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The nutritional attributes of legumes

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1 Executive summary

1.1 Introduction

There is little information on the health benefits of the fresh legumes that are the subject of this report; most research relates to their mature, dried seeds and to other legume species, particularly soy. So the applicability and relevance of findings from these studies to the vegetables described in this report are difficult to determine.

Pulses are known to contain antinutritional components, which may affect absorption of some macro and micronutrients. While this can be a problem if diets are heavily reliant on these vegetables, there is nothing in the literature to suggest that they constitute major health threats to well nourished populations, such as consumers in New Zealand. This may be either because they are only present at low levels or they are destroyed by cooking.

1.2 Peas

Peas are a particularly useful all-round food, containing good amounts of vitamin $B_{1,}$ (thiamin), as well as vitamins C, B_6 B_3 and $B_{2,}$ folate, provitamin A carotenoids, and iron and zinc. In addition they are one of the best vegetable sources of protein. In terms of phytochemicals, they are well endowed with the antioxidant carotenoids, lutein and zeaxanthin, which are thought to be especially important for protecting against eye problems, such as macular degeneration. They also contain isoflavones, which have oestrogenic effects and thus protect against some hormone-related cancers, but these are present at much lower levels than in soy, on which most of the study in this area has been focused. Both soluble and insoluble fibre are present in peas too. Insoluble fibre, or roughage, is believed to be important in maintaining bowel health. Soluble fibre is also thought to help with bowel health, particularly in protecting against bowel cancer, but, in addition, appears to benefit the cardiovascular system by lowering cholesterol and blood pressure. Because it swells in the gut, soluble fibre also delays stomach emptying. This has a positive effect upon glycaemic response, which is important for diabetes management as well as weight control, as it gives a feeling of satiety. Saponins are also present in peas and are thought to be beneficial, particularly by reducing cholesterol.

1.3 Edible pod peas

Snow peas contain excellent levels of vitamin C and good levels of pro vitamin A (in the form of β-carotene and α-carotene). They also supply useful amounts of thiamin, vitamin $B_{6,}$ iron, folate and both soluble and insoluble fibre. They are also low in calories and provide important sensory benefits, such as crunchiness and sweetness. There is little information on the phytochemicals in edible pod peas, though their high levels of vitamin C should provide antioxidant activity.

1.4 Beans

The major nutrients in green beans are folate, vitamins A (through β-carotene) and C, with thiamin, niacin, calcium, zinc and iron present at low levels. They also contain some fibre and are low in calories. There is little phytochemical information on beans, possibly because they do not show strong antioxidant activity. They consistently rate toward the lower end of the scale in comparisons with the antioxidant activity of other vegetables. Nonetheless, like edible pod peas, with which they have much in common, they have special sensory attributes and good nutrient density since their calorie content is not high.

1.5 Broad beans

Broad beans contain very good amounts of vitamin C and folate, good amounts of niacin, and small but useful levels of zinc and iron. Like peas, they are also an excellent vegetable source of protein and are also a very good source of both soluble and insoluble fibre.

They are also very interesting for their phytochemical content. They are one of the richest sources of catechins – the flavonoids made famous through their presence in tea, and chocolate. Many of the health benefits of catechin-rich foods, such as protecting against chronic diseases, including cardiovascular disease and cancer, are thought to be attributable to their antioxidant activity. *In vitro* studies have shown catechins to inhibit LDL oxidation and platelet aggregation, reduce inflammation and improve vascular endothelial function.

Broad beans also contain the medicinal compound L-dopa, used in treating Parkinson's disease. They can also cause potentially fatal haemolytic anaemia in certain ethnic groups with a genetic condition known as favism.

2 Background

This report provides material for incorporation into one of a series of promotional and educational booklets for the various Horticulture New Zealand sector groups. We have gathered relevant literature, including medical research and scientific papers, and, where possible, included information specific to New Zealand. This report focuses on the nutritional attributes of legumes – peas (green peas and edible pod peas such as snow peas and sugar snap), and beans (green and yellow), plus broad beans.

The amount of information available varies considerably; and in some areas where no specific information exists, research on related legumes may be cited. Factors that may influence the nutritional profile of these vegetables, such as agronomy, cooking or processing, and storage, are covered. Some additional material of general interest has also been included.

3 *Peas (*Pisum sativum*)*

3.1 Introduction

This report focuses on green or garden peas and edible pod varieties rather than peas that are grown to a fully mature stage and then dried (seed or field peas). However, information specifically relating to garden peas is relatively thin and sometimes the type of pea is not identified. Because most research is related to seed or field peas, reference to these types is sometimes made. However, it should be borne in mind that the composition of these types is likely to differ somewhat from green peas since they are grown for quite different purposes, such as for use as a pulse (like chickpeas), for flour, as a protein source, or for animal feed. Reasons for their differences are numerous, but, most obviously, different cultivars are involved, they are harvested at different stages of maturity, and different agronomic practices are employed.

Peas and beans both belong to the Fabaceae or Leguminosae family, along with plants as diverse as alfalfa and gorse. A feature that these plants have in common is that their “fruit” is a pod that opens along a seam. These seeds, especially when dried, are called “pulses”.

Cultivated for centuries for their dried seeds, peas do not appear to have been eaten young and fresh in European civilizations until popularised by the French king, Louis XIV in the 17th century. However, it is thought that the Chinese were the first to consume both the seeds and the pods.

Because of their relatively short season, fresh peas are not as frequently consumed as vegetables that are available all year round. Also, because frozen peas are a good alternative, retaining many nutrients, excellent taste and attractive appearance, there is less incentive for them to be grown in glasshouses out of season, or imported. The edible pod peas (snow peas (also known as mange tout) and sugar snap peas) are now available year-round and, in particular, contribute to stir fry dishes, though usually in small quantities.

3.2 Composition

A number of factors combine to determine the levels of both core nutrients and other phytochemicals in a food. These include not only the variety/cultivar of the plant, but also issues relating to the agronomy involved – soils, cultivation protocols (irrigation, pest control, use of fertiliser), degree of ripeness at harvest, and processing practices (harvesting, storage, method of processing). In addition, there can be issues such as the form in which the food was analysed – raw, fresh, canned, boiled, frozen – as well as analytical techniques and variations between the laboratories doing the analysis. These various factors may cause large differences in core nutrient levels, but even greater differences may occur in their phytochemical levels.

Where data is available, the extent and effect of this variation will be discussed later in this section, under Section 3.5, “Factors affecting health benefits”.

3.3 Core nutrients

Peas are not celebrity vegetables, the focus of scientific research and media attention like broccoli and tomatoes. They are, however, a particularly useful all-round food, containing excellent amounts of vitamin C, thiamin (vitamin B_1) and folate, as well as vitamins B_6 B_3 and $B_{2,}$ provitamin A carotenoids, and a range of minerals, notably iron and copper. They also include phosphorus, potassium, zinc and magnesium. In addition, they are one of the best vegetable sources of protein. Figure 1 shows the contributions of these major nutrients towards the Recommended Dietary Intake (RDI) – or Adequate Intake (AI) – if an RDI is not available. Note: RDIs and AIs are generally higher for males than females and thus the same amount gives a smaller percentage for males than females. Sometimes they are the same for both sexes, as in the case of vitamin C. In the case of iron, however, women of childbearing age (judged to be 19-50 years) require higher intakes, and this figure has been used to calculate the contribution toward the RDI for iron for women, depicted in this graph and others subsequently.

See Appendix I for full data from the New Zealand FOODFiles database.

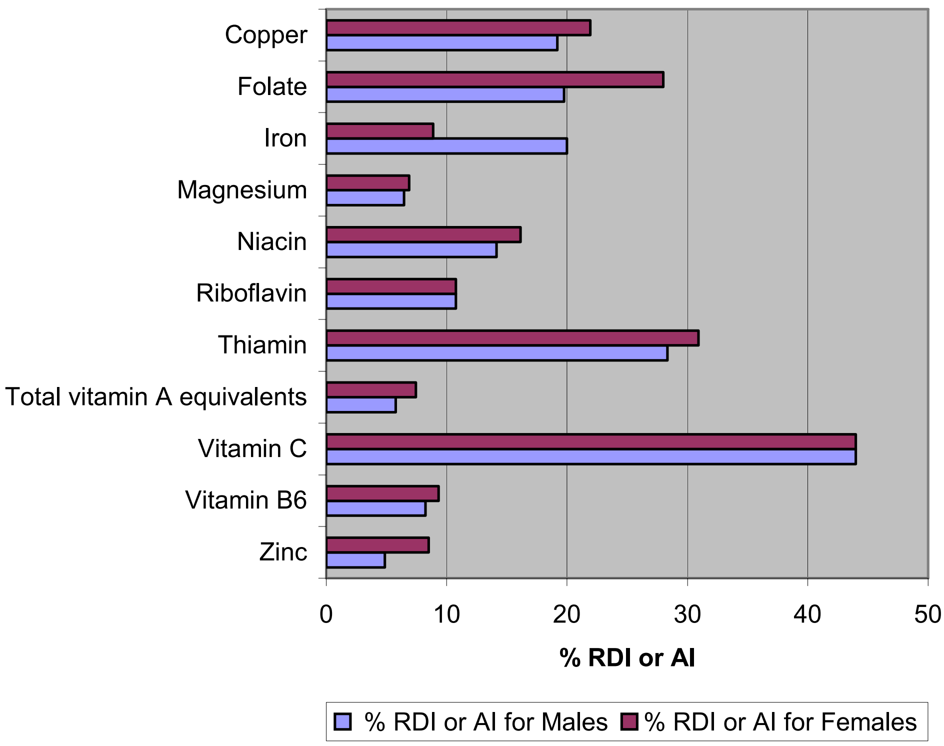

Figure 1: Contributions to RDI or AI by the major micronutrients in green peas adapted from Athar (2004) and NHMRC (2006).

