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Health attributes of yellow/orange vegetables

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1 Executive summary

1.1 Background

This report is intended to provide information from which material can be identified for incorporation into one of a series of promotional and educational booklets for the various VegFed 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 yellow/orange vegetables: carrot, corn, capsicum, pumpkin, and melon. Beauregard kumara has also been briefly mentioned. Factors that may influence the nutritional profile of these vegetables, such as agronomical issues, storage, processing and cooking are discussed. Some additional material of general interest has also been included.

"Yellow/orange vegetables" may appear an arbitrary grouping for a product group, but there are good reasons for this on a phytochemical basis. The major phytochemicals in this group of vegetables are the orange/yellow pigments, known collectively as carotenoids. This group comprises structurally similar compounds, though even the minor structural differences between them can result in different biological activities and health effects. The predominant carotenoids covered in this report include β-carotene, α-carotene, lutein/zeaxanthin, and β-cryptoxanthin. Lycopene, the other major carotenoid, has already been extensively covered in the report, *Health attributes of tomatoes* (Hedges and Lister 2005).

The carotenes α- and β-carotene and β-cryptoxanthin, are described as having "provitamin A activity", as they can all be converted into vitamin A (retinol) by the body. How efficiently this is achieved varies between these compounds as a consequence of their different structures. In addition, they can also function as antioxidants, which are believed to provide protection against many chronic diseases, including cardiovascular disease and cancer, as well as other conditions associated with ageing. β-carotene is the most ubiquitous of this family and has been the most extensively studied.

Lutein and zeaxanthin are xanthophylls. Interest in them has focused on a possible role in protecting against eye problems, such as macular degeneration and cataracts. They also have antioxidant effects and research has widened to include their potential effects on chronic diseases.

Because they are lipophilic, carotenoids are best absorbed into the body when consumed in a meal where some sort of oil or fat is present. They are often more bioavailable in cooked foods, rather than raw, as heat breaks down the food matrix, and carotenoids are released from their previously bound states.

1.1.1 *Carrots*

Carrots are a particularly rich source of β-carotene. In addition they contain a much less common phytochemical, falcarinol, a relatively newly-researched compound, which is showing some promising early results in animal-based cancer prevention research.

1.1.2 *Corn*

The carotenoids lutein and zeaxanthin are the carotenoids of most interest in corn. Research examining these compounds has centred particularly upon eye health and the prevention of problems such as macular degeneration and cataracts. Corn also contains a phenolic compound, ferulic acid, which has been shown to have strong antioxidant activity. Yellow corn has more carotenoids than paler corn.

1.1.3 *Capsicum*

All capsicum have excellent levels of vitamin C. Ripe, red peppers, however, contain more than unripe or differently-coloured peppers as well as being best endowed in terms of β-carotene and lutein/zeaxanthin. This notwithstanding, the predominant carotenoid in red capsicums is capsanthin, though this has not yet received much research attention.

1.1.4 *Pumpkins*

There are several types of pumpkin (winter squash) all with differing levels of carotenoids. The more-orange cultivars contain largely carotenes, but the yellower varieties contain higher levels of lutein/zeaxanthin. They are also an excellent source of a lesser known carotenoid, β-cryptoxanthin, which also has been relatively little studied, but may be important for cardiovascular health. Compared with other similarly textured vegetables, pumpkins are relatively low in calories.

1.1.5 *Melons*

Cantaloupe and other orange melons derive their colour from β-carotene. Most studies have found the varieties with more highly coloured flesh to have better antioxidant activity in laboratory assays than their paler relatives, such as honeydew. Watermelon contains the pigment lycopene, which has been extensively studied in relation to tomatoes, with interest focusing on a possible protective role against prostate cancer.

1.1.6 *Orange kumara*

American sweet potato, which has an orange flesh, similar to the Beauregard kumara, has been found to have amongst the highest levels of β-carotene of any fruit or vegetable.

2 *Carrots* (Daucus carota)

2.1 *Introduction*

The humble carrot, almost a staple in many countries, has had a colourful history. The original carrots were believed to be purple and grew in the region that is now Afghanistan about 5000 years ago. These purple carrots were depicted in Ancient Egyptian temple drawings and, along with white varieties, were also known to the ancient Romans, who used them as much for medicinal purposes as culinary. There are also records of red and yellow carrots, but the orange carrot was not known until the 16th century, when it was deliberately developed by Dutch growers to honour of the House of Orange. Interestingly, the older colours are now appearing in new carrot cultivars, with the British retail chain Sainsbury's selling purple orange-centred carrots in 2002. Seed companies are also now offering a rainbow of multi-coloured carrot varieties.

Carrots belong to the Umbelliferae or Apiaceae family, so named because their flowers form umbrella-shaped clusters. This is an illustrious family, which also includes many other plants with aromatic and flavourful qualities, such as parsnips, parsley, dill, celery, coriander, cumin, caraway and anise. Many of these have also been used medicinally as treatments for a wide range of problems.

Carrots are well known for assisting night vision. During World War 2, in order to keep the newly invented radar a secret, it was rumoured that the air crews' night vision had been substantially bolstered by eating larger quantities of carrots.

2.2 *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. This makes it difficult to be exact when comparing levels of these compounds.

These various factors may cause large differences in core nutrient levels, but even greater differences may occur in terms of phytochemicals.

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

2.3 Core nutrients

Carrots are an excellent source of vitamin A through the α- and β-carotene they contain (which the body converts into vitamin A). Moderate amounts of vitamin C, sodium, potassium and fibre are also present in carrots.

See Appendix 1 for full data from the New Zealand FOODFiles database.

2.4 Other phytochemicals

The major phytochemicals in carrots are the carotenoids α-carotene, β-carotene, β-cryptoxanthin, lutein, zeaxanthin and falcarinol, a polyacetylene compound. Whilst there are some phenolic compounds (Joseph et al. 2002), they appear to be present only at low levels (Vinson et al. 1998). Flavonoid data for carrots are unavailable on the USDA flavonoid database and are consequently judged to be of minimal importance.

2.4.1 Carotenoids

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 human body and are present solely as a result of ingestion from other sources. either the plant source 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 highest levels of carotenoids are found in dark green leafy vegetables, such as kale and spinach.

Carotenoids are lipids and consist of a long chain hydrocarbon molecule with a series of central, conjugated double bonds. (See Appendix III for structural diagrams of the major carotenoids in carrots.) These conjugated (alternating) double bonds not only confer colour, but are also responsible for the compounds' antioxidant properties. These compounds have been found to be especially effective in quenching singlet oxygen and peroxyl radicals. 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 both the skin and the macula lutea of the eye against the same 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. They are non-polar and hence tend to be located on the periphery of cell membranes. Lycopene and the xanthophylls lutein and zeaxanthin have no vitamin A capacity. The latter, being more polar, are believed to span cell membranes, with their hydrophobic hydrocarbon chain inside the lipid bilayer and their hydrophilic hydroxyl groups emerging on the other side (Gruszecki & Sielewiesiuk 1990). Because of their similarity, the two compounds are often reported as a combined total.

Carotenoids are fat-soluble compounds and thus are best absorbed in the body if accompanied by some form of oil or fat in the meal. It has also been shown that chopping and cooking assists in releasing carotenoids from the food matrix which also increases their bioavailability.

The carotenoid content of some common yellow/orange fruits and vegetables is shown in Table 1. Interestingly, although cooking increases the carotenoid contents in carrots and corn, particularly for β-cryptoxanthin, and lutein and zeaxanthin, the reverse seems to be the case for pumpkin.

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

Food	β-carotene	α-carotene	β-cryptoxanthin	Lycopene	Lutein + zeaxanthin
Apricot	1094	19	104	0	89
Capsicum, red, raw	1624	20	490	308	51
Capsicum, yellow, raw	120	N/A	N/A	N/A	N/A
Carrot, raw	8285	3477	125	1	256
Carrot, boiled	8332	3776	202	0	687
Corn (sweet), raw	52	18	127	0	764
Corn (sweet) boiled	66	23	161	0	967
Melon (cantaloupe)	2020	16	1	0	26
Orange	87	7	116	0	129
Peach	162	0	67	0	91
Persimmon	253	0	1447	159	834
Pumpkin, raw	3100	515	2145	0	1500
Pumpkin, boiled	2096	348	1450	0	1014
Sweet potato, raw	8506	7	0	0	0
Sweet potato. boiled	9444	0	0	0	0

2.4.2 *Falcarinol and falcarindiol*

Carrots also contain compounds called polyacetylenes, of which falcarinol ((9Z)-heptadeca1,9-dien-4,6-diyn-3-ol) has been found to be among the most bioactive and therefore of particular importance in terms of health (Hansen et al. 2003; Zidorn et al. 2005). (See Appendix III for a structural diagram of this compound.) It is also present in other plants of the Apiaceae family including celery and parsnip, as well as in some medicinal herbs of the Araliaceae family, such as ginseng root, *Panax ginseng* (Hansen et al. 2003). For this reason it is also known as panaxynol. It has been postulated by some researchers that various health benefits associated with carrots and attributed to β-carotene, may in fact be due to falcarinol. Similarly, the health effects of ginseng may in part be attributable to this compound (Hansen et al. 2003). Interestingly, although this compound is associated most strongly with carrots, a study identifying and quantifying polyacetylenes in the Apiaceae family showed that both parsnips and celery had higher levels (Zidorn et al. 2005). However, it is likely that carrots are a major source of dietary falcarinol because they are consumed relatively often, and in large amounts.

Falcarinol is sensitive to both heat and light. In the plant it appears to be evenly distributed throughout the whole root.

A number of compounds including eugenin, terpenoids, water soluble phenolics and particularly an isocoumarin called 6-methoxymellein, were initially thought to cause the bitter taste of some carrots (Czepa & Hofmann 2004). However, a recent study identified another polyacetylene, falcarindiol, (Z)-heptadeca-1, 9-dien-4,6-diyn-3,8-diol), as the major contributor to the bitter taste in carrots.

