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Nutritional attributes of legumes (2) Sprouted beans and seeds

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1 Executive summary

Once considered hippie or “new age” food, sprouted seeds have become relatively mainstream over the last decade. They are widely available in supermarkets, and the range has widened to include many different legumes as well as brassica and onion species. Rather than being largely garnishes, they are now frequently an integral component of salads and sandwiches. However, despite this increase in popularity, there has been little nutritional research and information about many sprouted foods is minimal.

1.1 Germination

The germination process has been used for centuries in many Asian cuisines. It has the beneficial effect of reducing anti-nutritional factors and increasing the bioavailability of both macro and micronutrients, such as protein and some minerals. Sprouting also affects phytochemical levels, depending on the sprouting process, seed type and temperature.

1.2 Microbial contamination

Although pathogen contamination, particularly with *E. coli* and *Salmonella* spp., was a serious issue worldwide for the industry in the 1980s and early 1990s, considerable research and industry effort has reduced the occurrence of such incidents. This has been largely due to treatments for contaminated seeds, the major cause of the problem, along with scrupulous hygiene during production processes.

1.3 Sprouted legumes

Information on individual sprouted legumes is somewhat patchy, with only isolated pieces of information rather than complete overviews. According to the information available, the major nutrients in most sprouted legumes are the B vitamins and some minerals. Most information is available on sprouted soy beans, which appear to be one of the most nutritious of this group, with around double the levels of nutrients compared with other sprouted legumes. However, this is partially explained by the fact that they also contain a much higher dry matter content than many of the other sprouts.

1.4 Sprouted brassicas

There are a number of papers specifically focusing on broccoli sprouts relating to the broccoli-associated isothiocyanate, sulforaphane. There is also considerable information about sulforaphane itself, as well as other isothiocyanates and glucosinolates. Broccoli sprouts, particularly a commercially available patented product that was used in many of the studies, can have extremely high levels of the sulforaphane glucosinolate, glucoraphanin, in levels several times higher than in the mature heads. However, it should be borne in mind that the average serving size of broccoli sprouts is considerably less than of broccoli florets.

1.5 Conclusions

It is likely that these products provide a good range of both core nutrients and phytochemicals, but until more information is available, this conclusion is not definitive. It is to be hoped that they receive more research attention, as they have the potential to satisfy many of the needs of tomorrow's consumer, being fresh, minimally processed, convenient and healthy.

2 Background

Note: This report is intended to be viewed as an adjunct to the report "The nutritional attributes of legumes". Unfortunately there is a dearth of research in the area of sprouted beans and seeds and it has not been possible to find information on all commercially available sprouts.

Sprouted beans and seeds have progressed from being dismissed as the domain of health food fanatics or hippie food to being regarded as healthy, convenient and tasty. The rise in popularity of certain ethnic cuisines, such as Thai and Chinese, has also helped raise awareness and acceptance of these foods and led consumers to consider them as more than just garnishes to a salad. Their presence in supermarkets means that they are also readily available and new technologies and production processes have meant fewer incidences of pathogenic contamination, which has periodically given these foods a bad reputation.

2.1 Germination and sprouting

The effects of germination depend both upon the nature of the plant and on the environmental conditions, although the general process is common to most plants. Germination is a period of intense metabolic activity in the plant. Following the uptake of water by the seed, metabolic processes oxidise oils and carbohydrates stored within the seed and break down storage proteins to provide the energy and amino acids necessary for normal physiological processes and for growth (Zielinski 2002; Urbano et al. 2006). Germination has also been documented as an effective means of removing some of the antinutritional factors present in the seeds, such as trypsin inhibitors, phytates and raffinose oligosaccharides. Some antinutritive components may be leached during soaking and others may be mobilised in the germinating seed into secondary metabolites. For example, trypsin inhibitors that impede the digestion of protein are reduced and phytic acid, which forms insoluble complexes with some minerals in seeds, is hydrolysed, allowing minerals to be more available for absorption.

Another obvious change is the accumulation of moisture, with sprouts having considerably higher water content than their seeds. For example, mung bean sprouts contain 93.2% water, whereas the raw seeds contain only 11% (Athar et al. 2004).

2.2 Microbial contamination

In the past there have been a number of incidences of various forms of microbial contamination of sprouted products, especially from *E. coli* and *Salmonella* spp. The consensus appears to be that contamination occurs primarily through the seed, although production and handling practices may also be involved. With sprouts there is particular potential for the growth of pathogenic bacteria because the conditions that are most favourable to the sprouting process are also favourable to the growth of many pathogens. In addition, sprouts are often hard to wash adequately without compromising organoleptic qualities and are frequently consumed raw.

There has been considerable research investigating methods of ensuring a pathogen-free product and this, coupled with greater industry awareness, should mean that high standards of food safety in today's products are possible. Such was the concern regarding this problem that in 1997 the National Advisory Committee on Microbiological Criteria for Foods was asked to review the current literature on sprout-associated outbreaks, identify the organisms and production practices of greatest public health concern, prioritise research needs, and provide recommendations on intervention and prevention strategies (1999; NACMCF 1999). The findings of this study, together with much subsequent research, appear to have considerably improved the food safety aspects of these foodstuffs.

3 Sprouted legumes

The major nutrients in sprouted legumes are the B vitamins, particularly thiamine. They also provide small amounts of a range of minerals. Some, such as alfalfa and pea shoots, have a high water content and thus have only low concentrations of the nutrients they supply, but are also low in calories. However, sprouted beans, such as soy and adzuki beans, contain more dry matter and higher levels of nutrients but more calories. Being young, most sprouts are sweet and tender and provide interesting textures, being crunchy rather than fibrous like older plants.

