 1995) and anti viral (Hodek *et al*., 2002) action of flavonoids is known. Anti proliferative effects such as cancers, cardio vascular and inflammatory diseases of dietary flavonoids are recognized. Scavenging activity of hydroxyl radicals, superoxide anion radicals and lipid peroxy radicals signifies the health promoting functions of flavonoids.

Phytic acid

Structure

Phytic acid (Inositol hexaphosphate Ins P_6) is the storage form of phosphorus in many crop plants (Raboy 2001). It contains about 28% phosphorus in the form of phosphoric acid. Phytic acid contains six phosphate groups thereby; it can act as metal chelator (calcium, iron and nickel) to inhibit the generation of highly reactive oxygen species such as OH hydroxyl free radicals (Jabri *et al*., 1995; Rimbach and Pallauf 1998; Grases *et al*., 2001). Salt of phytic acid with minerals or protein complexes are known as phytates.

Distribution

Phytic acid, a dietary phytochemical occurs in many cereals, soybean / other legumes and fibre rich foods. Rapeseed has been reported to contain phytic acid. Mature seed is the main source of phytic acid (Naczk *et al*., 1998).

Activity

Phytic acid has a number of biological activities (Singh *et al*., 2004; Ma *et al*., 1996). Anti-neoplastic activity on a variety of experimental models of carcinogenesis, however, is the most intriguing property (Midorikawa *et al*., 2001; Vucernik and Shamsuddin 2003, Singh *et al*., 2004b). It inhibited the metastasis of tumour (Weber *et al*., 1995; Baten *et al*., 1989; Shamsuddin *et al*., 1989). Singh *et al*. (2003), Alabaster *et al*. (1996) and Takaba *et al*. (1997) reported inhibition of renal stone formation, colon carcinogenesis and cholesterol reduction in serum of experimental rats. Xu *et al*. (2008) demonstrated significant neuro-protective effect of phytic acid in a cell culture model of Parkinson's disease. Because of chelation of multivalent cations (like Fe^{++}), phytic acid is generally considered as anti nutritional, however, it is beneficial for the same property (Graf *et al*., 1984; Reddy *et al*., 1996; Shears 2001).

Brassinosteroids

Structure

Brassinosteroids are naturally occurring poly-hydroxy steroids. About 42 brassinosteroid configurates have been characterized (Fujioka and Sakurai, 1997). Natural brassinosteroids have a common 5-alpha-cholestan skeleton. Structural variation however, arises from the kind and orientation of functional group on skeleton. They are classified as C_{27}, C_{28} or C_{29} brassinosteroids on the basis of substitution pattern of side chain (Fujioka and Sakurai 1997; Yokota, 1997). Brassinosteroids belong to C_{28} steroids having a 24 alpha-methyl group in the side chain and C_{27} brassinosteroids with no substitution at 24 (Fig. 6). C_{28} brassinosteroids (24 beta-methyl, 24-ethylidene, 24-methylene-25 methyl). Campesterol or its analogues are considered to be biosynthetic precursors of brassinolide.

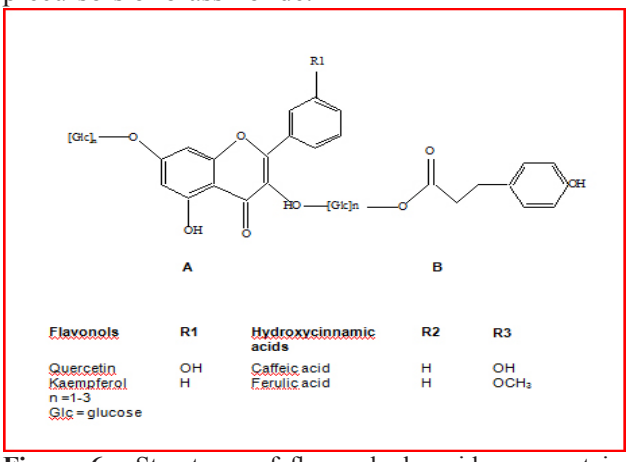


Figure 6a. Structures of flavonol glusosides present in Brassica (Oslen *et al*., 2009)

