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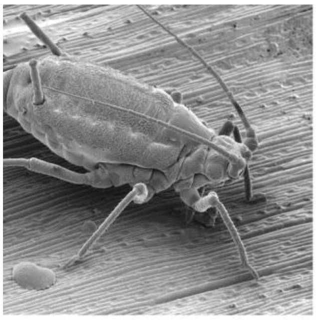
The composition and health benefits of potatoes—an update (2009-2013)

Lister CE

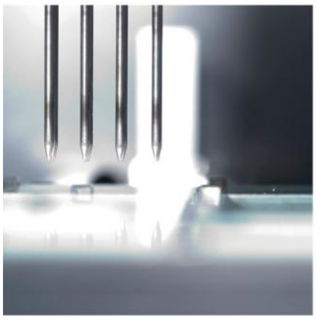
October 2013





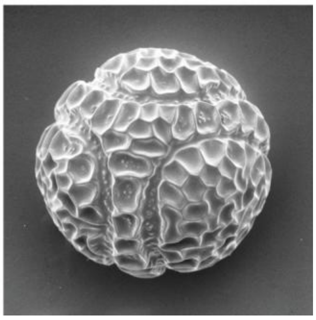










Report for:
Potatoes New Zealand Inc.

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Executive summary

The composition and health benefits of potatoes—an update (2009-2013)

Lister CE
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It is important to be able to accurately document the nutritional value of any food product, so that this information can be made available to customers and consumers. Although not mandatory on fresh produce, it can be useful to provide this information in a nutrition information panel (NIP) on pack and/or website. Nutrition information can also provide the data to enable health claims to be made and, if health claims are to be made, then a NIP must be included on pack. A new health claims standard (FSANZ Standard 1.2.7) came into force in January 2013 and allows an extended range of preapproved general level health claims on pack as long as certain criteria are met. New claims can also be self-substantiated if there is sufficient scientific evidence. The aim of this project for was to gather information on the health benefits and nutritional composition of potatoes. From these data the permitted claims could be ascertained.

Nutrition information panels provide information on the average amount of energy (in kilojoules or both in kilojoules and kilocalories), protein, fat, saturated fat, carbohydrate, sugars and sodium (a component of salt) in the food, as well as any other nutrients about which a nutrition/health claim is made. Looking at existing compositional data for potatoes those nutrients that deliver around 10% or more of the recommended dietary intake (RDI) or required intake for a nutrition claim are:

- Fibre
- Folate
- Niacin
- Pantothenic acid
- Potassium
- Vitamin C

In addition thiamin and vitamin B6 may reach sufficient levels to make claims but the current data are a little variable. Any future analysis should include these vitamins along with the above list. There is a long list of potential health claims associated with the above nutrients that could be linked to potatoes. Claims include:

- Contributes to regular laxation
- Necessary for normal blood formation
- Contributes to the reduction of tiredness and fatigue
- Contributes to normal growth and development in children
- Contributes to normal immune system function
- Contributes to normal energy production

- Contributes to normal collagen formation for the normal structure of cartilage and bones
- Necessary for normal water and electrolyte balance

These claims must always make reference to the nutrient but the wording is not specifically set. For example, ‘potatoes are a source of vitamin C and folate which contribute to a healthy immune system’; ‘potatoes are a good source of potassium which helps keep your body hydrated’ and ‘ potatoes are a source of some B vitamins (e.g. folate, niacin, pantothenic acid and thiamin) which contribute to healthy brain function’.

Although there has been considerable new research on the health benefits of potatoes (antioxidant, lowering blood pressure, cholesterol lowering, anti-inflammatory) there is insufficient evidence at present to make a self-substantiated health claim.

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1 Introduction

It is important to be able to accurately document the nutritional value of any food product so that it can be made available to customers and consumers. Food Standards Australia New Zealand (FSANZ) sets standards for what information must and can be used on food labels and for promotional purposes. A key component of a food label is the nutrition information panel (NIP) and the requirements for this are set out in standard 1.2.8 (Nutrition Information Requirements). A new health claims standard (FSANZ Standard 1.2.7) came into force in January 2013 and allows an extended range of preapproved general level health claims on pack. It also allows additional claims to be made via self-substantiation (review of the scientific evidence).

1.1 Standard 1.2.8: Nutrition Information requirements

Standard 1.2.8 prescribes when nutritional information must be provided, and the manner in which such information is provided. Nutrition information panels (NIPs) provide information on the average amount of energy (in kilojoules or both in kilojoules and kilocalories), protein, fat, saturated fat, carbohydrate, sugars and sodium (a component of salt) in the food, as well as any other nutrients about which a nutrition claim is made. For example, if a food had a ‘good source of fibre’ claim then the amount of fibre in the food must be shown in the nutrition information panel. The nutrition information panel must be presented in a standard format which shows the average amount per serve and per 100 g (or 100 mL if liquid) of the food (a template is shown in Table 1). There are a few foods, including fruits and vegetables, which do not require a nutrition information panel. However, if a nutrition claim is made about any of these foods (for example, ‘good source of calcium’, ‘low fat’), a nutrition information panel must be provided. Percentage daily intake (DI) of nutrients and recommended daily intake (RDI) of vitamins and minerals may also be included in the panel. There are set values to be used for calculating these and the requirements on the label (see Appendix 1 and 2 for details).

Table 1. Format of a standard nutrition information panel as prescribed by Food Standards Australia New Zealand (FSANZ).

NUTRITION INFORMATION Servings per package: (insert number of servings) Serving size: g (or mL or other units as appropriate)		
	Quantity per Serving	Quantity per 100 g (or 100 mL)
Energy	kJ (Cal)	kJ (Cal)
Protein	g	g
Fat, total	g	g
– saturated	g	g
Carbohydrate	g	g
Sugars	g	g
Sodium	mg (mmol)	mg (mmol)
(insert any other nutrient or biologically active substance to be declared)	g, mg, µg (or other units as appropriate)	g, mg, µg (or other units as appropriate)

1.2 Standard 1.2.7: Nutrition content claims and health claims

Standard 1.2.7 sets out the requirements for making health claims on foods, including nutrient content claims. **Nutrition content claims** are claims about the content of certain nutrients or substances in a food, such as ‘low in fat’ or ‘good source of calcium’. These claims will need to meet certain criteria set out in the Standard. For example, with a ‘good source of calcium’ claim, the food will need to contain more than the amount of calcium specified in the Standard. Health claims refer to a relationship between a food and health rather than a statement of content. There are two types of health claims:

- **General level health claims** refer to a nutrient or substance in a food and its effect on a health function. They must not refer to a serious disease or to a biomarker of a serious disease. For example: **calcium is good for bones and teeth.**
- **High level health claims** refer to a nutrient or substance in a food and its relationship to a serious disease or to a biomarker of a serious disease. For example: **Diets high in calcium may reduce the risk of osteoporosis in people 65 years and over.** An example of a biomarker health claim is: **Phytosterols may reduce blood cholesterol**.

Food businesses wanting to make **general level health claims** will be able to base their claims on one of the more than 200 pre-approved food-health relationships in the Standard or self-substantiate a food-health relationship in accordance with detailed requirements set out in the Standard. **High level health claims** must be based on a food-health relationship pre-approved by FSANZ. There are currently 13 pre-approved food-health relationships for high level health claims listed in the Standard. All health claims are required to be supported by scientific evidence to the same degree of certainty, whether they are pre-approved by FSANZ or self-substantiated by food businesses. Food-health relationships derived from health claims approved in the European Union, Canada and the USA have been considered for inclusion in the Standard. Health claims will only be permitted on foods that meet the nutrient profiling scoring criterion (NPSC). For example, health claims will not be allowed on foods high in saturated fat, sugar or salt. Thus, because fresh fruit and vegetables (including potatoes) are low in these components they are well placed to make the most of nutrition and health claims.

An updated literature review will be undertaken to gather as much information as possible on the nutritional composition and health benefits of potatoes. This information will serve two purposes:

1. In combination with composition data we have already gathered it will highlight what pre-approved claims are possible for potatoes.
2. To determine if there is enough evidence to indicate there may be health claims worth self-substantiating.

Once the review is completed it will be possible to pull together the relevant preapproved claims for potatoes, i.e. content claims such as “potatoes are a good source of vitamin C”, and low level health claims (nutrient/function claims) such as “vitamin C contributes to normal immune function”. These claims can then be linked together for promotional purposes to tell the story that, because of the vitamin C content, potatoes may support immunity. There will be quite a number of possible claims and it may be necessary to distil out the most significant ones (e.g. areas where two or more nutrients present at source levels support a claim).