Without their hard seed coats, these young plants are potentially vulnerable, and so have evolved defence mechanisms through protective phytochemicals. Levels of these appear to fluctuate and they may change form during the germination process, such as from glycosylated compounds to aglycones or vice versa.

3.1 *Adzuki beans (*Vigna angularis*)*

New Zealand data on adzuki bean sprouts are not available, but it is likely that adzuki beans will have a roughly similar nutrient profile to other sprouted beans in this report (see Appendix I).

One of the few studies involving adzuki sprouts related to levels of bioactive compounds over a 4-day period of germination/sprouting. High levels of phenolic compounds, including flavonoids, were measured in the seed, and are attributed to their strongly coloured maroon seed coats. These mainly contain proanthocyanins, according to two early studies (Ariga et al. (1988) and Ariga & Hamaon (1990), cited in Lin & Lai (2006)). Lin & Lai (2006) also observed the extremely high *in vitro* radical scavenging activity of these procyanindins.

Lin & Lai (2006) found that over short-term germination (1 day), levels of total phenolics and flavonoids decreased, which was attributed to loss of pigments in the seed coats. This was confirmed visually with staining of the coloured cheesecloth in the container in which the seeds were soaked. After 4 days of germination total phenolics increased again, although total flavonoids decreased. Antioxidant activity, measured according to reducing power, initially declined and then increased to around the same level as present in the seed. Radical scavenging ability progressively increased over the germination process (Table 1). (See Section 3.5 of the report "Nutritional attributes of legumes", which describes the health benefits of phenolic compounds and the importance of antioxidant activity.) Of the four sprouted legumes investigated (soy, black soy, mung and adzuki), the adzuki sprouts had the highest levels of total flavonoids and moderately high levels of total phenolics. Reducing power for both seeds and germinated forms of adzuki beans was around the highest of the four species, although radical scavenging, as measured by the DPPH assay, was towards the lowest.

Table 1: DPPH scavenging ability of mature and germinated seeds of one adzuki bean cultivar (Lin & Lai 2006).

Seed	1-day germinated	4-day germinated
0.4 EC_{50} (mg/ml)	0.6 EC_{50} (mg/ml)	2.5 EC_{50} (mg/ml)

3.2 *Alfalfa sprouts (*Medicago sativa*)*

The main core nutrients in alfalfa sprouts are the B vitamins, particularly thiamin (Figure 1). Further detail is provided in Appendix I and the major functions of the various micronutrients are summarised in Appendix II.

One of the few *in vivo* studies using sprouts involved a 3-day germinated mix of equal quantities of alfalfa, broccoli, radish and clover sprouts (Gill et al. 2004). Volunteers were fed 113 g of a commercially available sprout mix daily for 14 days, after which a range of parameters were measured, including DNA damage in lymphocytes, the activity of three detoxifying enzymes, antioxidant status, plasma antioxidants, blood lipids and plasma levels of lutein and lycopene. There was no significant effect upon detoxifying enzymes, nor were plasma antioxidant levels altered. However, there was a significant antigenotoxic effect against H_2O_2-induced DNA damage in peripheral blood lymphocytes of the volunteers. The authors concluded that these results supported the theory that cruciferous vegetable consumption reduces the risk of cancer by protecting DNA from damage. A parallel *in vitro* study showed that colorectal cells preincubated for 24 hours with the sprout extract were better able to resist H_2O_2 damage to DNA (Gill et al. 2004).

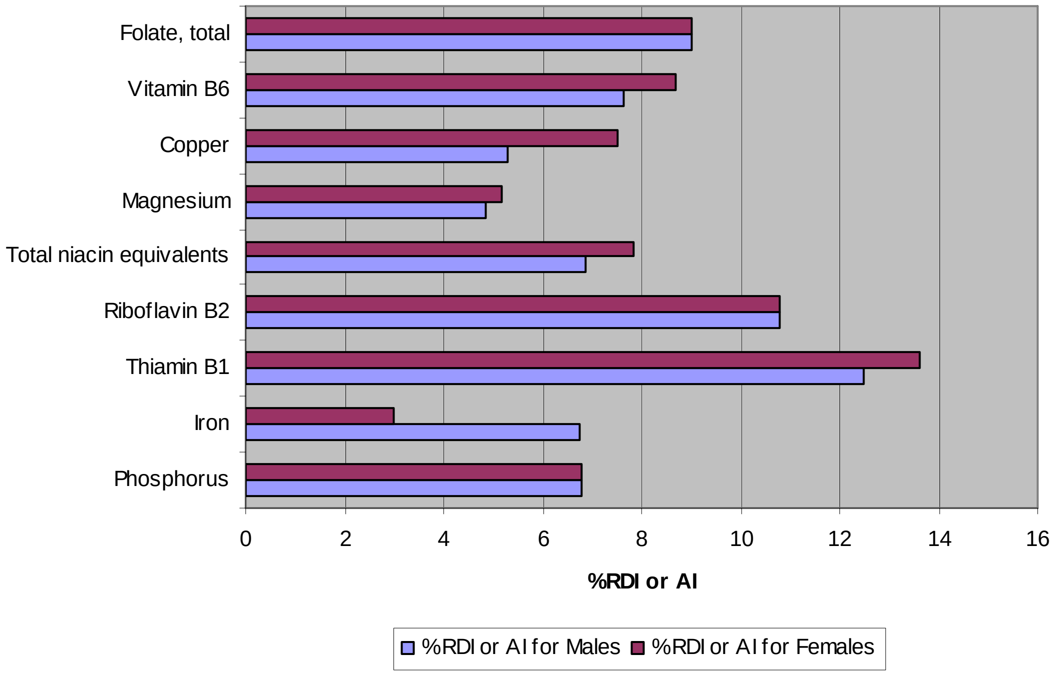

Figure 1: Contributions to RDI (recommended daily intake) or AI (adequate intake) by the major micronutrients in 100 g alfalfa sprouts, adapted from Athar et al. (2004) and NHMRC (2006).

