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Nutritional attributes of salad vegetables

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1 Executive summary

1.1 Background

This report provides information that may be incorporated into promotional and educational booklets for VegFed sector groups. We have gathered relevant literature, including medical research and scientific papers, and have provided information specific to New Zealand when it is available. This report focuses on the nutritional attributes of salad vegetables — lettuce, rocket, watercress, mesclun, cucumber, radish and celery. Factors that may influence the nutritional profile of these vegetables, such as agronomical issues, cooking or processing and storage, are covered. Some additional material of general interest has also been included.

Note: The amount of research on the vegetables covered in this report varies somewhat. This is reflected in the volume and depth of the detail in the various sections of the report so some sections may appear less substantial than others.

1.2 Lettuce

The common notion that lettuce is a nutritional desert does not do this vegetable justice, particularly the newer cultivars. These are often more strongly coloured than the traditional Iceberg-type cultivars, and the pigments that confer colour have a range of nutritional benefits. Most cultivars contain the pigments β-carotene, lutein and zeaxanthin, chlorophyll, with the red cultivars additionally containing anthocyanins. β-carotene is the major vitamin A precursor, so as well as contributing vitamin A activity, it also plays a role in preventing some cancers. Lutein and zeaxanthin are believed to maintain vision and eye health. Chlorophyll has been relatively little studied, but new nutritional roles for this photosynthetic compound, including anti-cancer activity, are being investigated. Red cultivars of lettuce also contain anthocyanins, which are of particular interest in relation to protecting against health problems associated with ageing. Other phytochemicals in lettuce include lignans, which have an oestrogenic effect, as well as the core nutrients of vitamin C, iron, folate and fibre.

Whilst it is true that lettuce is composed largely of water, this is an advantage in providing low calorific bulk, which is important in terms of satiety. It serves as a base for other salad ingredients as well as providing a range of sensory qualities. The fact that it is eaten so frequently means that its overall nutritional contribution may be quite high.

1.3 Rocket

Rocket contains similar core nutrients to those in lettuce and also shares many of the same phytochemicals (though not anthocyanins.) Besides its characteristic nutty flavour, what is distinctive about rocket is that it also provides glucosinolates. When the plant tissue is damaged, by cutting or chewing, these compounds are enzymatically converted to other compounds, including isothiocyanates. The latter protect against cancer through a number of mechanisms, particularly the induction of phase 2 enzymes and encouraging apoptosis. It is these compounds that impart the pungent mustardy taste. Although rocket is not alone in providing glucosinolates, it is eaten raw. Therefore, the enzyme that converts glucosinolates into isothiocyanates is not destroyed during cooking, ensuring that conversion to isothiocyanates is optimised.

1.4 Watercress

Watercress is a nutritional heavyweight, rich in both core nutrients and phytochemicals. Of particular interest is its range of glucosinolates, which, like in rocket, are converted into different isothiocyanates and similar compounds called indoles upon damage to the plant tissue. Phenethyl isothiocyanate (PEITC) and other watercress isothiocyanates were initially shown to protect against the major cancer-causing compounds in cigarette smoke. The mechanism by which this occurs is thought to be the induction of phase 2 enzymes, in concert with the inhibition of harmful phase 1 enzymes. More recently these compounds have been studied with respect to anti-inflammatory activity and the prevention of autoimmune diseases. Indole-3-carbinol, another glucosinolate-derived compound, has been found to be particularly promising in the prevention of hormone-related cancers. As with other glucosinolate-containing plants, such as rocket, the enzyme that catalyses the conversion of glucosinolates to other metabolites remains at optimum levels because watercress is generally eaten raw.

1.5 Mesclun

The mix of plants in a mesclun salad provides a range of phytochemicals in addition to visual, taste and textural appeal. Although the constituent plants used for a mix may differ, mesclun should provide good levels of core nutrients as well as phytochemicals. Mesclun will typically contain many major pigments – chlorophyll, carotenoids and anthocyanins – as well as glucosinolates and various phenolic compounds. How phytochemical and core nutrient levels differ between immature and adult plants appears to have been little studied.

1.6 Cucumber

The contribution of cucumber to the diet would appear to be more sensory than nutritional. It is relatively poor in terms of nutrient content, but is refreshing and provides interesting texture. Consuming the skin as well as the seeds maximises its nutritional benefits.

1.7 *Radish*

Radish has good levels of vitamin C, but is not especially rich in core nutrients. Its most important phytochemicals are glucosinolates, similar to those in rocket and watercress, and anthocyanins, which, like those in red lettuces, are thought to help prevent health problems associated with ageing.

1.8 *Celery*

Celery has some history and documented use as a herbal remedy, but to date there has been relatively little scientific interest in this vegetable. It is high in sodium and has reasonable levels of potassium, to which some researchers have attributed its purported ability to lower blood pressure, though other researchers believe this is due to another class of constituent compounds, phthalides. It is also one of a few plants to contain the flavonoid luteolin, which has not been extensively studied but may help prevent atherosclerosis.

2 *Lettuce* (Lactuca sativa *L.*)

2.1 *Introduction*

Lettuce has sometimes disparagingly been referred to as a 'nutritional desert'. While the most common of the lettuce varieties, Iceberg, is probably the least nutritious of this family, even it is not without nutritional value. Also, there has recently been an explosion of new cultivars in the marketplace with different colours, textures and forms. Not only do these add visual interest to a salad, they also significantly increase its phytochemical content and provide an excellent range of the important phytochemical groups. Whilst a vegetable comprising 96% water cannot be as nutritious as a denser product, it does make an important contribution both to the appeal of our food and our diets, especially given how frequently it is consumed.

Lettuces are an ancient food, featuring in Ancient Egyptian tomb drawings dating back to around 2500 BC. They have been documented throughout history, although they were probably rather different plants to the lettuces we know today. For example, it might be surprising to a consumer today that the Ancient Romans believed them to have soporific effects and consequently served them at the end of a meal. However, possibly because they tasted bitter, the sleep-inducing compounds have been bred out of modern forms.