3.4 Other phytochemicals

Although there has not been a great deal of research specifically on peas, some information is available on general databases and in studies comparing their composition or antioxidant activity.

The major phytochemicals in peas are the carotenoids, including lutein and zeaxanthin and β-carotene, chlorophyll, phenolic compounds, including some flavonoids as well as phenolic acids. Fibre should also be mentioned here, as it can have physiological effects similar to that of some phytochemicals. Saponins can have both positive and negative health effects and are also present in peas. Legumes also often contain other anti-nutritive compounds, such as trypsin inhibitors, phytates and α-galactosides (Vidal-Valverde et al. 2003), but these do not appear to be an issue with green peas, probably because they are harvested before completely mature when maximum concentrations are reached, and/or because they are destroyed during cooking.

3.4.1 Carotenoids

Epidemiological studies have demonstrated that high intakes of fruit and vegetables protect against a range of chronic diseases and problems associated with ageing. Some of the benefits of fruit and vegetable consumption have been attributed to their constituent compounds, including a class of phytochemicals called carotenoids. The most important carotenoids in peas are the xanthophylls, lutein and zeaxanthin, but they also contain the carotenes, α- and β-carotene.

The carotenoids are a group of yellow-orange-red pigments, found in a variety of fruits and vegetables as well as in algae, fungi and bacteria. Carotenoids cannot be synthesised in the body and are present solely as a result of ingestion from other sources, either from a plant itself or a product from an animal that has consumed that plant source. Often the colours of the carotenoids present in plants are masked by chlorophyll, to the extent that some of the largest amounts of carotenoids are found in dark green leafy vegetables, such as kale and spinach.

Carotenoids consist of a long-chain hydrocarbon molecule with a series of central, conjugated double bonds. (See Appendix II for structural diagrams of the major carotenoids in legumes.) These conjugated (alternating) double bonds confer colour and the compound’s antioxidant properties. They appear to act synergistically with other carotenoids and other antioxidants. In plants, these pigments assist in the light-capturing process in photosynthesis and protect against damage from visible light. In humans, one of their various benefits is believed to be protecting the skin and the macula lutea of the eye against photoxidative damage (Sies & Stahl 2003).

There are two general classes of carotenoids – the carotenes, and their oxygenated derivatives, the xanthophylls. The two groups are almost structurally identical, except that the xanthophylls have a terminal hydroxyl group. Their structure determines their properties and thus also their activities and physiological roles. The body can convert α-carotene, β-carotene and β-cryptoxanthin into retinol, or vitamin A, whereas lycopene and the xanthophylls, lutein and zeaxanthin, have no vitamin A capacity. Because of their similarity, amounts of the latter two compounds are often reported as a combined total.

Because carotenoids are fat-soluble they are best absorbed in the body if accompanied by some form of oil or fat in the meal. Chopping and cooking assists in releasing carotenoids from the food matrix and this also increases their bioavailability.

The carotenoid content of some common fruit and vegetables is shown in Table 1. Whilst peas contain respectable levels of the carotenes, they are present at much lower levels than in other highly vegetables, such as carrots and spinach. It is interesting to note that boiled frozen peas rate much more highly in terms of β-carotene than raw peas. It is likely that this results from freezing and boiling processes as these break down cell structure, releasing compounds that were previously bound to other components. Levels of lutein and zeaxanthin are amongst the highest in these carotenoid-rich fruit and vegetables, however. Whilst significantly lower than in spinach, levels in peas are several fold higher than in most other legumes.

Table 1: Carotenoid content of assorted fruit and vegetables (mcg/100 g) from USDA National Nutrient Database for Standard Reference Release 18, 2005 (USDA 2005) 2006.*

Food	β-carotene	α-carotene	Lutein + zeaxanthin
Apricot	1094	19	89
Beans,* green, raw	376	69	640
Beans, yellow, boiled*	49	0	709
Broad beans	32	0	0
Broccoli, raw	361	25	1403
Capsicum, red, raw	1624	20	51
Carrot, raw	8285	3477	256
Corn (sweet), raw	52	18	764
Corn (sweet) boiled	66	23	967
Orange	87	7	129
Peas (raw)*	449	21	2447
Peas (edible pod)*	630	44	740
Peas (frozen, boiled)*	1250	20	2400
persimmon	253	0	834
Pumpkin, raw	3100	515	1500
Spinach, raw	5626	0	12198

3.4.2 *Phenolics*

Phenolics are a group of over 4000 compounds occurring widely in the plant kingdom. Of these, there are two classes of compounds with particular dietary relevance — the flavonoids and phenolic acids. In the plant they serve a variety of purposes, including protecting against fungal disease, insect attack and strong sunlight as well as attracting pollinators and seed dispersers. Often these compounds impart taste (often bitter or astringent) and some also provide aroma and colour.

Structurally phenolics all contain at least one phenol ring and at least one hydroxyl group, which is important as these are partially responsible for their antioxidant activity. (See Appendix II for structural diagrams of some of the phenolics in peas and beans.) They are water-soluble, which affects some of their functional properties.

Synthesised in response to light, phenolic compounds are often most concentrated in the skins of fruit and vegetables. This was demonstrated in a Spanish study of "dark peas" (Duenas et al. 2006) where the highest concentrations of glycosides of the flavonoids, quercetin, luteolin and apigenin were present in the seed coat, though they were also present in the cotyledon (body of the pea). Most of the phenolic acids (largely hydoxybenzoic compounds) were present in the cotyledon. There were also small amounts of catechins, which occurred in both parts of the seed. However, levels differed considerably according to cultivar. It is important to note though that in this study a number of factors were not reported, including the pea type (green/seed or field) and their level of maturity at harvest. Thus the relevance of these findings to green peas is not clear. A Polish study found proanthocyanidins (condensed tannins) in the seed coats of white and coloured varieties of peas to be a major source of antioxidant activity, along with phenolic acids (Troszynska et al. 2002). However, again the level of maturity and type of pea were not reported. None of the flavonoids routinely quantified by the USDA appear to have been detected in raw, green peas according to its flavonoid database, though quercetin was identified in both frozen and canned peas at 0.15 mg/100 g edible portion and 0.11 mg/100 g edible portion respectively (USDA 2003). Quercetin was also the major flavonoid identified by Ewald et al. (1999) in a study on the effects of processing. In a comparison of phenolic compounds in a range of commonly consumed foods in the United States (Table 2), frozen peas were found to contain moderately good levels of phenolics (Wu et al. 2004), though they were towards the bottom in the large group of Asian vegetables studied by Kaur and Kapoor (2002).

Table 2: Total phenolics in some commonly consumed vegetables in the US (Wu et al. 2004).

	Total phenolics expressed as milligrams gallic acid equivalents per gram (mg GAE/g) in raw form, unless stated otherwise
Beans	0.92
Broccoli	3.37
Cabbage	2.03
Carrots	1.25
Corn	2.11
Lettuce (iceberg)	0.50
Onions	0.91
Peas (frozen)	1.87
Peppers (green)	2.71
Potatoes (red)	1.38
Spinach	2.17
Tomatoes	0.80

Isoflavones

Isoflavones are a sub-group of the flavonoid class of compounds, and are present in a number legumes. They have been of particular interest recently because of postulated oestrogenic activity and a potential role in protecting against hormone-related cancers and assisting with other hormone-related complaints, such as menopausal symptoms. Because of this, along with other compounds with similar effects, they are also known as phytoestrogens. Soy is particularly rich in isoflavones, specifically genistein and daidzein and has been the most intensively studied. Peas have been found to contain either none or only minimal amounts of these compounds (Nakamura et al. 2001; Boker et al. 2002). There is no entry under fresh or frozen peas for the isoflavones quantified in the USDA database for isoflavones, although a value is given for dried, split, mature peas (USDA 1999). Despite the low content relative to soy products cited in Boker et al. (2002), these authors maintained that for their population group of post menopausal Dutch women, peas and beans were the main source of almost all isoflavones in the diet, though acknowledging that general phytoestrogen intake was low in this population.

Table 3: Estimated isoflavone intake in different population groups.

Isoflavone intake (mg/day)	Population group	Author
0.88	White Dutch women	Keinen et al. (2002)
0.76	American white women	Kleijn et al (2002)
2.9	Whites, Latino-Americans, African-Americans	Horn-Ross et al (2000) cited in Keinen et al. (2002)
39.26	Chinese women in Shanghai	Chen et al (1999)

3.4.3 Fibre

Peas are also a good source of both soluble and insoluble fibre (Garcia-Domingo et al. 1997; Li et al. 2002). Investigating the “indigestible fraction” in frozen and canned peas, Garcia-Domingo et al. (1997) found that it comprised mainly non-starch polysaccharides followed by resistant starch and resistant protein. Lignin and oligosaccharides were present, but only at very low levels. Because fibre compounds can cause flatulence, it is possible that, to some extent, they have deliberately been bred out of these vegetables when intended for human consumption.

In simplified terms, dietary fibre is the edible part of a food that cannot be broken down by human digestive enzymes. It is often divided into soluble and insoluble fibre. Insoluble fibre cannot be dissolved in water, but can attract water. It is what is popularly called roughage and present in whole grain cereals and baked beans. Soluble fibre does dissolve in water and is often associated with oat bran, but fruits and vegetables, including legumes are also good sources. According to the New Zealand Food Composition Database, FoodFiles, vegetable peas contain good amounts of the fibre components, soluble and insoluble non-starch polysaccharides, both in comparison with other legumes and other vegetables (Table 4).

Table 4: Soluble and insoluble non-starch polysaccharides in legumes and assorted common vegetables (Athar et al. 2004).

