Quantification of antioxidant capacity and phytonutrients in four Québec-grown potato cultivars

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Dedicated to my dear parents Mohamed Ansar Munshi and Zubeda Munshi,
and sister Reshma Munshi.

ABSTRACT

Four Québec-grown potato (*Solanum tuberosum* L.) cultivars (cvs; Chieftain, Goldrush, Russet Burbank, and Yukon Gold) were examined for selected antioxidant indices and phytonutrient content. Cultivars showed significant variation in content of antioxidant indices, total soluble protein, and 2 of 9 minerals (copper and iron), in one serving (150 g fresh weight). Total antioxidant capacity was greatest in the cvs. Goldrush (pale yellow flesh) and Russet Burbank (white flesh). Cultivar Yukon Gold (yellow flesh) showed the greatest total carotenoids and total soluble protein. Cultivar Chieftain (white flesh) had the greatest caffeic acid and ferulic acid content and was similar to cv. Russet Burbank for greatest iron content. Cultivar Goldrush showed the greatest content of total phenolics, chlorogenic and ascorbic acids and was similar to cv. Chieftain for greatest rutin content. The cultivars varied in their dietary contribution to recommended dietary allowance of ascorbic acid, copper, and iron (on a per serving basis). All cultivars met the recommended dietary allowance of selenium on a per serving basis. Periderm (skin) of cultivars contributed significantly to certain antioxidants and phytonutrients in one serving, although this contribution of skin was cultivar-dependent. Potato skin can play an important role in increasing the dietary intake of specific antioxidants and phytonutrients. Consumers are advised to eat the entire tuber, including the skin. Dietary preference of one cultivar over another could result in significantly improved dietary intake of the above reported antioxidants and phytonutrients. Combinations of cultivars could also improve the nutrient composition of the diet. Selling potatoes under cultivar names would clearly help consumers make informed choices for dietary consumption.

RESUME

Certains indices de pouvoir antioxydant et teneurs en phytonutriments furent évalués pour des portions (150 g, poids frais) provenant de quatre cultivars de pomme de terre (*Solanum tuberosum* L.) élevés au Québec. Ces cultivars (cvs; Chieftain, Goldrush, Russet Burbank, and Yukon Gold) présentèrent d'importantes différences en pouvoir antioxidant, teneur en protéines solubles, et quant à leur teneur en 2 d'entre 9 minéraux (cuivre et fer). Les niveaux de pouvoir antioxydant les plus élevés furent associés aux cvs. Goldrush (chair jaune pâle) et Russett Burbank (chair blanche). Parmi tous les cultivars, les teneurs les plus élevées en caroténoïdes et protéines solubles furent associés au cv. Yukon Gold (chair jaune). Le cv. Chieftain (chair blanche) présenta les teneurs en rutine, et en acides caféique et férulique les plus élevées, et en commun avec Goldrush les teneurs les plus élevées en fer et en rutine. Ce dernier cultivar présenta les teneurs en composés phénoliques, et acides chlorogénique et ascorbique les plus élevés. La fraction de l'apport nutritionnel recommandé en acide ascorbique, cuivre et fer contribué par l'apport nutritionnel d'une portion de chair varia selon le cultivar. Tous les cultivars ont realisé l'apport nutritionnel recommandé de sélénium dans une portion. Néanmoins, le périderme (peau) des pommes de terre peut contribuer d'importantes quantités d'antioxydants et phytonutriments à chacune des portions. La peau de la pomme de terre peut donc représenter une importante contribution d'antioxydants et phytonutriments aux apports alimentaires de la pomme de terre. On recommande donc aux consommateurs de manger les tubercules entiers, incluant la peau. Une préférence alimentaire pour un cultivar plutôt qu'un autre peut donc améliorer de façon significative l'apport alimentaire en antioxydants et phytonutriments de la pomme de terre. Une combinaison de différents cultivars de pommes de terre pourrait aussi améliorer l'apport nutritionnel d'un tel régime alimentaire. La vente des pommes de terre identifiées selon leur cultivar aiderait le consommateur à prendre des décisions averties quant à leur régime alimentaire.

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CONTRIBUTION OF AUTHORS

Manuscript: Quantification of antioxidants and phytonutrients in four Québec-grown potato cultivars

Shirin Munshi (Candidate): Performed protocols for total phenolic compounds, mineral quantification using ICP-OES, performed experimental assays and organized and analysed data. The candidate wrote the above mentioned manuscript with the help of co-authors.

Stan Kubow (Supervisor, Associate Professor, School of Dietetics and Human Nutrition, McGill University): Provided advice and guidance on all aspects of the study including literature review, methodology, inference of the study and helped edit the manuscript.

Danielle Donnelly (Co-supervisor, Associate Professor, Department of Plant Science, McGill University): Guided the candidate on study design, statistical analysis, interpretation, and helped edit the manuscript.

Melissa Fernandez (NSERC summer undergraduate research student): Modified protocol for quantification of total carotenoids. She performed the spectrophotometric assay for estimation of total carotenoids with the candidate, organized the data and shared the results with the candidate.

Kebba Sabally (Postdoctoral Fellow): Ordered materials for all assays, provided guidance regarding protocol modification, and helped in running samples on HPLC and ICP-OES, along with solving equipment problems.