The standard Iceberg-type lettuce is in fact a relative newcomer. It and cultivars bred from it are believed to originate from what at the time was a larger, firmer crisphead lettuce called Great Lakes in 1941. This cultivar was known as Iceberg because in pre-refrigeration days lettuces were transported packed in ice.

The term "lettuce" today includes a host of different cultivars and sometimes even non-lettuces such as endive. New Zealand lettuces can be divided into head lettuces such as Iceberg or Buttercrunch and leaf lettuces such as Romaine (Cos) or Lollo Rosso. In China a stem lettuce is the predominant form and in Egypt a cultivar is grown specifically for oil seed production. Since the lettuce belongs to the same family as sunflowers, perhaps this is not too surprising.

The recent trend for coloured cultivars is in fact a return to forms that existed centuries ago. Other trends include new textures and forms and the use of baby leaves. In the US 40% of production is now non Iceberg, with Romaine becoming increasingly popular. The widespread popularity of the Caesar salad may account in some part for this.

2.2 Composition

A host of variables can affect the composition of any item of fresh produce. Perhaps the most obvious of these is cultivar, but growing conditions, level of maturity and postharvest treatment are also important.

2.2.1 Core nutrients

Most kinds of lettuce are a good source of vitamin C, folate, fibre and pro vitamin A (in the form of β-carotene). Further detail from the New Zealand Food Composition Database is provided in Appendix I.

2.2.2 Other phytochemicals

Most cultivars provide the carotenoids β-carotene and lutein/zeaxanthin and assorted flavonoids. The latter include flavanols (mostly quercetin) and flavones (apigenin and luteolin), with the red cultivars in addition possessing anthocyanins. Although not a major dietary source, lettuces also contain lignans and, like all green plants, chlorophyll. This can vary from low levels in pale Iceberg to high levels in more strongly coloured cultivars, such as Cos. As already mentioned, although masked by other pigments, it is also present in the red-leafed cultivars.

2.3 Nutritional attributes

2.3.1 Health benefits of core nutrients

See Appendix II.

Fibre

Lettuce may lower cholesterol absorption. In an animal study, the inclusion of red oak leaf lettuce in the diet lowered cholesterol, the authors attributing this to the presence of fibre (Nicolle et al. 2004).

See also Appendix II.

2.3.2 Health benefits of phytochemicals in lettuce

Carotenoids

The carotenoids are a group of yellow-orange-red pigments present in a range of fruits and vegetables as well as in algae, fungi and bacteria. They cannot be synthesised in the body and are present solely as a result of ingestion, of material from other sources, either of the plant itself or of a product made from an animal that has consumed that plant source. The carotenoids that make egg yolks yellow are an example of this. 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 comprise a long chain hydrocarbon molecule with a series of central, conjugated double bonds. These conjugated (alternating) double bonds confer colour and are responsible for the compounds' antioxidant properties. These compounds are especially effective in quenching singlet oxygen and peroxyl radicals. They appear to act synergistically with other carotenoids and other antioxidants. In plants, these pigments partake 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 macula lutea of the eye and the skin against the same photoxidative damage (Sies & Stahl 2003).

There are two general classes of carotenoids, the carotenes, and their oxygenated derivatives, the xanthophylls. Structurally, the two groups are almost identical except that the xanthophylls have a terminal hydroxyl group. Their structure determines their properties and thus also their activities and physiological roles. The carotenes possess pro-vitamin A activity and are non-polar and hence in the body tend to be located on the periphery of cell membranes. Xanthophylls have no vitamin A capacity, and, being non 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).

Carotenes

Those carotenoids with at least one unsubstituted beta-ring and an unchanged side chain (e.g. β-carotene, α-carotene, cryptoxanthin, γ-carotene) may be converted to vitamin A in the body and are known as carotenes. Such carotenoids are referred to as having provitamin A activity. Many carotenoids are being considered as potential cancer prevention agents, although trial results are mixed.

Studies of β-carotene indicate that its antioxidant activities and health benefits only occur when it is derived from food and not supplements. β-carotene has been used as a so-called oral sun protectant due to its antioxidant properties, and its efficacy has been proven in studies (Stahl et al. 2000).

Xanthophylls

Another group of carotenoids, the xanthophylls (e.g. lutein and zeaxanthin), have specific distribution patterns in human tissue, especially in the retina of the eye (Zaripheh & Erdman 2002).

These carotenoids are thought to be important for normal eye function and play a role in the prevention of various eye diseases, including macular degeneration, glaucoma and cataracts (Head 1999, 2001).

Levels of these in some common foods are given in Table 1. Because of their similarity, the two compounds are often reported as a combined total, as is the case with information from the USDA carotenoid database used for Table 1. Whilst it is apparent that lettuce does not contain extraordinarily high levels of lutein + zeaxanthin in comparison with some other foods, it should be borne in mind that it is frequently consumed in many households and so is an important dietary source of these compounds.

Table 1: Lutein and zeaxanthin levels in selected foods (mcg per 100 g edible portion) (USDA 2003).

	Lutein + zeaxanthin
Lettuce, green leaf, raw	1730
Lettuce, Iceberg	352
Broccoli, cooked boiled drained, without salt	1517
Egg, raw	331
Corn, sweet, yellow, frozen, kernels cut off cob, drained, without salt	730
Corn, sweet, yellow, whole kernel, canned, drained solids	1029
Corn, sweet, yellow, raw	764
Kale, cooked	18346
Oranges, raw, all commercial varieties	129
Persimmons, Japanese, raw	834

Flavonoids and other phenolic compounds

There is huge structural diversity within the large group of antioxidant compounds known as phenolics. Several thousands of natural polyphenols have been identified in plants, many of them in plant foods (Shahidi & Naczk 1995), although only a more limited number are present at significant levels in most human diets. The chemical structure of polyphenols affects their biological properties, including their bioavailability, antioxidant activity, and specific interactions with cell receptors and enzymes. There has been little specific study of the role that lettuce flavonoids, and other phenolics, may play in human health. However, this group of compounds has received considerable attention in general, but particularly those compounds in red wine, tea, chocolate and onions.