	Soluble non-starch polysaccharides	Insoluble non-starch polysaccharides
Beans, green raw	0.9	1.3
Beans, butter raw	0.6	0.8
Broad beans	1.4	5.1
Broccoli	1.5	2.2
Cabbage	0.7	1.2
Carrot	1.6	1.6
Lettuce	0.4	0.4
Peas	1.2	3.1
Potato (Rua) raw	0.9	0.6
Snow peas	1.0	1.3
Sweet potato	1.2	1.5
Tomatoes	0.6	0.7

A wider concept of dietary fibre also includes resistant starch as it is not digested by enzymes in the intestine but fermented in the bowel (Garcia-Domingo et al. 1997). Like many legumes, peas contain resistant starch that is locked within cells walls and thus inaccessible to digestive enzymes. It was present in the raw peas studied by de Almeida Costa et al. (2006) and also in cooked peas, though at reduced levels. The type of pea were used in this study was not reported, but it is likely that they were seed rather than green peas.

3.4.4 *Chlorophyll*

Their green colour is evidence of the chlorophyll present in peas. It is well known as the pigment that gives plants and algae their green colour, and it is the primary compound involved in photosynthesis. Two different types of chlorophyll (chlorophyll a and chlorophyll b) are found in plants, each absorbing light at slightly different wavelengths.

3.4.5 *Saponins*

Saponins are a diverse group of biologically active glycosides, widely distributed in the plant kingdom (Curl et al. 1985). Structurally they comprise a carbohydrate portion attached to an aglycone base, which is either a steroid or triterpene (Sparg et al. 2004). Named for their ability to form stable, soap-like solutions with water, they possess both useful and deleterious bioactive qualities. Although not apparent in green peas, saponins can create a bitter or astringent taste.

A number of different saponins have been isolated in peas. Soyasoponin I appears to be predominant (Curl et al. 1985; Daveby et al. 1997; Murakami et al. 2001). The saponin content of green peas is listed in Savage & Deo (1989) at 2.5 g/kg, though it is unclear what type of pea this refers to or their stage of maturity. Soyasaponin 1 ranged from 0.82 to 2.5 g/kg in different varieties of Swedish field peas (Daveby et al. 1997).

Saponins are heat-sensitive and water-soluble (Shi et al. 2004), so short cooking with minimal water would enable maximum retention of these compounds.

3.4.6 *Anti-nutritional factors*

Although peas contain a number of compounds that can have detrimental effects upon the nutritive value of peas, such as trypsin inhibitors, oxalates, and haemagglutinins (Savage & Deo 1989), there does not appear to be any evidence that the consumption of peas causes health problems in humans. Anti-nutritional factors are of most importance in relation to animal feeds, where the diet is largely unvaried. Also, in human food, they appear to be present at relatively low levels and cooking appears to reduce or destroy the majority of these compounds (Savage & Deo 1989).

3.5 *Health benefits*

3.5.1 *Core nutrients*

If dried legumes are excluded, peas are one of the best plant sources of protein. Although they do not contain the complete range of essential amino acids in the necessary proportions for this vegetable to be classed as ideal protein, if combined with other grain foods or cereals, the range of amino acids is complemented, compensating for this deficiency. They also contain complex carbohydrates, which are important for sustained release of energy, providing satiety and thus assisting in weight control, and managing glucose response. Peas are also one of the best sources of vitamin B_1 or thiamin, which is a co-enzyme for many critical bodily functions relating to energy metabolism. It is also necessary for nerve transmission and muscle function.

The major functions of the various micronutrients are summarised in Appendix I.

3.5.2 *Carotenoids*

Lutein and zeaxanthin

Carotenoids are probably best known for their antioxidant activity, but those predominant in peas, lutein and zeaxanthin have been most researched in relation to eye diseases. To determine the biological roles of a compound, scientists frequently consider its abundance and distribution in body tissues, as well as its variation in abundance across population groups. In a review of the roles of lutein and zeaxanthin in human health, Granado et al. (2003) noted that a number of studies had shown these compounds to be selectively accumulated in different parts of the eye, where they were by far the most abundant of the major carotenoids present. Lutein and zeaxanthin are especially concentrated at the centre of the retina in the eye (the macula) and in fact are often referred to as macular pigments. These high concentrations in the eye, plus the presence of certain proteins specific to binding these compounds, has led to the suggestion that they may be important in protecting against age-related eye problems, particularly macular degeneration and the formation of cataracts. It has also been hypothesised that lutein and zeaxanthin could slow the progression of these diseases as well as the group of degenerative retinal diseases, retinitis pigmentosa.

Mares-Perlman et al. (2002) summarised a number of studies linking light exposure to eye diseases. Because these carotenoids absorb blue light, it was suggested that they protect the retina from photochemical damage that could occur from light at these wavelengths. Exposure to light has been found to increase the levels of free radicals in the lens and retina (Dayhaw-Barker 1986, cited in Mares-Perlmann et al. 2002) and exposure of the retina to light has been postulated as a cause of macular degeneration (Borges et al. 1990, cited in Mares-Perlmann et al. 2002).

Within the macula there is a distinct pattern in the distribution of these xanthophylls. Zeaxanthin is most concentrated in the inner macula, but lutein predominates further from the centre. This distribution suggests a possible function for lutein in protecting the rods that are concentrated in the peripheral retina, and for zeaxanthin in protecting the cones that are concentrated in the central retina (Granado et al. 2003; Mares-Perlman et al. 2002).

It has been shown that intake of these carotenoids increases their levels in macular tissue (Hammond et al. 1997; Landrum et al. 1997, cited in Mares-Perlman et al. 2002) and serum (Olmedilla et al. 2002), although variations in individual responses have been noted.

It appears plausible that lutein and zeaxanthin play a protective role in the eye, but there is a scarcity of data. This is partly because it is a relatively new field of research and partly because it is difficult to carry out this research using cells or animals. Only primate eyes have a macula, and therefore the usual laboratory animals, such as rats, cannot be used. In one study, in which monkeys were fed diets lacking plant pigments, changes to the retina resembling the ocular degenerative changes in humans occurred over several years (Malinow et al. 1980, cited in Mares-Perlman et al. 2002). Another study, found an inverse relation between the level of zeaxanthin in quail retina (quails have a macula similar to that of primates) and light-induced retinal cell death (Dorey et al. 1997, cited in Mares-Perlman et al. 2002).

Some epidemiologic evidence does suggest that lutein and zeaxanthin protect against macular degeneration and this is summarised below (from Sies & Stahl 2003 and Mares-Perlman et al. 2002). Lower risk for this disease has been found in conjunction with consumption of foods rich in lutein and zeaxanthin (Goldberg et al. 1988); higher overall levels of lutein and zeaxanthin in the diet (Mares-Perlman et al. 2002; Seddon et al. 1994); higher levels of lutein and zeaxanthin in the blood (Eye Disease Case-Control Study Group 1992); and higher levels of lutein and zeaxanthin in the retina (Bone et al. 2000; Beatty et al. 2001).

However, these relationships were not observed in other studies, or were only observed in subgroups of the study population (Granado et al. 2003; Mares- Perlman et al. 2002).

Mares-Perlman et al. (2002) describe findings with respect to the relationship between lutein and zeaxanthin and reducing cataract risk as “somewhat consistent”. Two studies showed a higher incidence of cataracts in those in the lowest quintile of lutein and zeaxanthin intake compared with the highest, and three prospective studies found that those in the highest quintiles had a 20–50% lower risk of experiencing cataract problems.

Although concentrations are generally highest in ocular tissue, a number of studies have established the presence of lutein and zeaxanthin in serum and body tissues. The fact of their antioxidant activity has led to speculation that higher consumption of these chemicals will lead to higher levels in body tissues, and that this may lower the risk of chronic disease. It is possible that, along with other carotenoids with antioxidant activity, lutein, which is more widely dispersed in the body, may protect against diseases such as cancer and cardiovascular disease as well as positively affecting immune function.

α- and β-carotene

α- and β-carotene differ only very slightly in terms of structure. They are very commonly occurring carotenoids and are antioxidants, as well as having other potential health benefits. As mentioned earlier, both can be converted into vitamin A by the body, though β-carotene has about twice the provitamin A activity as α-carotene. Sometimes carotenoid content is measured as retinol (pre- formed vitamin A) equivalents; β-carotene has 1/6 the vitamin A activity of retinol, α-carotene and β-cryptoxanthin each about 1/12.

Note: Although there is some controversy internationally regarding the carotenoid/retinol conversion rate, the rates above are used in New Zealand and Australia in accordance with the FAO/WHO decision (National Health and Medical Research Council of Australia and New Zealand Ministry of Health 2004).

β-carotene has been the focus of most research. Epidemiological studies have demonstrated that high intakes of fruit and vegetables protect against a range of chronic diseases and problems associated with ageing. Carotenoid-rich foods have also been associated with health benefits for some time and this has been attributed largely to the β-carotene they contain. It was hypothesised that β-carotene might help prevent the formation of lesions that led to cancer, and *in vitro* cell experiments have indicated that carotenoids also possess properties consistent with anti-cancer activity, e.g. they may play an important role in the cell communication that leads to the demise of pre-cancerous cells. However, results have been somewhat inconsistent (Cooper et al. 1999). Mixed results have also been reported from studies relating to prostate and colorectal cancer.

Similarly, there have been mixed results regarding the effect of dietary β-carotene on cardiovascular disease. It has been established that the development of cardiovascular disease involves the oxidation of low-density lipoprotein (LDL) and its subsequent uptake by foam cells in the vascular endothelium, where it can lead to the development of atherosclerotic lesions. It was hypothesised that β-carotene, which itself is carried in LDL, might help prevent this oxidation as a number of *in vitro* studies had shown it to be capable of scavenging potentially damaging radicals. However, whilst some research has shown higher plasma levels of carotenoids to be associated with better vascular health and lower cardiovascular disease risk, other studies have shown no effect (Higdon 2005; Cooper et al. 1999). Further, some recent studies have produced contradictory results regarding the ability of β-carotene to stabilise LDL against oxidation (Cooper et al. 1999). None of these studies have specifically investigated the effect of consuming green peas.