ABBREVIATIONS

AA	Ascorbic acid
AAE	Ascorbic acid equivalents
ABTS	2,2'-Azino-bis(3-ethylbenzthiazoline-6-sulphonic acid)
ACE	Angiotensin converting enzyme
AEPTQ	Association des Emballeurs de Pomme de Terre du Québec
AI	Allowable intake
AMD	Age-related macular degeneration
AOC	Antioxidant capacity
BHA	Butylated hydroxyanisole
BHT	Butylated hydroxytoluene
BV	Biological value
Ca	Calcium
CA	Caffeic acid
CAT	Catalase
CGA	Chlorogenic acid
CGAE	Chlorogenic acid equivalents
CI	Confidence interval
Cu	Copper
Cu/Zn-SOD	Copper- and zinc-containing superoxide dismutase
Cv(s)	Cultivar(s)
DDW	Double distilled water
DPPH	1,1-diphenyl-2-picrylhydrazyl
DRI	Dietary reference intake
DW	Dry weight
FA	Ferulic acid
FC	Folin Ciocalteau
Fe	Iron
FPPTQ	Fédération des Producteurs de Pomme de Terre du Québec
FRAP	Ferric ion reducing antioxidant power
FW	Fresh weight
GPx	Glutathione peroxidase

HAOC	Hydrophilic antioxidant activity
HF	Hydrophilic fraction
HPLC	High performance liquid chromatography
ICP-OES	Inductively coupled plasma-optical emission spectroscopy
K	Potassium
LAOC	Lipophilic antioxidant activity
LDL	Low density lipoprotein
LF	Lipophilic fraction
Mg	Magnesium
Mn-SOD	Manganese dependent superoxide dismutase
MPOD	Macular pigment optical density
NRV	Nutrient reference value
Na	Sodium
P	Phosphorous
ORAC	Oxygen radical antioxidant capacity
PPE	Potato peel extracts
PPP	Potato peel powder
RDA	Recommended dietary allowance
ROS	Reactive oxygen species
RU	Rutin
SE	Standard error
Se	Selenium
SOD	Superoxide dismutase
TAOC	Total antioxidant capacity
TBARS	Thiobarbituric acid reactive substances
TC	Total carotenoids
TE	Trolox equivalents
TEAC	Trolox equivalent antioxidant capacity
TP	Total (poly)phenolic compounds
TSP	Total soluble protein
Zn	Zinc

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I. INTRODUCTION

1.1 Statement of the problem

Over the past few decades, there has been a dramatic increase in the incidence of chronic degenerative diseases all over the world (Gaziano, 2005). Chronic diseases constitute the main cause of premature mortality in both developing and developed countries (WHO, 2003). The relationship between diet and chronic disease has now been well established (Popkin *et al.*, 2006). Plant foods contain large groups of nutrient and non-nutrient compounds (Holst and Williamson, 2008). Some of these non-nutrient components, known as secondary metabolites or phytochemicals, guard plants against a variety of stresses and diseases. When consumed by humans as food, these phytochemicals elicit a similar effect on the human body, protecting against risk of certain chronic diseases. Many of these phytonutrients, involved in enhancing human health, show antioxidant capacity, including ascorbic acid, carotenoids, and polyphenolic compounds (Andre *et al.*, 2007b). These antioxidants are known to play a key role in defending the body against reactive oxygen species (ROS) involved in the pathogenesis of many degenerative diseases. Other than these antioxidant compounds, certain micronutrient minerals such as copper, iron, manganese, selenium and zinc are found in noteworthy quantities in certain plant foods and are involved in a number of redox reactions in humans (Fraga, 2005). Consumption of these nutrients and antioxidants is likely to aid in combating biological disturbances resulting from oxidative stress. Therefore, in the face of emerging chronic diseases associated with diet, like cancer, diabetes, and cardiovascular diseases, population-based epidemiological studies emphasize the importance of dietary changes that lead to improved health (Andre *et al.*, 2007a). Inclusion of fruits and vegetables in the diet is shown to exhibit a protective effect against certain chronic degenerative diseases (Dragsted *et al.*, 2006). Although potato (*Solanum tuberosum* L.) is a vegetable, it has been under-appreciated in comparison to other vegetables, since it has been subject to nutritional controversies at various times (Burlingame *et al.*, 2009). Since studies

showed that most potatoes have a high glycemic index (GI), which is one of the factors that is implicated to lead to diabetes, nutritional recommendations were made to replace potato with low GI foods in the diet. This concept may have promoted a poor reputation for potato as a food among some healthcare professionals (Miller *et al.,* 1996). Potato began to be labelled as fattening and a contributor to obesity, diabetes, and their co-morbidities (Burlingame *et al.*, 2009). Since dietary fat is directly associated with obesity, when potato is cooked with fatty food additions such as butter and mayonnaise, it may partly contribute to the association of obesity with potato consumption (Bray and Popkins, 1998). Potatoes have been shown to contain relatively high concentrations of certain phytonutrients with health benefits (Burlingame *et al.,* 2009). However, the nutritional contributions appear to be cultivar dependent. For example, on a per 150 g fresh weight basis, different potato cultivars can contribute nutritionally variable quantities of ascorbic acid (4.2 – 63 mg), potassium (359 – 1048 mg), soluble proteins (1.28 – 6.3 g), iron (0.21 – 15.6 mg), zinc (0.33 – 1.14 mg), copper (0.08 – 0.23 mg) and varying amounts of antioxidants, e.g., total carotenoids (up to 4050 µg), chlorogenic acid (up to 2355 µg) and caffeic acid (0.02 – 235.5 mg) (Burlingame *et al.,* 2009).

Cultivar, therefore, could be a very significant determinant of nutrient content and composition of potatoes (Toledo and Burlingame, 2006). This variation in potato cultivars is likely to affect the nutritional and antioxidant content of the diet due to high consumption of potato as a dietary staple in many countries (Burlingame *et al.,* 2009). However, the variations in phytonutrient and antioxidant content of potato cultivars has been little studied, including potato cultivars grown in North America.