Phenolic compounds, because of their structure, are very efficient scavengers of free radicals and are metal chelators (Shahidi et al. 1997). In addition to these antioxidant characteristics, other potential health-promoting bioactivities of the flavonoids include anti-allergic, anti-inflammatory, anti-microbial and anti-cancer properties (Cody et al. 1986; Harbourne 1993). There are many ways in which flavonoids may act to prevent cancer, including inducing detoxification enzymes, inhibiting cancer cell proliferation, and promoting cell differentiation (Kalt 2001). Some flavonoids are also beneficial against heart disease because they inhibit blood platelet aggregation and provide antioxidant protection to low density lipoprotein (LDL) (Frankel et al. 1993). Studies on the health benefits of the phenolic acids to date have largely focused on their antioxidant activity.

Anthocyanins are one of the various classes of flavonoids and are the pigments responsible for the red/blue/purple colours of some, though not all, fruits and vegetables. These pigments account for the reddish colours of the red cultivars of lettuce, the skins of red radishes and the purple of raddichio. They have strong antioxidant activity and in blueberries particularly have been studied for their contribution to protecting the brain against the effects of ageing. In addition, anthocyanins are believed to lower the risk of some cancers and help prevent cardiovascular disease by preventing inflammation and the oxidation of LDL cholesterol (Joseph et al. 2002).

Lignans

Lignans are plant compounds that are converted into mammalian oestrogens by gut bacteria. For this reason they are known as phytoestrogens or plant oestrogens. In the human body they have a weak oestrogenic effect and may help prevent hormone-related cancers, such as breast cancer (Joseph et al. 2002).

Chlorophyll

Relatively little is known about the health effects of chlorophyll, the primary photosynthetic pigment 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 from proliferating. A very recent study suggests that chlorophyll has weak phase 2 enzyme inducer potency, and although its activity is relatively weak compared with some other phytochemicals (see Sections 3, 4 and 7), 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).

2.4 Factors affecting nutritional attributes of lettuce

As mentioned earlier, a host of factors can potentially influence the nutrients and the levels of those nutrients present in any plant. This area of research is relatively new and as a result information is sparse.

2.4.1 Cultivar

Different cultivars can have both different levels of shared nutrients as well as some totally different phytochemicals, with colour/pigment differences perhaps the most obvious example. As a general rule, strongly coloured cultivars contain higher phytochemical levels than do less coloured ones (Wu et al. 2004). Red cultivars e.g. (Lollo Rosso, Red Oak, Oakleaf) also provide anthocyanins (Wu & Prior 2005), which are believed to contribute to their superior antioxidant activity, when compared to their green counterparts.

Tables 2 and 3 illustrate inter-cultivar variations for various core nutrients and phytochemicals. One striking difference is that in terms of core nutrients, Iceberg is generally well below those of the others listed, with Cos and Red Leaf sharing the highest levels for these nutrients between them. Cos is particularly outstanding in terms of vitamin C and folate, with Red Leaf possessing more β-carotene or pro vitamin A.

Table 2: Comparison of some nutrients in different varieties of lettuce (American data) USDA National Nutrient Database for Standard Reference, Release 17 (www.nal.usda.gov/fnic/foodcomp/index.html.

	Vit C (mg)	Vit E (mg)	Folate (μg)	Iron (mg)	B-carotene (μg)	Lutein & zeaxanthin (μg)
Butterhead	3.7	0.18	73	1.24	1987	1223
Cos/Romaine	24	0.13	136	0.97	3484	2312
Iceberg	2.8	0.18	29	0.41	299	277
Red Leaf	3.7	0.15	36	1.20	4495	1724

As is shown above, not only do core nutrients vary considerably according to the kind of lettuce (around 9 fold in terms of vitamin C), but so also do the carotenoid pigments, with a 15 fold difference for β-carotene. This is also true for other phytochemicals. Using the flavonoid class as an example (Table 3), it can be seen how these can vary even more, with a 690 fold difference between Iceberg and Lollo Rosso (DuPont et al. 2000).

Table 3: Flavonoids in eight varieties of lettuce (DuPont et al. 2000).

Cultivar	Total flavonoids (μg/g fresh weight)
Iceberg	0.3
Green Batavia	0.7
Cos Remus	9.6
Green Salad Bowl	19.9
Green Oak Leaf	32.9
Red Oak Leaf	76.2
Lollo Biondo	95.7
Lollo Rosso	207

In contrast to the above, however, and perhaps relating to differences in the other factors mentioned earlier that influence composition, an American study showed that Iceberg had higher phenolic content and similar antioxidant levels to that of Romaine (Kang & Saltveit 2002).

2.4.2 *Growing conditions*

Growing conditions can involve a large number of agronomic factors, any one of which could have an impact on the nutritional profile of the plant. These include soil type, hours of sunlight, irrigation, pest control, weather, growing location, cultivation methods and others.

Information in this area is far from comprehensive, although with growing interest in the health benefits of phytochemicals, research on ways of maximising levels may increase. The following two studies relating specifically to lettuce are evidence of interesting differences. In a comparison of young greenhouse and open-air grown plants of an Italian cultivar (Audran) it was found that all open-air grown samples had higher levels of polyphenol compounds than those grown in greenhouses (Romani et al. 2002). Similarly, field-grown curly lettuces had higher carotenoid levels than those grown hydroponically (Kimura & Rodriguez-Amaya 2003).