3.5.3 Phenolics

Phenolic compounds are primarily of interest with regards to human health because of their antioxidant activity. Because of their structure, they are very efficient scavengers of free radicals and are also metal chelators (Shahidi & Naczk 1995). In addition to the antioxidant characteristics of flavonoids, other potential health-promoting bioactivities include anti-allergic, anti-inflammatory, anti-microbial and anti-cancer properties (Cody et al. 1986; Harbourne 1993). There are many ways in which flavonoids may act to prevent cancer, including inducing detoxification enzymes, inhibiting cancer cell proliferation and promoting cell differentiation (Kalt 2001). Some flavonoids are also beneficial against heart disease because they inhibit blood platelet aggregation and provide antioxidant protection to LDL (Frankel et al. 1993). Studies on the health benefits of the phenolic acids to date have largely focused on their antioxidant activity.

Flavonols

The predominant flavonoid in peas is quercetin, which is present as a glycoside (with an attached sugar molecule). Like most flavonoids, it is believed to have a number of cancer-fighting properties. It has been shown to inhibit the growth of malignant cells, encourage apoptosis (self-destruction) of cancerous cells, and interfere with proliferative activities of certain cancer cells. Quercetin's antioxidant activity is also believed to be responsible for some of the observed cardio protective qualities of onions, which are well endowed with this compound (Joseph et al. 2002).

Isoflavones

Compared with soy and soy products, peas contain only low levels of isoflavones (Kleijn et al. 2001; Boker et al. 2002), and it is thus unclear how applicable research focusing on soy and isoflavones are to the health attributes of peas. Nonetheless, peas together with beans were found to contribute most isoflavones to the diets of groups of both Dutch and US women (Kleijn et al. 2001; Boker et al. 2002) and this warrants mention in this report. It is likely that the situation would be similar in New Zealand. The 1997 National Nutrition Survey found that 73% of males and 64% of females consumed peas at least once a week C Russell et al. 1999).

Isoflavones belong to a group of compounds known collectively as phytoestrogens. They are structurally similar to the human hormone, oestrogen, and have been shown to have weak oestrogenic activity. They were initially of interest because it was observed in epidemiological studies that Asian women who had a high intake of isoflavones through traditional soy foods, appeared to have lower incidences of hormone-related health problems, such as breast cancer and menopausal symptoms. Because of their structural similarity to oestrogen, genistein and daidzein, the main isoflavones in peas as well as in soy, are able to bind to oestrogen receptors. This activity is thought to be responsible for their part in reducing the risk for hormone-related cancers, since the proliferation of these kinds of cancer cells is oestrogen dependent (Higdon 2005; Steer 2006).

Soy isoflavones have also been studied in relation to reducing cholesterol and antioxidant effects in preventing LDL cholesterol oxidation. Antioxidant activity is thought to be responsible for other observed anti-carcinogenic effects too, including the inhibition of free radical reactions, cell mutation, cell proliferation and angiogenesis (Steer 2006).

3.5.4 Chlorophyll

Relatively little is known of the health effects of chlorophyll. Some research suggests that it may be important in protecting against some forms of cancer by binding to potential carcinogens, such as aflatoxin and heterocyclic amines to prevent their absorption (Joseph et al. 2002). A recent study found that chlorophyll had phase 2 enzyme-inducing potential and, although its activity was relatively weak, its high concentration in so many edible plants may be responsible for some of the protective effects observed in diets rich in green vegetables (Fahey et al. 2005). An *in vitro* study in which chlorophyll was extracted from spinach demonstrated anti-inflammatory activity as well as anti-proliferative effects against breast, colon, stomach, central nervous system and lung cancer cell lines (Reddy et al. 2005).

3.5.5 Fibre

Insoluble fibre

For many years, the term “fibre” referred only to what is now known as insoluble fibre, or, colloquially, roughage. Although it is insoluble in water, it has water-attracting properties, which help assist stool bulking and reduce the transit time through the gut. It is thus important in preventing constipation and conditions such as diverticulitis and bowel cancer.

Soluble fibre

Soluble fibre is not as readily identifiable as fibre as is insoluble fibre. It includes compounds like gums, pectins, inulin and the oligosaccharides (compounds containing 3-10 sugar molecules) that are present in many legumes. Although not strictly speaking fibre, resistant starch is often considered alongside soluble fibre as it behaves similarly and has similar physiological effects. Also present in peas, it is starch that is sequestered in cell walls and therefore is not available to digestive enzymes and can occur naturally, or be caused through processing, or cooling and reheating. Because these compounds cannot be digested, they pass to the colon where they are fermented by colonic bacteria. During the fermentation process, short chain fatty acids (SCFA) are produced together with gases. The latter are responsible for the flatulence that frequently arises from consumption of foods containing these compounds. SCFAs are thought to have several beneficial effects, including providing energy for colonic mucosa, protection against various diseases of the colon, including cancer, and lowering colonic pH, so preventing the transformation of primary bile acids to co-carcinogenic secondary bile acids. A number of laboratory studies have shown that peas give rise to a high proportion of the SCFA, butyric acid, which is thought to be particularly beneficial (Garcia-Domingo et al. 1997; Ekvall et al. 2006). Garcia-Domingo et al. (1997) suggest that this is due to the high levels of resistant starch in peas. Some soluble fibre, particularly that which is viscous also inhibits cholesterol absorption and reduces blood glucose response (Ekvall et al. 2006).

The viscous kinds of fibre, such as pectins, some gums, mucilages and β-glucans, form gels in water and it is this property that explains why some fibres slow stomach emptying, delay absorption of some nutrients and reduce cholesterol. Although there have been several trials using dried legumes, which have shown beneficial effects upon cholesterol (Anderson & Major 2002), little published material relates specifically to green peas. In addition to fibre, several of the other compounds present in legumes may also assist in this hypocholesterolaemic effect, including, in order of importance, vegetable protein, oligosaccharides, isoflavones, phospholipids and fatty acids and saponins (Anderson & Major 2002). Besides lowering cholesterol, consumption of pulses may also reduce risk for cardiovascular disease through lowering blood pressure, as well as beneficially affecting glycaemia and reducing the risk of diabetes and obesity (Anderson & Major 2002).

3.5.6 Saponins

Saponins are believed to have a beneficial effect on human health particularly in terms of lowering cholesterol (Cheeke 1996 cited in Daveby et al. 1998). It is thought that saponins cause the adsorption of bile acids on to dietary fibre in the intestine, which is then excreted in the faeces. To compensate for this loss, serum cholesterol is converted by the liver into bile acids, thus lowering levels of cholesterol in the blood (Savage & Deo 1989). They are also believed to protect against cancer, by breaking down the cholesterol-rich membranes of cancer cells. Because saponins are not well absorbed into the blood stream, they are thought to be most useful in exerting a localised effect in the intestinal tract, such as combating colon cancer (Joseph et al. 2002). Some members of the saponin family have also been shown to have anti-fungal, antibacterial and anti-inflammatory activity (Sparg et al. 2004).

Although some saponins have also been shown to have anti-nutritive effects, including haemolytic and cytotoxic activity, there appears to be no evidence of harmful effects of pea saponins in humans (Sparg et al. 2004).

3.5.7 Antioxidant activity

Epidemiological studies have shown that large intakes of fruit and vegetables protect against a range of chronic diseases and problems associated with ageing, and this is generally attributed to their phytochemical content. One of the most important ways in which phytochemicals are believed to exert this protective effect is through antioxidant activity.

Antioxidants deactivate free radicals and other oxidants, rendering them harmless. Free radicals are highly unstable molecules, present in the body both from external sources (e.g. pollution, smoking, carcinogens in the environment) and internal sources, the result of normal physiological processes. If uncontrolled, free radicals can damage cell components, interfering with major life processes. For example, they may damage DNA, leading to cancer, or oxidise fats in the blood, contributing to atherosclerosis and heart disease. Although the body produces its own antioxidants and has other defence mechanisms, it is thought that antioxidants from the diet also have an important role.

The major antioxidants in peas are vitamin C, the carotenoids and various phenolic compounds. There are a number of different methods for measuring antioxidant activity and, to give a full picture, a range of these methods should be used. Unfortunately, however, peas have been relatively little studied and there is a shortage of data in this area. In one study comparing antioxidant activity in 21 commonly consumed vegetables, (frozen) peas ranked moderately low at 6 micromoles Trolox equivalents/gram with values for other vegetables ranging from around 1 to 94 micromoles Trolox equivalents/gram (excluding dried legumes) (Wu et al. 2004). In this study it appeared that hydrophilic compounds, probably mostly phenolics, were responsible for the majority of this activity. In another study, peas were ranked lowest of 13 vegetables according to two different antioxidant assays, FRAP and ORAC (Ou et al. 2002). Similarly, and also using the FRAP assay, Halvorsen et al. (2002) measured antioxidant activity in peas and found that it was amongst the lowest in the large range of vegetables and pulses in the study.

3.6 Factors affecting health benefits

As already mentioned, a number of variables combine to affect how consumption of a particular food will affect human health. Major factors include how well nutrients are absorbed and used by the body, agronomic issues and the effects of processing.

3.6.1 Bioavailability

Bioavailability broadly addresses the issue of how well a compound is absorbed to be used by the body and made available at the site of physiological activity. Absorption may be determined by a range of variables, such as the chemical structure and nature of the compound, the amount consumed, the food matrix in which it is contained, the presence of other compounds within the meal and the nutrient status of the subject.

Carotenoids

The large difference between the numbers of carotenoids ingested as plant material and those absorbed into human plasma indicates selective uptake.