1.2 Study rationale

The nutritive value of the potato within the human diet is often ignored (Pihlanto *et al.*, 2008). Potato, a source of health-promoting phytonutrients, shows huge biodiversity with approximately five thousand known cultivars of potato; most of them belonging to *S. tuberosum* (Burlingame *et al*., 2009). In most food composition data resources such as national food composition tables as well as in nutrition and agriculture

journals, the part of the potato stem tuber (e.g., flesh, flesh with skin) and cooked state (e.g., raw or cooked) are generally mentioned. However, the cultivar name is often missing. Due to the relatively high per capita intake of potatoes in North America and other locations (Chun *et al.*, 2005; Lutaladio and Castaldi, 2009), nutrient content variations in potato cultivars could have a significant impact on nutritional status of the population. Moreover, nutritional assessment surveys are likely to inaccurately estimate the intakes of certain nutrients as they utilize data from food composition tables, which lacks nutritional information specific to cultivars. There is evidence suggesting that potato cultivars are not equivalent in their phytonutrients and antioxidant content. There is likely to be variation between potato cultivars having different colours, e.g., pigmented potatoes (red or blue fleshed) displayed significantly greater antioxidant capacity than white or yellow fleshed potato (Brown, 2005; Lachman and Hamouz, 2005). For some cultivars, antioxidant capacity could have been affected by carotenoid pigments, e.g., there is an increase in concentration of total carotenoids with increase in intensity of the yellow colour of flesh (Nesterenko and Sink, 2003). Tubers having coloured skin contained greater concentrations of polyphenolic compounds compared to white-skinned tubers (Lewis *et al.*, 1998a, b).

Despite the likelihood of difference in nutrient content with varying cultivars, potato cultivars are generally not differentiated in either nutrient declarations nor nutrient content claims. Under the Codex Alimentarius food labelling guidelines for 'source' and 'good source' of nutrients, some cultivars would qualify for the claims, while others would not (Codex Alimentarius, 2007; Burlingame *et al.*, 2009). Further, available studies highlight the fact that distribution of nutrients may not be uniform throughout all tissues and may vary between tissues of periderm (skin), cortex (storage tissue external to the vascular ring) and pith (storage tissue including and internal to the vascular ring). For example, vitamin C has been found to be in greater concentration in the pith than in the cortex (Mondy *et al.*, 1987). Similarly, distribution of phenolic compounds is also not uniform in the potato tuber, e.g., about 50% of the phenolic compounds are present in periderm and adjoining tissues in the tuber, while the

remaining ones progressively decrease in concentration from the exterior tissues toward the tuber centre (Hasegawa *et al.*, 1966). Concentration of total soluble protein (TSP) was significantly greater in periderm/outer cortex than in inner flesh tissues on a dry weight basis (Ortiz-Medina *et al.*, 2009).

Depending upon cultivar and tuber tissue, potatoes may show a wide concentration range of human health-beneficial phytonutrients per serving. Such cultivar and tissue differences in nutrient content could lead to differences in the number of servings required to meet the recommended dietary allowance (RDA) and adequate intake (AI) of certain nutrients. Identification of nutritionally superior cultivars of potato could increase the dietary contribution of potatoes resulting in improved population health (Lachman and Hamouz, 2005). For this reason, the phytonutrient composition of the four cultivars grown in Québec was examined for the possible dietary implications of cultivar differences. The extent that commonly consumed potato cultivars grown in Québec vary in phytonutrient composition and antioxidant capacity or whether such compositional differences are nutritionally significant has not been studied. The four cultivars were chosen for the study by the Fédération des Producteurs de Pomme de Terre du Québec (FPPTQ) and the Association des Emballeurs de Pomme de Terre du Québec (AEPTQ) after taking into consideration results of a previous study (Piccolomini *et al.,* 2008a, b) wherein certain potato cultivars were examined for their antioxidant content.

1.3 Research question and hypotheses

The objectives of this thesis were to:

1. Compare on a per serving basis (virtual tuber of 150 g fresh weight) the tuber phytonutrient content and antioxidant capacity of four Québec-grown potato cultivars (Figure 1.1; Chieftain, Goldrush, Russet Burbank, and Yukon Gold). The specific phytonutrients and biochemical assays are outlined in Table 1.1 and include antioxidant components and functional assays (ascorbic acid, total antioxidant capacity, total carotenoids, total phenolic content, and selected polyphenolic compounds), minerals (calcium, Ca; copper, Cu; iron,

Fe; potassium, K; magnesium, Mg; sodium, Na; phosphorous, P; selenium, Se; and zinc, Zn), and total soluble protein (TSP).

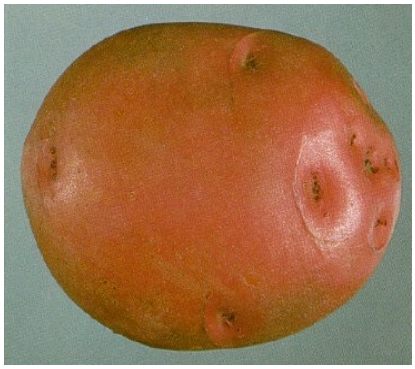
2. Examine differences in relative contribution of tissues (periderm, cortex, and pith) to the total content of antioxidants and phytonutrients in one serving (virtual tuber of 150 g fresh weight).
3. Examine differences between cultivars with regard to the dietary contribution of one serving to the recommended dietary allowance (RDA) or adequate intake (AI) of phytonutrients.