2.5 *Promotional messages/tips*

- Because of their high water content, lettuces are not as nutrient dense as some other vegetables, but this also means they are good 'fillers' for weight watchers and supply fibre. However, in providing bulk, they provide a low calorie base for a salad or sandwich filling as well as sensory attributes. Also, this 'bulk' provided by lettuce may have a further benefit of inducing satiety. Not only does the stomach feel fuller, but the act of chewing affects a hormone in the brain, histamine, which helps promote satiety (Sakata et al. 1997).
- The large assortment of lettuces currently available provide not only colour, texture and taste, but a variety of phytochemicals with their associated health benefits.
- Although lettuce is not nutrient dense, the frequency with which it is consumed means that the nutrients it contains make a sizeable overall contribution to dietary intake.
- Many of the phytochemicals in lettuces are carotenoids and are more bioavailable if consumed along with fats, e.g. good quality oil as in (non fat free) salad dressings.

3 *Rocket* (Eruca sativa *Mill. syn* Eruca vesicaria *L.)*

3.1 Introduction

Also known as arugula or roquette, rocket has a long history of medicinal use. Of all its attributes, its purported aphrodisiac qualities are one of the most frequently mentioned. These were described by Virgil as well as Dioscorides and Galen. Some herbalists of the time recommended that rocket be mixed with lettuce in salads to dilute this undesirable effect! This was also the reason why it was apparently forbidden in monasteries. Another of its virtues was in treating eye complaints, with both Pliny and the Bible reporting its efficacy (Nuez & Hernandez Bermejo 1994; Morales & Janick 2002; Barillari et al. 2005).

Today rocket is probably best known as an integral part of a mesclun mix, imparting a distinctive nutty flavour. It also often accompanies carpaccio.

3.2 Composition

Like all produce, composition is determined by a host of variables including cultivar, agronomy, level of maturity and postharvest treatment. Cultivar is a less important factor with respect to rocket, as different cultivars do not appear to be currently available in New Zealand.

3.2.1 Core nutrients

Rocket contains pro vitamin A (as β-carotene) vitamin C, folate, calcium and fibre. Further detail from the USDA National Nutrient Database 2005 is provided in Appendix I.

3.2.2 Other phytochemicals

Rocket also provides carotenoids (lutein, β-carotene), vitamin C, flavonoids and glucosinolates (glucoerucin) and fibre.

3.3 Nutritional attributes

3.3.1 Health benefits of core nutrients

See Appendix II.

3.3.2 Health benefits of phytochemicals

For general discussion of carotenoids, fibre, flavonoids see Section 2.3.2.

Glucosinolates

Rocket belongs to the Brassicaceae family, like broccoli, and like broccoli it contains glucosinolates, the compounds indirectly responsible for the characteristic pungent taste of this family. The range of these in rocket, however, is not the same as those in broccoli. Rocket has not enjoyed the scientific attention that broccoli has, perhaps because it is less well known but also perhaps because it has lower levels of the phase 2 enzyme-inducing activity for which broccoli is famous. Most study regarding glucosinolates has to do with a broccoli glucosinolate called glucoraphanin, which is converted to another kind of compound, an isothiocyanate called sulforaphane, when the plant tissue is damaged in some way – eaten by insects, cut by the chef's knife, or chewed by humans. Sulforaphane is best known for inducing phase 2 enzymes, such as quinone reductase, which detoxifies potential carcinogens, induces apoptosis (cell suicide) in cancer cells, and inhibits harmful phase 1 enzymes. The plant glucosinolates are converted to isothiocyanates by the enzyme myrosinase. However, because myrosinase is not heat stable it is destroyed by cooking and the conversion cannot take place. Although some conversion is carried out by bacteria in the gut, it is believed to be a much less efficient process. The pungent, mustardy taste is attributable to these isothiocyanates.

The main glucosinolate in rocket is glucoerucin, which the enzyme myrosinase converts to the isothiocyanate, erucin. An Italian study showed that erucin not only possesses indirect antioxidant activity (in inducing phase 2 enzymes, like sulforaphane), but that it additionally had direct antioxidant activity, decomposing hydroperoxides and hydrogen peroxide (which are often the catalysts that trigger the cancer cascade). Moreover, the by-product of this radical scavenging activity was sulforaphane itself, the most potent phase 2 enzyme inducer in the isothiocyanate family (Barillari et al. 2005). An advantage of rocket over broccoli is that it is most commonly eaten raw so the myrosinase remains at optimal levels. Although this study was carried out on rocket seeds and sprouts, the adult leaves also contain glucosinolates. Research results vary as to which glucosinates predominate; in one study it was glucoerucin (Nitz & Schnitzler 2002) while in another it was a new glucosinolate, 4-mercaptobutyl glucosinolate (Bennett et al. 2002).

3.4 *Factors affecting nutritional attributes*

No information relating specifically to factors that affect the nutritional attributes of rocket was available, apart from the fact that myrosinase is destroyed through heating.

3.5 *Promotional messages/tips*

- Rocket is nutrient dense, besides providing a distinctive taste.
- It contains glucosinolates and, because it is eaten raw, the enzymes required to convert glucosinolates to isothiocyanates remain intact. Erucin, a major isothiocyanate in rocket, may have good direct and indirect antioxidant activity as well as acting as a precursor to sulforaphane in certain conditions.
- The younger the leaves, the milder they will taste. If too pungent, older leaves can be chopped like herbs and sprinkled on the salad.

4 *Watercress* (Rorippa nasturtium aquaticum *(L.) Hayek syn* Nasturtium officinale *R. Br.*)

4.1 Introduction

Watercress was a much more valued part of the diet historically than it is today. The ancient Greeks believed it could instil courage, strength, character and even wit, the Romans that it would cure baldness, and the Victorians that it could get rid of hiccups and freckles!