The upper end of the phloem was deemed to be more bitter than the lower end (and contained higher concentrations of falcarindiol) and removing the peel, as well as green and dark parts, removed much of the bitter taste (Czepa & Hofmann 2004). Heat processing in this study did not affect the taste components of the compound.

2.5 Health benefits

2.5.1 Core nutrients

The roles of core nutrients are outlined in Table 4 in Appendix II.

2.6 Phytochemicals

2.6.1 Carotenoids

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 (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 removal of pre-cancerous cells. However, results have been somewhat inconsistent. For example, although a review of case control studies looking at diet and breast cancer found a significant inverse association between β-carotene intake and breast cancer in 4 studies, 5 studies found no association and 7 studies found only a loose association, which was not statistically significant (Cooper et al. 1999). Similarly, although early studies observed a protective effect of β-carotene on lung cancer, more recent studies have found no significant association between dietary β-carotene intake and lung cancer risk. A study evaluating the effect of β-carotene supplements on lung cancer risk in smokers and other at-risk groups, found that the risk of developing lung cancer actually increased in those taking supplements. However, no such effect has been found in studies where the β-carotene was consumed as part of a food as opposed to a supplement form, where the compound has been isolated and concentrated. 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 hypothesized 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).

Carotemia is a condition arising from excessive intake of carotenoids in which high levels of β-carotene stored in the skin give it a yellowish appearance. The condition is harmless and disappears with lower consumption of carotenoid-rich foods.

α-carotene

α-carotene is less well-known and studied than β-carotene, but it has shown some promising results. Some studies have shown α-carotene to be even more effective than β-carotene at inhibiting cancer cells.

β-cryptoxanthin

This carotenoid is orange-yellow in colour and is found in various fruits and vegetables, including pumpkins. There are indications that it may play an important role in cardiac health.

Lutein and zeaxanthin

These two carotenoids are often grouped together as they have very similar structure and functions (see Appendix III for structure) and it is only relatively recently, with technology such as high performance liquid chromatography (HPLC), that it has been possible to differentiate between the two individual compounds. Lutein and zeaxanthin are essential for maintaining proper vision and may help to prevent macular degeneration and cataracts. They may also help reduce the risk of certain types of cancer. These pigments will be covered in greater detail in Section 3.

Falcarinol

Scientific research has only relatively recently focused on falcarinol. However, in the few studies undertaken to date it shows some promise in selected areas. As discussed earlier, whilst there are a number of polyacetylenes present in carrots, falcarinol has been shown to exhibit the most bioactivity, with pronounced cytotoxic effects against human tumor cells (Hansen et al. 2003; Brandt et al. 2004; Zidorn et al. 2005). At low concentrations, as would be available through normal dietary intake, falcarinol delayed or hindered the development of large, precancerous lesions and tumours in rats (Kobaek-Larsen et al. 2005). Together, these studies suggest that, besides the better-known carotenoids, falcarinol may contribute significantly to the health-promoting properties of carrots.

Falcarinol is a natural pesticide at high concentrations (Kobaek-Larsen et al. 2005) and polyacetylenes in general have potent antifungal and antibacterial properties (Zidorn et al. 2005). These attributes do not yet appear to have been investigated in terms of human health. Although falcarinol has been shown to be toxic at extremely high concentrations, to consume a fatal dose an estimated 400 kg carrots would have to be consumed over a short time frame (BBC News 2005). It is not unusual for plant constituents that have beneficial effects in normal quantities, to have detrimental effects in extremely high doses. The chemoprotective compound, sulphoraphane, found in broccoli is another such example. It would be almost humanly impossible to consume toxic quantities of these sorts of compounds as foods, or accidentally as part of a normal diet.

Phenolic compounds

The only flavonoid listed for carrots in the USDA flavonoid database is a small amount of quercetin. According to Joseph et al. (2002), carrots also contain apigenin and some phenolic acids, but Vinson et al. (1998) reported that carrots contained only low levels of phenolics.

2.7 Factors affecting health benefits

As explained in Section 2.2 above, a range of factors impact upon the composition of a food and thus the health benefits that it may deliver. Where information is available, this section deals with those factors as well as the issue of bioavailability.

2.7.1 Cultivar

Differences in the levels of some or all of the major bioactive compounds have been demonstrated in different cultivars of carrots in a number of studies (Hansen et al. 2003; Czepa & Hofmann 2004; Kidmose et al. 2004). Variation also occurred in some of the compounds, but not the major bioactives, in relation to the size of the root (Kidmose et al. 2004).

2.7.2 Storage and processing

Kidmose et al (2004) found that the carotenoid content appeared to be stable in carrots that had been stored raw and refrigerated for 4 months and those that had been raw frozen at -24° C for 4 months. It was suggested that the 4-month time frame was possibly not long enough for the enzyme responsible for carotenoid degradation to show an effect. Nor was there any significant difference in carotenoid levels between raw-frozen and steam-blanched-then-frozen carrots. The authors postulated that this was because the steam blanching process was relatively short and mild and thus did not markedly degrade the carotenoids, although it did make them more extractable. (Pre-freezing blanching is a common industrial process that aims to prevent the development of an off-taste brought about by the release of fatty acids (Hansen et al. 2003)).

In contrast to carotenoid levels, Kidmose et al. (2004) found polyacetylene levels to be significantly higher in refrigerated carrots than in frozen carrots. The authors suggested that this was the result either of polyacetylene production or slower degradation of these compounds. In this study, steam blanching resulted in a 50% loss of falcarinol, but after 4 months frozen storage was nonetheless higher in carrots that had been blanched before freezing than in those that had been raw frozen. However, Hansen et al. (2003) measured a 35% falcarinol loss through blanching, and observed similar falcarinol losses in both frozen blanched carrots and raw frozen carrots. Interestingly, falcarinol content in refrigerated carrots was relatively stable for 1 month post-harvest, after which there was a steady decline.

2.7.3 Growing conditions

Carrots have been found to contain an antifreeze protein which has been shown to positively affect storage performance. It was found that carrots grown in temperatures of less than 6°C accumulated higher levels of this protein and subsequently had less electrolyte leakage from cells, slightly higher dry matter and less fungal infestation than carrots grown in warmer temperatures (Galindo et al. 2004). Kidmose et al. (2004) also found that variation also occurred between growing locations.

2.7.4 *Bioavailability*

The area of bioavailability broadly addresses the issue of how well a compound is absorbed so that it can be utilised by the body. It involves the degree and rate at which a substance is absorbed into a living system or is 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.

2.7.5 *Carotenoids*

The large difference between the number 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 (green, leafy vegetables)
- dissolved in oil droplets in chromoplasts, which are readily extracted during digestion (mango, papaya, pumpkin and sweetpotato) (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 (Borel 2003). 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.

It should be noted that hydrocarbon carotenoids (e.g. β-carotene, lycopene) are absorbed differently from xanthophylls (e.g. lutein, zeaxanthin). Within the intestinal lumen, the non-polar carotenes are thought to locate in the hydrophobic core of lipid emulsions and bile salt micelles, whereas the more polar xanthophylls are thought to locate at the surface (Borel et al. 1996).

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 impacts upon 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 (West & Castenmiller 1998). Polyunsaturated fatty acid-rich dietary fat increases serum response to β-carotene more than does mono-unsaturated fatty acid-rich dietary fat. The solubility of β-carotene and zeaxanthin decreases with increased chain length in triglyceride fatty acids.

Protein present in the small intestine also assists absorption through the stabilisation of fat emulsions and enhanced micelle formation with associated carotenoid uptake (West & Castenmiller 1998). Lecithin may also promote the absorption of fat-soluble vitamins and carotenoids as well as triglycerides through facilitating micelle formation. Similarly, long-chain fatty acids which increase cholesterol absorption, may also increase the absorption of solubilised lipophilic phytochemicals (West & Castenmiller 1998).

Dietary fibre has a negative effect on β-carotene bioavailability. It is thought that fibre may entrap carotenoids and, through its interaction with bile acids, lead to increased excretion of bile acids. This, in turn, may result in a reduction in the absorption of fats and fat-soluble substances, including carotenoids (Yeum & Russell 2002). The presence of soluble fibre, in the form of citrus pectin, has been shown to reduce the increase in β-carotene absorption following ingestion of a β-carotene capsule (Rock & Swendseid 1992, cited in West & Castenmiller, 1998). Similarly, Hoffmann et al. (1999) showed that dietary fibre, pectin, guar and cellulose supplementation decreased antioxidant activity of a carotenoid and α-tocopherol mixture (Yeum & Russell 2002).

High bioavailability

Formulated carotenoids in water-dispersible beadlets (natural or synthetic)

Carotenoids – oil form (natural or synthetic)

Fruits (peach, apricot, melon)

Tubers (sweetpotato, yam, squash)

Processed juice with fat containing meal (e.g. tomato)

Lightly cooked yellow/orange vegetables (carrots, peppers)

Raw juice without fat (tomato)

Raw yellow/orange vegetables (carrots peppers)

Raw green leafy vegetables (spinach, silver beet)

Low bioavailability

Figure 1: Relative bioavailability of carotenoids according to food matrix (adapted from Boileau et al. 1998; Lister 2003)

2.7.6 *Falcarinol*

Further work needs to be done regarding the bioavailability of falcarinol as well as its possible direct effect upon the cells and tissues present in the human gut. That it is likely to be bioavailable is supported by a rat study showing rapid absorption by a closely related compound, panaxytriol (Hansen et al. 2003).

2.7.7 *Tips and quotes*

- “Eating a carrot a day is like signing a life insurance policy” – Irena Chalmers in The Great Food Almanac.
- Carrots should be eaten both raw and cooked. Whilst some nutrients may be lost in the cooking process, others are made more bioavailable. Including some form of oil in the meal will assist in absorbing the carotenoids.
- Providing they are stored appropriately, carrots should continue to provide good levels of nutrients for a reasonable length of time.