Carotenoids occur in plants in three forms:

- as part of the photosynthetic apparatus, where they are complexed to proteins in chromoplasts and trapped within the cell structures, and are thus protected from absorption (in green, leafy vegetables);
- dissolved in oil droplets in chromoplasts, which are readily extracted during digestion (mango, papaya, pumpkin and sweet potato) (West & Castenmiller 1998);
- as semi-crystalline membrane-bound solids (carrot, tomato), which, though soluble in the intestinal tract, probably pass through too quickly to allow much solubilisation.

These differences in location and form strongly affect absorption and explain differences in bioavailability in different food matrices (Galeotti et al. 1990). Particle size and cooking, which breaks down the cell matrix of the food, also influence uptake, presumably by making the carotenoid more available for absorption in the lumen.

The carotenes appear to be absorbed differently from the xanthophylls on account of their differing polarities. Lutein appears to be better absorbed than β-carotene (van het Hof et al. 1999; Zaripheh & Erdman 2002) and absorption takes place in different locations within the gut (Goni et al. 2006).

The presence of fat or oil, either as part of the meal (e.g. in whole milk, cheese or a dressing) or used in cooking, also positively affects absorption. Because carotenoids are fat-soluble compounds, they are absorbed in parallel with fat metabolism, and it has been estimated that a fat intake of at least 5 g of fat per day is necessary for an adequate uptake of dietary carotenoids. The type of fat present, including fatty acid length, and the presence of protein also influences absorption (West & Castenmiller 1998).

Insoluble and soluble dietary fibre are also thought to have a negative effect on β-carotene bioavailability (Hammond et al. 1997; Rock & Swendseid 1992, cited in West & Castenmiller 1998).

Phenolics

There have been few studies on the bioavailability of hydroxycinnamic acids, and not specifically those in peas or beans. However, in two studies reviewing the bioavailability of dietary polyphenols, phenolic acids were among the best absorbed (Scalbert et al. 2002; Karakaya 2004).

Although there have been a number of studies regarding soy isoflavones, there do not appear to be any regarding isoflavones in peas. Soy isoflavones appear to be well absorbed in the gastrointestinal tract and achieve peak concentrations within a few hours of consumption (de Pascual-Teresa et al. 2006). In general it appears that for humans genistein and daidzein aglycones are more bioavailable than their conjugated forms and genistein is more bioavailable than daidzein (Lin & Lai 2006). It has also been found, however, that there are population differences in the way in which isoflavones are metabolised, which affects their bioactivity. An example of this is the metabolising of daidzein to equol, which has higher oestrogenic activity than daidzein itself, but only occurs in 33% of people in Western populations (Higdon 2005).

Saponins

Saponins do not appear to be well absorbed and consequently their effects take place largely in the gastro-intestinal tract (Joseph et al. 2002).

3.6.2 Agronomic factors

A number of studies have shown large differences between pea cultivars in terms of their constituent compounds (Savage & Deo 1989; Troszynska & Ciska 2002; Troszynska et al. 2002; Vidal-Valverde et al. 2003; Duenas et al. 2006).

3.6.3 Level of maturity

Numerous studies document changes in the constituent compounds of plants during different stages of growth, but there appear to be few specifically on peas. Daveby et al. (1997) observed a considerable decrease in soyasaponin I, the major saponin in peas, during maturation, though their level in vegetable peas, harvested at a fully developed but immature stage, is unknown.

3.6.4 Processing

Processing, such as cooking, freezing or pureeing, can have both positive and negative effects upon the nutrients present in foods. For example, whilst cooking decreases levels of heat labile compounds like vitamin C and folate and saponins, it can increase the bioavailability of carotenoids and destroy anti-nutritional factors. The small amount (0.15 mg/100 g) of quercetin measured in blanched peas by Ewald et al. (1999) was little affected by further processing by cooking, frying or warm holding. The effect of blanching on the quercetin content of raw peas was not measured in this study. The evidence of soy isoflavones in a variety of processed foods would suggest that processing does not substantially compromise these compounds.

3.7 Quotes and trivia

- "Petits pois [peas] are like children – you have to understand them" James de Coquet (French author) writing in Le Figaro.
- Peas and beans belong to a family known popularly as legumes. The word "legume" is derived from the French légume, which means vegetable, probably testament to their importance as staples in earlier times. Legumes all have fruit pods that usually open on both sides. Peanuts are actually legumes, along with beans, alfalfa and gorse.
- Peas have a place in the history of science as the plants with which Gregor Mendel deduced the laws of genetic inheritance.
- In Chinese traditional medicine peas were prescribed for diuretic, anti-inflammatory and stomachic purposes (Murakami et al. 2001).

4 Snow peas, sugar snap peas

Although these terms are sometimes used interchangeably, this is erroneous and they are in fact a little different. Snow peas are flat wide pods with only miniature immature seeds. Their pods lack the "parchment" present in regular green peas and have strings on one or both sides of the pods. Snap peas have larger, often very sweet seeds, their pods similarly do not contain "parchment" and they have no strings (Goulden pers. comm. 2006).

Snow peas contain excellent levels of vitamin C and good levels of pro vitamin A (in the from of β-carotene and α-carotene). They also supply useful amounts of thiamin, vitamin B_6, iron, folate and both soluble and insoluble fibre. Because they are also low in calories, they are considered reasonably nutrient dense. In addition they provide important sensory benefits, such as crunchiness and sweetness to dishes in which they are used.

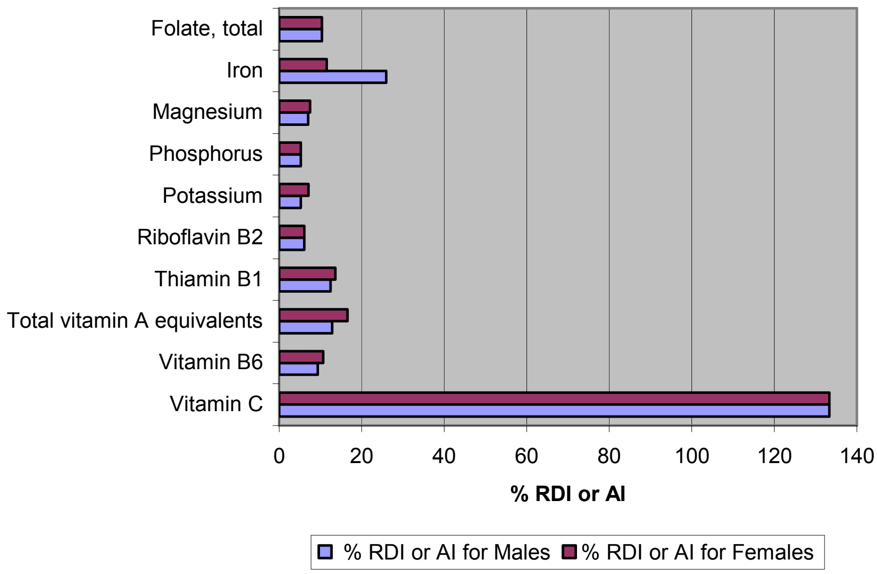

Figure 2: Contributions to RDI or AI by the major micronutrients in snow peas adapted from Athar et al. (2004) and NHMRC (2006).

There is little information on the phytochemicals in edible pod peas, though the high levels of vitamin C in this vegetable should provide antioxidant activity. An Indian study that investigated the antioxidant activity and phenolic content of "pea pods", placed them in a medium antioxidant activity group, but with fairly low levels of phenolics (Kaur & Kapoor 2002). An early study of dietary fibre in South-east Asian vegetables found snow peas to be one of the richest sources of dietary fibre (Candlish et al. 1987), though this is at odds with data from the New Zealand FOODFiles database. There are various reasons for this, including differences in cultivar, growing conditions and analytical methods.

5 *Beans (*Phaseolus vulgaris*)*

5.1 Introduction

Beans can roughly be sorted into three groups:

- edible pod beans – green beans, string beans, snap beans, butter beans, scarlet runners,
- seed beans – those grown primarily for use as mature, dry beans, such as kidney beans, black beans, and
- fresh semi-mature seed beans – broad beans that are eaten fresh rather than dried (though they can also be dried and often are in Middle Eastern and some Mediterranean countries).

They all belong to the same family, though can be different genera and/or different cultivars. Equally they are obviously harvested at different stages of maturity. Seed beans are not covered in this report and broad beans are dealt with in a separate section.

Both seed beans and pod beans are generally referred to as “common beans”. It is believed that these originated in South America, possibly Peru, and over time spread throughout South and Central America. Along with maize and squash they were known as the “Three Sisters”, the three staple foods that sustained early Native American populations. Like many other vegetables, they were introduced to Europe by Spanish explorers on their return from the Americas in around the 16^{th} century.

Note: There is potential confusion regarding the term “butter beans”. In New Zealand this terms refers to beans of the same genus as the common green beans, and differ only in that they are yellow. In other countries the term is an alternative name for lima beans, where the seed can be used either dry or fresh in the same way as broad beans. The yellow “green” beans are usually known as “yellow” or “wax” beans overseas.

5.2 Composition

Green beans are not nutritional stars, but because they are eaten with reasonable frequency it is likely that their nutrients make a fair contribution to the diet. According to the 1997 National Nutrition Survey they were consumed by 46-48% of the population at least once a week (Russell et al. 1999).

5.2.1 Core nutrients

The major nutrients in green beans are folate, vitamins A (through β-carotene) and C, with thiamin, niacin, calcium, zinc and iron present at low levels. They also contain some fibre and are low in calories. See Appendix I for more data.