Records show that there was large-scale cultivation of watercress in European countries from the eighteenth century. Although green watercress appears to be the only species currently cultivated, in England a brown watercress (*Nasturtium microphyllum*) was also popular during the 19th century (Palaniswamy & McAvoy 2001).

4.2 Composition

Composition varies according to a host of different factors, including cultivar, growing conditions, level of maturity and postharvest treatment.

4.2.1 Core nutrients

Watercress contains a large number of nutrients including pro vitamin A (from β-carotene), vitamin C, fibre, iron, potassium, calcium and some α-linolenic acid. Further detail from the New Zealand Food Composition Database is provided in Appendix I.

4.2.2 Phytochemicals

Watercress is well endowed with phytochemicals, including chlorophyll, lutein, β-carotene, and the glucosinoltes gluconasturtiin (which is converted to the isothiocyanate phenethyl isothiocyanate, or PEITC), glucoraphanin (which is converted to the isothiocyanate, sulforaphane), glucobrassican (which is converted to indole-3-carbinol or I-3-C , a compound similar to an isothiocyanate).

4.3 Nutritional attributes

4.3.1 Core nutrients

See Appendix II.

4.3.2 Other phytochemicals

- See Section 2.3.2 for general discussion of carotenoids (β-carotene, lutein), flavonoids and chlorophyll.
- See Section 3.3.2 for health effects of glucosinolates/isothiocyanates.

Phenethyl isothiocyanate

Besides providing an excellent range of phytochemicals and at reasonable levels, one of the distinctive features of watercress is its postulated ability to protect against cancer-causing nitrosamines in cigarette smoke. This was thought to be due to the presence of phenethyl isothiocyanate (PEITC) and was initially shown in a study using rats. A small human study of 11 smokers consuming watercress at each meal demonstrated that PEITC blocked the metabolic activation of one of the carcinogenic compounds in cigarette smoke, which was demonstrated through the excretion of detoxified metabolites (Hecht 1999; Rose et al. 2000).

A later study suggested, however, that contrary to expectations the observed induction of the phase 2 enzyme, quinine reductase (QR), was not associated with PEITC (which is rapidly lost to the atmosphere upon tissue disruption due to its volatility) or with a naturally occurring PEITC-glutathione conjugate, but instead with other watercress isothiocyanates (ITCs), 7-methylsulfinyheptyl and 8-methylsulfinyloctyl ITCs. While it was confirmed that PEITC does induce QR, 7-methylsulfinyheptyl and 8-methylsulfinyloctyl ITCs were more potent inducers. Thus, although watercress contains three times more phenethyl glucosinolate than methylsulfinylalkyl glucosinolates, ITCs derived from methylsulfinylalkyl glucosinolates may be more important phase 2 enzyme inducers than PEITC, having 10 to 25 fold greater potency. The authors concluded that watercress might have exceptionally good anticarcinogenic potential because it combined a potent inhibitor of phase 1 enzymes (PEITC) with at least three inducers of phase 2 enzymes (PEITC, 7-methylsulfinylheptyl ITC and 8-methylsulfinyloctyl ITC (Rose et al. 2000).

Other research has subsequently shown that watercress compounds may also prove beneficial in terms of other health problems. A recent study showed how PEITC and 8-methylsulphinyloctyl (MSO) isothiocyanates decreased levels of pro-inflammatory compounds that can cause chronic inflammation conditions, including auto immune diseases such as rheumatoid arthritis, multiple sclerosis, and Alzheimer’s disease as well as cancer (Rose et al. 2005). The major metabolite of PEITC, phenethyl isothiocyanante N-acetylcysteine (PEITC-NAC), has also been shown to inhibit the growth and proliferation of xenografted human prostate cancer cells (Chiao 2004). Like with sulforaphane, it was postulated that this was achieved through cell cycle arrest and the induction of apoptosis. PEITC and sulforaphane were also shown to be effective in preventing the formation of colonic cancer cells (Chung 2000).

Indoles

Another important compound in watercress is an indole called glucobrassicin or indole-3-carbinol (I3C). An indole is similar to an isothiocyanate, and can similarly be formed through enzymatic conversion upon damage to the plant tissue. Indoles have been particularly investigated for their anti-oestrogenic effect; they block oestrogen receptors in the breast cells and thus assist in preventing oestrogen-sensitive breast cancers. They have also been found to induce apoptosis or cell suicide in tumour cells. Besides breast cancer, animal studies have shown I3C also assists in the prevention of endometrial and cervical cancers (Auborn et al. 2003) as well as prostate cancer (Nachshon-Kedmi et al. 2003).

4.4 Factors affecting nutritional attributes

Most research regarding watercress has concentrated upon the medicinal effects of some of the purified constituent compounds. There does not appear to be much information concerning the health benefits of the plant material itself, nor research into the effects of factors that may affect its nutritional content.

4.5 Promotional messages/tips

- Watercress is deserving of far more popularity than it actually enjoys. It is a nutritional heavyweight with plenty of carotenoids, good levels of lutein, plus the isothiocyanates and indoles of the brassicas and phenolics.
- Watercress is an exceptionally rich dietary source of PEITC as well as other glucosinolates that inhibit the detrimental phase 1 enzymes, which are responsible for activating many carcinogens, and induce phase 2 enzymes, which have been found to have potent anticarcinogenic activity.
- Because is it is often consumed raw, the enzyme myrosinase, which converts the glucosinolates to isothiocyanates, remains intact to do its job.
- Watercress adds crunch and spiciness to salads.
- It can be cooked (though some phytochemicals may be impaired) or consumed raw.
- Food safety has been an issue with wild watercress, which can be contaminated with *E. coli, Campylobacter*, lead and arsenic (from an ESR report, article in NZ Herald 08/08/05). Commercially grown produce is likely to be safer.