Alfalfa sprouts are sweet and crunchy, but relatively bland. They are consequently often mixed with other sprouts, such as onion, which have more pungent flavours and different bioactive components. Onions contain flavonoids, fructans and organosulfur compounds. These bioactives have been found to have many beneficial health effects, including reducing the risk of thrombosis, protecting against cancer and cardiovascular disease, and having anti-bacterial activity. Interestingly, there is very little difference between levels of the main core nutrients in the pure alfalfa mix as opposed to the alfalfa/onion mix, except that the mix has a greater amount of thiamin (Figure 2).

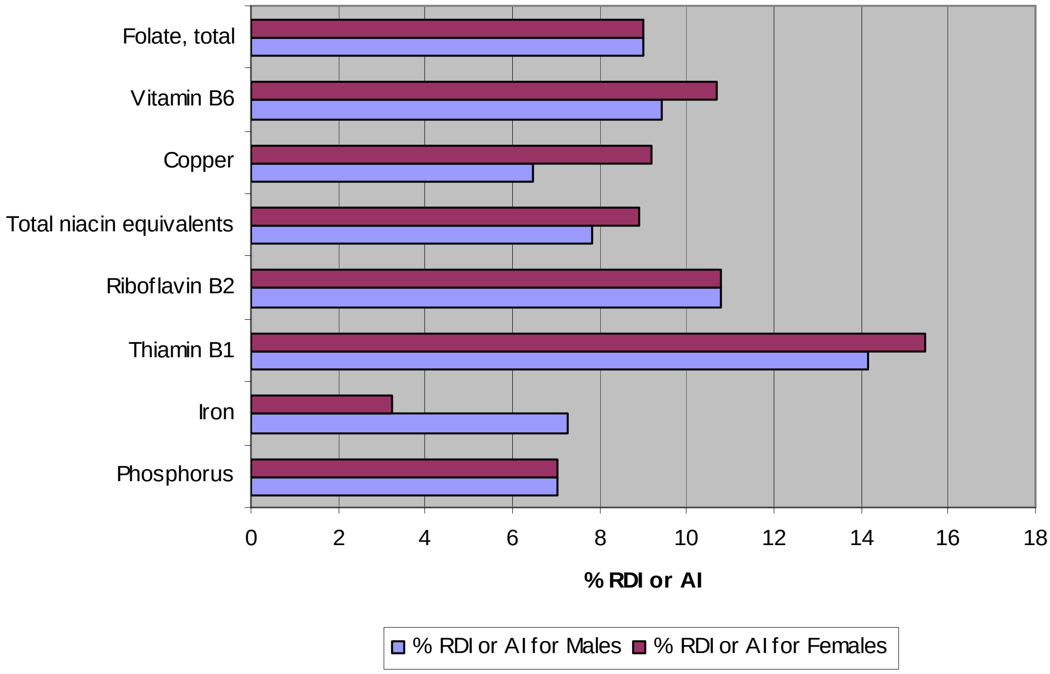

Figure 2: Contributions to RDI (recommended daily intake) or AI (adequate intake) by the major micronutrients in 100 g of alfalfa and onion sprouts, adapted from Athar et al. (2004) and NHMRC (2006).

3.3 *Lentil sprouts (*Lens culinaris*)*

New Zealand data on lentil sprouts are not available, but it is likely that their nutritional profile would be similar to that of other legume sprouts.

Vidal-Valverde (2003) showed a dramatic decrease in antinutritional factors, including trypsin inhibitors and phytates, over the course of 6 days' germination. However, the amount of tannins and catechins in both varieties studied increased. (The latter are well known antioxidant compounds, more commonly associated with chocolate and tea.) After 6 days, catechin levels were measured at 1.0 and 1.2 mg/g (dry weight) for the two varieties. Converting to fresh weight values on the basis of USDA data (USDA 2005), this equates to 36.26 and 43.51 mg/100 g. These levels are similar to those reported in tea and red wine. (See Sections 6.2 and 6.3 of the "Health attributes of legumes" report for further detail on catechins and their health benefits.) Ziielinski (2002) showed that germinated lentil seeds were more effective than germinated soy seeds when their peroxyl-trapping capacity was compared and that this fluctuated over the course of the 7-day germination period.

3.4 *Mung beans (*Vigna radiata *syn* Phaseolus aureus*)*

As with others in this group, the major core nutrients in mung bean sprouts are the B vitamins (Figure 3).

Mung bean sprouts had moderate levels of phenolic compounds when compared with soy and adzuki beans and sprouts and similar levels of flavonoids and reducing power to sprouted soy (Lin & Lai 2006). See Section 3.5.3 of the ‘Health attributes of legumes” report for a discussion of phenolic compounds and their benefits.