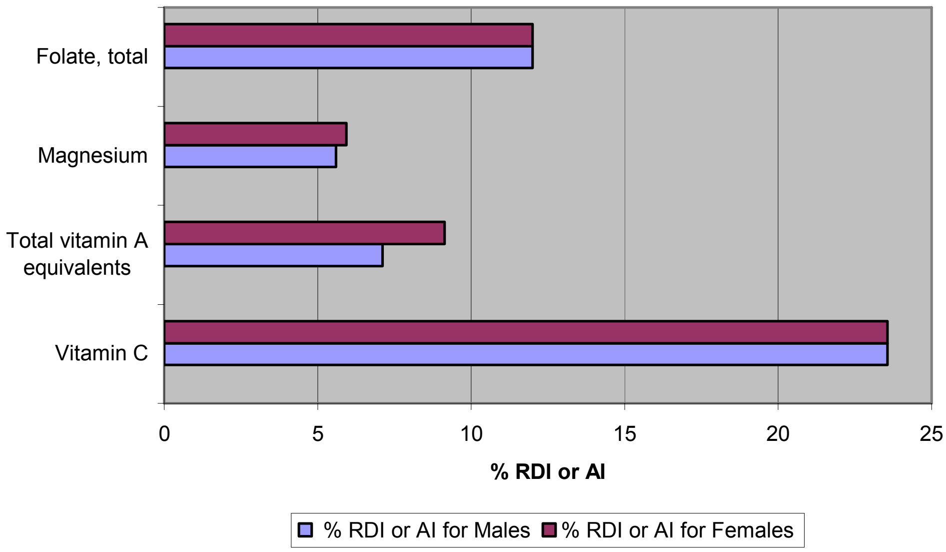

Figure 3: Contributions to RDI or AI by the major micronutrients in green beans adapted from Athar et al. (2004) and NHMRC (2006).

5.2.2 Other phytochemicals

There is very little information on phytochemicals in green beans. They do however, contain some β- and α-carotene, and good amounts of lutein and zeaxanthin (see Table 1). Raw green beans also contain chlorophyll and reasonable amounts of the flavonoids quercetin and kaempferol at 2.73 mg/100 g and 0.41 mg/100 g respectively (USDA 2003). Yellow beans contain slightly higher levels of both (3.03 mg/100 g and 0.42 mg/100 g) (USDA 2003).

5.3 Health benefits

No studies investigating bioactives or health benefits specifically of green beans have been found. However, the information covered in Section 2.5 relating to the phytochemicals above should also be relevant to beans.

5.3.1 Antioxidant activity

In a number of studies comparing antioxidant activity and/or phenolic content by assorted assays, beans rank in the low to average range (Cao et al. 1996; Vinson et al. 1998; Pellegrini et al. 2003; Chun et al. 2005; Zhou & Yu 2006).

5.4 Factors affecting health benefits

Apart from the differences between cultivars of green and yellow beans documented in Table 1 and Appendix I, nothing relating specifically to green beans has been found. The same general issues regarding bioavailability that applied to peas will also apply to these kinds of beans, and processing is likely to affect the nutrients common to both peas and beans similarly.

5.5 Tips and trivia

- A bean feast, which now means a party or social gathering was originally a dinner party put on by an employer for his employees.

6 *Broad beans (*Vicia fava*)*

6.1 Introduction

A different genus from “common beans”, which originate from South America, broad beans are an ancient food source, native to North Africa and south-west Asia. In most Western countries they are usually consumed fresh (or frozen) when the seeds are developed though not fully mature, but in Middle Eastern, Mediterranean and Asian cuisine, the fully mature, dried seeds are usually used. For example, falafel is traditionally made from a small-seeded variety of broad bean. The term fava bean is often used in Mediterranean cuisine and also sometimes in the US. Although both the immature pod and seeds can be eaten, this report deals only with the (immature) seeds, as this is the stage at which they are commonly sold and consumed in New Zealand.

Broad beans have a number of little known, but important idiosyncrasies. They are one of the richest sources of the flavonoids made famous through their presence in tea, and chocolate, they contain the medicinal compound L-dopa, used in treating Parkinson’s disease, and they can also cause potentially fatal haemolytic anaemia in certain ethnic groups with a genetic condition known as favism.

6.2 Composition

6.2.1 Core nutrients

Not surprisingly, given that they are both seeds, nutritionally broad beans have more in common with peas, than with green beans. They contain good amounts of many B vitamins, as well as folate, small amounts of provitamin A carotenoids, zinc and iron and are also an excellent vegetable source of protein. Like peas, they are also a very good source of both soluble and insoluble fibre. See Appendix I for full data.

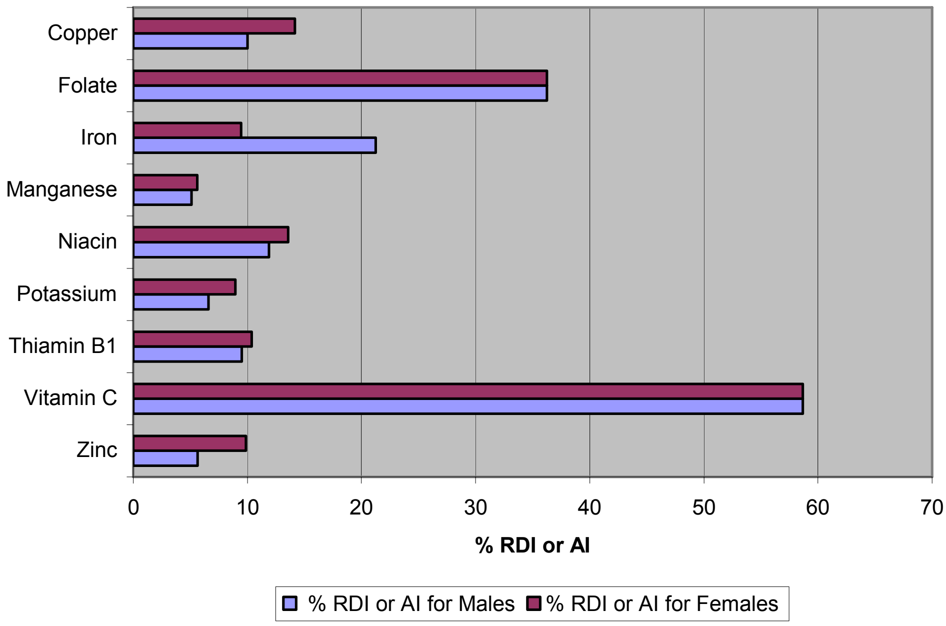

Figure 4: Contributions to RDI or AI by the major micronutrients in frozen uncooked broad beans, adapted from Athar et al. (2004) and NHMRC (2006).

6.2.2 Other phytochemicals

Broad beans contain only very small amounts of carotenoids (USDA, 2005; Athar et al. 2004), with a little β-carotene and, unlike peas, no lutein or zeaxanthin (see Table 1). However, they do contain a number of phenolic compounds, including the flavonols, quercetin and myricetin, and additionally are an excellent source of other flavonoids known as catechins, flavanols or flavan-3-ols (USDA 2003).

Catechins

According to a study by Auger et al. (2004), broad beans contain the highest levels of catechins by far of all the selected fruits, vegetables and other foods analysed, which included grapes, apples and chocolate, foods often referred to as having high levels of catechins (Table 5).

Table 5: Catechin levels in fruits, vegetables and other products adapted from Auger et al. (2004).

Food	Catechin content (mg/100 g fresh weight solids, mg/100 mL liquids)
Broad beans	184
Chocolate	7
Pinto beans	7
Lentils	3
Plums	49
Apples	10-43
Berries	5-20
Cherries	13
Tea	25-43
Red wine	56

Although such high catechin levels are not mirrored in USDA data (total catechins content ~ 50 mg/100 g), in comparison with other foodstuffs, the levels reported in broad beans are still among the highest listed. The levels of individual broad bean catechins from the USDA Flavonoid Database are shown in Table 6, with epicatechin the most prevalent. The greatest concentrations of these catechins were found by Borowska et al. (2003) to occur in the seed coat. The chemical structures of catechin and epicatechin are given in Appendix III.

Table 6: Individual catechins identified in immature raw broad bean seeds, mg/100 g fresh weight (USDA 2003).

(-)-Epicatechin	22.51
(-)-Epigallocatechin	14.03
(+)-Catechin	12.83

Isoflavones

A Japanese study showed that the major isoflavonoids in a sample of Chinese broad beans was of a lesser known and studied compound, biochanin A (Nakamura et al. 2001). USDA data on raw, mature seeds lists a small amount of daidzein (0.03 mg/100 g edible portion) and no genistein and for fried broad beans, no daidzein, but 1.29 mg/100 g edible portion of genistein (USDA 1999). Although these amounts are higher than for most other beans listed in this database, levels are minuscule compared with soy whose values for total isoflavonoids in raw beans range from 59.75 to 144.99 mg/100 g edible portion, depending on the country of origin.

Levodopa

Broad beans also contain a chemical called levodopa or L-dopa, which is used medicinally in the treatment of Parkinson's disease. Although it is present in the whole plant, young pods and beans contain more L-dopa than mature dried beans. It has been estimated that around 85 grams of fresh green fava beans may contain between 50 and 100 mg of levodopa (Holden 2001).

Fibre and resistant starch

The New Zealand food composition database, FoodFiles, lists frozen uncooked broad beans as having 6.5 g of fibre per 100 g, comprising 1.4 g soluble non starch polysaccharides and 5.1 g insoluble non starch polysaccharides (Athar et al. 2004). In a Polish study of fully mature seeds it was observed that the broad bean cultivars studied were good sources of resistant starch as well as dietary fibre. Around half of the latter was concentrated in the seed coat. Soluble dietary fibre ranged from 11.81 to 15.89% of total fibre (Giczewska & Borowska 2003).

6.3 Health benefits

The health benefits of some of the nutrients in broad beans have already been covered earlier. See Section 2.5.5 for fibre and Section 2.5.3 for flavonols.

6.3.1 Catechins

Catechins are present in both wines and tea, and it is thought that these compounds may be partly responsible for some of the health benefits attributed to these beverages. Recently there has also been a surge of scientific interest in cocoa and cocoa products such as chocolate, whose major catechins, like those in broad beans, are epicatechin and catechin. Whilst there does not appear to have been any research relating specifically to broad beans, the general findings regarding catechins are likely to be of some relevance.