3 *Sweetcorn* (Zea mays)

3.1 *Introduction*

Sweetcorn belongs to the grass family and is the same species as field or dent corn (*Zea mays*). However, field corn is grown primarily as animal fodder or for cooking oil, whereas sweetcorn is produced primarily for human consumption. Field corn was purportedly grown in North America before 200 BC (Schultheis 1994) but sweetcorn is relatively new, arising from a mutation believed to have taken place in the 19th century (Peet 2003). This mutation at the sugary locus causes the endosperm in the kernel to accumulate roughly two times more sugar than field corn. It also has a thinner pericarp, making it more tender (Peet 2003). Once harvested though, the sugars in the kernel convert rapidly to starch, leading to a floury taste.

A number of genes affect sweetness in corn (oregonstate.edu 2002). These are recessive mutants of the starchy gene found in field corn (*Su*) and their modifiers, and other genes. Normal sweetcorn has the recessive mutant of field corn (*su*). Modifiers and other genes include the sugary-extender gene (*se*) and the supersweet or shrunken gene (*sh2*). These make up three major genetic classes of importance in commercial production:

- Normal sugary (*su*) corn is the standard corn grown for processing and much of the fresh market.
- Sugary-enhanced (*se*) corn results in slightly increased sugar levels. Kernels are very tender with good "corn" flavour.
- Supersweet or extra sweet (*sh2*) corn produces kernels with two to three times the complex sugars of the standard corn varieties. The texture is crispy rather than creamy as with the standard and enhanced varieties. Fresh market shelf life is extended because of the slower conversion of sugars to starch after harvest. Seed kernels are smaller, lighter in weight and shrunken in appearance (giving the gene the name "shrunken").

The three genetic classes mentioned above are categorised into six major sugar-mutant types and these may be represented by yellow, white, or bi-colour varieties. Other categories exist, such as decoratively coloured, or “Indian”, corn, but are not of commercial importance. Sweetcorn comes in variations of yellow and white and is sometimes bicoloured. There is no relationship between colour and sweetness, but, as will be discussed below, there is some correlation between colour and nutritional value.

3.1.1 *Composition*

See Section 2.2 regarding the large number of possible factors that can influence composition. Where data are available, the extent and effect of this variation will be discussed later in this section, under “Factors affecting health benefits”.

3.1.2 *Core nutrients*

Sweetcorn contains many nutrients including vitamin C (ascorbic acid), folate, zinc, iron, thiamine, riboflavin, selenium and potassium along with fibre, starch and protein (Athar et al. 2004). Interestingly, corn has more protein than many vegetables (Joseph et al. 2002). There appear to be few data that indicate a distinction between sweet and supersweetcorn.

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

3.1.3 *Other phytochemicals*

The most important phytochemicals identified to date in corn include the xanthophylls, lutein, zeaxanthin and cryptoxanthin, the carotenes α- and β-carotene, and phenolic compounds, primarily ferulic acid.

3.1.4 *Carotenes*

The main carotenes present in sweetcorn are β-carotene and α-carotene. (See Appendix III for structural diagrams of these compounds.) Corn also contains a variety of lesser known and less abundant carotenes including ζ-carotene, phytoene, phytofluene, α-zeacarotene and β-zeacarotene.

Xanthophylls (lutein and zeaxanthin)

Of the phytochemicals found in corn, those of most interest are lutein and zeaxanthin. (See Appendix III for structural diagrams of these compounds.) Esters of these compounds may also be present. Other xanthophylls present in sweetcorn include α-cryptoxanthin, β-cryptoxanthin, antheraxanthin, violaxanthin and neoxanthin. Some plants have a special biosynthetic capacity and produce carotenoids found almost exclusively in that genus or even species, although sometimes they have a slightly wider distribution. *Zea mays,* which contains zeinoxanthin, is one such species. Zeinoxanthin or α-cryptoxanthin, is the monohydroxy derivative of α-carotene. Other than in sweetcorn, it is only found in citrus, yellow peppers and squash (Gross 1991).

Levels of lutein and zeaxanthin in some common yellow/orange foods have been given in Table 1. Because of their similarity (and hence the difficulty in separating them by standard HPLC methods) the two compounds are often reported as a combined total, as is the case in the USDA carotenoid database used for Table 1. Corn does not contain extraordinarily high levels of lutein and zeaxanthin in comparison with some other foods, but it should be borne in mind that corn products are eaten with reasonable frequency in many households and this makes it an important dietary source of these compounds. It is interesting to note that boiled corn has higher levels of these compounds than raw corn.

In contrast to the combined lutein/zeaxanthin levels, which do not appear particularly high in corn, the level of zeaxanthin does appear to be higher than in most other fruit or vegetables.

3.1.5 Phenolic compounds

Phenolic compounds are a large group of secondary plant products that differ in chemical structure and reactivity. They are present in most, if not all, plants. The chemical structures range from quite simple compounds, like caffeic acid, to highly polymerised substances, like tannins. Their contribution to the pigmentation of plants is well recognised, although not all phenolics are coloured. There are numerous different groups of phenolics, but the most common phenolics found in foods generally belong to phenolic acids, flavonoids, lignans, stilbenes, coumarins and tannins (Harborne 1993). They are of interest primarily because of their radical scavenging and antioxidant activities, which are determined by their structure, particularly the number and configuration of H-donating hydroxyl groups (Soobrattee et al. 2005).

Vinson et al. (1998) reported that corn had a total phenolic content of 4.9 µmol/g FW (or 1.42 mg/g) and ranked fifth of 23 vegetables examined. In another study the total free phenolic content of raw sweetcorn was 250 µg/g, while the bound phenolic content was 470 µg/g (Dewanto et al. 2002).

Most of the phenolics in corn appear to be phenolic acids, predominantly ferulic acid, with smaller amounts of *p*-coumaric and syringic acids. In addition, isoquercitrin and quercetin 3-glucoside may be present (Harborne 1967).

Ferulic acid, 4-hydroxy-3-methoxy-cinnamic acid, is a phenolic compound present in many plants including rice, wheat, barley, oat, tomatoes, asparagus, peas and citrus fruits (Graf 1992). Its structure (see Appendix III), a phenolic nucleus with an extended conjugated side chain, confers significant antioxidant potential, enabling it to scavenge free radicals and suppress UV radiation-induced oxidative reactions.

In vegetables, most of the phenolics exist in free or soluble conjugate forms as glycosides (Vinson et al. 1998). In grains, however, phytochemicals exist in a combination of three forms: free, soluble conjugate, and insoluble bound forms, with a significant proportion in the latter form. A study examining the antioxidant activity of grains found that, of those studied, corn had the highest antioxidant activity and that bound phytochemicals were the major contributors to this activity (Adom & Liu 2002). About 74% of the phenolics were bound and about 87% of antioxidant activity came from bound compounds. Sosulski et al. (1982) also reported high levels of insoluble-bound phenolic acids in corn, constituting 69% of the total phenolic content. It is difficult to determine how relevant this is to sweetcorn because maturity has an impact upon phytochemical levels and sweetcorn is always eaten at an immature stage, in contrast to the mature grains examined in this study. Dewanto et al. (2002) researched the antioxidant activity of sweetcorn. They looked closely at the ferulic acid content and established that, in the raw state, by far the greatest amount was in a bound form. They also found that heat treatment released ferulic acid from the bound form to free ferulic acid and that antioxidant activity correspondingly increased.

3.2 Health benefits of sweetcorn

3.2.1 Core nutrients

The roles of core nutrients are outlined in Table 4 in Appendix II.

3.2.2 Other phytochemicals

The health benefits of α- and β-carotene have already been discussed in Section 2 above. The following sections focus primarily on the antioxidant benefits and health effects of lutein and zeaxanthin.

Antioxidant activity of sweetcorn

Several studies have examined the antioxidant activity of sweetcorn/maize, among other vegetables. Cao et al. (1996) gave corn an antioxidant score of 7.2 (based on ORAC scores with three different radicals), ranking it ninth of the 22 vegetables examined. On a fresh weight basis, corn ranked 13th in one study of 23 vegetables (Vinson et al. 1998). Halvorsen et al. (2002) reported an antioxidant activity of 0.19 mmol/100 g as measured by the FRAP assay; this value was relatively low compared to many other common vegetables (25th out of 32). The ORAC (oxygen radical absorbance capacity) of sweetcorn has been reported at 450 ORAC units, which is about the middle of the range for vegetables (Natural Food Hub 2003).

Carotenoids as antioxidants

Conjugated double bonds are highly effective in quenching singlet oxygen, and both lutein and zeaxanthin have the same high number of double bonds. However, zeaxanthin has an extra conjugated double bond. This conjugated double bond, compared with lutein’s allylic hydroxyl end group double bond, is potentially a more effective oxygen quencher (and hence, antioxidant).

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 them 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 there is a difficulty in carrying 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 occured 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 epidemiological 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 of 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.

Cancer

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 confer protection against diseases such as cancer and cardiovascular disease as well as positively affecting immune function.

One specific mechanism of cancer chemoprevention is the ability to induce detoxifying enzymes (Phase I and/or Phase II enzymes in liver and/or other organs (Talalay et al. 1995)). Interestingly, corn has shown Phase II enzyme-inducing activity (Wettasinghe et al. 2002). Few vegetables, apart from Brassicas, have this ability. Aqueous extracts of corn induced quinine reductase activity, an important Phase II enzyme, at rates of about 13-fold more than for kale.

Studies have shown that several carotenoids, both individually and in concert with others, can scavenge free radicals, be antimutagenic, prevent tumour development and assist immune function. Iannone et al. (1998) and Sujak et al. (1999) have shown that *in vitro*, lutein and β-carotene quench peroxyl radicals and exhibit antioxidant activity (cited in Mares-Perlman et al. 2002). It has also been found that carotenoids in combination appear to act synergistically, producing a greater effect than when acting alone. Stahl et al. (1998) found that lutein in combination with lycopene produced the greatest such effect. Synergistic effects such as these emphasise the advantages of foods, which contain a whole array of phytochemicals, over supplements, which contain a more limited number of components.