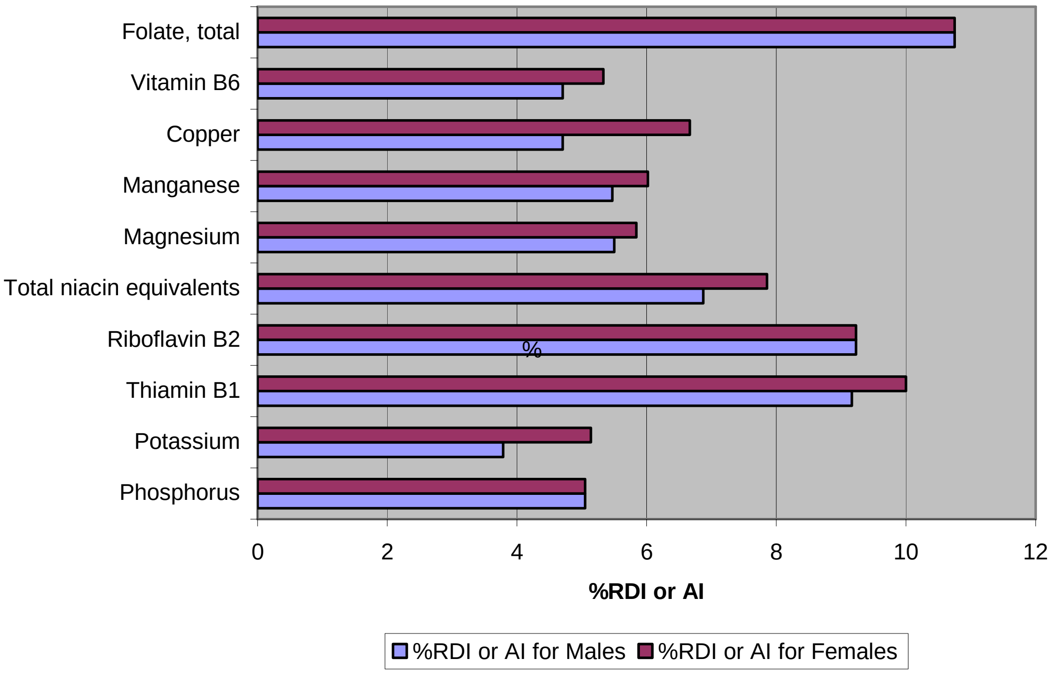

Figure 3: Contributions to RDI (recommended daily intake) or AI (adequate intake) by the major micronutrients in 100 g of mung bean sprouts, adapted from Athar et al. (2004) and NHMRC (2006).

3.5 *Pea sprouts (*Pisum sativum*)*

The major core nutrients in pea sprouts are again the B vitamins (Figure 4). Further detail is provided in Appendix I and the major functions of the various micronutrients are summarised in Appendix II.

One of the few studies found on pea sprouts involved looking at the effect of germination on levels and bioavailability of certain minerals. Although soaking prior to germination caused the leaching of zinc and magnesium, in this animal study the improved bioavailability after germination more than compensated for such losses (Urbano et al. 2006). This study also found that the optimum time for sprouting was 4 days and that whether sprouting took place in the dark or light made no difference to the levels of these minerals or their bioavailability.

A very recent *in vitro* study showed that a phenolic extract from 5- and 8-day old pea sprouts exhibited dose dependent anti-*Helicobacter pylori* activity (Ho et al. 2006). Phenolic content was also measured and found to fluctuate between 0.35

and 0.75 mg/g (fresh weight) and to be highest on days 1 and 5. However, these levels would be considered low in comparison with other vegetables (Wu et al. 2004b), being around the same as those in iceberg lettuce.

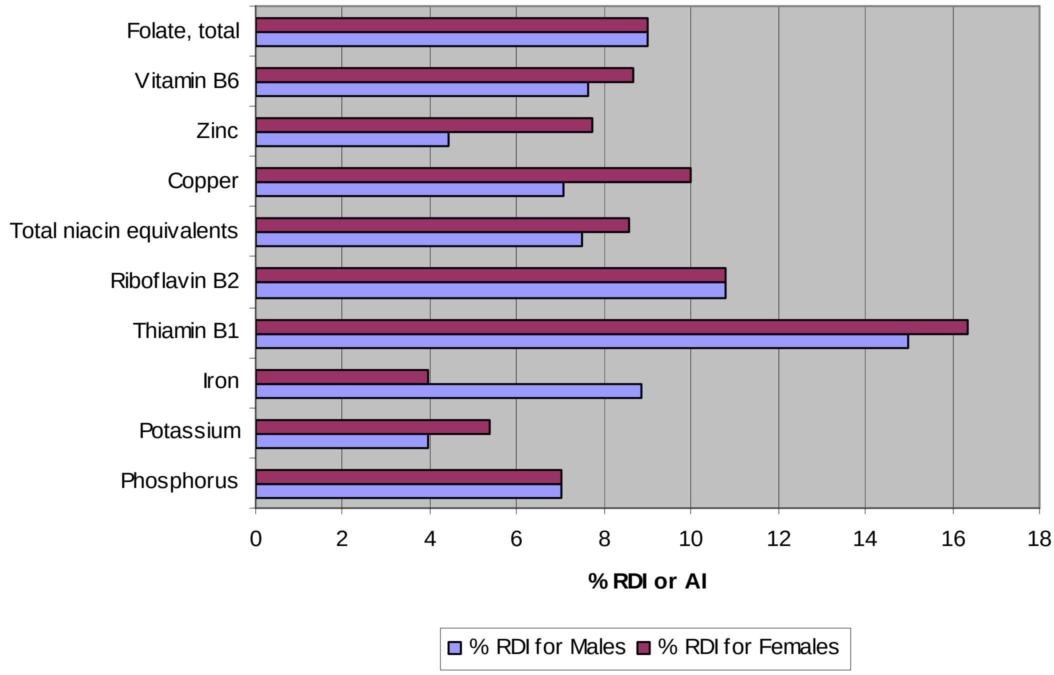

Figure 4: Contributions to RDI (recommended daily intake) or AI (adequate intake) by the major micronutrients in 100 g of snow pea shoots, adapted from Athar et al. (2004) and NHMRC (2006).