Hypotheses

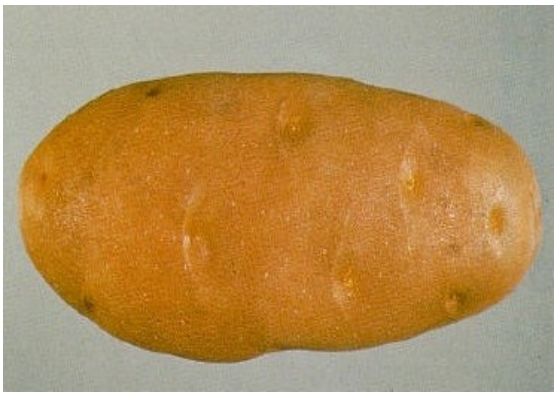
1. There are nutritionally significant differences in the phytonutrient content and antioxidant capacity measures of four Quebéc-grown potato cultivars on a per serving basis.
2. There are significant differences between tissues of skin, cortex, and pith in their contribution to the content of antioxidants and phytonutrients in one serving (virtual tuber of 150 g fresh weight).
3. There are significant differences between these cultivars with regard to the dietary contribution of one serving to the recommended dietary allowance (RDA) or adequate intake (AI) of phytonutrients.

Figure 1.1: Illustrates the four Québec-grown potato cultivars used in this study (photos from the Canadian Food Inspection Agency website, 2010).

Chieftain



Goldrush



Russet Burbank

Yukon Gold

Table 1.1 Summary of components quantified, methods used, and key references for these methods, used in this thesis.

Component Quantified	Method Used	Key Reference
Total polyphenolic compounds	Folin-Ciocalteau	Singleton *et al.*, 1998; Chirinos *et al.*, 2007
Chlorogenic acid, caffeic acid, ferulic acid, rutin and ascorbic acid	High pressure liquid chromatography (HPLC)	Shakya and Navarre, 2006
Antioxidant capacities (hydrophilic, lipophilic and total).	1,1-diphenyl-2-picrylhydrazyl (DPPH) & Ferric ion Reducing Antioxidant Power (FRAP)	Nair *et al.*, 2007; Teow *et al.*, 2007
Total carotenoids	Spectrophotometry	Britton, 1985
Total soluble protein	Spectrophotometry	Ortiz-Medina, 2007
Minerals (calcium, copper, iron, potassium, magnesium, sodium, phosphorous, selenium, and zinc)	Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES)	Anderson *et al.*, 1999

II. REVIEW OF LITERATURE

2.1 Introduction

Potato cultivation began about 8000 years ago in Peru's Central Andes and potatoes were taken to Europe by the Spanish in the 16th century (Lutaladio and Castaldi, 2009). Since potato can be grown quickly and cheaply, it freed populations from hunger and nourished the emerging urban working class.

Potato is a versatile, carbohydrate-rich food prepared and served in a variety of ways. It is one of the world's most widely grown crops and represents an important staple source of nutrients and energy in many different countries (Leo *et al.*, 2008). Over 1 billion undernourished people in the world, the majority of them living in developing countries, depend on potatoes as a primary or secondary source of nutrition (Lutaladio and Castaldi, 2009; FAO, 2009). Potato consumption more than doubled in developing countries between 1960 and 2005 increasing to 22 kg per capita per year (FAO, 2005). By 2020, world potato demand is expected to be double that of 1993 (Scott *et al.*, 2000). The Canadian agriculture sector for potato made $902 million in 2004, which underlines the importance of potato breeding, production and consumption in Canada (McLaughlin, 2005).

Unlike major cereals, the potato is not a globally traded commodity and prices are usually determined by local production costs (Lutaladio and Castaldi, 2009). Increasingly, the potato is being seen as a vital food-security crop and as a substitute for costly cereal imports. The nutrient-rich potato can contribute to improved diets, and reduce mortality rates caused by malnutrition.

Potato, since ancient times, has been traditionally used for its medicinal properties by people from the Andean region (Campos *et al.*, 2006). There is recent evidence that some varieties of potatoes may possess health attributes that warrant attention since potato may contain notable quantities of components beneficial to health (Brown *et al.*, 2008; Stushnoff *et al.*, 2008). Although potato is a vegetable, it apparently has not received attention deserved by its nutritional benefits in contrast to the healthy

reputation most vegetables occupy in the minds of health professionals (Brown *et al.*, 2008; Leo *et al.*, 2008). Potatoes have been labelled as fattening and contributors to diabetes and obesity (Burlingame *et al.*, 2009). However, it is also notably recognized as a source of high-quality protein, carbohydrates, ascorbic acid, pyridoxine, niacin, and certain minerals such as potassium, phosphorus, and magnesium together with negligible fat and abundant fiber from skins (Subar *et al.*, 1998). Beyond these basic nutrients, potatoes have been found to contain significant amounts of phytochemicals with antioxidant properties such as polyphenolic compounds, carotenoids, and ascorbic acid (AA) (Al-Saikhan *et al.*, 1995; Andre *et al.*, 2007a, 2007b; Lewis *et al.*, 1998a, 1998b; Burlingame *et al.*, 2009). Considering its high level of production and consumption world over, the potato could be an ideal source of health-promoting antioxidant phytochemicals that unfortunately has not been much appreciated (Brown, 2005; Andre *et al.*, 2007b).