2 Literature review

As identified in earlier reports potatoes contain a range of valuable nutrients and phytonutrients (Lister & Monro 2000; Lister 2001, 2009). There has been considerable new research over the last 4 years, and in fact there has been renewed interest in the nutritional content as well as the phytonutrients.

Regular consumption of fruits, vegetables, whole grains, and other plant foods has been negatively correlated with the risk of the development of chronic diseases. In the USA per capita availability (PCA) data for vegetables-often used as a proxy for vegetable consumption-show that vegetable consumption, including consumption of white potatoes, declined in the past decade (Storey & Anderson 2013b). In addition, potatoes are often maligned in nutrition circles because of their suspected link to obesity, and popular potato foods often contain more fat calories than carbohydrate calories. Some food guides do not include potatoes in the vegetable group because of their association with high-fat diets. Also white vegetables, such as potatoes, are often ignored or less favoured compared to coloured vegetables. However, potatoes in their natural state are not a high fat food. Opinion is now that they should be included in the vegetable group because they contribute critical nutrients and deserve a prominent position in food guides (King & Slavin 2013). All white vegetables, including white potatoes, provide nutrients needed in the diet.

2.1 Nutritional composition

The potato is a concentrated source of carbohydrate, dietary fibre, and resistant starch, and continues to be the staple food of choice for many cultures (King & Slavin 2013). Potatoes are also a good source of vitamin C and potassium. Dietary fibre and potassium have been designated as nutrients of concern in the 2010 Dietary Guidelines for Americans. This is probably the same for many other countries around the world as fruit and vegetable consumption is well below recommended levels. Another study cites that potatoes serve as one of the low-fat foods with a spectrum of nutrients and phytochemicals present and are particularly rich in vitamin C, vitamin B6, potassium and manganese (Liu 2013). Potatoes also provide 25% of vegetable phenolics in the American diet, the largest contributors among the 27 vegetables commonly consumed.

Using dietary data for participants in the NHANES 2009-2010 study, total vegetable, white potato, and French-fried potato consumption among all age-gender groups as well as mean energy, potassium, and dietary fibre intakes were examined (Storey & Anderson 2013b). Mean total energy intake for the US population (≥2 y old) was 2080 kcal/d, with white potatoes and French-fried potatoes providing ~4% and ~2% of total energy, respectively. Individuals who consumed white potatoes had significantly higher total vegetable and potassium intakes than did non-consumers. In addition, the proportion of potassium and dietary fibre contributed by white potatoes was higher than the proportion that they contributed to total energy. Among white potato consumers aged 14-18 y, white potatoes provided ~23% of dietary fibre and ~20% of potassium but only ~11% of total energy in the diet. It was concluded that the nutrient-dense white potato may be an effective way to increase total vegetable consumption and potassium and dietary fibre intake.

Several studies in the last few years have factored in both cost and nutrient delivery in looking at what foods should be recommended in a dietary context. This helps consumers identify foods that provide optimal nutrition at an affordable cost. The Nutrient Rich Foods (NRF) Index is a formal scoring system that ranks foods on the basis of their nutrient content (Drewnowski 2010).

In this study potatoes, along with milk, citrus juices, cereals, and beans had more favourable overall nutrient-to-price ratios than did many vegetables and fruit. Energy-dense grains, sweets, and fats provided most of the calories but fewer nutrients per dollar. Another study tested the hypothesis that white potatoes (WP), oven-baked fries (OBF), and French fries (FF) contribute important nutrients within energy needs to children's and adolescents' diets (Freedman & Keast 2011). Vegetables are important sources of dietary fibre, vitamins and minerals in the diets of children. Results indicated that approximately 35% of children and adolescents consumed WP + FF + OBF; 18% consumed FF on a daily basis. Intakes were lower in children compared with adolescents ($P < .01$). Among adolescents, more boys than girls consumed FF ($P < .05$); boys ate larger amounts of WP + FF + OBF (134 g/d) and FF (100 g/d) ($P < .01$). Both WP + FF + OBF and FF provided 9% to 12% of total daily energy (but was within energy requirements in the highest consumers); 8% to 15% of daily fat (>75% monounsaturated fatty acids + polyunsaturated fatty acids); >= 10% dietary fibre, vitamin B(6), and potassium; 5% or greater thiamin, niacin, vitamin K, phosphorus, magnesium, and copper; and less than 5% sodium intake, for all sex-age groups. The combination WP + FF + OBF provided 5% or greater vitamin C for all sex-age groups and 5% or greater vitamin E and iron for most groups; FF provided 5% or greater vitamin E intakes for all. These cross-sectional data show that WP, including FF, provided shortfall nutrients within energy requirements to children and adolescents and, when consumed in moderate amounts, can be part of healthful diets.

Another study estimated the cost impact of meeting the USDA requirements using 2008 national prices for 98 vegetables, fresh, frozen, and canned (Drewnowski & Rehm 2013). Food costs were calculated per 100 grams, per 100 calories, and per edible cup. Rank 6 score, a nutrient density measure was based on six nutrients: dietary fibre; potassium; magnesium; and vitamins A, C, and K. Individual nutrient costs were measured as the monetary cost of 10% daily value of each nutrient per cup equivalent. ANOVAs with post hoc tests showed that beans and starchy vegetables, including white potatoes, were cheaper per 100 calories than were dark-green and deep-yellow vegetables. For the more frequently consumed vegetables, potatoes and beans were the lowest-cost sources of potassium and fibre.

2.1.1 Minerals

There have been numerous studies from all around the world examining the mineral content of potatoes Within the macrominerals, the highest contribution to the intakes was observed for potassium, while iron was the trace element with the largest contribution to the proposed intake (Luis et al. 2011). Another study reported that one serving per day of some potato cultivars ('Russet Burbank', 'Freedom', 'Yukon Gold') provides a significant contribution to the % RDI for the macrominerals magnesium, phosphorus, and potassium and the trace minerals copper, iron, selenium, and zinc (Nassar et al. 2012). It was noted that differences in mineral content occurred between cultivars at each site, specific cultivars at different sites, and collectively between sites. Another study also found statistically significant differences regarding the influence of cultivar, location and their interaction on mineral composition (Rusinovci et al. 2012).

The distribution of minerals varies greatly within the potato tuber. The concentrations of most minerals were higher in the skin than in the flesh of tubers. The potato skin contained about 17% of total tuber zinc, 34% of calcium and 55% of iron. On a fresh weight basis, most minerals were higher in tuber flesh at the stem end than the bud end of the tuber. Potassium, however, displayed a gradient in the opposite direction. The concentrations of phosphorus, copper and calcium decreased from the periphery towards the centre of the tuber (Subramanian et al. 2011). Low concentrations of some minerals relative to those in leaves may be due to their low mobility in phloem, whereas high concentrations in the skin may reflect direct uptake from the soil across the periderm. In tuber flesh, different minerals show distinct patterns of distribution in the tuber, several being consistent with phloem unloading in the tuber and limited onward movement. These findings have implications both for understanding directed transport of minerals in plants to stem-derived storage organs and for the dietary implications of different food preparation methods for potato tubers.

It is sometimes stated that organically grown vegetables are superior nutritionally to those conventionally grown. In a retail market study in a Western US metropolitan area, differences in mineral composition between conventional potatoes and those marketed as organic were analysed (Griffiths et al. 2012). Potatoes marketed as organic had more copper and magnesium ($p < 0.0001$), less iron ($p < 0.0001$) and sodium ($p < 0.02$), and the same concentration of calcium, potassium and zinc as conventional potatoes. Although statistically significant, these differences would only minimally affect total dietary intake of these minerals and be unlikely to result in measurable health benefits.

Mineral micro- and macronutrients in tubers of 21 Andean potato cultivars were investigated in a field trial under control and drought conditions (Lefevre et al. 2012). Mineral concentrations in potato tubers were highly variable between genotypes. Some minerals were significantly and positively correlated with each other, the most noteworthy associations being NaCa, MnMg and ZnFe. These correlations occurred in both control and drought-stressed plants. Overall, increasing yields are related to lower concentrations of some nutrients, although some higher-yielding cultivars contained nutritionally significant concentrations of nutrients. Water depletion resulted in an increase in the concentration of the majority of the analysed cations in a large number of cultivars; some of them, such as potassium, may be related to water homeostasis and/or to sucrose loading and unloading in phloem sap. Tuber mineral concentrations were not related to drought tolerance in terms of tuber productivity. It would appear that some potato cultivars are able to maintain good yield stability in association with high mineral contents under water deprivation. This may be especially important in light of changing climatic conditions and cultivation of the potato as a staple crop in non-optimal cultivation areas.