3.6 *Soy bean shoots (*Glycine max*)*

In comparison with other sprouted legumes, soy bean sprouts appear to be nutritionally superior. However, it should be borne in mind that they are also a far denser product, with a water content of only 69.1 g/100 g fresh weight, than mung bean sprouts which have a water content of 93.2 g/100 g fresh weight. It is not surprising therefore that their energy content is 141 kcal as opposed to 23 kcal for mung bean sprouts. Unlike many other legume sprouts they also contain reasonable amounts of vitamin C.

Soy beans have received significant attention because of their isoflavone content, and it is these same phytochemicals that have mostly interested researchers with respect to the sprouts. The major isoflavones in sprouts according to Zhu et al. (2005) are genistein, followed by daidzein. They are predominantly present as aglycones (Nakamura et al. 2001), which is important as they reportedly have higher antioxidant activity and are absorbed faster and in higher amounts than when in their carbohydrate-bound forms (McCue & Shelly 2004). Plaza et al. (2003) observed a 2.8 fold increase in genistein and a 3.7 fold increase in daidzein from the dry beans to the sprouts. Genistein and daidzein were highest just after soaking, and high levels of free phenolics and antioxidant activity in dark-germinated sprouts were reported in a genetically modified glyphosate-resistant cultivar (McCue & Shelly 2004). (See Sections 3.4.2 and 3.5.3 of the “Nutritional attributes of legumes” report for further detail on the nature of these compounds and their health effects.)

As with other sprouted legumes, germination brought about decreased levels of trypsin inhibitors and flatulence-causing oligosaccharides as well as increases in vitamin C and riboflavin, according to Zhu et al. (2005). Plaza et al. (2003) also observed increases in vitamin C of 4-20 times the original level, reaching a maximum after 4-5 days.

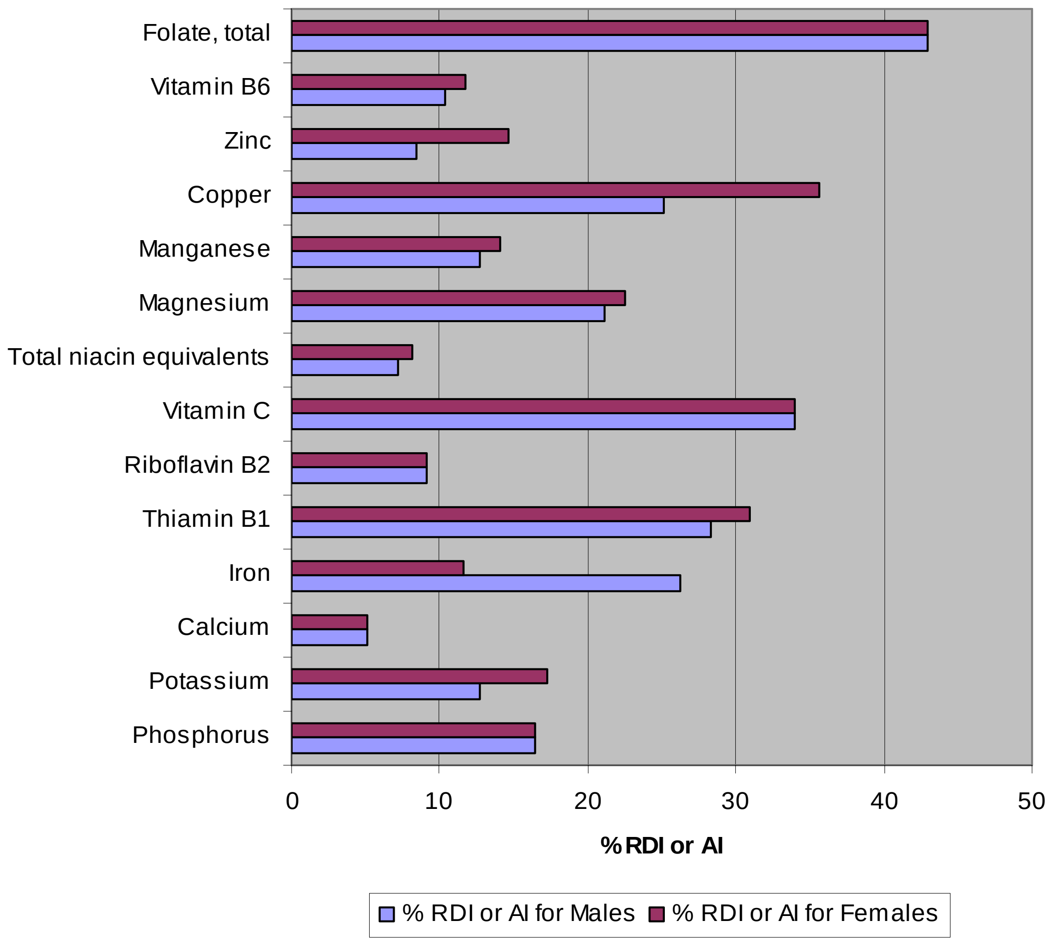

Figure 5: Contributions to RDI (recommended daily intake) or AI (adequate intake) by the major micronutrients in soy bean sprouts, adapted from Athar et al. (2004) and NHMRC (2006).

4 Sprouted brassica vegetables

4.1 *Broccoli sprouts (*Brassica oleracea*)*

There appear to be only a few studies relating specifically to the health effects of broccoli sprouts, but there is a large and growing body of research regarding sulforaphane, the compound most famously associated with the ability of broccoli to protect against cancer. The initial focus was on its anti-cancer properties, with studies across a range of different cancers, including the bladder, breast, liver, lung, prostate and skin. Research has recently included other health problems such as hypertension, cardiovascular disease, joint health, Alzheimer's disease, stomach health and eye health.