Two studies have considered the anticarcinogenic effects of lutein. It has been shown to counteract known mutagens, 1-nitropyrene and aflatoxin B1 (Gonzalez de Mejia et al. 1997) and in addition may stimulate certain protective genes (Park et al. 1998). Epidemiological research regarding the influence of these particular carotenoids on site specific cancers is relatively new and sparse. The most promising areas of research would appear to be in relation to skin cancer, in combination with other carotenoids (Slattery et al. 2000; Stahl et al. 2000) and breast cancer (Park et al. 1998; Sumantran et al. 2000; Freudenheim et al. 1996; Dorgan et al. 1998; Zhang et al. 1999; Toniolo et al. 2001, cited in Mares-Perlman et al. 2002). However, results are not clear, with some studies finding no associations and others reporting only inconsistent results. As is often the case in studies of fruit and vegetable compounds, it is uncertain whether the benefits are the result of the compounds themselves, or of some other component in the fruits and vegetables, whose role in human health is yet to be recognised.

Cardiovascular disease

As already discussed, a number of studies have established that lutein and other carotenoids have antioxidant properties. This has implications not only for cancer but also for the development of cardiovascular disease (CVD). Studies have found high serum levels of lutein and zeaxanthin to be associated with a reduced risk of coronary heart disease (Dwyer et al 2001; Irribaren et al. 1997). Additionally, the consumption of green leafy vegetables (which also contain lutein and zeaxanthin) was associated with a reduced incidence of stroke in the Nurse's Health and Health Professionals Follow-up study (Joshipura et al. 1999).

Immune function

There is a possibility that these xanthophylls may have immune-enhancing properties. One study showed an enhanced immune effect in cats, but there have been no human or epidemiological studies to investigate this further (Kim et al. 2000, cited in Mares-Perlman et al. 2002).

3.3 Factors affecting health benefits

As discussed in Section 2.2 above, a range of factors impact upon the composition of a food and thus the health benefits it may deliver. Where information is available, this section deals with those factors as well as the issue of bioavailability.

In addition, as mentioned earlier, in many databases all xanthophylls are combined to give only a total xanthophyll content. This should be borne in mind when comparing data.

3.3.1 Variety/cultivar

Hundreds of varieties of sweetcorn exist and information regarding the relative quantities of phytochemicals in each variety is very limited. One study by Lee et al. (1981) examining the provitamin A activity of several cultivars of sweetcorn, illustrates how nutrient levels may vary between cultivars (Table 2).

Table 2: Major provitamin A carotenoids (µg/100 g) in four cultivars of sweetcorn (adapted from Lee et al. 1981).

Carotenoid	Jubilee	Iosweet	70-2499	Stylpak
Hydrocarbon	89.0	41.4	45.0	45.6
Monohydroxy	98.5	92.7	101.6	89.5
Polyhydroxy	58.5	19.6	35.0	51.5
α-carotene	24.6	5.0	8.4	8.1
β-carotene	9.8	5.3	14.0	8.4
β-zeacarotene	15.7	16.8	14.5	17.0
γ-carotene	15.1	8.9	7.5	10.6
Zeinoxanthin	79.2	66.0	77.2	68.9
β-cryptoxanthin	18.9	18.3	15.1	18.4

A major study by Kurilich & Juvic (1999) included 44 genotypes chosen for a number of variables (each homozygous for one of four different endosperm carbohydrate mutations). Amongst these variables was that of kernel pigmentation – there is a recognised association between colour and carotenoid concentration. Of the genotypes selected on the basis of colour, it was established that the dark yellow kernels had the greatest total carotenoid content, followed by light yellow, orange and pale yellow. Those identified as having higher levels of carotenoids were largely, though not exclusively, *sh2* or supersweet lines. Interestingly, some of the lowest levels also belonged to this line.

Agronomic effects

Depending on location and variety, corn matures at around 18-24 days after pollination (Kurilich & Kuvik 1999). It is recommended that harvesting is carried out in the early morning or at night, as at this time the corn is cool and less additional cooling is needed to reduce the temperature to the optimal storage temperature of around 0°C (and relative humidity of around 95%). Rapid cooling to this temperature and maintaining it through transportation and appropriate storage is important in preserving sweetness and texture. It is also recommended that the cobs are closely trimmed, as the kernels lose moisture if long flags and shanks remain (Peet 2003).

Provitamin A carotenoids in raw corn from different geographical areas ranged from 0.6 to 2.1 µg/g FW and were higher in autumn varieties than in spring varieties (Klein & Perry 1982).

In a 3-year trial of organically and conventionally grown sweetcorn, no difference was found in the vitamin C or E content of kernels grown using either method in any year (Warman & Havard 1998). There were, however, some significant differences from year to year, with the same trends for both organically and conventionally grown crops.

Maturity

When carotenoid levels were tested at 18, 21, 24 and 27 days after pollination, Kurilich and Juvic (1999) found that the concentration of some, but not all, depended on the state of maturity. Their results indicated that β-cryptoxanthin and lutein levels tended to increase with age, but that there was no consistent change in zeaxanthin, α-carotene or β-carotene levels. There were substantial increases in γ-tocopherol as kernels matured (Kurilich & Juvik 1999).

Warman & Harvard (1998) examined the effect of harvest date on vitamin C content for a single cultivar (Sunnyvee). A large difference in ascorbic acid content of the kernels was observed from one week to the next (varying from 55 to 300 mg/kg FW).

3.4 Bioavailability

3.4.1 Carotenoids

A discussion of the general bioavailability of carotenoid compounds has already been covered in Section 2.4.2.

3.4.2 Phenolic compounds

There have been a few studies on the bioavailability of hydroxycinnamates, such as ferulic acid, although not specifically in sweetcorn. In general, results suggest that ferulic acid is more bioavailable than most other individual dietary flavonoids and phenolics so far studied (Bourne et al. 2000).

Ferulic acid is widely present in cereals. However, the cereal matrix appears to severely limit its bioavailability, at least for wheat (Adam et al. 2002). The inherently low bioavailability of ferulic acid in cereals probably reflects ferulic acid's association with the fibre fraction through cross-linking with arabinoxylans and lignins. Zhao et al. (2003) found the form of ferulic acid in the plant/diet affected its absorptivity, its absorption site, and its fate in the gastrointestinal tract. They also determined that microbial degradation in the gut may play an important role in bioavailability and the amount of microbial degradation depended on the form of ferulic acid. How ferulic acid bioavailability may be affected in fresh sweetcorn, especially once it has been cooked, remains to be seen. Since Dewanto et al. (2002) found that heat treatment reduced the amount of the bound form of ferulic acid and that antioxidant activity correspondingly increased, it is possible that bioavailability may also be enhanced by processing. This is similar to the situation with lycopene in tomatoes.

3.4.3 Tips and trivia

- Lutein and zeaxanthin are the most important compounds in corn in terms of potential health benefits. Although lutein is present in greater amounts, it is a ubiquitous compound, occurring in many fruits and vegetables and in reasonable amounts. Zeaxanthin, in contrast, is present in far fewer food sources and usually in much smaller amounts.

- Dietary sunglasses? Lutein and zeaxanthin appear to have unique functions in the macular luteum of the eye, where they may confer protection against oxidative damage from light. It is possible that they may also protect against other chronic diseases. Is corn an ear that helps you see?
- The average ear of corn has 800 kernels.

4 *Capsicum* (Capsicum annuum)

4.1 *Introduction*

Capsicums belong to the Solanaceae family, which also includes potatoes, tomatoes, petunias and deadly nightshade. Although there are about 26 species of this ”pepper”, most of these are wild, with cultivated varieties belonging to one of the five major groups:

- *Capsicum annuum*, including the Bell and Jalapeno varieties, a mild and sweet form, from which paprika is produced,
- *C. frutescans* including the Tabasco variety,
- *C. chinense*, including the Habanero variety,
- *C. baccatum*, including the Aji varieties
- C*. pubescans* including the Manzano variety.

In New Zealand, the most common of these are *C. annuum* and *C. frutescens*, although the diversification of culinary tastes and interest from gardeners has led to the availability of other varieties for niche uses both for food and as ornamental plants. However*, C. annuum* is the primary focus in this group for this report, as it is by far the most commonly grown commercially.

As the name suggests, *C. annuum* is an annual plant, grown in temperate regions and used mostly as a vegetable. The latter four varieties are grown in hotter regions as perennials – but can be grown in New Zealand where they tend to be cultivated as annuals – and are used more as spices. Capsicum fruit come in an assortment of colours, including red, orange, yellow and purplish black, and can be a multitude of shapes and sizes. In terms of taste, the plants originating from hotter regions seem to produce fruit with a hotter taste. It is also sometimes said that the smaller and thinner the pepper, the hotter it is.

It is generally believed that the greatest “heat” is in the seeds, though some sources state that it is contained in the “placenta” of the fruit, the tissue that attaches the seeds to the pod (Anon 2005). Although the degree of pungency in the fruit is sometimes erroneously linked to colour, “heat” in fact depends largely on the level of capsaicin, a phenolic substance (trans-8-methyl-N-vanillyl-6-nonemamide) not associated with colour. The pharma-cological and toxicological properties of this substance have been investigated in a number of experimental and clinical investigations (Suhr 2002). Naturally, since levels of this compound determine pungency, the *C. annuum* cultivars have lower concentrations than do fruits of *C. frutescens*, but do contain a similar compound.

Most popular information regarding the health effects of capsicum relate to hot or chilli peppers, with uses ranging from aiding digestion and circulation to alleviating pain, reducing flatulence and treating dropsy (Chevallier 1996). It has also been postulated that capsicums may be beneficial for cardiac health by preventing platelet aggregation (Wang et al., cited in Suhr 2002).

4.2 Composition

See Section 2.2 for a fuller explanation regarding factors that impact upon the composition of a food and thus the health benefits it may deliver.

A number of differently coloured capsicums are now available and this means that they contain different phytochemicals in the form of these pigments. Like other fruit, capsicums change colour as they ripen. Whether they end up red, yellow, orange or black, they all start off green.