Potassium

The mineral potassium has received considerable attention in the last couple of years (Freedman & Keast 2011; King & Slavin 2013; Nassar et al. 2012; Ronaldo 2012; Storey & Anderson 2013a & b; Weaver 2013). Potassium is an important electrolyte (a substance that conducts electricity in the body and these electrical impulses enable your cells to send messages back and forth between themselves) and plays a number of other roles in human health. It was one mineral identified as a shortfall nutrient by the Dietary Guidelines for Americans 2010 Advisory Committee. The committee concluded that there was a moderate body of evidence of the association between potassium intake and blood pressure reduction in adults, which in turn influences the risk of stroke and coronary heart disease. Evidence is also accumulating of the protective effect of adequate dietary potassium on age-related bone loss and reduction of kidney stones. In modern societies, Western diets have led to a decrease in potassium intake with reduced consumption of fruits and vegetables and a concomitant increase in sodium consumption through increased consumption of processed foods. Consumption of white vegetables is associated with decreased risk of stroke, possibly related to their high potassium content. Potatoes are the highest source of dietary potassium, but the addition of salt should be limited. Low potassium-to-sodium intake ratios are more strongly related to cardiovascular disease risk than either nutrient alone. Potassium is one of the key nutritional attributes that could be promoted for potatoes.

Iron

Iron is a key component of red blood cells and many enzymes which play a vital role in the production of energy. A healthy immune system also requires sufficient iron. Iron deficiency in humans occurs in all regions of the world. Potatoes contain some iron, although it is not always high enough to be classed at source levels (see Section 3.5). One recent study in the US has shown considerable variation in levels (Brown et al. 2010). Overall the range of mean iron content on a clonal basis was 17 to 62 ug per gram dry weight (equates to around 0.4-1.4 mg/100 g FW, based on dry matter of 22%). The values at the upper end of this range are three times higher than generally reported values of potato. These results suggest that genetic variation for tuber iron content exists and that breeding for enhanced iron content would be feasible. However, there has been some concern about developing high iron varieties because high iron has been implicated in after cooking darkening (Wurster and Smith 1965). However, the highest clones in the study by Brown et al. (2010) were not associated with high after-cooking darkening in cooking tests. It was suggested that some clones would demonstrate high dietary iron bioavailability based on high iron and ascorbic acid contents (Cook and Reddy 2001; Reddy et al. 2000). Fairweather-Tait (1983) demonstrated high iron availability in rats from potato in particular. However, there has been no further study in this area to confirm this and it is worth further investigation. Our internal studies have shown that there is considerable variation in iron levels in New Zealand grown potatoes, with considerable interaction between genotype and environment. This is being investigated further in a Plant & Food research funded project.

Magnesium

Another mineral present in potatoes is magnesium, although according to New Zealand data it does not consistently reach the ‘source’ levels required to make a claim (see Section 3.5). Magnesium is the fourth most abundant mineral and the second most abundant intracellular divalent cation, and has been recognized as a cofactor for >300 metabolic reactions in the body. Because of magnesium's many functions within the body, it plays a major role in disease prevention and overall health. Low levels of magnesium have been associated with a number of chronic diseases including migraine headaches, Alzheimer's disease, cerebrovascular accident (stroke), hypertension, cardiovascular disease, and type 2 diabetes mellitus. There has been some recent study of magnesium in potatoes. A recent paper did comment that good food sources of magnesium include unrefined (whole) grains, spinach, nuts, legumes, and potatoes (Volpe 2013). Another study reported magnesium levels from 787 to 1,089 µg per gram dry weight (Brown et al. 2012). Genotype and environment interactions had a significant impact on magnesium levels. It was concluded that potato is not a rich source of magnesium for the human diet, but genetic variation exists among potato clones that might be useful.

Zinc

Zinc has a crucial role in human health as a micronutrient. Zinc deficiency mainly occurs among the poorest of the world's populations and hence has been the focus of some studies to look at stable foods that can deliver zinc. In a US study, genotype mean zinc content ranged from 12 to 18 µg per gram dry weight (Brown et al. 2011). However, a 100 g serving of the highest zinc genotype would only provide around 4% of the adult recommended dietary intake. This study suggested that potato from this breeding pool would not appear to be a good candidate for biofortification of zinc through traditional breeding. Some other earlier studies have suggested that zinc biofortification through breeding may be warranted in potato for populations with high potato consumption and high risk for zinc deficiency in the Andes of South America. Zinc is not a key focus for the New Zealand population and probably does not warrant further detailed study at this point. However, we have tacked some zinc analysis on to our project on iron to determine how much variability there is.

2.1.2 Folate

Folate deficiency is a global nutritional problem and is problematic even in the developed world. Potatoes do not have exceptionally high folate content, but are a source of this B vitamin due to the amount and frequency of consumption. It has been noted that potatoes supply about 10% of the total folate intake of the people in European countries such as the Netherlands, Norway and Finland (Navarre et al., 2009). One study has found that folate concentrations were higher in younger tubers and substantially higher in some cultivars (Goyer & Navarre 2009). Folate was highest in young tubers and dropped 2.6- to 3.4-fold by the time of harvest. These researchers also measured folate concentrations in tubers of different sizes harvested from the same plant (i.e. all tubers were harvested under the same environmental conditions). In all five genotypes examined there was a general decreasing trend in folate concentrations ranging from 20 to 35% decrease between very small and large tubers. They concluded that small tubers on mature plants were not physiologically equivalent to small tubers on young plants. Thus new potatoes may confer a nutritional advantage beyond just small tuber size. The following calculations were made: “Assuming a 20% dry matter content, a 175 g serving of young ‘Russet Burbank’ tubers would provide 17.8% of the American Recommended Daily Allowance (RDA) (400 µg day−1) compared with 6.5% for a mature tuber serving. Therefore potato is a much better source of folate than other major staple foods such as white rice (maximum reported value would provide ~4% of the RDA per 175 g serving).” The only current entry in the New Zealand Food Composition database is for canned new potatoes. Thus, it may be worth analysing new potatoes and promoting their nutritional composition if these data are confirmed.

2.1.3 Thiamin (vitamin B1)

Thiamin is an essential nutrient in the human diet. Although severe thiamin deficiency is very rare in industrialized countries, marginal deficiency remains a real health concern and it has been suggested that developing crops with increased thiamin content could have a positive impact on human health. Potato contains modest amounts of thiamin (New Zealand data are variable and it do not always reach source levels, see Section 3.4.3) but there has been limited study of the variability in potatoes. A recent US study determined thiamin concentrations in freshly harvested unpeeled tubers of 54 potato clones (Goyer & Haynes 2011). Thiamin concentrations ranged from 29 to 132 µg per 100 gram fresh weight. Thirteen clones/varieties contained >69 µg per 100 gram fresh weight and four had > 80 µg per 100 gram fresh weight over multiple harvests, indicating that these genotypes would contribute a significant amount of thiamin in the diet (>10% of the Recommended Daily Allowance based on a 175- or 150-g serving, respectively). Genetic variation accounted for about 50% of the observed variation. There were significant clone and clone x environment effects. After accounting for environmental variation, 25 clones were unstable across environments. Tubers harvested at a mature stage late in the growing season had higher amounts of thiamin than tubers harvested at a young stage early in the season (opposite to findings for folate as mentioned earlier). Storage at cold temperature did not lead to significant thiamin loss; instead, thiamin concentrations slightly increased during storage in some genotypes. These results suggest that increasing the concentration of thiamin in potato is feasible.

2.1.4 Vitamin B6

Vitamin B6 is an essential nutrient in the human diet that contributes to a variety of human health benefits. Although biosynthesis of the vitamin has been well resolved in recent years, the main research is currently based on *Arabidopsis thaliana* with very little work done on major crop plants. A recent study has examined interactions and expression profiles of genes for vitamin B6 biosynthesis in potato and how vitamin B6 content varies in tubers of different genotypes (Mooney et al. 2013). They concluded that "potato is an excellent resource for this vitamin and that strong natural variation in vitamin B6 content among the tested cultivars indicates high potential to fortify vitamin B6 nutrition in potato-based foods". The New Zealand Food Composition Database data show considerable variation in thiamin levels but it is not possible to ascertain the reasons for the variation. This vitamin is worth further measurement/study in potatoes.

2.1.5 Vitamin C

There has been considerable study of vitamin C in potatoes and they are a major dietary contributor of this important water-soluble vitamin. Recent studies of vitamin C in potatoes have focused on processing effects. Vacuum-impregnation (VI) has been successfully used for enriching the ascorbic acid content of whole potatoes (Hironaka et al. 2011). A steam-cooking study showed that 100 g of the 25 min steam-cooked VI potatoes could provide adults with 90-100 mg of vitamin C. The storage study showed that VI whole potatoes had a relatively high vitamin C concentration (50 mg/100 g), even at 14 days of storage at 4ºC. The effects of storage on intact potatoes have also been investigated. Twelve Colorado-grown specialty potato clones were evaluated for ascorbic acid content (along with other measures) at harvest and after 2, 4, 6 and 7months' cold storage at 4ºC (Kulen et al. 2013). Vitamin C content was higher in 'Yukon Gold' than in the other clones. The highest level of vitamin C in all clones was at harvest and after 2 months in cold storage. Vitamin C content in all potato clones dropped rapidly with longer intervals of cold storage.