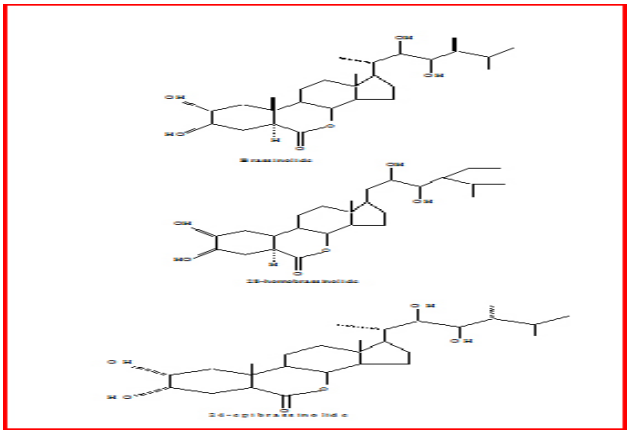


Figure 6b. Brassinosteroid isolated from Brassica (Fujioka, 1999).

Distribution

Brassinosteroids, a group of steroidal substance, first isolated from the pollen of *Brassica napus* is considered as the sixth group of phytoharmones (Rao *et al*., 2002). Distribution of brassinosteroids has been reported in pollen and seed of *Brassica napus* and *Brassica campestris*, respectively. Extremely low level (10-9 g) of brassinosteroids is reported from plants. Its concentration varies with plant tissues. Pollen and immature seeds have higher concentration in comparison to shoots and leaves (Takatsuto, 1994). Brassinolide and castasteron are the two important brassinosteroids occurring in higher plants (Khripach *et al*., 2000).

Activity

Brassinosteroids are reported to act in response to stress factors in the process of plant growth and development such as cell division, elongation and differentiation, seed germination, vegetative growth, apical dominance, reproductive growth and senescence (Sasse *et al*., 1998).Brassinosteroids are reported to have strong and unique biological activities at nano or micro molar level concentrations to plant tissues (Mandava, 1988; Sakurai and Fujioka, 1993). Brassinolide is the most biologically active among the naturally occurring brassionsteroids in many bioassay systems (Yokota, 1997). Wachsman et al. (2000, 2002) reported medical application of brassionsteroids. Substantial anti viral activity against pathogenic viruses including herpes simplex virus type 1 (HSV 1), RNA viruses and measles virus of 28-homocastasterone and 24 epibrassinolide and synthetic analogues of these compounds were observed. In in vitro test 10 to 18 fold higher activities of the several brassionsteroids was observed to reference drug ribavirin towards HSV 1 and RNA viruses. Both brassionsteroids inhibited cell growth of breast and prostate cancer cell lines in a close dependent manner at micro molar concentrations (Wachsman *et al*., 2000, 2002; Malikova *et al*., 2008).

Conclusion

Among the available bio active compounds in Brassica, only glucosinolates have been extensively investigated and vast information has been available regarding its role in minimizing the risk of cancer and several other diseases. However, studies should be carried out on the effect of genotype, environment and their interaction as well as crop management on the efficacy of these bioactive substances. Further, in depth planned and systematic clinical investigations of these bio molecules are required to elucidate their role in imparting resistance against diseases and their mode of action. Presently, studies have been underway at this directorate to characterize prevalent rapeseed-mustard varieties for phenolics, flavonoids, ascorbic acid, glucosinolates, phytic acid and anti oxidant activities in seeds and leaves. Furthermore, use of glucosinolates, phenolics, flavonoids, phytic acid and other bio active components from *Brassica* in functional food, their bio-availability studies may provide additional evidences for the utilization of fascinating natural products.

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