4.2.1 Core nutrients

Capsicums are an exceptional source of vitamin C, with much more than the traditional vitamin C source, oranges. The ripe fruit also contain significantly more than unripe (170 mg vs 100 mg per 100 g fresh) (Athar et al. 2003).

See Appendix I for detailed data (including information on different cultivars) from the New Zealand database FOODfiles.

4.2.2 Other phytochemicals

The major phytochemicals present in capsicums include α-carotene, β-carotene, β-cryptoxanthin, lutein and zeaxanthin, lycopene, capsanthin, chlorophyll (green capsicum), capsaicin (hot varieties only), small amounts of the flavonoids quercetin and luteolin (USDA 2005, Marin et al. 2004) and other phenolic compounds known collectively as hydroxycinnamic acid derivatives (Marin et al. 2004). “Bell peppers” (maturity and cultivar unknown) posses only moderate levels of phenolic compounds according to Vinson et al. (1998).

4.3 Health benefits

4.3.1 Core nutrients

The roles of core nutrients are outlined in Table 4 in Appendix II.

4.3.2 Other phytochemicals

Carotenoids

Information regarding the phytochemical composition of yellow and orange capsicum cultivars is sparse. A study of β-carotene and total carotenoid content in an assortment of differently coloured capsicum fruit showed, surprisingly, that the two yellow cultivars contained not only very low levels of β-carotene, but also low levels of total carotenoids. The two orange varieties contained higher levels, but both were well below the average of those in red cultivars (Wall et al. 2001). The major carotenoids in yellow capsicums are β-carotene and lutein/zeaxanthin (Lee et al. 2005). These compounds are also present in red capsicum, and at generally much higher levels (Wall et al. 2001). The health benefits of these are discussed in general terms in Section 2.3.

As mentioned above, although they too contain α- and β-carotene, in fully mature red, ripe capsicum, capsanthin is the major carotenoid. Because this is a relatively uncommon compound and is relatively specific to capsicum species, there has been little research concerned specifically with capsanthin. However, a Japanese study investigating capsanthin isolated from paprika powder showed strong anti-tumour activity in an *in vitro* and *in vivo* mouse study (Maoka et al. 2001).

Capsaicin

The pharmacological and toxicological properties of capsaicin, the compound responsible for the heat of chilli-type peppers, have been investigated in a few experimental and clinical investigations (Suhr, 2002). Naturally, since levels of this compound determine pungency, *C. annuum* cultivars have lower concentrations than do fruits of *C. frutescens.* Instead *C. annuum* cultivars have a capsiate hydroderivative compound which shares some of capsaicin’s biological activities (Sancho et al. 2002). Much research has focused on the use of capsaicin to treat pain and inflammation, and there is at least one pharmaceutical preparation for this purpose.

Polyphenols

Many phenolics display antioxidant activity and thus may help reduce the risk of heart disease and certain types of cancer, but they may also have other health benefits. Capsicums contain the flavonoids quercetin and luteolin. Quercetin is the most widely studied as it is the predominant flavonoid found in foods (Cook & Samman 1996). It is most abundant in onions, kale, tea, apple skin, berries, broccoli, and lettuce.

Quercetin is a very strong antioxidant but it has also been found to reduce inflammation and inhibit the growth of certain cancer cells, as well as causing malignant cells to self-destruct, through a process called apoptosis (Joseph et al. 2002). Quercetin is also hypothesised to be effective in preventing atherosclerosis and thrombosis by protecting low density lipoproteins (LDL) against oxidation, as well as by lowering the cytotoxicity of oxidised LDL and platelet aggregation (Manach et al. 1998).

Chorophyll

Relatively little is known about the health effects of chlorophyll, the primary photosynthetic pigment and responsible for the green colour in plants and many algae. Some research suggests that it may be important in protecting against some forms of cancer, as, it is postulated, the chlorophyll binds to the mutant DNA and prevents it proliferating. A recent study suggests that chlorophyll has weak Phase II enzyme inducer potency, and although its activity is relatively weak compared with some other phytochemicals, because of its concentration in many of the plants we eat it may be responsible for some of the protective effects that have been observed with diets that are rich in green vegetables (Fahey et al. 2005).

4.4 Factors affecting health benefits

As discussed in Section 2.2, a range of factors impact upon the composition of a food and thus the health benefits it may deliver. Where information is available, this section deals with those factors as well as the issue of bioavailability.

4.4.1 Cultivar

Several studies have shown phytochemical levels to vary considerably between cultivars. Lee et al. (2005) investigated differences in β-carotene, lutein, zeaxanthin, quercetin and luteolin content and found colour-related variations as well as differences between the *C. annuum* and *C. chinense* samples. Howard et al. (1994) found that provitamin A activity ranged from 27.3 to 501.9 retinol equivalents (RE/100g) and that vitamin C ranged from 76.1 to 243.1 mg/100g in assorted mature cultivars. Wall et al. (2001), Russo & Howard (2002) and Lee et al. (2005) all reported a wide variation for both β-carotene and total carotenoid levels. The latter study also looked at levels of the other major carotenoids in capsicum and found a similarly wide range.

4.4.2 Growing conditions

A study comparing individual carotenoids found significantly higher levels in glasshouse-grown capsicums than in those grown in the field (Russo & Howard 2002). Wall et al. (2001) also observed substantial differences in β-carotene and total carotenoid levels in the same cultivars grown in the same location over two successive seasons. It was postulated that this was the result of different climatic conditions. Whilst temperatures were similar during the growth period of both seasons, they averaged 3°C cooler in the two months prior to harvest when the fruit were ripening and accumulating pigment, and this resulted in lower levels of carotenoids. Lee et al. (2005) also reported variations between two different growing locations.

4.4.3 *Maturity*

The maturity of capsicums has been shown to strongly influence phytochemical concentrations. Howard et al. (1994) found that both vitamin C and provitamin A activity increased with maturity in all cultivars. Phenolic compounds such as flavonoids and hydroxycinnamic acid derivatives were generally at much higher concentrations in immature and unripe peppers than in mature red peppers, which had higher concentrations of vitamin C and carotenoids. Marin et al. (2004) found four times the total carotenoid levels in mature red peppers than in immature green fruit, with xanthophyll and capsanthin the predominant carotenoids. Mature red peppers also had the highest levels of provitamin A activity and the highest concentrations of β-carotene and β-cryptoxanthin (Marin et al. 2004). This study also found that phenolic compounds were contained largely in the peel. A study investigating β-carotene and total carotenoid content in a variety of capsicum species and cultivars, showed, perhaps surprisingly, that red cultivars not only had higher levels of total carotenoids than the yellow and orange cultivars tested, but also tended to have higher levels of β-carotene (Wall et al. 2001).

4.4.4 *Bioavailability*

The general bioavailability of carotenoids has been covered in Section 2.4.2. Section 3.4.2 discusses the bioavailability of hydroxycinnamic acid and ferulic acid.

Quercetin bioavailability has been shown to be affected by the food matrix, though it is also thought to be influenced by the particular sugars that are attached to the quercetin molecule (Hollman et al. 1997b). Originally, the absorption of flavonols from the diet was considered to be negligible due to the fact that they were bound to sugars (glycosides) present in plants. It was thought that only aglycones were absorbed. However, this view has since been discounted with various studies showing greater, and faster, absorption of quercetin glucoside than aglycones or quercetin rutinoside (rutin) (Hollman et al. 1995; Hollman & Katan 1997; Hollman & Katan 1999). Additionally, absorption was better from some food sources than from others. For example, Hollman et al. (1997a) found that in humans quercetin compounds from onions (quercetin glucosides) were better absorbed than those from apples (quercetin glucosides and galactosides) or from pure rutin (quercetin rutinoside). In a rat trial, the quercetin aglycone was absorbed more quickly than rutin (Manach et al. 1997).

Even though flavonoid glycosides have less free radical quenching ability than aglycones *in vitro*, it appears that the presence of glycosides (in particular, glucosides) enables their hydrolysation to aglycone and subsequent absorption, thus rendering them more bioavailable.

4.4.5 *Tips and trivia*

- Capsicums have some of the highest levels of vitamin C of all vegetables.
- Cooking will reduce the amount of vitamin C, but will increase the bioavailibility of carotenoids.
- Red peppers generally have much higher levels of both vitamin C and carotenoids than immature or yellow or orange types. Immature green peppers have higher levels of flavonoids.

5 *Pumpkin (*Cucurbita *spp)*

5.1 *Introduction*

A pumpkin or a squash? Pumpkins belong to the squash family Cucurbitaceae which also includes cucumber, gourd, and melons. The vegetables that are generally considered “pumpkins” in New Zealand are hard skinned, hard fleshed mature fruit, generally harvested in autumn. In the United States and some other countries these are known as “winter squash”, in contrast to the likes of zucchini, scaloppini and marrow, which are termed “summer squash”. The term “pumpkin” seems to be used in those parts of the world solely for the types of squash that are carved to make Jack O’ Lanterns at Halloween. These are fibrous, have a large seed cavity and are not used for eating.

It is ironic that although squash originated in the Americas, in the area between Guatemala and Mexico, in the US they are only rarely consumed as a food. It is estimated that only 1% of the annual crop is used as a food. By far the vast majority is grown for decorative purposes, including the making of Jack O’ Lanterns. The British also make little use of this vegetable, eating it mostly in the form of pumpkin pie or as an extender in products such as jams. In New Zealand pumpkins are available year round and are eaten in an assortment of dishes, forming an integral part of our diet. Despite this, the majority of the crop is exported, mostly to Japan. Kabucha (meaning “sweet mama”), a kind of buttercup squash, is one of the favourite varieties in Japan.

5.2 *Composition*

See Section 2.2 regarding the large number of possible factors that can influence composition. Where data are available, the extent and effect of this variation will be discussed later in this section, under “Factors affecting health benefits”.