2.2 Significance of antioxidants and phytonutrients found in potato for human health

Oxidation caused by reactive oxygen species (ROS) is a major cause of chronic degenerative diseases such as cancer and cardiovascular diseases (Battin and Brumaghim, 2009). Generally, in healthy individuals, naturally occurring antioxidants and antioxidant enzymes remove these free radicals (Rimbach *et al.*, 2005). However, since many antioxidant compounds cannot be synthesized de novo in the human body, their presence in human tissues depends upon their intake through diet (Andre *et al.*, 2007b). Oxidative stress can cause oxidative damage to DNA, proteins, and lipids (Valko *et al.*, 2006). Since many clinical conditions are associated with increased indices of oxidant stress, this suggests that overwhelming the antioxidant defence system initiates a disturbance in equilibrium of pro-oxidant-antioxidant reactions in living cells and propagates processes involved in the pathogenesis of many diseases (Halliwell and Gutteridge, 1990). Antioxidant compounds (hydrophilic and lipophilic) found in plant foods can neutralize some of these harmful effects, via the classes of enzymatic antioxidant biological defence system which include superoxide

dismutase (SOD), glutathione peroxidase (GPx) and catalase (CAT) enzymes (Aliyu *et al.*, 2009). Hydrophilic and lipophilic antioxidants each have their own function, acting in different ways, but working together (Pulido *et al.*, 2003). Antioxidant intake therefore potentially prevents or ameliorates many chronic disease disorders (Delanty and Dichter, 2000). Various phytochemical antioxidants such as phenolic compounds and carotenoids have been extracted from different plant materials such as fruits, vegetables, and seeds, that have elicited radical scavenging activities and prevented lipid peroxidation (Sun *et al.*, 2002; Aqil *et al.*, 2006).

Owing to its high level of consumption throughout the world, potato may significantly contribute to phytochemical antioxidant dietary intake (Lachman *et al.*, 2000; Brown, 2005; Andre *et al.*, 2007a) and provide health benefits (Robert *et al.*, 2006). Potato extracts contain several classes of coloured and colourless phytochemicals that exhibit anticancer activity, including anthocyanins, carotenoids, flavonoids and phenolic acids (Brown, 2005). Significant levels of hydrophilic antioxidants, particularly polyphenols and vitamin C along with moderate levels of lipophilic carotenoids have been reported in potato (Lewis *et al.*, 1998a, 1998b; Lachman *et al.*, 2000; Brown, 2005; Shakya and Navarre, 2006). Certain potato cultivars are also rich in certain essential minerals and containing good quality protein. As stated in a recent critical review by Burlingame et al. (2009), "Many varieties of potatoes have been found to contribute nutritionally important amounts of dietary fibre (up to 3.3%), and content of ascorbic acid (up to 63 mg), potassium (up to 1041 mg), total carotenoids (up to 4050 μg), and antioxidant phenols such as chlorogenic acid (up to 2355 μg) in 150 g FW." There is evidence reflecting major differences in potato phytonutrients, including polyphenolics, ascorbic acid, carotenoids, proteins, minerals, and antioxidant capacity in different cultivars (Lewis *et al.*, 1998a; Anderson *et al.,* 1999; Lachman *et al.*, 2000; Brown, 2005; Shakya and Navarre, 2006; Ortiz-Medina, 2007).

2.2.1 Phenolic compounds

Polyphenolic compounds are secondary plant metabolites characterised by antioxidative activity found in numerous plant species,

including potato (Graf, 1992; Adom and Liu, 2002; Kikuzaki *et al.*, 2002; Brown, 2005). Phenolics are composed of several classes of compounds including flavonoids (flavones, isoflavones, and flavanones), anthocyanins and catechins. They are characterized by cyclic rings with hydroxyl substitutions at various positions that readily react with the damage-causing free radicals that frequently attack cells (Duthie *et al.,* 2000). Phenolic compounds are distributed mostly between the cortex and skin (peel) tissues of the potato (Reeve *et al.,* 1969).

Phenolics in vegetables are present in both free and bound forms. While chlorogenic acid, gallic acid, and caffeic acid are some of the major phenolic compounds found in potato, other phenolic compounds include ferulic acid, rutin, *p*-coumaric acid and small amounts of quercetin, myricetin, kaempferol, naringenin, and other flavonoids (Rodriguez De Sotillo *et al.*, 1994; Al-Saikhan *et al.*, 1995; Reyes *et al.*, 2005; Nara *et al.*, 2006). In a comprehensive review on potato polyphenols, Friedman (1997) reported that chlorogenic acid constitutes up to 90% of the total phenolic content of potato tubers. Chlorogenic acid and caffeic acid are free-form phenolics while ferulic acid, which is linked to cell wall polysaccharides, is a bound-form phenolic (Nara *et al.*, 2006). Taking the sum of bound and free phenolic compounds as total phenolic compounds, there is suggestive evidence that about 40% of the total phenolic content in potatoes is present in the bound form, mainly as alpha-glycosides (Chu *et al.*, 2002). These survive upper gastrointestinal digestion and exhibit physiological bioactivity when absorbed in the colon (Nara *et al.*, 2006).

Oxidative stress plays a major role in tumour development. Therefore, the cancer preventive effects associated with vegetable consumption can be partly attributed to their content of antioxidant polyphenols (Singh and Agarwal, 2002; Davis-Searles *et al.*, 2005). Chronic inflammation, uncontrolled proliferation of prostatic epithelial cells, and inappropriate regulation of apoptosis may also play an important role in prostate cancer promotion and progression (Ho *et al.*, 2004). In addition to antioxidant activity, polyphenols also exhibit in vitro and in vivo anti-inflamatory, anti-proliferative, and proapoptotic properties suggesting their role as chemo-preventive agents (Nijveldt *et al.*, 2001; Yang *et al.*, 2001;

Reddivari *et al.*, 2007b). This inhibition of cancer development could be due to their ability to scavenge potentially DNA-damaging electrophiles and free radicals, to inhibit enzymes activating pre-carcinogens to carcinogens and to induce detoxification of carcinogens via enzyme systems (Friedman and Smith, 1984; Tanaka *et al.*, 1993; Tanaka, 1994). It is estimated that one-third of cancer deaths could be avoided through an appropriate intake of polyphenolics or other antioxidants based on daily fruit and vegetable consumption (Chun *et al.*, 2005). Polyphenols have been said to inhibit low density lipoprotein (LDL) oxidation, decrease the formation of atherosclerotic plaques and reduce arterial stiffness therefore leaving arteries more responsive to vasodilatation (Arai *et al.,* 2000; Duthie *et al.,* 2000; Moline *et al.,* 2000).