Many of the health benefits of catechin-rich foods are thought to be attributable to their antioxidant activity, which is conferred by their structures, including the hydroxylation of a flavan ring structure, particularly the 3,4 dihydroxylation of the B-ring, the oligomer chain length and stereochemical features of the molecule (Keen et al. 2005). Their antioxidant activity includes radical scavenging and metal chelating properties. This is believed to be important in protecting against several chronic diseases, including cardiovascular disease and cancer.

In vitro studies have shown catechins to inhibit LDL oxidation as well as platelet aggregation, reduce inflammation and improve vascular endothelial function through the activation of nitric oxide synthesis (Auger et al. 2004; Hollenberg et al. 2004; Keen et al. 2005; Williamson & Manach 2005). In a review of human intervention studies, Williamson & Manarch concluded that catechins increased plasma antioxidant activity, decreased plasma lipid peroxide and malondialdehyde concentrations, and increased the resistance of LDL to oxidation. These authors also concluded that catechins appeared to have the deleterious effect of decreasing non-heme iron absorption.

6.4 Factors affecting health benefits

6.4.1 Bioavailability

The bioavailability of carotenoids and some phenolic compounds has already been covered in Section 2.6.1. Whilst not as well absorbed as isoflavones, catechins are better absorbed than most of the other phenolics, though this differs markedly between the catechins themselves. However, a number of studies have shown measurable levels of catechins (particularly epicatechin) in plasma after consumption of chocolate or cocoa, the major catechins being the same as those in broad beans (Manach et al. 2005).

6.4.2 Agronomy

Borowska et al. (2003) found the major difference between the bioactive components in small- and large-seeded broad bean varieties was in terms of phenolic compounds, which were nearly twice as high in large seeds as in small seeds, though there were also differences in antinutritional components (phytates and trypsin and amylase inhibitors). There were also differences in concentrations in all components studied between the cotyledon and the seed coat, which also varied according to variety. Similarly Giczewska & Borowska (2003) found varietal differences in terms of starch and fibre content.

6.4.3 Processing

See Section 2.6.5 for general effects of processing, which apply to most legumes. Data from the USDA (Table 7) suggest that cooking reduces catechin levels. There is very little information available on the effect of heat on broad bean catechins, though it is known that tea catechins are epimerised by heat, so it is possible that although losses of the original compounds were observed with cooking, the resulting epimers were not identified and quantified. Kobayashi et al. (2005) showed that both native tea catechins and heat-epimerised tea catechins were equally effective in lowering cholesterol in an animal study.

Table 7: Catechin levels in raw and boiled broad beans (UDSA 2003).

	(-)-Epicatechin	(-)-Epigallocatechin	(+)-Catechin
Broad beans, immature seeds, raw	22.51	14.03	12.83
Broad beans, immature seeds, cooked, boiled	7.82	4.65	8.16

6.5 Tips and trivia

- Broad beans were part of the diet in many ancient cultures, though not in Ancient Egypt. Priests there forbade the eating of these, believing they each contained the soul of a dead man.
- Some ethnic groups, including some Mediterranean peoples (usually males), lack the gene that codes for the enzyme glucose-6-phoshate dehydrogenase (G6PD). Compounds present in the beans or the pollen of the flowers are metabolised into compounds, which, without G6PD, attack red blood cells causing anaemia, which in severe cases can be fatal. This condition is known as favism, after the broad bean.
- Voting in Ancient Rome took place with broad beans. White beans counted for and black beans against. This is possibly the origin of the term “bean counter”.

7 Overall summary

- Peas and broad beans are excellent all-round vegetables. They contain a wide range of micronutrients and are one of the best vegetable sources of protein.
- The insoluble fibre contained in peas and beans is thought to be particularly important for bowel health, including protecting against bowel cancer. Peas and broad beans also contain soluble fibre and resistant starch, which may also protect against bowel cancer through other mechanisms and have additional health benefits such as preventing other gastro-intestinal problems, cardiovascular disease, diabetes and obesity.
- Peas contain very high levels of the antioxidant carotenoids, lutein and zeaxanthin, which are thought to protect against eye diseases, particularly macular degeneration.
- Broad beans contain very high levels of catechins – the same antioxidants more commonly associated with chocolate, red wine and tea.
- Peas and broad beans also contain isoflavonoids, which have weak oestrogenic effects. Although these phytoestrogens are only present at low levels, it is likely that peas and broad beans are major sources in Western diets. Whilst there is evidence that high levels of isoflavones from soy in the diets of Oriental women may protect against some hormone-related conditions, the health implications of pea and broad bean isoflavones in the diets of Western women is unclear.
- Peas and broad beans both contain saponins, which are thought to lower cholesterol as well as have anti-inflammatory, anti-bacterial and anti-fungal properties.
- Although the edible pod vegetables are less nutrient dense than the seed types, they also have particular dietary benefits. For example, besides

their distinctive sensory attributes, snow peas contain very high levels of vitamin C and beans are an excellent low calorie vegetable.

- Although legumes can contain anti-nutritional compounds, there is no evidence that they pose a threat to the majority of the population.

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Appendices

Appendix I Data from FOODFiles

		Peas,Green,raw
Water	g	77.1
Energy	kcal	62
Protein	g	5.08
Total fat	g	0.5
Carbohydrate, available	g	9.3
Dietary fibre (Englyst, 1988)	g	4.2
Ash	g	0.78
Sodium	mg	5
Phosphorus	mg	72
Potassium	mg	155
Calcium	mg	22
Iron	mg	1.6
Beta-carotene equivalents	µg	311
Total vitamin A equivalents	µg	52
Thiamin	mg	0.34
Riboflavin	mg	0.14
Niacin	mg	2.26
Vitamin C	mg	20
Cholesterol	mg	0
Total saturated fatty acids	g	0.187
Total monounsaturated fatty acids	g	0.158
Total polyunsaturated fatty acids	g	0.056
Dry matter	g	22.9
Total nitrogen	g	0.81
Glucose	g	0.3
Fructose	g	0.4
Sucrose	g	5.1
Lactose	g	0
Maltose	g	0
Total available sugars	g	5.8
Starch	g	3.52
Alcohol	g	0
Total niacin equivalents	mg	3.07
Soluble non-starch polysaccharides	g	1.2
Insoluble non-starch polysaccharides	g	3.1
Energy	kJ	257
Magnesium	mg	22
Manganese	µg	260
Copper	mg	0.336
Zinc	mg	0.68
Selenium	µg	0.286
Retinol	µg	0
Potential niacin from tryptophan	mg	0.813
Vitamin B6	mg	0.14

Folate, total	µg	78
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.64

T=trace

		Peas,Snow,peapod,raw
Water	g	88.9
Energy	kcal	29
Protein	g	2.8
Total fat	g	0.2
Carbohydrate, available	g	4.09
Dietary fibre (Englyst, 1988)	g	2.3
Ash	g	0.56
Sodium	mg	4
Phosphorus	mg	53
Potassium	mg	200
Calcium	mg	43
Iron	mg	2.08
Beta-carotene equivalents	µg	695
Total vitamin A equivalents	µg	116
Thiamin	mg	0.15
Riboflavin	mg	0.08
Niacin	mg	0.6
Vitamin C	mg	60
Cholesterol	mg	0
Total saturated fatty acids	g	0.039
Total monounsaturated fatty acids	g	0.021
Total polyunsaturated fatty acids	g	0.089
Dry matter	g	11.1
Total nitrogen	g	0.48
Glucose	g	2.6
Fructose	g	0.3
Sucrose	g	0.47
Lactose	g	0
Maltose	g	0
Total available sugars	g	3.37
Starch	g	0.72
Alcohol	g	0
Total niacin equivalents	mg	1.12
Soluble non-starch polysaccharides	g	1
Insoluble non-starch polysaccharides	g	1.3
Energy	kJ	122
Magnesium	mg	24
Manganese	µg	244
Copper	mg	0.079
Zinc	mg	0.27
Selenium	µg	T
Retinol	µg	0
Potential niacin from tryptophan	mg	0.6

Vitamin B6	mg	0.16
Folate, total	µg	41.7
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.39
T=trace		

		Beans,Green,raw
Water	g	90.7
Energy	kcal	18
Protein	g	1.22
Total fat	g	0.2
Carbohydrate, available	g	2.8
Dietary fibre (Englyst, 1988)	g	2.2
Ash	g	0.48
Sodium	mg	3
Phosphorus	mg	27
Potassium	mg	159
Calcium	mg	48
Iron	mg	0.33
Beta-carotene equivalents	µg	382
Total vitamin A equivalents	µg	64
Thiamin	mg	0.037
Riboflavin	mg	0.028
Niacin	mg	0.5
Vitamin C	mg	10.6
Cholesterol	mg	0
Total saturated fatty acids	g	0.046
Total monounsaturated fatty acids	g	0.009
Total polyunsaturated fatty acids	g	0.105
Dry matter	g	9.35
Total nitrogen	g	0.2
Glucose	g	1.4
Fructose	g	0.3
Sucrose	g	0.3
Lactose	g	0
Maltose	g	0
Total available sugars	g	2
Starch	g	0.79
Alcohol	g	0
Total niacin equivalents	mg	0.7
Soluble non-starch polysaccharides	g	0.9
Insoluble non-starch polysaccharides	g	1.3
Energy	kJ	74
Magnesium	mg	19
Manganese	µg	202
Copper	mg	0.059
Zinc	mg	0.13
Selenium	µg	0.16
Retinol	µg	0

Potential niacin from tryptophan	mg	0.2
Vitamin B6	mg	0.032
Folate, total	µg	48
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.11