Although many studies have shown nutritionally relevant levels of vitamin C in potatoes there has not been specific study of its bioavailability (i.e. intestinal absorption of vitamin C from orally ingested potatoes and its transfer to the blood). A recent study determined whether the dietary consumption of potatoes affected vitamin C concentration in plasma and urinary excretion of vitamin C in human subjects (Kondo et al. 2012). After overnight fasting, five healthy Japanese men between 22 and 27 years of age consumed 282 g mashed potatoes, 87 g potato chips, 50 mg vitamin C in mineral water or mineral water. Each portion of potatoes contained 50 mg of vitamin C. The vitamin C levels in potato-fed subjects were higher than those of water, but did not differ significantly from those of vitamin C in water. Less vitamin C tended to be excreted in urine during the 8 h test than vitamin C in water alone. These results demonstrate that vitamin C from mashed potatoes and potato chips is effectively absorbed in the intestine and transferred to the blood.

2.2 Phytochemical composition

In addition to supplying energy and important vitamins and minerals, potatoes contain a number of health-promoting phytonutrients such as phenolics (flavonoids, anthocyanins) and carotenoids. Although these are attracting considerable scientific interest, the challenge at present is that no health claims are permitted for these compounds. Further study is required to substantiate their benefits and determine the optimal level of intake (there are no recommended dietary intakes for these compounds at present).

2.2.1 Phenolics (including flavonoids)

Phenolics are one of the main groups of secondary metabolites in plants. Phenolics have attracted a lot of interest because they have high antioxidant activity *in vitro*. However, there has being growing debate about how they work *in vivo*. Even if phenolics do not act as antioxidants *in vivo* they have a whole range of other activities (Stevenson and Hurst 2007; Crozier et al. 2009). The amount and composition of phenolics varies between plants. As noted in previous reports (Lister & Monro 2000; Lister 2001, 2009), in potatoes the predominant phenolic compound is chlorogenic acid, which constitutes about 80% of the total phenolic acids. The tuber skin can contain much higher levels of phenolic compounds than the flesh. There has been further study of variation in phenolic content. In one study potatoes from over 50 genotypes representing cultivars, breeding lines, primitive germplasm and wild species were analysed for phenolic content and hydrophilic antioxidant capacity (Navarre et al. 2011). Genotypes with markedly higher amounts than the most commonly consumed potatoes were identified. Chlorogenic acid was the most abundant phenolic and ranged from 22 to 473 mg/100 g dry weight. Rutin and kaempferol- 3-rutinose were the most abundant flavonols. Total phenolics ranged from 180 to 1,100 mg/100 g DW and antioxidant capacity from 2.7 to 21.9 mmol TE/100g DW. The highest-phenolic genotypes were coloured-flesh potatoes. However, consumers tend to prefer white-flesh potatoes. White-flesh potatoes with higher amounts of phenolics than found in standard cultivars were observed.

There has been continued study of coloured potato cultivars. The main anthocyanin of 'Red Laura' and 'Mayan Twilight' was characterized as pelargonidin-3-coumarylrutinoside-5-glucoside by LC-ESI-MS (Burmeister et al. 2011). The blue pigment of the 'Shetland Black' cultivar was petunidin-3-coumaroylrutinoside-5-glucoside. 'Red Laura' contained 10 mg anthocyanins per gram dry weight and 'Shetland Black' 31 mg anthocyanins per gram dry weight. The total pigment content was decreased by heat processing in all cultivars. In another study which included purple- and red-fleshed potato varieties, average total anthocyanin content ranged from 61.5 to 573.5 cyanidin mg per kg of fresh weight (Hamouz et al. 2011). The highest content was in 'Violette' and 'Vitelotte' varieties with dark purple flesh, and the lowest content the 'Blue Congo' variety with light purple, marbled flesh. Antioxidant activity was lowest in varieties with yellow or white flesh while in red-fleshed varieties it was higher by 4.34 times, and in a group of purple-fleshed varieties even 5.03 times higher. There was a strong correlation between antioxidant activity and anthocyanin content (r = 0.8099).

The impact of selected factors – cultivar, storage, cooking and baking on the content of total anthocyanins in coloured-flesh potato cultivars has been studied (Lachman et al. 2012). Anthocyanin content was statistically significant between cultivars and ranged from 248.5 to 2257.8 mg per kg dry matter. Cold storage (4ºC) influenced anthocyanin content differentially. In the 'Violette' and 'Highland Burgundy Red' cultivars, anthocyanins increased by 18.5% and 12.1% respectively, and in the 'Valfi' cultivar it decreased by 33.9%. Baking increased anthocyanin content 3.34 times whereas cooking in boiled water increased it 4.22 times. There was correlation between antioxidant activity and anthocyanin content ($r^2 = 0.659$). The 'Violette', 'Vitelotte' and 'Highland Burgundy Red' cultivars with the highest anthocyanin content showed high antioxidant activity and the 'Shetland Black' cultivar and the cultivars 'Salad Blue' and 'Blue Congo' with a "marbled" texture showed the lowest anthocyanins and antioxidant activity. The effects of cooking seem to vary between studies. Another study examined three potato cultivars – 'Gogu Valley' (red skin, yellow flesh), 'Purple Valley' (purple skin, purple flesh) and 'Superior' (yellow skin, yellow flesh) – using different cooking methods (boiling, steaming, microwaving, frying) (Li et al. 2012). Antioxidant activity and phenol contents were decreased after different cooking treatments compared with uncooked treatment. The 'Purple Valley' cultivar in all cooking treatments, and microwaving treatment in all cultivars, had the highest retention of antioxidant activity and phenol contents.

There have been many other studies examining factors affecting phenolics in potatoes. High-phenolic purple potatoes grown in environmentally diverse locations in North America (Alaska, Texas and Florida) have been studied (Payyavula et al. 2012). Phenolics, including chlorogenic acid (CGA), were higher in samples from the northern latitudes. Anthocyanins were more abundant in Alaskan samples. The most abundant anthocyanin was petunidin-3-coum-rutinoside-5-glu, which ranged from 4.7 mg per gram in Alaska to 2.3 mg per gram in Texas. Two purple breeding clones and the yellow-fleshed cultivar ‘Agave’ were grown in the glasshouse under control with drought stress conditions for two consecutive years (Wegener & Jansen 2013). After harvest, the tubers were analysed for concentrations of antioxidants measured as ascorbic acid equivalent (ACE) and trolox equivalent (TXE) in fresh tissue and after wounding. In addition, the peroxidase enzyme (POD) activities and total amounts of anthocyanins (Ac) were assayed. Drought stress caused a significant decrease in tuber yield but had no significant effect on Ac, POD, ACE and TXE. Wounding stress significantly induced the POD activity in control and drought stressed tubers of all genotypes. Also the ACE and TXE were notably increased by wounding in ‘Agave’. This increase was less pronounced in the purple clones. In general purple clones displayed a higher level of antioxidants. The results revealed significant differences between genotypes and that the effect of drought stress on the level of antioxidants is smaller than that of wounding stress.

Postharvest storage may also impact on phenolic levels in potatoes. Kumar and Ezekiel (2009) found that phenols content in the peels and flesh of three Indian potato varieties decreased after 90 days of storage at 2–4°C, 10–12°C and in heap storage, a traditional method of storage. Effect of storage of potatoes at 4 or 20°C for 110 days on phenolic content was studied by Blessington et al. (2010). No significant differences in total phenolic content, chlorogenic acid, caffeic acid and vanillic acid were observed after storage at 4 or 20°C. There was an increase in rutin, p-coumaric acid and quercetin dehydrate contents after storage at 4 or 20°C. When 4°C stored potatoes were reconditioned for 10 days at 20°C, there was a significant increase in total phenolic content, chlorogenic acid, caffeic acid, rutin, vanillic acid, p-coumaric acid, and quercetin dehydrate levels. All the three storage treatments resulted in increased carotenoid content but caused no significant differences in phenolic content and antioxidant activity in most of the eight genotypes studied. In another study, 12 Colorado-grown specialty potato clones were evaluated for total phenolic content and antioxidant activity at harvest and after 2, 4, 6 and 7 months’ cold storage at 4ºC (Kulen et al. 2013). Pigmented potato genotypes had significantly higher total phenolic content and antioxidant activity at all data points than yellow- and white-fleshed cultivars. Although total phenolic content and antioxidant activity fluctuated during cold storage, after 7months of cold storage their levels were slightly higher than at harvest.

