How to maximise the health benefits of Brassica vegetables

Integrated Crop Protection
PROTECTING CROPS

Introduction

Vegetables are good for us!

Consumers know it, and Brassicas are high on the list. They have a reputation for providing health benefits to consumers, which has been confirmed by recent market surveys showing that health is one of the key drivers of purchase for Brassica vegetables by Australian consumers.

What did our parents say? Something like: “Eat your brussels sprouts, they are good for you”.

Well, it turns out they were right! And, not just brussels sprouts, but broccoli, cauliflower, cabbage, rocket and other leafy Brassicas.

In Australia, broccoli and cauliflower are the preferred Brassica vegetables by consumers and this is reflected at the checkout. Broccoli and cauliflower are the fifth and ninth most purchased vegetables in Australia.

Brassicas contain high levels of vitamin C, A, E, K, as well as folate, calcium, iron, potassium and phosphorus. They are a good source of dietary fibre and have something that no other fruits or vegetables contain, namely ***glucosinolates***.

Glucosinolates are naturally occurring bioactive sulphur-rich compounds, and are the main components responsible for the health benefits of Brassicas.

Glucosinolates also provide the characteristic bitter or mustard flavours in many Brassica vegetables. Striking a balance between flavour and bioactive levels will be important in increasing the popularity of Brassica vegetables, in addition to promoting health benefits.

Recent research has demonstrated clear health benefits to humans from eating Brassicas in protecting us against some common cancers and cardiovascular disease.

The dietary intake of the health-promoting compounds found in Brassica vegetables have been shown in epidemiological studies to reduce the risks of

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atherosclerosis in which the arteries are clogged by the deposits of fatty material. Brassica vegetables are a potential sources of anticarcinogenic glucosinolates, antioxidant metabolites (vitamin C, β-carotene, lutein and zeaxanthin), phenolic acids, flavonols and anthocyanins.

Which Brassicas are the healthiest?

Broccoli has been labelled a "superfood" because of its well-documented health-promoting benefits. It is popular among health-conscious consumers because it offers a high level of nutrition at a very low caloric cost, making it one of the most nutrient-dense vegetables available.

Kale: The popularity of kale has increased sharply in recent years. It has become popular among Australian consumers, not for its appearance or flavour, but because people think it's good for them. Consumers are buying kale for its ***nutritional*** and ***phytochemical*** value. Kale is high in the carotenoids lutein and beta-carotene, as well as vitamin C, polyphenols, and antioxidant activity as well as being an excellent source of minerals.

Brussels sprouts are perhaps the next Brassica vegetable to become popular for their health benefits. They are naturally high in glucosinolates – that's what gives them the strong, distinctive flavour. Perhaps Brussels sprouts need some promotion to tell consumers about the health benefits.

How to maximise the levels of beneficial bioactives in Brassicas

Crop nutrition: management – sulphur and nitrogen

A number of field and greenhouse experiments involving soil, hydroponic, and tissue culture media with several Brassica vegetables have shown that sulphur (S) fertilisation generally results in increased glucosinolate content. Results are dependent upon species, stage of the plant development, amount of sulphur applied, soil type, and nitrogen level in the plant.

Broccoli: In Australia, applying sulphur at 92 kg S/ha (e.g. about 600 kg/ha gypsum) to field-grown broccoli doubled the total glucosinolate content compared to control, and similar results have been achieved overseas.

A nitrogen:sulphur ratio (N:S) ratio of between 7 and 9 will result in maximising the glucosinolate content of broccoli.

N:S ratios above 10 are likely to reduce glucosinolate content due to a deficiency in available sulphur. For broccoli, applied sulphur is more effective at the intermediate stages of head development.

Kale: High rates of applied nitrogen (180 kg/ha) tend to increase yield and sugars and reduce bitterness, but also reduce the glucosinolate content of kale, and lower rates of nitrogen (90 kg/ha) have the opposite effect. These studies suggest that in kale production, N and S fertiliser management and also cultivar selection can be used as tools to enhance glucosinolate content and eating quality.

These results suggest that for Brassicas, N supply should be balanced with S application, as plants can generally only benefit from having an optimal N supply when sufficient S is available to allow the synthesis of S-containing substances such as glucosinolates. The effectiveness of applying sulphur to increase glucosinolates content probably depends on S levels in the soil.

Micronutrients

Zinc added at a rate of 0.05-25 mg/L to the nutrient solution of hydroponically grown *Brassica rapa* (e.g. mizuna, bok choy) in the USA increased glucosinolates content, whereas rates of 50–200 mg/L caused severe Zn toxicity. There is limited information on the effects of micronutrients on shelf-life and phytochemicals content in Brassica vegetables.

Climate

The importance of growing broccoli in the correct seasonal and geographical location to optimise yield and quality has been demonstrated in Australia, the USA and Europe. Eight varieties of broccoli grown in Spain, in spring, had generally higher contents of glucosinolates, total phenolics and vitamin C than plants grown early in winter. In Sweden, broccoli grown in spring or autumn had higher antioxidant activity than crops grown in summer.

Cabbage in South Korea had a higher anthocyanin content in spring compared to those grown in autumn. Kale grown in Brazil in summer had higher carotenoid contents than winter.