T=trace

		Beans,Butter,raw
Water	g	91.6
Energy	kcal	19
Protein	g	2.3
Total fat	g	0.2
Carbohydrate, available	g	2.1
Dietary fibre (Englyst, 1988)	g	1.5
Ash	g	0.5
Sodium	mg	3
Phosphorus	mg	27
Potassium	mg	230
Calcium	mg	16
Iron	mg	0.4
Beta-carotene equivalents	µg	90
Total vitamin A equivalents	µg	15
Thiamin	mg	0.06
Riboflavin	mg	0.09
Niacin	mg	1
Vitamin C	mg	15
Cholesterol	mg	0
Total saturated fatty acids	g	0.046
Total monounsaturated fatty acids	g	0.009
Total polyunsaturated fatty acids	g	0.105
Dry matter	g	8.4
Total nitrogen	g	0.37
Glucose	g	0.4
Fructose	g	1
Sucrose	g	0.4
Lactose	g	0
Maltose	g	0
Total available sugars	g	1.8
Starch	g	0.3
Alcohol	g	0
Total niacin equivalents	mg	1.4
Soluble non-starch polysaccharides	g	0.6
Insoluble non-starch polysaccharides	g	0.8
Energy	kJ	81
Magnesium	mg	22
Manganese	µg	202
Copper	mg	0.06
Zinc	mg	1.5
Selenium	µg	0.16

Retinol	µg	0
Potential niacin from tryptophan	mg	0.4
Vitamin B6	mg	0.03
Folate, total	µg	48
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.11

T=trace

		Beans,Broad,frozen, uncooked
Water	g	78.8
Energy	kcal	58
Protein	g	5.29
Total fat	g	0.3
Carbohydrate, available	g	8.6
Dietary fibre (Englyst, 1988)	g	6.5
Ash	g	0.81
Sodium	mg	6.4
Phosphorus	mg	96
Potassium	mg	250
Calcium	mg	29
Iron	mg	1.7
Beta-carotene equivalents	µg	195
Total vitamin A equivalents	µg	33
Thiamin	mg	0.114
Riboflavin	mg	0.036
Niacin	mg	1.9
Vitamin C	mg	26.4
Cholesterol	mg	0
Total saturated fatty acids	g	0.052
Total monounsaturated fatty acids	g	0.061
Total polyunsaturated fatty acids	g	0.127
Dry matter	g	21.3
Total nitrogen	g	0.85
Glucose	g	0.7
Fructose	g	0.3
Sucrose	g	1.4
Lactose	g	0
Maltose	g	0
Total available sugars	g	2.4
Starch	g	6.22
Alcohol	g	0
Total niacin equivalents	mg	2.8
Soluble non-starch polysaccharides	g	1.4
Insoluble non-starch polysaccharides	g	5.1
Energy	kJ	242
Magnesium	mg	25
Manganese	µg	280
Copper	mg	0.17
Zinc	mg	0.79

Selenium	µg	0.11
Retinol	µg	0
Potential niacin from tryptophan	mg	0.9
Vitamin B6	mg	0.04
Folate, total	µg	145
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.11

T=trace

Appendix II Table of major functions of main micronutrients contained in legumes

Main micronutrients in legumes and their physiological functions, adapted from Medscape (2004) and BUPA (2006).

Name	Major function
Vitamin A Retinol (animal origin) Some carotenoids (plant origin, converted to retinol in the body)	Important for normal vision and eye health Involved in gene expression, embryonic development and growth and health of new cells Assist in immune function May protect against cancers and atherosclerosis
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 some cancers Involved in hormone and neurotransmitter synthesis
Thiamin vitamin B1	Coenzyme in the metabolism of carbohydrates and branched-chain amino acids Needed for nerve transmission Involved in formation of blood cells
Riboflavin vitamin B2	Important for skin and eye health Coenzyme in numerous cellular redox reactions involved in energy metabolism, especially from fat and protein
Niacin vitamin B3 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 B6 Pyridoxine, pyridoxal, pyridoxamine	Coenzyme in nucleic acid metabolism, neurotransmitter synthesis, haemoglobin synthesis. Involved in neuronal excitation Reduces blood homocysteine levels Prevents megaloblastic anemia

Name	Major function
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 Involved in energy metabolism, especially carbohydrates May also be involved in calcium metabolism
Folate Generic term for large group of compounds including folic acid and pterylpolyglutamates	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 B12 May protect against colonic and rectal cancer
Calcium	Structural component of bones and teeth Role in cellular processes, muscle contraction, blood clotting, enzyme activation, nerve function
Iron	Component of haemoglobin and myoglobin in blood, needed for oxygen transport Role in cellular function and respiration
Potassium	Major ion of intracellular fluid Maintains water, electrolyte and pH balances Role in cell membrane transfer and nerve impulse transmission
Phosphorus	Structural component of bone, teeth, cell membranes, phospholipids, nucleic acids, nucleotide enzymes, cellular energy metabolism pH regulation Major ion of intracellular fluid and constituent of many essential compounds in body and processes
Zinc	Major role in immune system Required for numerous enzymes involved in growth and repair Involved in, sexual maturation Role in taste, smell functions

Appendix III Chemical structures of major phytochemicals in legumes

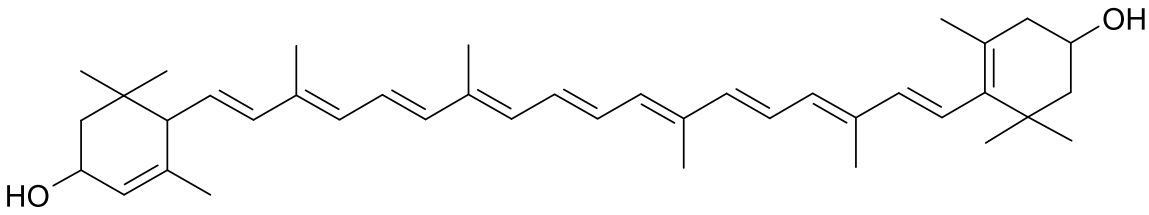

Figure 1: Lutein

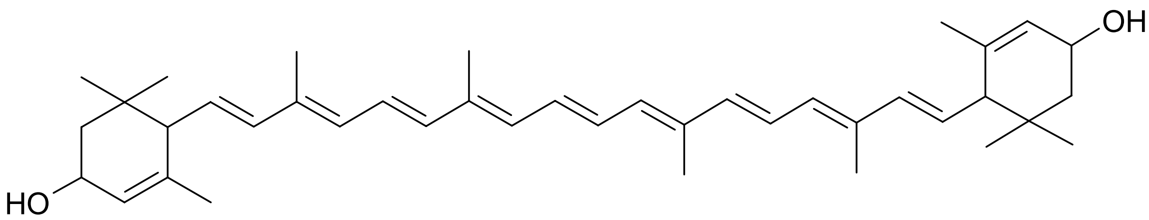

Figure 2: Zeaxanthin

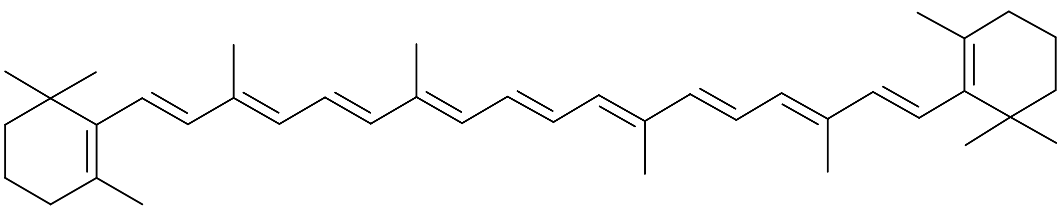

Figure 3: β-carotene

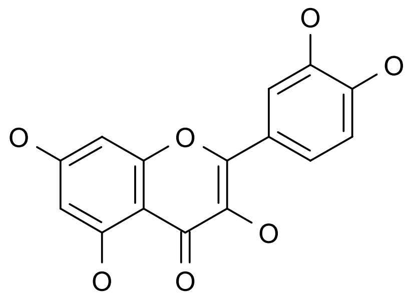

Figure 4: Quercetin

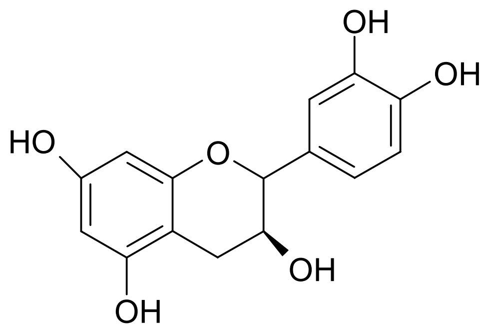

Figure 5: Catechin

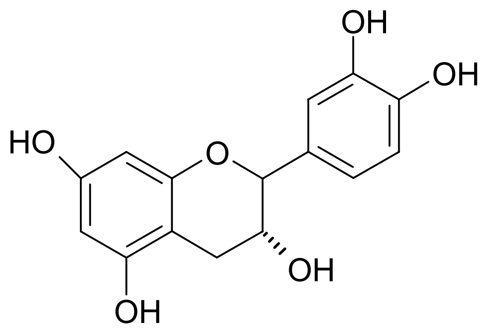

Figure 6: Epicatechin

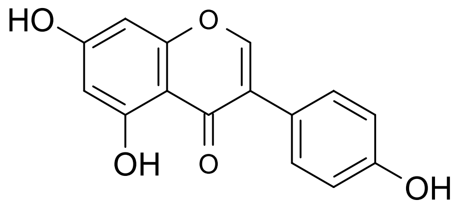

Figure 7: Genistein

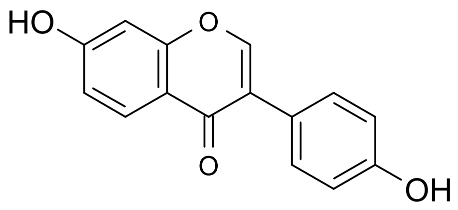

Figure 8: Daidzein