It is important to understand the impacts of cooking on phenolics in potatoes since they are not eaten in their raw state. There are conflicting reports about the effects of cooking on phenolic content of potatoes. Faller and Fialho (2009) reported that boiling, microwave baking and steaming decreased the phenolic content. However, the recovery of polyphenols was higher after boiling as compared to microwave cooking and it was least in steamed potatoes. They observed that, unlike in other vegetables such as carrot, onion and cabbage, cooking caused an increase in antioxidant capacity in potatoes, however different cooking methods did not show significant differences. Their results indicate that, though cooking caused a decrease in polyphenols contents, it resulted in an increase in antioxidant capacity in potatoes. In raw vegetables, hydrolyzable polyphenols showed higher correlation with antioxidant capacity whereas in cooked vegetables, soluble phenols showed a better correlation with antioxidant capacity (Faller and Fialho 2009). The formation of novel substances, such as products of Maillard reaction, could also increase the antioxidant capacity in potatoes (Manzocco et al. 2001). Microwaving and frying have also been reported to cause a loss of flavonoids but phenolic acids were not examined in this study (Abida et al. 2011).

In another study, the total phenolic content and antioxidant activity did not show any difference between raw and in boiled potatoes but were higher in baked, fried or microwaved potatoes (Blessington et al. 2010). Greater amounts of phenolics may be extracted out of the potato matrix into water during boiling and into the oil during frying since phenolic compounds are hydrophilic. Baked, fried and microwaved potatoes had greater levels of caffeic acid and p-coumaric acid, and microwaved potatoes had a higher level of (−) epicatechin. Baking, boiling, frying and microwaving did cause a significant decrease in quercetin. Navarre et al. (2010) also determined losses in phenolics after cooking by microwaving, steaming, boiling or baking and found that none of these cooking methods decreased the amount of chlorogenic, cryptochlorogenic and neochlorogenic acids. The contents of these compounds and total phenolics either remained the same or increased after cooking. They also reported no significant loss in the concentrations of rutin or kaempferol-rutinose and an increase in the concentration of these compounds after cooking was attributed to an increase in recoverable compounds, as there is little biosynthesis of these compounds during cooking. Cooking may facilitate the extractability of these compounds by altering the matrix, resulting in higher recoveries and inactivating enzymes that otherwise consume these compounds. Antioxidant capacity of baked, boiled, microwaved or steamed potatoes was reported to be higher as compared to uncooked potatoes, and the highest values were observed for steamed or baked potatoes. The effect of boiling on concentrations of total phenolics (TP), total anthocyanins (TA) and phenolic acids (PA) and on antioxidant activity (AA) of purple-fleshed potatoes belonging to *Solanum andigenum* was determined in four native Andean accessions (Burgos et al. 2013). The predominant PA in raw and boiled potato tubers was chlorogenic acid (CA). Caffeic acid was also present in raw tubers but drastically decrease in boiled tubers. For all accessions, the concentrations of TP and AA determined in boiled tubers were higher than in raw tubers. However, with the exception of ‘Guincho’, the TA and CA concentrations determined in raw and boiled tubers of the accessions were not significantly different.

The reasons for differences in effects of cooking may be varied, including analytical issues. There may also be differences in response of different varieties. For the varieties ‘Blaue Elise’ and ‘Blue Salad Potato’, processing significantly increased total phenol content, with slight increases in monomeric anthocyanins and chlorogenic acids (Hillebrand et al. 2011). In the cultivar ‘Blauer Schwede’, cooking and steam boiling reduced the levels of monomeric anthocyanins, but increased the content of chlorogenic acids. Thermal treatment significantly enhanced the release of phenolic compounds [bound-form phenolics] from potato peel, but also accelerated the breakdown of the released compounds.

Coloured potatoes have also been investigated as a source of antioxidants for food (Nayak et al. 2011a). Retention of total antioxidants in fresh coloured potatoes and processed potato flakes prepared as potential ingredients for snack foods was studied. Peeled purple potatoes were blanched and dehydrated by freeze drying (FD), drum drying and refractance window drying to prepare potato flakes. Results showed no significant losses in total antioxidant capacity and total phenolic content in flakes in all drying methods obtained under study. However, 45, 41 and 23% losses in total anthocyanins content were observed in potato flakes after FD, drum drying and refractive window drying, respectively. Purple potato flour has been used in extrusion products (Nayak et al. 2011b). Interestingly extruded products had significantly higher ($P < 0.05$) content of total phenolics, ORAC antioxidant activity, and flavonoids, compared to the raw formulations. The processing probably releases bound phenolics. Another study also examined a commercial production process for dehydrated potato flakes, but for a non-coloured potato (Mader et al. 2009). Processing potatoes to potato flakes diminished the phenolic content, mainly due to peeling and leaching. The influence of thermal exposure was less significant. About 43% of the initial phenolic acids and 10% of the glycoalkaloids remain after processing. Steam peeling has a higher influence on glycoalkaloid losses compared to that on phenolics. The highest amounts of phenolic compounds and glycoalkaloids were found in peeling by-product. During processing, the amount of chlorogenic acid decreased, whereas the concentration of neochlorogenic acid increased due to isomerization.

2.2.2 Carotenoids

Plant carotenoids are lipid soluble pigments that play key roles in numerous plant functions. They also play significant roles in the human diet by serving as precursors for vitamin A synthesis and by reducing the occurrence of certain diseases. As noted in the previous report (Lister 2009) carotenoids are present in the flesh of all potatoes to varying degrees. Contents mentioned in the literature range from 50 to 100 µg/100 g fresh weight in white-fleshed varieties to 2,000 µg/100 g FW in deeply yellow- to orange-fleshed cultivars. The carotenoids in potato are primarily lutein, zexanthin and violaxanthin, all of which are xanthophylls. There is just a trace of either alpha- or beta-carotene, meaning that potato is not a source of pro-vitamin A carotenes.

In more recent study tubers of the closely related species *Solanum tuberosum* (potatoes) and *Solanum phureja* have been examined for their pigment content. The main carotenoids in raw tubers of all cultivars were are 9-cis-violaxanthin, lutein and one unidentified carotenoid (Burmeister et al. 2011). Minor compounds were identified as neoxanthin and neochrome. Additionally, zeaxanthin and one further unidentified carotenoid could be found in ‘Red Laura’ and ‘Mayan Gold’. No differences in the carotenoid composition between peel and flesh could be found. Total carotenoid content in pigmented potatoes ranged from 2.6 µg per gram dry weight in ‘Shetland Black’ to 14.8 µg per gram dry weight in ‘Red Laura’ (calculated as beta-carotene-equivalents). In heat-processed tubers, a large proportion of carotenoids either changed from all-trans to 9-cis and 13-cis-isomeric forms or were degraded. The total pigment content was decreased by heat processing in all cultivars. In other studies examining tubers of accessions of *S. Phureja,* two accessions were identified with a very high concentration of zeaxanthin at 1290 µg/100 g FW (Burgos et al. 2009). Bonierbale et al. (2009) also identified two varieties with high zeaxanthin concentrations (above 1000 µg/100 g FW) and a group of 43 accessions with relatively high β-carotene concentrations (above 10 µg/100 g FW). However, this is not high enough to have any significance nutritionally in terms of contribution to vitamin A activity. Diretto et al. (2007) claimed that 50% of the RDA of vitamin A can be met by consuming 250 g of carotenoid-enriched genetically engineered potatoes. This appears the only way to achieve nutritionally significant vitamin A levels. Consumer acceptance remains to be seen though and since vitamin A can easily be delivered by other vegetables, e.g. carrots and sweet potato, there is probably little merit in this approach.

The effect of boiling on the concentrations of total and individual carotenoids was determined in a group of native Andean potato accessions with diverse intensities of yellow flesh colours (Burgos et al. 2012). Changes in concentrations due to boiling varied significantly among accessions. Boiling significantly reduced the violaxanthin and antheraxanthin concentration of all the accessions. However, the lutein and zeaxanthin concentrations of boiled tubers were not affected or were higher than the concentrations in raw tubers. The intermediate yellow-fleshed accession 701862 showed the highest lutein concentration (above 200 µg/100 g) and the deep yellow-fleshed accession 704218 showed the highest concentration of zeaxanthin (above 1000 µg/100 g) in raw and boiled tubers. Boiled potatoes of deep yellow-fleshed varieties are a significant source of zeaxanthin (above 500 µg per 100 g).