An early review of epidemiological studies in relation to *Brassica* vegetable consumption showed inverse associations in the majority (67%) of cases (Verhoeven et al. 1996) and it was postulated that their protective effect may at least in part have been due to glucosinolate content. After reviewing the results of 87 case-control studies and 7 cohort studies, the authors concluded that high brassica vegetable consumption was most strongly associated with a decreased risk of lung, stomach, colon and rectal cancer and least consistent for cancers of the prostate, ovaries and endometrium. However, the authors noted that various factors are believed to lead to inconsistent results in epidemiological studies, including trial design, with retrospective case-control studies being the most likely to be distorted by selection bias and dietary recall. More recently too, human genetics have been found to play an important role in the metabolism of these compounds, and thus there are differences in the health effects that they are able to exert. For further information on this area see the earlier report, "Nutritional attributes of brassica vegetables".

Most of the considerable research that has taken place has used purified sulforaphane, rather than broccoli or broccoli sprouts. Of those using broccoli sprouts, a number have used a specially produced high-sulforaphane content cultivar, which may or may not be nutritionally equivalent to other commercially available products.

An early research project identified that 3-day-old sprouts of certain brassica species contained 10-100 times the level of glucoraphanin, the parent glucosinolate of sulforaphane, compared to the corresponding mature plants (Fahey et al. 1997). However, it should be borne in mind that sprouts are consumed in much smaller quantities (average serving size 5 g, 1 cup ~35 g) than the mature heads (average serving size 100 g).

Studies relating specifically to broccoli sprouts include:

- broccoli sprout extracts were extremely effective in reducing the incidence of mammary tumours in rats that had been treated with a known mammary cancer-inducing compound (Fahey et al. 1997);
- a large placebo-controlled blind human clinical trial of 100 participants and 100 controls found that consuming a liquid broccoli extract over two weeks resulted in lower levels of biomarkers of DNA damage. Tests of the subjects'

urine also showed that carcinogens present in the diet were being detoxified and removed from the body (Kensler et al. 2005);

- a small Japanese pilot study found that subjects who ate at least 3.5 oz (~100 g) of broccoli sprouts daily over the course of a week reduced their LDL (bad) cholesterol, whilst increasing their HDL (good) cholesterol and improving biomarkers of oxidative stress (Murashima et al. 2004). However, as stated earlier, given that 1 cup of broccoli sprouts weighs about 35 g, this would involve eating nearly 3 cups daily, which many people would not find possible;
- an intake of high glucosinolate broccoli sprouts lowered blood pressure, decreased oxidative stress, and inflammation in the kidneys and cardiovascular system in an animal study using spontaneously hypertensive rats (Wu et al. 2004a).

The Brassica Protection Products LLC website www.brassica.com provides extensive information regarding broccoli sprouts, broccoli, and sulforaphane research as well as general information.

5 Conclusions

It is to be hoped that as the popularity of these foods grows, so too will research interest in them. Satisfying growing consumer demand for nutritious, convenient and minimally processed foods, they are low calorie, but from the (incomplete) information available, seem to be relatively nutrient dense. Although information is scanty, it does appear that now microbial contamination is currently rare, they could provide a useful contribution to the diet. It is highly likely that these will prove to be useful additional sources of many nutrients, but more information on both the core nutrients of lesser-known sprouts and the range of bioactives within these species is necessary.

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Appendices

Appendix I Data from FOODFiles

		Sprouts, Alfalfa, raw
Water	g	92.3
Energy	kcal	21
Protein	g	3.7
Total fat	g	0.7
Carbohydrate, available	g	T
Dietary fibre (Englyst, 1988)	g	0.97
Ash	g	0.33
Sodium	mg	6.1
Phosphorus	mg	67.8
Potassium	mg	83.2
Calcium	mg	12.5
Iron	mg	0.54
Beta-carotene equivalents	µg	96
Total vitamin A equivalents	µg	16
Thiamin	mg	0.15
Riboflavin	mg	0.14
Niacin	mg	0.5
Vitamin C	mg	T
Cholesterol	mg	0
Total saturated fatty acids	g	0.069
Total monounsaturated fatty acids	g	0.056
Total polyunsaturated fatty acids	g	0.409
Dry matter	g	7.71
Total nitrogen	g	0.64
Glucose	g	T
Fructose	g	T
Sucrose	g	T
Lactose	g	T
Maltose	g	T
Total available sugars	g	T
Starch	g	0
Alcohol	g	0
Total niacin equivalents	mg	1.1
Soluble non-starch polysaccharides	g	0.39
Insoluble non-starch polysaccharides	g	0.58
Energy	kJ	88
Magnesium	mg	16.5
Manganese	µg	165
Copper	mg	0.09
Zinc	mg	0.03
Selenium	µg	2.3
Retinol	µg	T
Potential niacin from tryptophan	mg	0.6
Vitamin B6	mg	0.13
Folate, total	µg	36

		Sprouts, Alfalfa, raw
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0
T=trace		

		Sprouts, Alfalfa and Onion, raw
Water	g	92.3
Energy	kcal	20
Protein	g	4.01
Total fat	g	0.44
Carbohydrate, available	g	T
Dietary fibre (Englyst, 1988)	g	1.01
Ash	g	0.33
Sodium	mg	6.75
Phosphorus	mg	70.4
Potassium	mg	92.2
Calcium	mg	13.4
Iron	mg	0.58
Beta-carotene equivalents	µg	96
Total vitamin A equivalents	µg	16
Thiamin	mg	0.17
Riboflavin	mg	0.14
Niacin	mg	0.65
Vitamin C	mg	T
Cholesterol	mg	0
Total saturated fatty acids	g	T
Total monounsaturated fatty acids	g	T
Total polyunsaturated fatty acids	g	T
Dry matter	g	7.66
Total nitrogen	g	0.69
Glucose	g	T
Fructose	g	T
Sucrose	g	T
Lactose	g	T
Maltose	g	T
Total available sugars	g	T
Starch	g	0
Alcohol	g	0
Total niacin equivalents	mg	1.25
Soluble non-starch polysaccharides	g	0.32
Insoluble non-starch polysaccharides	g	0.68
Energy	kJ	84
Magnesium	mg	15.7
Manganese	µg	174
Copper	mg	0.11
Zinc	mg	0.38