5.2.1 *Core nutrients*

Pumpkins are an excellent source of vitamin A, containing high levels of provitamin A, the carotenoids α- and β-carotene, as well as β-cryptoxanthin. Some vitamin C, potassium and fibre are also present in pumpkins. See

Appendix I for detailed data (including information on different cultivars) from the New Zealand database FOODfiles,

Perhaps surprisingly, pumpkin is relatively low in calories. Although pumpkins contain more energy than carrots, they contain fewer calories than other vegetables with similar cooking uses and textures. It is also versatile, being used in both sweet and savoury dishes.

Table 3: Energy content of selected vegetables (per 100 g raw, fresh sample) (Athar et al. 2004)

Vegetable	Energy (kcal)
Carrot	18
Corn	115
Kumara	108
Parsnip	54
Potatoes	72
Pumpkin	31

5.2.2 *Other phytochemicals*

Pumpkins contain excellent levels of both α- and β-carotene (see Section 2), and lutein and zeaxanthin (see Section 3). In addition, they are one of the richest sources of β-cryptoxanthin, a phytochemical more commonly found in fruits. (Dragovic-Uzelac et al. 2005) found the major phenolic compound in pumpkin was chlorogenic acid, though neither Joseph (2002) nor Pratt & Matthews (2004) mention it.

5.3 *Health benefits*

There have been few studies examining the health benefits of these vegetables. This is not because they are nutritionally worthless, but rather, reflects the fact that for some reason they are not particularly popular in the USA or Europe.

The health benefits of the major phytochemicals present in pumpkins have already been covered in Sections 2 and 3.

Chlorogenic acid has been found to have some antioxidant/radical quenching activity. In particular it is believed to help combat the effects of carcinogenic nitrosamines, such as those in some processed meats and cigarette smoke (Joseph et al. 2002).

5.3.1 *Factors affecting health benefits*

As discussed in Section 2.2 a range of factors impact upon the composition of a food and thus the health benefits it may deliver. Where information is available, this section deals with those factors as well as the issue of bioavailability.

5.3.2 *Cultivar*

(Murkovic et al. 2002) found considerable variation in phytochemical levels between cultivars when they analysed a range of produce in the Austrian market. They found that high carotene levels were present in the more orange-coloured fruit but that high levels of lutein/zeaxanthin and lower levels of the carotenes were present in fruit of a bright yellow colour. For 100 g of fresh product, β-carotene levels ranged from 0.6 to 7.4 mg; α-carotene from undetectable to 7.5 mg; and lutein/zeaxanthin from undetectable to 17 mg. Generally β-carotene was the most abundant carotenoid, though in the *Cucurbita maxima* types, which are commonly grown in New Zealand and include the cultivars kumi kumi, Whangaparoa crown and triamble, lutein was the major carotenoid.

5.3.3 *Bioavailability*

Bioavailability has already been discussed in Sections 2.4.2 and 3.4.2. It would be expected that cooking would increase the bioavailability of pumpkin carotenoids as it does with carrots, since the food matrix is similar.

5.4 *Tips and trivia*

- The brighter and stronger the colour of the flesh, the more carotenoids the pumpkin will contain.
- Pumpkin is surprisingly low in calories and thus a good alternative for more starchy, energy dense vegetables such as potatoes and kumara.
- It can be used in both savoury and sweet dishes.
- The name “squash” is derived from the Native American word, askutasquash.
- Q: What is pumpkin pi? A: What you get if you divide the circumference of a pumpkin by its diameter.

6 *Cantaloupe and other melons:* Cucumis melo *(melon);* Citrullus lanatus *(watermelon)*

6.1 Introduction

Like pumpkins, melons belong to the Cucurbitaceae family and include cantaloupe, also known as rockmelon or muskmelon. They are a multi-coloured family, with flesh that can be red, orange, green or white, and vary in size and shape from huge to small and from round to cylindrical. Some, including cantaloupe and pumpkin, contain their seeds in an internal cavity, whilst others, such as watermelon and cucumbers, have their seeds dispersed throughout the flesh. The focus in this report will be on orange-fleshed types.

6.2 Composition

See Section 2.2 regarding the large number of possible factors that can influence composition. Where data are available, the extent and effect of this variation will be discussed later in this section, under “Factors affecting health benefits”.

Melons contain large amounts of water, which accounts for their refreshing taste and their low energy content. More comprehensive detail from New Zealand data on assorted varieties is contained in Appendix I.

6.2.1 Core nutrients

Despite their high water content, melons have high levels of vitamin C and moderate amounts of potassium. Orange varieties also contain β-carotene which is converted to vitamin A in the body.

6.2.2 Other phytochemicals

Carotenoids

As its orange flesh would indicate, cantaloupe contains good amounts of β-carotene, its major phytochemical (see Table 1). Watermelon, with its red flesh, contains a different carotenoid pigment, lycopene.

Phenolics

Vinson et al. (2001) found cantaloupe, honeydew and watermelon all contained phenolic compounds, although they did not specify which ones. Honeydew and cantaloupe were at the lower end of the range, whereas watermelon was in the moderate to high range. Another study, which included only honeydew, found it to have the lowest antioxidant capacity of the 14 popular fruits investigated (Chun et al. 2005). Similarly, Pellegrini et al.

(2003) and Wu et al. (2004) found all three types to have amongst the lowest antioxidant activity levels of a larger selection of popular fruits. These results are somewhat perplexing, given that both cantaloupe and watermelon contain reasonable levels of β-carotene and lycopene respectively, both of which have demonstrated antioxidant activity in other studies.

Note: Lycopene is the same pigment that makes tomatoes red and has been of considerable interest to researchers in terms of preventing a number of cancers – in particular, prostate cancer. Because it has strong antioxidant activity it is also thought to aid in the prevention of heart disease, as well as other conditions such as diabetes and eye disease. It also appears to have good bioavailability. For example, Edwards et al. (2003) found the bioavailability of lycopene from red watermelon juice was similar to that found in tomato juice. In a study of Chinese men, Jian et al. (2005) found that the risk of prostate cancer declined with increasing intake of both cooked tomatoes and watermelon.

As explained in Section 2.4.2 carotenoids from a raw source are generally less bioavailable than those from a cooked source. However, this was not borne out in the study above, where lycopene was well absorbed from both (raw) watermelon juice and (processed/heated) tomato juice (Edwards et al. 2003). This may be because the soft texture of its food matrix does not hinder absorption.

The health benefits of lycopene are covered in considerable detail in Hedges and Lister (2005).

6.3 Factors affecting health benefits

As discussed in Section 2.2, a range of factors impact upon the composition of a food and thus the health benefits it may deliver. Where information is available, this section deals with those factors as well as the issue of bioavailability.

6.3.1 Variety/cultivar

The different flesh-colours of these fruits indicate different kinds of pigment phytochemicals, with some varieties, such as honeydew, appearing to lack any such pigments. This might explain their low antioxidant activity rating. Beyond this, no specific data has been found in this area.

6.3.2 Bioavailability

β-carotene is the major phytochemical present in cantaloupe and its bioavailability is covered in Section 2.4.2.

6.3.3 Tips and trivia

- "Success to me is having ten honeydew melons, and eating only the top half of each one." Barbra Streisand.
- "Watermelon – it's a good fruit. You eat, you drink, you wash your face." Enrico Caruso.

- "The true Southern watermelon is a boon apart, and not to be mentioned with commoner things. It is chief of this world's luxuries, king by the grace of God over all the fruits of the earth. When one has tasted it, he knows what the angels eat. It was not a Southern watermelon that Eve took; we know it because she repented." Mark Twain (1835-1910).

7 *Orange-fleshed kumara (*Ipomea batatas *cv. Beauregard)*

Kumaras will be covered in detail in a future report focusing on root vegetables, but it is appropriate to make mention of orange-fleshed kumara here. No information specific to Beauregard kumara has been found. However, this cultivar is an American variety and consequently is likely to be similar to data on the American database for sweet potato. The data contained in Table 1 show how sweet potato has the highest β-carotene content of all the vegetables, though few other carotenoids. Although it is unknown how the samples evaluated for the USDA compare with the New Zealand-grown Beauregard cultivar, it is likely that Beauregard kumara also has high levels of β-carotene, with some also in the skin. It is likely that the health benefits ascribed to β-carotene in Section 1 would be relevant to this vegetable cultivar.

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Appendices

Appendix I

Nutritional information on assorted yellow/orange vegetables (per 100 g edible portion) from FOODFiles 2004

X31~Carrot,flesh,raw~CARROT~~~Flesh~Raw~~~~Daucus~carota~~		
Water	g	90.1
Energy	kcal	18
Protein	g	0.6
Total fat	g	0.2
Carbohydrate, available	g	3.49
Dietary fibre (Englyst, 1988)	g	3.2
Ash	g	0.8
Sodium	mg	27
Phosphorus	mg	26
Potassium	mg	340
Calcium	mg	30
Iron	mg	0.2
Beta-carotene equivalents	µg	6160
Total vitamin A equivalents	µg	1030
Thiamin	mg	0.034
Riboflavin	mg	0.013
Niacin	mg	0.55
Vitamin C	mg	7
Cholesterol	mg	0
Total saturated fatty acids	g	0.044
Total monounsaturated fatty acids	g	0.012
Total polyunsaturated fatty acids	g	0.113
Dry matter	g	9.93
Total nitrogen	g	0.09
Glucose	g	0.9
Fructose	g	0.8
Sucrose	g	1.55
Lactose	g	T
Maltose	g	T
Total available sugars	g	3.25
Starch	g	0.24
Alcohol	g	0
Total niacin equivalents	mg	0.65
Soluble non-starch polysaccharides	g	1.6

Insoluble non-starch polysaccharides	g	1.6
Energy	kJ	75
Magnesium	mg	10
Manganese	µg	160
Copper	mg	0.04
Zinc	mg	0.18
Selenium	µg	0.3
Retinol	µg	0
Potential niacin from tryptophan	mg	0.1
Vitamin B6	mg	0.012
Folate, total	µg	12
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.84