5 Mesclun

5.1 Introduction

The name 'mesclun' was originally a French term simply meaning mixture. It is used to refer to a mixture of young leaves used in a salad. This mixture provides variations of colour, taste, texture and a spread of nutrients. Assortments vary, but usually include different varieties of lettuce, rocket, and may contain some or all of the following: corn salad, red chard, raddicihio, tatsoi, curly endive baby spinach and leafy herbs.

5.2 Composition

Composition of a mesclun mix will vary according to the mix of the various plants included. As always, it will be affected by factors such as cultivar, growing conditions, maturity, storage, and postharvest treatment. Many of the lesser known plants have not yet been analysed, so comprehensive data are lacking. Data on lettuce are included in Section 2 and on rocket in Section 3. The known nutrients in the other various component plants are listed in Table 4.

The taxonomy and spelling of some of the newer Asian salad greens does not appear to be consistent in the published and web-based information available.

Table 4: Core nutrients and phytochemicals in some component plants of a mesclun mix.

Vegetable	Core nutrients	Phytochemical(s)
Bok choy / pak choy (*Brassica rapa chinensis*)	Vitamin A, vitamin C, calcium, iron, riboflavin, vitamin B6, magnesium, manganese, thiamine, niacin, folate, zinc	Glucosinolates, folate, lutein and zeaxanthin, β-carotene, chlorophyll
Chicory/curly endive/frisee (*Chicorium endivia* L.)	N/A	β-Carotene, folate, lutein, chlorophyll
Lamb's lettuce/ mache /corn salad (*Valeriana locusta*)	N/A	Chlorophyll
Mizuna (*Brassica campestris*)	N/A	Glucosinolates, folate, lutein and zeaxanthin, β-carotene, chlorophyll
Raddichio (red witloof) (*Chicorium intybus*)	N/A	Anthocyanins
Red chard (*Beta vulgaris* L.)	Vitamin A, vitamin C, calcium, iron, Vitamin E, vitamin K, riboflavin, magnesium, copper, manganese	Folate, lutein and zeaxanthin, β-carotene, betalains
Red mustard (*Brassica juncea* L.)	Vitamin A, vitamin C, calcium, iron, vitamin E, vitamin K, thiamine, riboflavin, vitamin B6, folate, magnesium, copper, manganese	Glucosinolates
Spinach (*Spinacea oleracea* L.)	Vitamin A, vitamin C, vitamin E, vitamin K, thiamin, riboflavin, vitamin B6, calcium, copper, iron, folate, potassium	Lutein and zeaxanthin, β-carotene, glutathione, alpha-lipoic acid, chlorophyll, oxalates
Tatsoi (*Brassica rapa*) var. *rosularis*	N/A	Glucosinolates, folate, lutein and zeaxanthin, β-carotene, chlorophyll

5.3 Nutritional attributes

5.3.1 Health benefits of core nutrients

See Appendix II.

5.3.2 Health benefits of other phytochemicals

The variation in a mesclun mix also provides for a range of phytonutrients; their high levels of vitamin A are indicative of β-carotene content (see Section 2) while anthocyanins (Section 2) and glucosinolates/isothiocyanates originate from members of the Brassica family that are present – tatsoi, mustard, chard – as well as rocket (Section 3).

To date there appears to be little specific information on the effect of leaf maturity on phytochemical levels in these plants. One study showed how baby leaves of endive and Boston lettuce contained lower levels of carotenoids than mature leaves, though this was not true for another of the samples investigated – New Zealand spinach, *Tetragonia expansa* (not silver beet) (de Azevedo-Meleiro & Rodriguez-Amaya 2005).

5.4 Factors affecting nutritional attributes

A study investigating the shelf life of baby leaf salad mixes found that mechanical stress, in the form of 100 paper strokes daily, promoted smaller leaf sizes and lessened leaf plasticity. This resulted in an estimated increase in shelf life of 33% in the assortment of baby Lollo Rosso, Cos and spinach leaves (Clarkson et al. 2003).

5.5 Promotional messages/tips

- Consuming a salad mix, such as mesclun, is an excellent and convenient way of obtaining a range of dietary phytochemicals in one dish.
- Like rocket, raw Brassica leaves are a potentially good way of obtaining the isothiocyanates from glucosinolate-rich foods because the enzyme myrosinase has not been destroyed by cooking.

6 *Cucumber* (Cucumis sativus *L.*)

6.1 Introduction

With a water content of around 96% (Athar et al. 2003), it is not surprising that cucumbers are cool and refreshing. Popular and ethnobotanical uses centre around its soothing effect upon the skin. Some home remedies recommend cucumber slices being applied topically to promote skin tone around the eyes, and there are various commercial preparations based upon cucumber extract in products such as skin lotions. Not surprisingly, in Chinese cuisine cucumber is considered a Yin or cooling food.

6.2 Composition

Composition varies according to a number of factors, including cultivar, growing conditions, level of maturity and postharvest treatment.

6.2.1 Core nutrients

Cucumber contains some vitamin C, pro vitamin A as β-carotene in the skins, fibre in skin and seeds, and potassium. Further detail from the New Zealand Food Composition Database is provided in Appendix I.

6.2.2 Phytochemicals

β-carotene, chlorophyll

6.3 Nutritional attributes

6.3.1 Health benefits of core nutrients

See Appendix II.

6.3.2 Health benefits of phytochemicals

Cucumber is not a nutrient-dense food. For example, in a comparison of 10 common vegetables, selected on the basis of per capita consumption, cucumber (cultivar unspecified), ranked at the bottom in terms of antioxidant activity, phenolic compound content and antiproliferative activity in relation to human liver cancer cells (Chu et al. 2002).

One compositional feature that makes cucumber interesting is that it is one of only a few foods to contain silicon. This is a less common mineral in the diet so levels are not quoted in the New Zealand Food Composition Database nor in that of the USDA. Dr Duke's database does confirm that cucumbers contain silica (Duke 2003), a fact alluded to in the popular literature. One source stated that silicon is important in connective tissue, such as skin, hair and nails (Atkinson 1982).