		Sprouts, Alfalfa and Onion, raw
Selenium	µg	2.51
Retinol	µg	T
Potential niacin from tryptophan	mg	0.6
Vitamin B6	mg	0.16
Folate, total	µg	36
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0

T=trace

		Beans, Mung, sprouts, raw
Water	g	93.2
Energy	kcal	23
Protein	g	2.88
Total fat	g	0.77
Carbohydrate, available	g	1.1
Dietary fibre (Englyst, 1988)	g	0.89
Ash	g	0.41
Sodium	mg	2.98
Phosphorus	mg	50.5
Potassium	mg	144
Calcium	mg	18.6
Iron	mg	0.4
Beta-carotene equivalents	µg	13
Total vitamin A equivalents	µg	2
Thiamin	mg	0.11
Riboflavin	mg	0.12
Niacin	mg	0.6
Vitamin C	mg	T
Cholesterol	mg	0
Total saturated fatty acids	g	0.223
Total monounsaturated fatty acids	g	0.107
Total polyunsaturated fatty acids	g	0.282
Dry matter	g	6.79
Total nitrogen	g	0.46
Glucose	g	T
Fructose	g	0.5
Sucrose	g	T
Lactose	g	T
Maltose	g	T
Total available sugars	g	0.5
Starch	g	0.6
Alcohol	g	0
Total niacin equivalents	mg	1.1
Soluble non-starch polysaccharides	g	0.39
Insoluble non-starch polysaccharides	g	0.5

		Beans, Mung, sprouts, raw
Energy	kJ	95
Magnesium	mg	18.7
Manganese	µg	301
Copper	mg	0.08
Zinc	mg	0.33
Selenium	µg	1.36
Retinol	µg	T
Potential niacin from tryptophan	mg	0.5
Vitamin B6	mg	0.08
Folate, total	µg	43
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.06

T=trace

		Shoots, Snow Pea
Water	g	93.3
Energy	kcal	18
Protein	g	3.99
Total fat	g	0.23
Carbohydrate, available	g	T
Dietary fibre (Englyst, 1988)	g	0.8
Ash	g	0.42
Sodium	mg	0.99
Phosphorus	mg	70.3
Potassium	mg	150
Calcium	mg	6.66
Iron	mg	0.71
Beta-carotene equivalents	µg	16
Total vitamin A equivalents	µg	2.7
Thiamin	mg	0.18
Riboflavin	mg	0.14
Niacin	mg	0.6
Vitamin C	mg	T
Cholesterol	mg	0
Total saturated fatty acids	g	T
Total monounsaturated fatty acids	g	T
Total polyunsaturated fatty acids	g	T
Dry matter	g	6.72
Total nitrogen	g	0.69
Glucose	g	T
Fructose	g	T
Sucrose	g	T
Lactose	g	T
Maltose	g	T
Total available sugars	g	T
Starch	g	0

		Shoots, Snow Pea
Alcohol	g	0
Total niacin equivalents	mg	1.2
Soluble non-starch polysaccharides	g	0.29
Insoluble non-starch polysaccharides	g	0.51
Energy	kJ	75
Magnesium	mg	15
Manganese	µg	236
Copper	mg	0.12
Zinc	mg	0.62
Selenium	µg	0.18
Retinol	µg	T
Potential niacin from tryptophan	mg	0.6
Vitamin B6	mg	0.13
Folate, total	µg	36
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0

T=trace

		Soybean, sprouts, raw
Water	g	69.1
Energy	kcal	141
Protein	g	13.1
Total fat	g	6.7
Carbohydrate, available	g	7
Dietary fibre (Englyst, 1988)	g	2.5
Ash	g	1.59
Sodium	mg	14
Phosphorus	mg	164
Potassium	mg	484
Calcium	mg	67
Iron	mg	2.1
Beta-carotene equivalents	µg	6
Total vitamin A equivalents	µg	1
Thiamin	mg	0.34
Riboflavin	mg	0.118
Niacin	mg	1.15
Vitamin C	mg	15.3
Cholesterol	mg	0
Total saturated fatty acids	g	0.929
Total monounsaturated fatty acids	g	1.52
Total polyunsaturated fatty acids	g	3.78
Dry matter	g	31
Total nitrogen	g	2.26
Glucose	g	0.5
Fructose	g	0.5

		Soybean, sprouts, raw
Sucrose	g	1
Lactose	g	0
Maltose	g	0
Total available sugars	g	2
Starch	g	5
Alcohol	g	0
Total niacin equivalents	mg	1.15
Soluble non-starch polysaccharides	g	1.2
Insoluble non-starch polysaccharides	g	1.3
Energy	kJ	587
Magnesium	mg	72
Manganese	µg	702
Copper	mg	0.427
Zinc	mg	1.17
Selenium	µg	2
Retinol	µg	0
Potential niacin from tryptophan	mg	T
Vitamin B6	mg	0.176
Folate, total	µg	172
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.06

T=trace

Appendix II Table of major functions of main micronutrients contained in sprouted seeds and beans

Activities of Vitamins and Minerals and Fibre (adapted from

misc.medscape.com/pi/editorial/ clinupdates/2004/3341/table.doc and

www.bupa.co.uk/health_information/html/healthy_living/lifestyle/exercise/diet_exercise/vitamins.html)