T = trace

X272~Capsicum,Red,raw~CAPSICUM~RED~~~Raw~~~~~~~		
Water	g	91.1
Energy	kcal	35
Protein	g	1.7
Total fat	g	0.2
Carbohydrate, available	g	6.7
Dietary fibre (Englyst, 1988)	g	1.6
Ash	g	0.3
Sodium	mg	1
Phosphorus	mg	34
Potassium	mg	180
Calcium	mg	2
Iron	mg	0.3
Beta-carotene equivalents	µg	1470
Total vitamin A equivalents	µg	245
Thiamin	mg	0.04
Riboflavin	mg	0.05
Niacin	mg	1
Vitamin C	mg	170
Cholesterol	mg	0
Total saturated fatty acids	g	0
Total monounsaturated fatty acids	g	0
Total polyunsaturated fatty acids	g	0
Dry matter	g	8.9
Total nitrogen	g	0.29
Glucose	g	2.5
Fructose	g	3.6
Sucrose	g	T
Lactose	g	0
Maltose	g	0
Total available sugars	g	6.1
Starch	g	0
Alcohol	g	0
Total niacin equivalents	mg	1.2
Soluble non-starch polysaccharides	g	1.3
Insoluble non-starch polysaccharides	g	0.3
Energy	kJ	146
Magnesium	mg	2

Manganese	µg	T
Copper	mg	0.01
Zinc	mg	0.4
Selenium	µg	T
Retinol	µg	0
Potential niacin from tryptophan	mg	0.2
Vitamin B6	mg	0.36
Folate, total	µg	21
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.8

T = trace

X44~Corn,Sweet,kernels,raw~CORN~SWEET~On cob~Kernel~Raw~~~~Zea~mays~~		
Water	g	68
Energy	kcal	115
Protein	g	3.8
Total fat	g	2.21
Carbohydrate, available	g	19.9
Dietary fibre (Englyst, 1988)	g	2
Ash	g	0.7
Sodium	mg	6
Phosphorus	mg	76
Potassium	mg	249
Calcium	mg	3.68
Iron	mg	0.24
Beta-carotene equivalents	µg	176
Total vitamin A equivalents	µg	29
Thiamin	mg	0.04
Riboflavin	mg	0.074
Niacin	mg	0.9
Vitamin C	mg	11.1
Cholesterol	mg	0
Total saturated fatty acids	g	0.3
Total monounsaturated fatty acids	g	0.54
Total polyunsaturated fatty acids	g	0.91
Dry matter	g	32.1

Total nitrogen	g	0.61
Glucose	g	0.9
Fructose	g	0.2
Sucrose	g	0.4
Lactose	g	0
Maltose	g	0
Total available sugars	g	1.5
Starch	g	18.4
Alcohol	g	0
Total niacin equivalents	mg	1.3
Soluble non-starch polysaccharides	g	0.1
Insoluble non-starch polysaccharides	g	1.9
Energy	kJ	475
Magnesium	mg	22
Manganese	µg	185
Copper	mg	0.07
Zinc	mg	1.09
Selenium	µg	0.256
Retinol	µg	0
Potential niacin from tryptophan	mg	0.405
Vitamin B6	mg	0.05
Folate, total	µg	48
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.2

T = trace

X111~Pumpkin,combined cultivars,flesh,raw~PUMPKIN~~Combined cultivars~Flesh~Raw~~~~Cucurbita~maxima~crown~		
Water	g	89.5
Energy	kcal	31
Protein	g	0.97
Total fat	g	0.26
Carbohydrate, available	g	6.2
Dietary fibre (Englyst, 1988)	g	2.7
Ash	g	0.69
Sodium	mg	2.01
Phosphorus	mg	22.7
Potassium	mg	315
Calcium	mg	20.7
Iron	mg	0.31
Beta-carotene equivalents	µg	3530
Total vitamin A equivalents	µg	589
Thiamin	mg	0.029
Riboflavin	mg	0.004
Niacin	mg	0.203
Vitamin C	mg	18.1
Cholesterol	mg	0
Total saturated fatty acids	g	0.157
Total monounsaturated fatty acids	g	0.039
Total polyunsaturated fatty acids	g	0.015
Dry matter	g	10.5
Total nitrogen	g	0.16
Glucose	g	1.48
Fructose	g	1.22
Sucrose	g	1.44
Lactose	g	0
Maltose	g	0
Total available sugars	g	4.1
Starch	g	2.03
Alcohol	g	0
Total niacin equivalents	mg	0.4
Soluble non-starch polysaccharides	g	1.03
Insoluble non-starch polysaccharides	g	1.67
Energy	kJ	128

Magnesium	mg	12.8
Manganese	µg	63.3
Copper	mg	0.066
Zinc	mg	0.15
Selenium	µg	0.198
Retinol	µg	0
Potential niacin from tryptophan	mg	0.2
Vitamin B6	mg	0.064
Folate, total	µg	13
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	1.06

T = trace

X108~Pumpkin,Kumi Kumi,flesh,raw~PUMPKIN~KUMI KUMI~~Flesh~Raw~~~~Cucurbita~maxima~~		
Water	g	92.5
Energy	kcal	19
Protein	g	0.74
Total fat	g	0.19
Carbohydrate, available	g	3.7
Dietary fibre (Englyst, 1988)	g	1.94
Ash	g	0.59
Sodium	mg	1.25
Phosphorus	mg	23.8
Potassium	mg	256
Calcium	mg	18.8
Iron	mg	0.34
Beta-carotene equivalents	µg	494
Total vitamin A equivalents	µg	82
Thiamin	mg	0.028
Riboflavin	mg	0.003
Niacin	mg	0.167
Vitamin C	mg	21.3
Cholesterol	mg	0
Total saturated fatty acids	g	0.113
Total monounsaturated fatty acids	g	0.028
Total polyunsaturated fatty acids	g	0.011
Dry matter	g	7.53

Total nitrogen	g	0.12
Glucose	g	0.99
Fructose	g	0.82
Sucrose	g	0.58
Lactose	g	0
Maltose	g	0
Total available sugars	g	2.4
Starch	g	1.32
Alcohol	g	0
Total niacin equivalents	mg	0.4
Soluble non-starch polysaccharides	g	0.74
Insoluble non-starch polysaccharides	g	1.2
Energy	kJ	81
Magnesium	mg	13.6
Manganese	µg	87.2
Copper	mg	0.052
Zinc	mg	0.19
Selenium	µg	0.2
Retinol	µg	0
Potential niacin from tryptophan	mg	0.2
Vitamin B6	mg	0.016
Folate, total	µg	13
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	1.06

T = trace

X109~Pumpkin,Triamble,flesh,raw~PUMPKIN~TRIAMBLE~~Flesh ~Raw~~~~Cucurbita~maxima~~		
Water	g	87
Energy	kcal	42
Protein	g	1.13
Total fat	g	0.4
Carbohydrate, available	g	8.5
Dietary fibre (Englyst, 1988)	g	3.36
Ash	g	0.74
Sodium	mg	1.43
Phosphorus	mg	21
Potassium	mg	359

Calcium	mg	18.9
Iron	mg	0.3
Beta-carotene equivalents	µg	6180
Total vitamin A equivalents	µg	1030
Thiamin	mg	0.029
Riboflavin	mg	0.005
Niacin	mg	0.268
Vitamin C	mg	14.2
Cholesterol	mg	0
Total saturated fatty acids	g	0.239
Total monounsaturated fatty acids	g	0.06
Total polyunsaturated fatty acids	g	0.023
Dry matter	g	13.1
Total nitrogen	g	0.18
Glucose	g	1.97
Fructose	g	1.63
Sucrose	g	2.11
Lactose	g	0
Maltose	g	0
Total available sugars	g	5.7
Starch	g	2.77
Alcohol	g	0
Total niacin equivalents	mg	0.5
Soluble non-starch polysaccharides	g	1.28
Insoluble non-starch polysaccharides	g	2.07
Energy	kJ	174
Magnesium	mg	11.4
Manganese	µg	50.1
Copper	mg	0.059
Zinc	mg	0.22
Selenium	µg	0.2
Retinol	µg	0
Potential niacin from tryptophan	mg	0.2
Vitamin B6	mg	0.122
Folate, total	µg	13
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	1.06

T = trace

X192~Squash,Buttercup,flesh,raw~SQUASH~BUTTERCUP~~ Flesh~Raw~~~~~~~		
Water	g	83.7
Energy	kcal	52
Protein	g	1.39
Total fat	g	0.22
Carbohydrate, available	g	11.2
Dietary fibre (Englyst, 1988)	g	1.03
Ash	g	0.81
Sodium	mg	0.79
Phosphorus	mg	31
Potassium	mg	471
Calcium	mg	17.9
Iron	mg	0.66
Beta-carotene equivalents	µg	3180
Total vitamin A equivalents	µg	530
Thiamin	mg	0.079
Riboflavin	mg	0.005
Niacin	mg	0.411
Vitamin C	mg	25.5
Cholesterol	mg	0
Total saturated fatty acids	g	0.051
Total monounsaturated fatty acids	g	0.019
Total polyunsaturated fatty acids	g	0.105
Dry matter	g	16.3
Total nitrogen	g	0.22
Glucose	g	2.44
Fructose	g	2.35
Sucrose	g	T
Lactose	g	0
Maltose	g	0
Total available sugars	g	4.8
Starch	g	6.35
Alcohol	g	0
Total niacin equivalents	mg	0.7
Soluble non-starch polysaccharides	g	0.36
Insoluble non-starch polysaccharides	g	0.67

Energy	kJ	215
Magnesium	mg	9.5
Manganese	µg	40
Copper	mg	0.058
Zinc	mg	0.2
Selenium	µg	T
Retinol	µg	0
Potential niacin from tryptophan	mg	0.3
Vitamin B6	mg	0.099
Folate, total	µg	50
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	1.83