How do these condition relate to Australian growing conditions and seasons? Table 1 shows the results on an experiment where eight varieties of broccoli were grown in winter and spring in La Alberca, Spain with or without supplemental sulphur. The latitude of La Alberca is 40.8°N, roughly equivalent to Melbourne and East Gippsland in Australia.

The results clearly show that glucosinolate levels are increased by growing in moderately warm temperatures (15°C min, 26°C max) and with the addition of sulphur.

Table 1. Average total glucosinolate levels in the inflorescences of eight broccoli cultivars grown in winter and spring seasons with poor and rich sulphur fertilisation in La Alberca, Spain[1].

	TOTAL GLUCOSINOLATE IN BROCCOLI HEADS (MOL/KG DW)	
Sulphur levels	Low temperature (winter) (8°C min, 19°C max)	Moderate temperature (spring) (15°C min, 26°C max)
Low sulphur (15 kg S/ha)	39.5	44.3
High added sulphur (150 kg S/ha)	45.8	49.5

Varieties

There can be significant effects of variety on the glucosinolate content of Brassica vegetables. Figure 1 shows the range in glucosinolate levels in eight broccoli varieties grown in Spain ranging from 34 to 66 mol/kg[1]. In Australia, the Vital Vegetables project developed a new broccoli variety (*Booster Broccoli*) which had 40% more active antioxidant than standard varieties.

[1] Vallejo, F. et al. 2003. Total and individual glucosinolate contents in inflorescences of eight broccoli cultivars grown under various climatic and fertilisation conditions. Journal of the Science of Food and Agriculture, 83, 307–313.

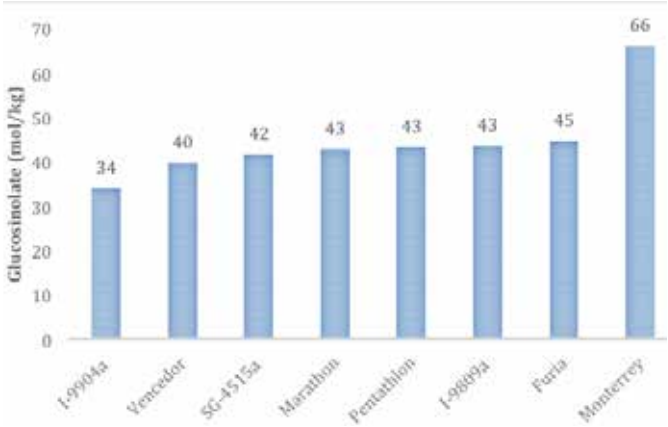

Figure 1. Average total glucosinolate levels in the inflorescences of eight broccoli cultivars grown in La Alberca, Spain[1]

Time of day at harvest and crop maturity

Two studies in Argentina showed that broccoli heads harvested at the end of the day compared to early morning, and held at 20°C for 4–5 days, had a day longer shelf-life, were greener and had higher contents of total soluble and reducing sugars, antioxidants and phenolic compounds[2].

The contents of vitamin C, flavonoids and phenolic acids in broccoli increase steadily with age, reaching a maximum when the head is at the over-mature stage. In contrast, glucosinolates peak in the second or third of the five stages, depending on the degree of S fertilisation and cultivar. The stage at which most broccoli is harvested for market is stage 4.

In kale, lutein and β-carotene contents are higher in fully expanded mature leaves than in younger ones.

Water management: deficit irrigation

There are some studies which show that applying a mild water stress to broccoli plants about 14 days before harvest can result in increased shelf life of 3–6 days, delayed yellowing, but also causes slightly reduced head weight (yield) and floret size. The mild water stress increased the glucosinolate concentration and reduced the sugar levels, reducing the perception of sweetness and increasing bitterness.

How can I measure glucosinolates in my crops ?

The best way to get an estimate of the glucosinolate level in your Brassica crops is to send samples to a laboratory that can measure antioxidants such as BHA, BHT, tBHQ and polyphenols. In Australia, you can contact the National Measurement Institute (NMI) which offers this service on a commercial basis. The website is http://www.measurement.gov.au – look for the section on Food Composition and Labelling. You will find an online form and instructions on how to prepare the samples. Other reputable laboratories in Australia are also able to provide this service.

Conclusion

Most research on preharvest factors affecting quality of Brassica vegetables has focused on the impacts on product composition, especially glucosinolates content. In summary, the main opportunities to maximise glucosinolates in Brassicas are:

1. ***Crop nutrition***: Supplying adequate sulphur to crops is key to maximising the levels of glucosinolates, especially in broccoli and kale.

   At least one unit of sulphur should be included with every seven units of nitrogen applied to Brassica crops to maximise the glucosinolate content. This applies to all Brassicas including broccoli, cabbage, radish, turnip, kale and brussels sprouts. There are potential value-adding opportunities to manipulate the glucosinolate concentration of Brassicas to enhance their health-promoting properties.

2. ***Climate***: Mild growing conditions produce higher glucosinolate levels in Brassicas than cold conditions. This effect is further enhanced by applying sulphur in the fertiliser program.

3. ***Variety***: There are differences in glucosinolate content between varieties. Consult your seed company for the latest information.

4. ***Irrigation***: A mild water stress about 14 days before harvest can increase glucosinolate levels the plants, but can also have other effects which may not be desirable, e.g. reduced head size in broccoli.

[2] Hasperue et al., 2011; Hasperué et al., 2013

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