Fibre from skins and seeds (see Appendix II).

Chlorophyll (see Section 2.3.2).

6.4 Factors affecting nutritional attributes

No information on this topic has been found.

6.5 Promotional messages/tips

- Eating the skins and seeds maximises its health benefits. Alternating peeled and unpeeled strips of skin may make the concept more palatable.

- Crunchy cucumber adds texture, taste and body to a salad. Its coolness offsets other spicier tastes, as with raita accompanying curry dishes.
- Slices of cucumber can be added to a jug or glass of drinking water for a refreshing change.

7 *Radish* (Raphanus sativus *L.*)

7.1 Introduction

Although it grows underground, radish is really a swollen stem rather than a root. Radishes exist in a variety of shapes and sizes, as well as colour, ranging from red to white and even black.

7.2 Composition

Composition varies according to a host of different factors, including cultivar, growing conditions, level of maturity and postharvest treatment.

7.2.1 Core nutrients:

On a per weight basis radishes have high levels of vitamin C, more, for example than a fresh tomato (Athar et al. 2003). They also contain some fibre, potassium and folate, but like many salad vegetables are high in water so are not nutrient-dense. Further detail from the New Zealand Food Composition Database is provided in Appendix I.

7.2.2 Phytochemicals

The peppery taste of radishes is evidence of the presence of glucosinolates/isothiocyanates. Anthocyanins are present in red-skinned cultivars.

7.3 Nutritional attributes

7.3.1 Health benefits of core nutrients

See Appendix II.

7.3.2 Health benefits of phytochemicals

Radishes contain a variety of glucosinolates: glucoraphanin (Duke 2003), glucoraphenin, glucoerysolin and 4-methylthiobutanol (Schutze et al. 1999), glucoraphasatin (Scheuner et al. 2005). Many of these are also identified in seeds: glucoraphanin, glucoraphenin, 4-hydroxyglucobrassican and glucobrassican (West et al. 2004). Glucosinolates are also found in Brassicas such as broccoli and cabbage and their derivatives, isothiocyanates, have been found to have cancer protective properties (see Section 3.3). Cooking destroys the enzyme myrosinase, which converts the glucosinolates to isothiocyanates (see Section 3.3), so eating raw (as with radishes) is best. Sulforaphane, the isothiocyanate to which glucotaphanin is converted, is also being investigated with regard to treating *Helicobacter pylori* infection and blocking gastric tumour formation (Fahey et al. 2002).

Red cultivars contain anthocyanins in their skin (Stintzing & Carle 2004; Wu & Prior 2005). These compounds are believed to have a wide variety of benefits, including anti-inflammatory, anti-cancer, and cardiovascular protective (see Section 2.3.2), although most research has related to anthocyanins in fruit sources, such as berries.

7.4 Factors affecting nutritional attributes

A recent German study found that spraying the foliage of radish and broccoli plants with glutathione increased glucosinolates in broccoli heads but not in radishes (Scheuner et al. 2005).

7.5 Promotional messages/tips

- Radishes need not be just for decoration – radish glucosinolates are less studied than some others, but likely to have similar benefits to other members of the Brassica family.
- It also has the advantage of being consumed raw, so enzyme loss through heat treatment does not occur.
- The red skins contain anthocyanins, which have anti-inflammatory, anti-cancer, and cardiovascular protective properties.

8 Celery (Apium graveolens *L.*)

8.1 Introduction

Celery has a long history as a medicinal plant, but has only relatively recently been considered a food source and eaten as a vegetable. It was traditionally used as a diuretic, which is now attributed to its potassium and sodium content.

8.2 Composition

Composition varies according to a host of different factors, including cultivar, growing conditions, level of maturity and postharvest treatment.

8.2.1 Core nutrients

Celery contains some vitamin C, a small amount of vitamin A as β-carotene, sodium, potassium, calcium, and fibre. Further detail from the New Zealand Food Composition Database is provided in Appendix I.

8.2.2 Phytochemicals

Celery contains β-carotene, lutein/zeaxanthin and the flavones, luteolin and apigenin.

8.3 Nutritional attributes

8.3.1 Core nutrients

See Appendix II.

8.3.2 Phytochemicals

Most research to do with celery has investigated celery seed oil, probably due to its extensive use in ethnic remedies and herbal medicines combined with the fact that seeds often contain greater concentrations of bioactive compounds. In particular, the phthalides, 3-n-butylphthalide and sedanolide, have been identified, which are also believed to be responsible for the distinctive smell and taste of celery. This suggests they are also likely to be present in the stalks, though in lesser amounts.

In an animal experiment, 3-n-butylphthalide lowered blood pressure through its dilatory effect upon blood vessels. Previous animal experiments had also shown that a celery decoction decreased blood pressure in hypertensive dogs. This was similarly shown with a celery extract in rats (Tsi & Tan 1997).

One of the most commonly cited folk remedies using celery relates to treating inflammatory conditions such as gout and arthritis. Celery and celery seed supplements are often marketed as targeting these complaints. A Jordanian animal study investigating a number of traditional medicinal plants used to alleviate pain and inflammation described celery seed extract having both anti-inflammatory and analgesic effects (Atta & Alkofahi 1998). However, there appears to be little other scientific literature in this regard.

Celery, along with other vegetables such as capsicum and lettuce, contains a form of a compound called luteolin, a flavonoid that has been shown to have various beneficial health effects, such as antioxidant and anti-inflammatory activity. A Korean study showed how luteolin could inhibit the growth of vascular smooth muscle cells in the neointima, which would otherwise contribute towards the process of atherosclerosis and post angioplasty restinosis (Kim et al. 2005).

Apigenin, another flavonoid, has not been widely studied, but has been shown to have some anti-cancer and anti-inflammatory activity (Joseph et al. 2002; Smolinski & Pestka 2003).