2.3 Health benefits

In addition to investigating the composition of potatoes a number of research groups have examined the potential health benefits. A number of studies continue to show potatoes have antioxidant activity, especially coloured cultivars (Albishi et al. 2013; Andre et al. 2009; Blessington et al. 2010; Burgos et al. 2013; Hu et al. 2012; Kulen et al. 2013; Kumar & Ezekial 2009; Navarre et al. 2011; Perla et al. 2012; Wegener & Jansen 2013; Xu et al. 2009). These studies have promoted consumption of purple cultivars in preference to white- or yellow-fleshed cultivars and suggested the use of potato peels for extraction of antioxidants. In some cases antioxidant-rich potato products have been used in foods to prevent oxidation (e.g. Farvin et al. 2012; Jayawardana et al. 2012). However, as noted earlier, there is debate about the relevance of *in vitro* antioxidant activity measures and what they may mean *in vivo* and to disease outcome. There are a number of health areas where human trials have been conducted.

2.3.1 Lowering blood pressure

A study examining blood pressure in humans has concluded that two small helpings of purple potatoes (‘Purple Majesty’) a day decreases blood pressure without causing weight gain and these same potatoes also increase plasma antioxidant capacity (Vinson et al. 2012). In a single-dose study, six to eight microwaved potatoes with skins or a comparable amount of refined starch as cooked biscuits were given to eight normal fasting subjects; repeated samples of blood were taken over an 8 h period. Potato caused an increase in plasma and urine antioxidant capacity, whereas refined potato starch caused a decrease in both (i.e. it acted as a pro-oxidant). In addition the effects of eating 6-8 small microwaved purple potatoes twice a day on 18 volunteers, most of whom were overweight with high blood pressure, was investigated. The volunteers ate potatoes or no potatoes for four weeks, and then switched to the opposite regimen for another four weeks while researchers monitored systolic and diastolic blood pressure (the higher and lower numbers in a blood pressure reading, e.g. 120/80), body weight and other health indicators. There was no significant effect of potato on fasting plasma glucose, lipids, or HbA1c. There was no significant body weight increase. Diastolic blood pressure significantly decreased 4.3%, a 4 mm reduction. Systolic blood pressure decreased 3.5%, a 5 mm reduction. This blood pressure drop occurred despite the fact that 14 of 18 subjects were taking antihypertensive drugs. This is the first study to investigate the effect of potatoes on blood pressure. Thus, purple potatoes are an effective hypotensive agent and lower the risk of heart disease and stroke in hypertensive subjects without weight gain. Further study is required to confirm these effects before a ‘blood pressure lowering’ claim could be made for potatoes.

2.3.2 Anti-cancer

It has been reported that freeze-dried potato powder caused a 23% reduction in induced breast cancer in rats (Thompson et al. 2009). Freeze-dried potato powder, prepared from baked potato with skin, was incorporated into standard rat diet and the effects on the post-initiation phase of chemically induced breast carcinogenesis were evaluated. No adverse effects were observed in rats fed diets containing between 5% and 50% (w/w) freeze-dried potato powder. ‘Russet Burbank’ potato had marginal effects on the carcinogenic response. However, a red-pigmented cultivar (‘Mountain Rose’), with higher content of chlorogenic acid derivatives and anthocyanin content, showed greater inhibition of carcinogenesis. Overall, rats fed ‘Mountain Rose’ had a 23% reduction in cancer incidence and a 49% reduction in cancer multiplicity (number of tumours per rat). There was evidence of a dose-dependent effect on cancer multiplicity. Extracts from purple potato have also been shown to reduce breast cancer cell proliferation in vitro (Chong et al. 2009).

Studies have also shown effects on other cancer types. Coloured potato extracts and an anthocyanin-rich fraction have been reported to suppress lymph-node carcinoma of the prostate and prostate cancer-3 prostate cancer cell proliferation (Reddivari et al. 2010). Proliferation of colon cancer and liver cancer cells *in vitro* was significantly inhibited by potato antioxidant extracts (Quanyi et al. 2011). Analysis showed that Mexican wild species *S. pinnatisectum* had the highest total phenolic, and chlorogenic acid content and also the highest antiproliferative activity. An inverse correlation was found between total phenolics and the EC 50 of colon cancer cell, as well as liver cancer cell proliferation. Studies with individual phenolics suggested that chlorogenic acid may be the primary compound responsible for the antiproliferative activity. Purple-fleshed potatoes were more potent in suppressing proliferation and elevating apoptosis of colon cancer cells compared with white- and yellow-fleshed potatoes (Madiwale et al. 2011). The extracts from both fresh and stored potatoes (10-30 mu g/mL) suppressed cancer cell proliferation and elevated apoptosis compared with the solvent control, but these anticancer effects were more pronounced with the fresh potatoes.

Although there is accumulating evidence that potatoes may have benefits for cancer, this is an area where claims are unlikely because cancer is a serious disease.

2.3.3 Cholesterol lowering

The effect of purple potato flake on cholesterol metabolism was investigated in rats fed a high-cholesterol diet (Han et al. 2013). The potato flakes improved serum cholesterol metabolism without causing a difference in food intake. It was hypothesised that the combination of polyphenols, including anthocyanins, and phosphorus, may be responsible for this effect. However further work is necessary to prove this. Wan et al. (2012) also suggested that chlorogenic acid reduces plasma total cholesterol and LDL-cholesterol levels in hyper cholesterolaemic rats induced with a high-cholesterol diet. Studies have also shown that potato peptides have the ability to alter serum lipids when rats fed either on a cholesterol-free diet (Liyanage et al. 2008) or cholesterol enriched diet (Liyanage et al. 2009). Preparation method also influences cholesterol-lowering effects (Liyanage et al. 2010). Further research is before claims could be made for cholesterol-lowering effects for potatoes.

2.3.4 Anti-inflammatory

The effects of consumption of pigmented potatoes on oxidative stress and inflammation biomarkers in adult males has been studied (Kaspar et al. 2011). The secretion of pro-inflammatory cytokines such as IL-1, IL-6, and TNFa by lymphocytes is responsible for initiating inflammation in the pathogenesis of chronic diseases such as atherosclerosis and rheumatoid arthritis. Circulating cytokines and C-reactive protein are biomarkers for disease progression. Free-living healthy men (18-40 y; n = 12/group) consumed 150 g of cooked white-, yellow-, or purple-flesh potatoes once per day for 6 wk in a randomized study. DNA damage was assessed by plasma 8-hydroxydeoxyguanosine (8-OHdG), protein oxidation, lipid peroxidation, C-reactive protein (CRP), inflammatory cytokines, lymphoproliferation, NK cytotoxicity, and phenotypes. Compared with the white potatoes, the yellow potatoes had higher concentrations of phenolic acids and carotenoids, whereas the purple potatoes had higher concentrations of phenolic acids and anthocyanins. Men who consumed yellow- and purple-fleshed potatoes tended to have lower plasma IL-6 compared with those consuming white potatoes. Those eating purple potatoes tended to have a lower plasma C-reactive protein concentration than those eating white potatoes. The 8-OHdG concentration was lower in men who consumed either yellow potatoes or purple potatoes compared with white potatoes. Pigmented potato consumption reduced inflammation and DNA damage in healthy adult males. Rats and cell studies have also shown that anthocyanin-rich cultivars demonstrate anti-inflammatory activity (Hashimoto et al. 2010). Further research is required before claims in this area could be made.

3 Potato composition and health claims

3.1 Nutritional composition and the basis for claims

As discussed in section 1, with the implementation of FSANZ Standard 1.2.7 there are new opportunities for promoting the nutrition and health benefits of foods. The New Zealand Food Composition database (www.foodcomposition.co.nz) has a number of entries for potatoes and these have been used as the basis for the calculations below. As a benchmarking point for health claims the entry X99 has been used, which is for combined cultivars, raw including both flesh and skin. However, other data entries for specific cultivars, flesh only and various cooked forms (baked, boiled, microwaved, roasted) have also been examined (the data used can be provided in a spreadsheet if desired). In order to make nutrient content claims (e.g. 'source of vitamin C') or general level health claims (e.g. 'vitamin C supports a healthy immune system') there are set criteria that must be met for each nutrient and these are given in Appendix 1. Claims are made on the basis of serve size rather than per 100 g. A serve size must be realistic and for potatoes a serving size of one potato (150 g) is often used.