Name	Major function
Vitamin A Retinol (animal origin) Carotenoids (plant origin, converted to retinol in the body) Note: Retinol Equivalents (RE) 1 RE =1 mcg retinol or 6 mcg beta-carotene 1 IU = 0.3 mcg or 3.33 mcg = 1 mcg retinol = 1 RE	Important for normal vision and eye health. Involved in gene expression, embryonic development and growth and health of new cells. Aids immune function. May protect against epithelial cancers and atherosclerosis.
Vitamin D (calciferol) Two main forms cholecalciferol (animal origin) and ergocalciferol (plant origin) Cholecalciferol is formed by action of UV rays of sun on skin Note: 1 mcg calciferol = 40 IU vitamin D	Facilitates intestinal absorption of calcium and phosphorous and maintains serum concentrations. Maintains bone health and strong teeth. May be involved in cell differentiation and growth. May be involved in immune function.
Vitamin E A group of tocopherols and tocotrienols Alpha tocoferol most common and biologically active	Provides dietary support for heart, lungs, prostate and digestive tract. Reduces peroxidation of fatty acids. Non-specific chain-breaking antioxidant. May protect against atherosclerosis and some cancers.
Vitamin K Occurs in various forms including phyllo- and menaquinone	Coenzyme in the synthesis of proteins involved in blood clotting (prothrombin and other factors) and bone metabolism.

Name	Major function
	Involved in energy metabolism, especially carbohydrates. May also be involved in calcium metabolism.
Vitamin C Ascorbic acid	Necessary for healthy connective tissues – tendons, ligaments, cartilage, wound healing and healthy teeth. Assists in iron absorption. A protective antioxidant - may protect against certain cancers. Involved in hormone and neurotransmitter synthesis.
Thiamin vitamin B_1 Aneurin	Coenzyme in the metabolism of carbohydrates and branched-chain amino acids. Needed for nerve transmission. Involved in formation of blood cells.
Riboflavin vitamin B_2	Important for skin and eye health. Coenzyme in numerous cellular redox reactions involved in energy metabolism, especially from fat and protein.
Niacin vitamin B_3 Nicotinic acid, nicotinamide	Coenzyme or cosubstrate in many biological reduction and oxidation reactions required for energy metabolism and fat synthesis and breakdown. Reduces LDL cholesterol and increases HDL cholesterol.
Vitamin B_6 Pyridoxine, pyridoxal, pyridoxamine	Coenzyme in nucleic acid metabolism, neurotransmitter synthesis and haemoglobin synthesis. Involved in neuronal excitation. Reduces blood homocysteine levels. Prevents megaloblastic anaemia.
Vitamin B_{12} Cobalamin	Coenzyme in DNA synthesis with folate. Synthesis and maintenance of myelin nerve sheaths. Involved in the formation of red blood cells.

Name	Major function
	Reduces blood homocysteine levels. Prevents pernicious anemia.
Folate Generic term for large group of compounds including folic acid and pterylpolyglut-amates	Coenzyme in DNA synthesis and amino acid synthesis. Important for preventing neural tube defects Key role in preventing stroke and heart disease, including reducing blood homocysteine levels with vitamin B_{12}. May protect against colonic and rectal cancer.
Biotin	Important for normal growth and body function. Involved in metabolism of food for energy. Coenzyme in synthesis of fat, glycogen, and amino acids.
Pantothenic acid	Coenzyme in fatty acid metabolism and synthesis of some hormones. Maintenance and repair of cell tissues.
Sodium	Major ion of extracellular fluid. Role in water, pH and electrolyte regulation. Role in nerve impulse transmission and muscle contraction.
Potassium	Major ion of intracellular fluid. Maintains water, electrolyte and pH balances. Role in cell membrane transfer and nerve impulse transmission.
Chloride	Major ion of extracellular fluid. Participates in acid production in the stomach as component of gastric hydrochloric acid. Maintains pH balance. Aids nerve impulse transmission.
Phosphorus	Structural component of bone, teeth, cell membranes, phospholipids, nucleic acids, nucleotide enzymes and cellular energy metabolism.

Name	Major function
	pH regulation. Major ion of intracellular fluid and constituent of many essential compounds in body and processes.
Calcium	Structural component of bones and teeth. Role in cellular processes, muscle contraction, blood clotting, enzyme activation and nerve function.
Magnesium	Component of bones. Role in cellular energy transfer. Role in enzyme, nerve, heart functions, and protein synthesis.
Iron	Component of haemoglobin and myoglobin in blood, and needed for oxygen transport. Role in cellular function and respiration.
Iodine	Thyroid hormone production.
Chromium	Assists in insulin system for regulation of blood glucose.
Cobalt	Component of vitamin B_{12}.
Copper	Component of many enzymes. Many functions – blood and bone formation, and production of pigment melanin. Aids in utilization of iron stores. Role in neurotransmitters synthesis.
Fluoride	Helps prevent tooth decay.
Manganese	Part of many essential enzymes. Aids in brain function, bone structure, growth, urea synthesis, glucose and lipid metabolism.
Molybdenum	Aids in enzyme activity and metabolism.
Selenium	Important role in body's antioxidant defence system as component of key enzymes. May help prevent cancer and cardiovascular disease.
Zinc	Major role in immune system.

Name	Major function
	Required for numerous enzymes involved in growth and repair. Involved in sexual maturation. Role in taste and smell functions.
Fibre Fibre can be divided into insoluble and soluble fibre	Insoluble fibre: Adds bulk to stool and thus helps to prevent bowel problems, such as bowel cancer, irritable bowel syndrome and diverticulitis. Soluble fibre: Lowers cholesterol levels. Helps manage blood glucose.