In a comparison of 10 common vegetables, selected on the basis of per capita consumption, celery (cultivar unspecified) ranked around the middle in terms of antioxidant activity, towards the bottom for phenolic compound content and did not appear to have antiproliferative activity against human liver cancer cells (Chu et al. 2002).

8.4 Factors affecting nutritional attributes

No information was found in this area.

8.5 Promotional messages

- Celery is low calorie, refreshing and provides flavour as well as texture.
- It is one of the few sources of luteolin, a little studied compound as yet but one that may have cardiovascular benefits.

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Appendices

Appendix I Nutrients in selected vegetables/100 g fresh raw vegetable

	Water g	Energy kcal	Protein g	Total fat g	Available CHO g	Fibre (NSP) g	Sodium mg	Potassium mg	Ca mg	Iron mg	Zinc mg	Se mg	Total vit A equiv mg	Thiamin mg	Riboflavin mg	Total niacin equivmg	Vit B 6 mg	Folate mg	Vitamin C mg
Celery[1]	93	11	1	0.2	1.4	2	151	302	56	0.7	0.1	0.2	13	0.3	0.03	0.5	0.11	13	7.5
Cucumber[1]	96	10	0.6	0.1	1.7	0.6	13	139	23	0.3	0.2	0.1	6	0.04	0.04	0.3	0.04	16	7.9
Lettuce[1]	95	9	1.1	0.3	0.4	0.7	14	245	36	1	0.2	0.3	45	0.05	0.06	0.6	0.06	34	12
Lettuce,[1]* Hydroponic	95	18	1.9	0.3	1.8	0.6	13	280	61	1	0.2	T[†]	88	0.07	0.09	0.5	T[†]	55	T[†]
Radish[1]	94	19	1	0.5	2.6	1.3	56	229	42	1.8	0.4	0.3	2	0.04	0.02	0.3	0.1	23	23.9
Rocket[2] (arugula)	91.7	25	2.6	0.7	3.6	1.6	27	369	160	1.5	0.5	0.3	119	0.04	0.09	0.31	0.07	97	15
Spinach[1]	95	10	1.3	0.2	0.8	1	107	103	48	0.7	0.6	0.2	362	0.03	0.11	0.724	0.24	146	16
Watercress[1]	93	16	2.8	0.4	0.2	1.4	17	180	53	2.2	0.3	0.2	824	0.12	0.04	0.8	0.19	80	75

[1] Data taken from the Concise New Zealand Food Composition Tables (6th Ed).
[2] Data taken from the USDA National Nutrient Database for Standard Reference, Release 17.
* Composite of 'Rocket', 'Red Lettuce', 'Lolla Bionda Lettuce', 'Butterhead Lettuce', 'Frillice Lettuce' and 'Lollo Rossa Lettuce' cultivars.
[†] T - trace.

Appendix II Activities of vitamins and minerals and fibre

(Adapted from misc.medscape.com/pi/editorial/clinupdates/2004/3341/ table.doc and http://www.bupa.co.uk/health_information/html/healthy_ living/lifestyle/exercise/diet_exercise/vitamins.html).

Name	Major function
Vitamin A Retinol (animal origin) Carotenoids (plant origin, converted to retinol in the body) Note: Retinol Equivalents (RE) 1 RE = 1 mcg retinol or 6 mcg beta-carotene 1 IU = 0.3 mcg or 3.33 mcg = 1 mcg retinol = 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 D (calciferol) Two main forms: cholecalciferol (animal origin) and ergocalciferol (plant origin) Cholecalciferol is formed by action of UV rays of sun on skin Note: 1 mcg calciferol = 40 IU vitamin D	Facilitates intestinal absorption of calcium and phosphorus and maintains serum concentrations Maintains bone health and strong teeth May be involved in cell differentiation and growth May be involved in immune function
Vitamin E A group of tocopherols and tocotrienols Alpha tocoferol most common and biologically active	Provides dietary support for heart, lungs, prostate, and digestive tract Reduces peroxidation of fatty acids Non-specific chain-breaking antioxidant May protect against atherosclerosis and some cancers
Vitamin K Occurs in various forms 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

Name	Major function
Vitamin C Ascorbic acid	Necessary for healthy connective tissues – tendons, ligaments, cartilage, wound healing and healthy teeth Assists in iron absorption A protective antioxidant – may protect against certain cancers Involved in hormone and neurotransmitter synthesis
Thiamin vitamin B_1 Aneurin	Coenzyme in the metabolism of carbohydrates and branched-chain amino acids Needed for nerve transmission Involved in formation of blood cells
Riboflavin vitamin B_2	Important for skin and eye health Coenzyme in numerous cellular redox reactions involved in energy metabolism, especially from fat and protein
Niacin vitamin B_3 Nicotinic acid, nicotinamide	Coenzyme or cosubstrate in many biological reduction and oxidation reactions required for energy metabolism and fat synthesis and breakdown Reduces LDL cholesterol and increases HDL cholesterol
Vitamin B_6 Pyridoxine, pyridoxal, pyridoxamine	Coenzyme in nucleic acid metabolism, neurotransmitter synthesis, 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 maintenance 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

Name	Major function
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 constituent of many essential compounds in body and processes
Calcium	Structural component of bones and teeth Role in cellular processes, muscle contraction, blood clotting, enzyme activation, 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

Name	Major function
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 neurotransmitter 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 enzymes activity and metabolism
Selenium	Important role in body's antioxidant defence system as component of key enzymes May help prevent cancer and cardiovascular disease
Zinc	Major role in immune system Required for numerous enzymes involved in growth and repair Involved in sexual maturation Role in taste, smell functions
Fibre Fibre can be divided into insoluble and soluble fibre	Insoluble fibre: adds bulk to stool and thus helps to prevent bowel problems such as bowel cancer, irritable bowel syndrome and diverticulitis Soluble fibre: lowers cholesterol levels, helps manage blood glucose