The following tables (Table 2 and 3) provide mocked-up NIPs for potatoes. A serving size of 150 g has been chosen and the number of servings per pack will need to be inserted depending on pack size. The entries above the dotted lines are the essential requirements for the NIP. The only exception is dietary fibre, which is an optional declaration, but this is where it is included in the list. Entries below the dotted line are optional and any combination of these can be included. However, it is important to note that if reference is made anywhere on pack to a vitamin or mineral (e.g. 'a good source of vitamin C') then that vitamin or mineral must be included in the NIP. The following footnotes need to be included below the panel:

> % Daily Intakes are based on an average adult diet of 8700 kJ. Your daily intakes may be higher or lower depending on your energy needs
>
> RDI = Recommended Dietary Intake, ESADDI = Estimated Safe and Adequate Daily Dietary Intakes

Table 2. Example of a standard NIP for raw potatoes, data from FOODfiles 2012 Version 01 (www.foodcomposition.co.nz).

NUTRITION INFORMATION Servings per package: *[to be inserted]* Serving size: 1 potato 150 g			
	Quantity per Serve	% Daily intake per serve	Quantity per 100 g
Energy	461 kJ	5%	308 kJ
Protein	3.2 g	6%	2.1 g
Fat, total	0.1 g	0%	0.1 g
-saturated	0 g	0%	0 g
Carbohydrate	23.4 g	8%	15.6 g
- sugars	0.5 g	1%	0.3 g
Dietary fibre, total	2.4 g	8%	1.6 g
Sodium	5 mg	0%	3 mg
Folate	25 µg	13% RDI	17 µg
Niacin	2.1 mg	21% RDI	1.4 mg
Pantothenic acid	0.6 mg	12% RDI	0.4 mg
Potassium	701 mg	[a]	467 mg
Vitamin C	20 mg	50% RDI	13 mg

[a] note there is no labelling RDI for potassium but a claim can be made if a serve contains >200 mg per serve

Table 3. Example of a standard NIP for cooked potatoes with no added fat or salt (average of boiled, baked and microwaved), data from FOODfiles 2012 Version 01 (www.foodcomposition.co.nz).

NUTRITION INFORMATION
Servings per package: *[to be inserted]*
Serving size: 1 potato 150 g

	Quantity per Serve	% Daily intake per serve	Quantity per 100 g
Energy	513 kJ	6%	342 kJ
Protein	3.2 g	6%	2.2 g
Fat, total	0.3 g	0%	0.2 g
-saturated	0.1 g	0%	0.1 g
Carbohydrate	25.4 g	8%	16.9 g
- sugars	1.2 g	1%	0.8 g
Dietary fibre, total	2.8 g	9%	1.9 g
Sodium	3 mg	0%	2 mg
Folate	24 µg	12% RDI	16 µg
Niacin	2.0 mg	20% RDI	1.3 mg
Pantothenic acid	0.5 mg	10% RDI	0.3 mg
Potassium	602 mg	[a]	401 mg
Vitamin C	16 mg	40% RDI	11 mg

[a] note there is no labelling RDI for potassium but a claim can be made if a serve contains >200 mg per serve

3.2 Consumer relevance of claims

At the moment the wording for the claims in the sections below is taken straight out of the standard. It is important that the language used for claims is consumer friendly. Unlike some overseas claims, the wording we can use is not set by FSANZ. However, it is important that the meaning/intent of the claims is not changed. The general level claims are maintenance claims and refer to a requirement or contribution to normal function. It is important not to make reference to enhancement or inhibition of function. Verbs like "inhibit", "reduce", "boost", "increase" etc. would all imply either inhibition or acceleration of a normal physiological function and must not be used or regulations will be breached. Food manufacturers are also legally barred from making therapeutic claims for their foods – such as being capable of curing illness – unless they substantiate the claims with scientific testing and register the food as a medicine. Words like "treatment", "relief from", "symptoms", "prevention of", "medical", "therapeutic", and "symptoms" are generally descriptive of a therapeutic claim and should not be used.

Consumer acceptance of claims is also important. In a German study consumer acceptance of coloured-flesh potatoes rich in nutrients such as anthocyanins and carotenoids was studied (Wegner et al. 2009). In particular, willingness to purchase blue-fleshed potato varieties high in anthocyanins was examined. Relative importance of potato colour, flavour, pricing and health claims when making purchase decisions was assessed. Results showed that acceptance was markedly influenced by potato appearance and consumer degree of product awareness. Health claims for blue-fleshed potatoes were most effective when worded in simple language, rather than using scientific terminology.

In addition because there are many claims possible for potatoes, it is probably important to consider which ones may resonate most with the consumer and focus on them.

3.3 High level health claims

FSANZ Standard 1.2.7 allows a small number of high level health claims. There are no specific nutrients in potatoes that reach the criteria for making these claims. The folic acid claim around reducing the risk of neural tube defects is specific for the folic acid form and not the forms of folates found in fruit and vegetables such as potatoes (however other general level health claims are permitted for folate as outlined in Section 3.4). There are dietary context claims that could be used for fresh potatoes though, as outlined in Table 4. These claims are relevant for all fruits and vegetables in a fresh or minimally processed form (i.e. without added salt and/or fat). These claims have to be put in a dietary context rather than just mentioning potatoes. Rather than being messaging for packaging, etc they are worthwhile statements to include on website, etc.

Table 4. High level health claims relevant for fresh potatoes (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Context claim statements	Conditions
A high intake of fruit and vegetables	Reduces risk of coronary heart disease		Diet containing a high amount of both fruit and vegetables	(a) claims are not permitted on – (i) fruit juice or vegetable juice as standardised in Standard 2.6.1; or (ii) a food standardised in Standard 2.6.2; and (b) the food must contain no less than 90% fruit or vegetable by weight.
Increased intake of fruit and vegetables	Reduces risk of coronary heart disease		Diet containing an increased amount of both fruit and vegetables	(a) claims are not permitted on – (i) fruit juice or vegetable juice as standardised in Standard 2.6.1; or (ii) a food standardised in Standard 2.6.2; and (b) the food must contain no less than 90% fruit or vegetable by weight
Saturated fatty acids	Reduces total blood cholesterol or blood LDL cholesterol		Diet low in saturated fatty acids	The food must meet the conditions for making a nutrition content claim about low saturated fatty acids
Saturated and trans fatty acids	Reduces total blood cholesterol or blood LDL cholesterol		Diet low in saturated and trans fatty acids	The food must meet the conditions for making a nutrition content claim about low saturated and trans fatty acids
Sodium or salt	Reduces blood pressure		Diet low in salt or sodium	The food must meet the conditions for making a nutrition content claim about low sodium or salt

3.3.1 Carbohydrate and energy

Potatoes are often regarded negatively because of their carbohydrate and energy content. However, the wording around carbohydrate and energy are actually about normal metabolism (see Table 5) so may be more acceptable in the consumer’s eyes.

Table 5. General level health claims for carbohydrate and energy (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Dietary Context	Conditions
Carbohydrate	Contributes energy for normal metabolism			(a) carbohydrate must contribute at least 55% of the energy content of the food; or (b) the food must – (i) be a formulated meal replacement or a formulated supple-mentary food; and (ii) have a maximum 10% of carbo-hydrate content from sugars
	Contributes energy for normal metabolism	Young children aged 1-3 years		The food must – (a) be a formulated supplementary food for young children (as standardised in Standard 2.9.3 Division 4); and (b) have a maximum 10% of carbohydrate content from sugars
Energy	Contributes energy for normal metabolism			The food must contain a minimum of 420 kJ of energy per serving

3.4 Fibre

The fibre level for potatoes is typically around 1.7 g per 100 g, which equates to approximately 2.5 g per 150 g serve. This is over the requirement of 2 g per serve required to make a claim. There is one preapproved general level health claim for Fibre (See Table 6). Cooking does not impact on the claim as fibre level is maintained and even the database data for flesh only does not show an appreciable drop in fibre level.

Table 6. General level health claim for fibre (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Dietary Context	Conditions
Dietary fibre	Contributes to regular laxation			The food must meet the general conditions for making a nutrition content claim about dietary fibre

3.5 Vitamins

Potatoes contain a spectrum of vitamins in varying levels and there are a number that reach the level required to make a claim (10% RDI).

3.6 Folate

Folate levels in potatoes are generally around 14-22 µg per 100 g, which equates to 11-17% of the RDI in a 150 g serve. Thus this reaches the level required to make a source claim for folate and the associated general level health claims. There are a number of possible claims and these are outlined in Table 7.

Table 7. General level health claims for folate (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Dietary context	Conditions
Folate	Necessary for normal blood formation			The food must meet the general conditions for making a nutrition content claim about folate
	Necessary for normal cell division			
	Contributes to normal growth and development	Children		
	Contributes to maternal tissue growth during pregnancy			
	Contributes to normal amino acid synthesis			
	Contributes to normal homocysteine metabolism			
	Contributes to normal psychological function			
	Contributes to normal immune system function			
	Contributes to the reduction of tiredness and fatigue			

3.6.1 Niacin

Niacin (vitamin B3) levels reported in the NZ Food Composition database do vary considerably from around 0.8 mg/100 g to just over 2 mg per 100 g. There was no obvious pattern to the variations and although some of cooked samples did have lower niacin, some cooked samples were at the higher end of the range. However, all entries reach the 10% RDI level per 150 g serve required to make claims and in a couple of cases levels are above 25% RDI and could be classed as a good source of niacin. There are several different general level health claims that can be made for niacin (Table 8). Some of these claims are in common with other vitamins present at source levels in potatoes.