T = trace

X119~Squash,Butternut,flesh,raw~SQUASH~BUTTERNUT~~ Flesh~Raw~~~~Cucurbita~maxima~~		
Water		
Energy	g	86.4
Protein	kcal	44
Total fat	g	1.34
Carbohydrate, available	g	0.12
Dietary fibre (Englyst, 1988)	g	9.5
Ash	g	1.6
Sodium	g	0.77
Phosphorus	mg	1.5
Potassium	mg	23.3
Calcium	mg	342
Iron	mg	20.2
Beta-carotene equivalents	mg	0.35
Total vitamin A equivalents	µg	3470
Thiamin	µg	579
Riboflavin	mg	0.076
Niacin	mg	0.004
Vitamin C	mg	0.409
Cholesterol	mg	20
Total saturated fatty acids	mg	0
Total monounsaturated fatty acids	g	0.029

Total polyunsaturated fatty acids	g	0.011
Dry matter	g	0.06
Total nitrogen	g	13.6
Glucose	g	0.22
Fructose	g	2.1
Sucrose	g	2
Lactose	g	0.2
Maltose	g	0
Total available sugars	g	0
Starch	g	4.3
Alcohol	g	5.21
Total niacin equivalents	g	0
Soluble non-starch polysaccharides	mg	0.7
Insoluble non-starch polysaccharides	g	0.7
Energy	g	0.9
Magnesium	kJ	184
Manganese	mg	16.1
Copper	µg	63.5
Zinc	mg	0.053
Selenium	mg	0.17
Retinol	µg	0.544
Potential niacin from tryptophan	µg	0
Vitamin B6	mg	0.3
Folate, total	mg	0.088
Vitamin B12	µg	22
Vitamin D	µg	0
Vitamin E	µg	0

T = trace

L104~Melon,Cantaloupe,flesh,fresh~MELON~CANTALOUPE~~ Flesh~Fresh~~~~Cucumis~melo~cantaloupensis~		
Water	g	93.6
Energy	kcal	26
Protein	g	1
Total fat	g	0.1
Carbohydrate, available	g	5.2
Dietary fibre (Englyst, 1988)	g	0.81
Ash	g	0.7
Sodium	mg	14
Phosphorus	mg	30
Potassium	mg	320
Calcium	mg	19
Iron	mg	0.3
Beta-carotene equivalents	µg	951
Total vitamin A equivalents	µg	159
Thiamin	mg	0.05
Riboflavin	mg	0.03
Niacin	mg	0.5
Vitamin C	mg	25
Cholesterol	mg	0
Total saturated fatty acids	g	T
Total monounsaturated fatty acids	g	T
Total polyunsaturated fatty acids	g	T
Dry matter	g	6.4
Total nitrogen	g	0.16
Glucose	g	1.4
Fructose	g	2.5
Sucrose	g	1.3
Lactose	g	0
Maltose	g	0
Total available sugars	g	5.2
Starch	g	0
Alcohol	g	0
Total niacin equivalents	mg	0.5
Soluble non-starch polysaccharides	g	0.24
Insoluble non-starch polysaccharides	g	0.57
Energy	kJ	106

Magnesium	mg	12
Manganese	µg	30
Copper	mg	0.04
Zinc	mg	0.1
Selenium	µg	0.1
Retinol	µg	0
Potential niacin from tryptophan	mg	T
Vitamin B6	mg	0.07
Folate, total	µg	30
Vitamin B12	µg	0
Vitamin D	µg	0
Vitamin E	mg	0.1

T = trace

Appendix II

Table 4: Activities of vitamins and minerals (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 1IU = 0.3 mcg or 3.33 mcg = 1 mcg retinol = 1RE	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 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 includingt 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
Vitamin C Ascorbic acid	Neccesary 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

Name	Major Function
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, haemoglobin synthesis. Involved in neuronal excitation Reduces blood homocysteine levels Prevents megaloblastic anemia
Vitamin B_{12} Cobalamin	Coenzyme in DNA synthesis with folate. Synthesis and manitenance of myelin nerve sheaths Involved in the formation of red blood cells 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, cellular energy metabolism pH regulation Major ion of intracellular fluid and constuent 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, 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, needed for oxygen transport Role in cellular function and respiration

Iodine	Thyroid hormone production
Chromium	Assists in insulin system for use of blood glucose
Cobalt	Component of vitamin B_{12}
Copper	Component of many enzymes Many functions – blood and bone formation, production of pigment melanin Aids in utilisation 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 defense system as component of key enzymes May help prevent cancer and cardiovascular disease
Zinc	Major role in immune system Required for numerous enzymes involved in growth and repair Involved in sexual maturation Role in taste, smell functions

Note: This table is compiled and adapted from: Groff JL, Gropper SS. *Advanced nutrition and human metabolism*. 3rd ed. Belmont, CA: Wadsworth/Thomson Learning 1999.; Wardlaw GM. *Perspectives in Nutrition*. 4th ed. Boston, Mass: WCB/McGraw Hill, 1999; and *Dietary Reference Intakes: Vitamins* Available at: www.nap.edu.

Appendix III

Chemical structures of major phytochemicals in yellow/orange vegetables

Figure 2: β-carotene.

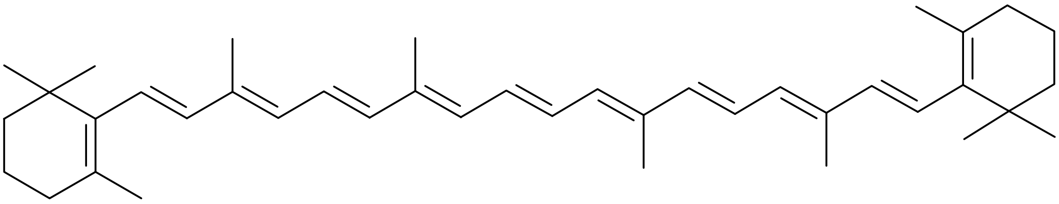

Figure 3: α-carotene.

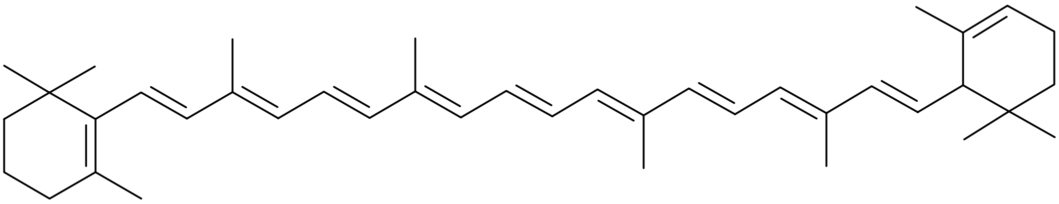

Figure: β-cryptoxanthin.

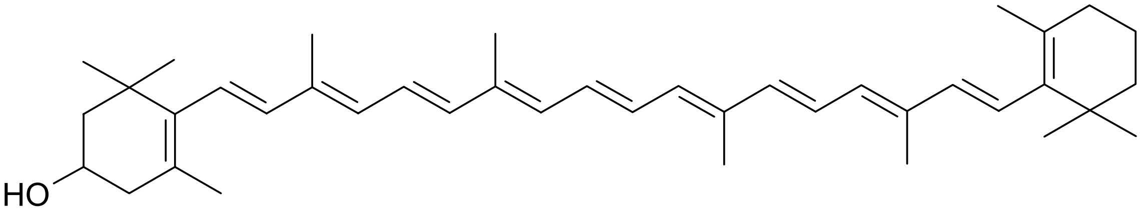

Figure 5: Lutein.

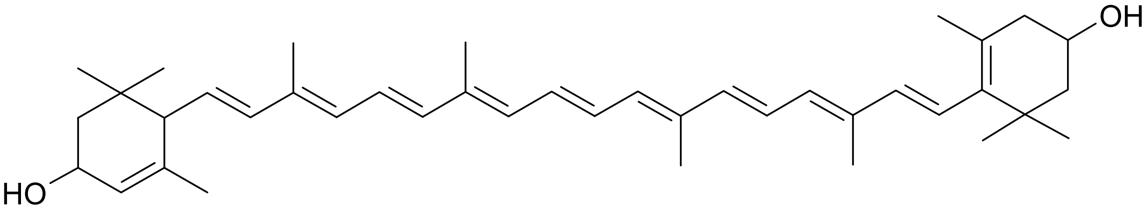

Figure 6: Zeaxanthin.

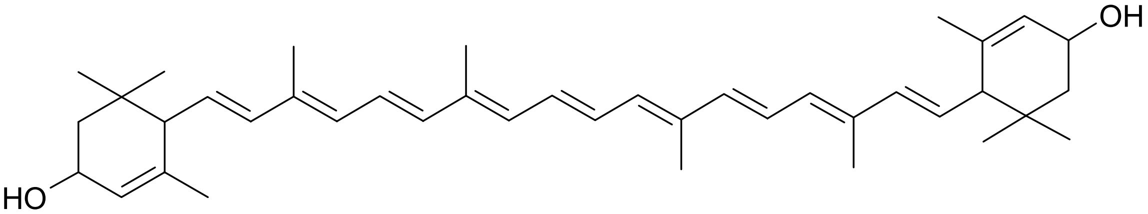

Figure 7: Falcarinol.

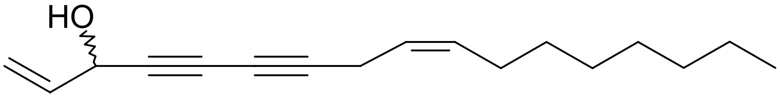

Figure 8: Ferulic acid.

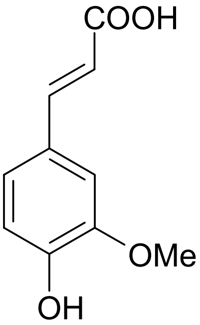

Figure 9: Quercetin.

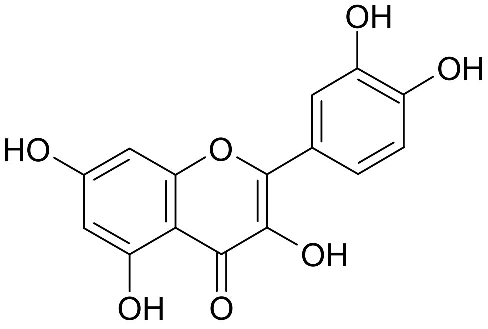

Figure 10: Luteolin.