Total antioxidant activity was found to be correlated with total phenolic content in a number of studies (Singh and Rajini, 2004; Reyes *et al.*, 2005; Leo *et al.*, 2008), which indicates that phenolic compounds are largely responsible for the above types of antiradical activity. Potato polyphenols can therefore be a major contributory factor to the antioxidant potential of the diet and so may constitute an important exogenous defence against oxidative stress (Sanchez-Moreno *et al.*, 1998; Pulido *et al.*, 2000; Sanchez-Moreno *et al.*, 2000).

Cultivar has a significant effect on phenolic content in potato (Dao and Freidman, 1992). Seven potato cultivars showed significant differences in the concentration of total phenolics (55.28 to 79.34 mg) and chlorogenic acid (14.55 to 28.05 mg) on a 150 g fresh weight (FW) basis.

In a detailed study by Lewis *et al.* (1998a), phenolic acid components of tuber skins were found to vary between 300 – 750 mg/150 g FW. Purple and red skinned tubers, and tubers with coloured flesh, contained many-fold greater concentrations of phenolics than white skinned and white fleshed tubers, respectively. Although a number of studies have reported quantities of phenolic compounds, extremely limited information is available that relates phenolic values to their potential nutritional and health contribution based on typical potato intake.

2.2.2 Ascorbic acid

Ascorbic acid (AA; vitamin C) plays multiple roles in human health (Han *et al.*, 2004). It is well documented that ascorbic acid protects living cells against oxidative stress induced by potentially toxic ROS, which include hydroxyl radicals, superoxide anions, singlet oxygen, and hydrogen peroxide (Gregory, 1996; Davey *et al.*, 2000). Vitamin C is important both for collagen formation and iron absorption and has been linked to cancer prevention, reduction in the likelihood of strokes, and decreased hypertension (Love and Pavek, 2008)

Ascorbic acid is also important to iron availability, a mineral that tends to be limiting in the human diet, particularly in individuals without access to fresh produce (Brown, 2008). Potato had a role in prevention of scurvy ever since its first contact with Europeans. The importance of potato in supplying AA partly because potatoes can be stored, allowing them to be a regular item in the diet. It is estimated that potatoes provide, on average, over 50% of the daily AA requirement in the USA and about 20% of the dietary intake in Europe (Love and Pavek, 2008).

Ascorbic acid is one of the two predominant hydrophilic antioxidants with its concentration varying to large extent in different potato cultivars. Brown (2005) found the average AA content in potatoes to be 45 mg per 150 g FW. Augustin (1975) documented AA content to range between 126 to 217.5 mg per 150 g FW; attributing this wide difference to cultivar, planting site, and storage conditions. Examination of 74 Andean potato cultivars showed a wide range of concentrations, between 217.7 and 689.5 µg/g DW (Andre *et al.*, 2007a). In Korean potatoes (cvs. Sumi, Dejima, Deso, and Chaju) the AA content ranged from 24 to 69 mg/150 g FW (Han *et al.*, 2004).

According to nutritional labelling guidelines (Codex Alimentarius, 2007) a “source of AA” provides 15% of the Nutrient Reference Value (NRV) per 100 g while a “high source” provides twice this amount. If RDA is chosen as the NRV (90 mg AA/day for adult males aged 19 – 50), then for a potato to be labelled as a “source” or “high source” of AA, it should provide 20.3 mg/150 g FW or 40.5 mg/150 g FW, respectively. Considering the results reported by the above studies, the content of AA in potatoes

ranges from 25.5 – 148.5 mg/150 g FW. Therefore, depending upon the cultivar the potato could be classified either as a “source” or a “high source” of AA.

Dietary surveys based on raw potato product purchased in USA and Europe showed that average AA intake varied from 73 to 86 mg per day (Hughes, 2000; Higdon, 2006). Love and Pavek (2008) derived values from a previous study (Pennington and Wilkening, 1997) and stated that potatoes provide 25 mg per 150 g serving (45% of RDA for adult males), as compared with 95 mg for red bell pepper, 60 mg for an orange, 60 mg for broccoli, 50 mg for strawberries and 35 mg for cantaloupe. The percent contribution of potato towards meeting the RDA for AA could vary widely with cultivar (Augustin, 1975; Lachman *et al.,* 2000; Han *et al.,* 2004; Brown, 2005; Andre *et al.,* 2007a). Some cultivars could be labelled as a source (15% contribution towards RDA) or good source (30% contribution towards RDA) of AA, depending upon their AA content (Codex Alimentarius, 2007). It therefore would be useful to identify Québec-grown cultivars meeting these criteria for AA.