Table 8. General level health claims for niacin (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Dietary context	Conditions
Niacin	Necessary for normal neurological function			The food must meet the general claim conditions for making a nutrition content claim about niacin.
	Necessary for normal energy release from food			
	Necessary for normal structure and function of skin and mucous membranes			
	Contributes to normal growth and development	Children		
	Contributes to normal psychological function			
	Contributes to the reduction of tiredness and fatigue			

3.6.2 Pantothenic acid

Pantothenic acid is another B vitamin and levels for New Zealand potatoes are fairly consistent and typically between 0.34 and 0.38 mg per 100 g. Potatoes deliver around 10-12% of the RDI in a 150 g serve and so claims can be made (Table 9).

Table 9. General level health claims for pantothenic acid (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Dietary context	Conditions
Pantothenic acid	Necessary for normal fat metabolism			The food must meet the general claim conditions for making a nutrition content claim about pantothenic acid
	Contributes to normal growth and development	Children		
	Contributes to normal energy production			
	Contributes to normal mental performance			
	Contributes to normal synthesis and metabolism of steroid hormones, vitamin D and some neurotransmitters			
	Contributes to the reduction of tiredness and fatigue			

3.6.3 Thiamin

Thiamin levels in potato entries in the New Zealand Food Composition Database are variable and although some entries reached the 10% RDI level, not all did. It would appear that cooking may result in some loss, although some cooked entries were above 10% RDI. On average the levels are sufficient to make claims as outlined in Table 10.

Table 10. General level health claims for thiamin (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Dietary context	Conditions
Thiamin	Necessary for normal carbohydrate metabolism			The food must meet the general claim conditions for making a nutrition content claim about thiamin
	Necessary for normal neurological and cardiac function			
	Contributes to normal growth and development	Children		
	Contributes to normal energy production			
	Contributes to normal psychological function			

3.6.4 Vitamin C

Potatoes are a good source of vitamin C with levels between 9 and 19 mg per 100 g. This equates to between 34% and 71% RDI per 150 g serve (only 25% RDI is required to make a ‘good source’ claim). Cooking, particularly boiling, results in some loss but does not take the vitamin C level below the 25% cut-off. Vitamin C has an extensive list of general level health claims that can be made (Table 11).

Table 11. General level health claims for vitamin C (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Dietary context	Conditions
Vitamin C	Contributes to iron absorption from food			The food must meet the general claim conditions for making a nutrition content claim about vitamin C
	Necessary for normal connective tissue structure and function			
	Necessary for normal blood vessel structure and function			
	Contributes to cell protection from free radical damage			
	Necessary for normal neurological function			
	Contributes to normal growth and development	Children		
	Contributes to normal collagen formation for the normal structure of cartilage and bones			
	Contributes to normal collagen formation for the normal function of teeth and gums			
	Contributes to normal collagen formation for the normal function of skin			
	Contributes to normal energy metabolism			
	Contributes to normal psychological function			
	Contributes to the normal immune system function			
	Contributes to the reduction of tiredness and fatigue			

3.6.5 Other vitamins

Of the other vitamins, levels are below the 10% RDI level to make claims. Biotin is only around 1% RDI, riboflavin 3-4% RDI, vitamin A is only present in trace amounts and vitamin E at around 1% RDI. In most samples vitamin B6 was below the 10% RDI level but it was above in three samples. This vitamin should be measured in any future studies to determine if it is possible to make claims.

3.7 Minerals

The only mineral that can consistently be claimed for potatoes is potassium. To make claims potassium level must reach 200 mg per serve and all potato entries in the database easily achieve this with levels between 390 and 915 mg per 150 g serve. There are several general level health claims that can be made for potassium (Table 12). Magnesium reaches source levels in some potato samples but not consistently. Iron and phosphorus levels sit around 7% RDI, although in some samples they are lower than this. Other minerals (e.g. calcium, copper, manganese, selenium and zinc) are generally present at only 1-5% RDI per 150 g serve and hence there is no chance of claims being made.

Table 12. General level health claims for potassium (from FSANZ Standard 1.2.7).

Food or property of food	Specific health effect	Relevant population	Dietary context	Conditions
Potassium	Necessary for normal water and electrolyte balance			The food contains no less than 200 mg of potassium per serving
	Contributes to normal growth and development	Children		
	Contributes to normal functioning of the nervous system			
	Contributes to normal muscle function			

4 Conclusions

Looking at existing compositional data for potatoes those nutrients that deliver around 10% or more of the recommended dietary intake (RDI) or required intake for a nutrition claim are:

- Fibre
- Folate
- Niacin
- Pantothenic acid
- Potassium
- Vitamin C

In addition thiamin and vitamin B6 may reach sufficient levels to make claims but the current data are a little variable. Any future analysis should include these vitamins along with the above list.

There is a long list of potential health claims associated with the above nutrients that could be linked to potatoes. These claims must always make reference to the nutrient but the wording is not specifically set. Some examples of claims that could be used include: ‘potatoes are a source of vitamin C and folate which contribute to a healthy immune system’; ‘potatoes are a good source of potassium which helps keep your body hydrated’ and ‘ potatoes are a source of some B vitamins (e.g. folate, niacin, pantothenic acid and thiamin) which contribute to healthy brain function’. Packaging probably needs to focus on a few strong claims but wider promotional material (e.g. website) could make reference to a wider spectrum of claims.

Although there has been considerable new research on the health benefits of potatoes (antioxidant, lowering blood pressure, cholesterol lowering, anti-inflammatory) there is insufficient evidence at present to make a self-substantiated health claim.

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Appendix 1. Reference values of nutrients for making claims

Nutrient*	Claimable amount	Source	Good source	Excellent source	Messaging
Fibre	≥2 g / serve	2 g/serve	4 g/serve	7 g/serve	*‘source of fibre’* *‘good source of fibre’* *‘excellent source of fibre’*
Potassium	≥200 mg / serve	-	-	-	*‘contains potassium’*
Carbohydrate	Must contribute 55% of the energy content				*‘carbohydrate for energy’*
Energy	≥420 kJ / serve	-	-	-	*‘contributes energy for normal metabolism’*
Fat	≤3 g / 100 g	-	-	-	*‘low in fat’*
Sodium/salt	≤120 mg / 100 g	-	-	-	*‘low in salt’*

*Nutrient levels for claims are specified in FSANZ Standard 1.2.7

Recommended dietary intakes (RDIs) and (ESADDIs) for vitamins and minerals

Vitamins/minerals*	Adult **	Source claim level requirement	Good source claim level requirement
Biotin	ESADDI = 30 µg	3 µg	7.5 µg
Folate	RDI = 200 µg	20 µg	50 µg
Niacin	RDI = 10 mg	1 mg	2.5 mg
Pantothenic acid	ESADDI = 5 mg	0.5 mg	1.25 mg
Riboflavin (vitamin B2)	RDI = 1.7 mg	0.17 mg	0.43 mg
Thiamin (vitamin B1)	RDI = 1.1 mg	0.11 mg	0.28 mg
Vitamin A	RDI = 750 µg	75 µg	188 µg
Vitamin B6	RDI = 1.6 mg	0.16 mg	0.4 mg
Vitamin B12	RDI = 2 µg	0.2 µg	0.5 µg
Vitamin C	RDI = 40 mg	4 mg	10 mg
Vitamin D	RDI = 10 µg	1 µg	2.5 µg
Vitamin E	RDI = 10 mg	1 mg	2.5 mg
Vitamin K	ESADDI = 80 µg	8 µg	20 µg
Calcium	RDI = 800 mg	80 mg	200 mg
Copper	ESADDI = 3 mg	0.3 mg	0.75 mg
Iodine	RDI = 150 µg	15 µg	37.5 µg
Iron	RDI = 12 mg	1.2 mg	3 mg
Magnesium	RDI = 320 mg	32 mg	80 mg
Manganese	ESADDI = 5 mg	0.5 mg	1.25 mg
Molybdenum	ESADDI = 250 µg	25 µg	62.5 µg
Phosphorus	RDI = 1000 mg	100 mg	250 mg
Selenium	RDI = 70 µg	7 µg	17.5 µg
Zinc	RDI = 12 mg	1.2 mg	3 mg

* Claimable nutrients specified in FSANZ Standard 1.1.1

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