2.2.3 Carotenoids

Carotenoids are another important class of lipophilic phytonutrients found in fruits and vegetables. Carotenoids found in mammalian systems originate exclusively in the diet (Landrum and Bone, 2001). They have been reported to exhibit biological activity similar to chemopreventive agents (Machlin, 1995) by inhibiting genetic damage, protecting against oxidative damage, increasing metabolic detoxification, restoring tumor suppressor function and/or inhibiting oncogene expression, enhancing the activity of gap junction communication, and stimulating immune response (Khachik *et al.*, 1999). As reported in a recent study, the carotenoid pattern found in potato extracts is dominated by antheraxanthin, lutein, neoxanthin, violaxanthin and zeaxanthin (Andre *et al.*, 2007b). Available evidence suggests that among the various potato genotypes, lutein generally predominates followed by varying amounts of zeaxanthin, violaxanthin, and others (Brown *et al.*, 1993; Lu *et al.*, 2001; Nesterenko and Sink, 2003).

Age related macular degeneration (AMD) is the leading cause of blindness in Western cultures (Vingerling *et al.*, 1995; Hyman, 1992). Lutein and zeaxanthin are biologically important carotenoids of the macular pigment with lutein being the predominant one at birth (Landrum and Bone, 2001) and they protect against age-related macular degeneration (Ahmed *et al.*, 2005). Lutein supplementation in the diet has been correlated with improvement in visual function in patients suffering from macular degeneration and cataracts (Olmedilla *et al.*, 2001). The effects of dietary supplementation of these two pigments have shown favourable increase in macular pigment optical density (MPOD) levels (Landrum *et al.*, 1996; Landrum *et al.*, 1997) and reduced risk of advanced AMD (Seddon *et al.*, 1994). Serum levels of lutein and zeaxanthin are dependent upon dietary intake (Landrum and Bone, 2001). However, serum levels associated with the normal diet are far below the maximal levels achieved with supplementation. It could therefore be favourable to identify potato cultivars rich in carotenoids for added health benefits through dietary consumption.

Iwanzik *et al.* (1983) examined thirteen German potato varieties and reported the following distribution on a 150 g FW basis: total carotenoids (TC; 41.1 – 493.4 µg), lutein (23.3 – 85.95 µg), violaxanthin (30.9 – 101.7 µg) lutein 5, 6-epoxide (8.6 – 44.9 µg), and neoxanthin (3.5 – 20.8 µg). Intensely yellow cultivars were found to have a carotenoid content of about 450 µg/150 g FW, whereas the white-fleshed cultivars had much lower TC levels of about 45 – 105 µg/150 g FW (Gross, 1991; cited by Hale 2003).

Breitbaupt and Bamedi (2002) examined four yellow and four white-fleshed cultivars from the German market. Yellow fleshed varieties showed lutein content between 25.5 – 61.5 µg/150 g FW and zeaxanthin content between 13.5 – 117 µg/ 150 g FW while the white fleshed ones had lesser total amounts of lutein (30 – 31.5 µg/150g) and zeaxanthin (4.5 – 25.5 µg/150 g FW). Total carotenoid content of steamed yellow fleshed Swedish cultivars was 120 – 390 µg/150 g FW (Von Elver, 1943; cited but not referenced by Hale, 2003).

Brown *et al.* (2005) surveyed the carotenoid content of different potato cultivars and breeding lines, with varying intensities of yellow flesh, and found a wide range of TC from 52.5 – 1192.5 µg/150 g FW. Total

carotenoids were maximum in dark yellow breeding lines (763.5 – 1192.5 µg/150 g FW), followed by red and yellow fleshed ones (163.5 – 460.5 µg/150 g FW), and least in light yellow cultivars (151.5 – 406.5 µg/150 g FW). Dark yellow cultivars showed approximately 10 times greater concentrations of total carotenoids than white fleshed cultivars. The lipophilic fraction of oxygen radical antioxidant capacity (ORAC) varied widely with values ranging between 6.9 – 23 nmoles α-tocopherol equivalents per 150 g FW.

A subsequent study analysed 74 Andean potato cultivars, and again found that TC ranged widely, from 2.83 – 36.21 µg/g of dry weight (DW) (Andre *et al.,* 2007a) while Brown *et al.* (2007) reported a total carotenoid range of 38 – 2020 mg zeaxanthin equivalents/100 g FW among 38 native potato cultivars from South America. According to a Spanish study, potato is the third main contributor (13 – 20%) to the dietary intake of zeaxanthin after citrus fruits and green vegetables (Garcia-Closas *et al.*, 2004). Lutein and zeaxanthin are present in high concentrations in some potato cultivars (Kotikova *et al.*, 2007). However, the carotenoid values reported in the literature, have not typically been related to their nutritional and potential health contribution based on typical potato dietary intake.

2.2.4 Protein

The potato yields more protein per unit growing area than cereals (Bamberg and Del Rio, 2005). Potatoes have been described as "an excellent source of lysine" (Friedman, 1996), making them superior to cereal protein generally deficient in lysine. Compared with other raw vegetable sources, potatoes are not typically considered to be a good dietary protein source due to their low overall protein content. However, potato protein has excellent biological value (BV) that ranges between 90 – 100 (Kasper, 2004; cited by Camire *et al.,* 2009).

Potato protein (patatin, which constitutes more than 40% of the total soluble protein in potato) acts as a storage protein and shows antioxidant activity in its purified form (Liu *et al.*, 2003). Patatin showed dose-dependent scavenging activity against DPPH radicals. The radical scavenging capacity of purified patatin on a nanomole basis, was similar to

that of butylated hydroxytoluene (BHT) and greater than that of reduced glutathione. The study further showed that purified patatin protected against DNA damage induced by hydroxyl radicals. Another study (Al-Saikhan *et al.*, 1995) used BHT and reduced glutathione as controls and reported that patatin at 33 mg/mL exhibited an antioxidant capacity similar to that of potato extracts.

Two previous animal model studies suggested that potato protein lowers plasma cholesterol concentration in rats compared to casein (De Schrijver, 1990; Morita *et al.*, 1997). Spielmann *et al.* (2009) assessed the effects of potato protein on concentration of lipids in plasma and lipoproteins in pigs. Formulated diets provided identical amounts of potato protein and casein (used as control) at the level of 116 g/day (first week) and 150 g/day (second and third week). Pigs fed potato protein had 10% lower cholesterol concentrations in plasma and 17% lower concentrations of low density lipoprotein (LDL) cholesterol than pigs fed casein. The high arginine: lysine ratio in potato could be a responsible for lipid lowering (Kritchevsky *et al.*, 1982; Salil and Rajamohan, 2001; Lin and Yin, 2008). Protein isolated from potatoes is characterized by high concentrations of cysteine and arginine as compared to casein. Literature has suggested that these two amino acids play a role in imparting hypolipidaemic effects to proteins (De Schrijver, 1990; Ascencio *et al.*, 2004; Shukla *et al.*, 2007). Cysteine has been shown to lower hepatic biosynthesis of triglycerides and cholesterol (Lin and Yin, 2008) and arginine reportedly lowers plasma cholesterol concentration by an increased conversion of cholesterol to bile acids (Salil and Rajamohan, 2001).

Pihlanto *et al.* (2008) isolated and hydrolysed potato protein from a variety of potatoes at different physiological states of maturity. When tested for the angiotensin converting enzyme (ACE) inhibitory activity and radical scavenging activity using 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) (ABTS) assay, the potato protein hydrolysates exhibited variation. The ACE-inhibitory and radical scavenging potencies of the hydrolysates were greater than the non hydrolysed protein. This may have been due to the generation of smaller peptides and amino acids during hydrolysis, which were better able to access the oxidant–antioxidant test system than larger

peptides and proteins (Moosmann and Behl, 2002). Potato protein has shown a wide range of variation in different cultivars. Total soluble protein (TSP) in 20 different cultivars ranged from 1 – 1.5% of tuber fresh weight (Ortiz-Medina, 2007). Total soluble protein content in potato varied from a low of <1% (1.5 g per 150 g serving) for the Argentinian cultivar Revolucion (Jimenez *et al.*, 2009) to a high of 4.2% (6.3 g per 150 g serving) of tuber fresh weight for the Spanish cultivar RojaRin (Ritter *et al.*, 2008).

According to nutritional labelling guidelines (Codex Alimentarius, 2007), a "source of protein" provides 10 % of NRV. If the RDA is chosen as the NRV for dietary protein, i.e., total soluble protein (56 g/day for adult males), then for potato to be labelled as a "source of protein", a content of 5.6 g protein per serving of 150 g is required. Considering the variation in protein values reported for potato cultivars, certain cultivars of potato may be closer to meeting this criterion. However, there is dearth of information that relates the protein content in different Québec-grown potato cultivars to the RDA for protein.

2.2.5 Antioxidant capacity

There are numerous methods mentioned in the literature that assess the antioxidant capacity of potatoes (Lukaszewicz *et al.,* 2004; Andre *et al.,* 2007a; Reddivari *et al.,* 2007a, 2007b; Lachman *et al.,* 2008; Al-Weshahy and Rao, 2009). Potato cultivars have shown wide variation in antioxidant capacities. Reddivari *et al.* (2007a) reported total antioxidant capacity (TAOC) of potato cultivars between 157 – 832 μg Trolox equivalents (TE)/g FW and 810 – 1662 μg TE/g FW, using the DPPH and ABTS, respectively. Another study found that TAOC ranged from 103 – 648 μM TE/g FW in potato cultivars (Hale, 2003).

There are several in vitro studies emphasizing the antioxidant capacity of whole or partitioned potato products. When potato peels extract (PPE), exhibiting high content of total phenolics (70.82 mg catechin equivalents/100 g FW) and chlorogenic acid (27.56 mg/100 g FW), was added to meat before radiation processing, it retarded lipid peroxidation of irradiated meat (Kanatt *et al.*, 2005). The antioxidant activity elicited by

potato peel extract was found to be comparable to the synthetic antioxidant BHT. Another study investigated the antioxidative effects of PPE when added at various concentrations to soybean oil (Zia Ur *et al.*, 2004) and showed that the effect of PPE was similar to the synthetic antioxidants butylated hydroxylanisole (BHA) and BHT. As there was no distinct difference between the effects of the synthetic antioxidants (200 ppm) and potato peel extract (PPE) (1600 ppm), the potato peel extract could be effectively used in oils, fats, and other food products as a natural antioxidant to suppress lipid oxidation.

Singh and Rajini (2008) examined the protection rendered by PPE in erythrocytes in terms of resistance to oxidative damage, morphological alterations and membrane structural alterations. The protein and lipid peroxidation induced by ferrous/ascorbate and H_2O_2 in erythrocytes was significantly suppressed by PPE. This result is strongly suggestive of the potential in vivo antioxidant properties of PPE. Potato extract was also significant in inducing apoptosis in cell lines with the apoptotic effect being similar to those observed for camptothecin, a known apoptotic-inducing agent (Reddivari *et al.*, 2007b).

Potato products and extracts have yielded interesting results when tested on animal models for their efficacy. Han *et al.* (2006) examined the antioxidant functions exhibited by purple potato flakes in terms of radical scavenging activity. Rats were fed purple potato flakes at 250 g/kg of diet for 4 wk while the control rats were fed a diet with cornstarch. The purple potato flake extract prevented the liver injury induced by D-galactosamine in rats, with enhanced serum trolox equivalent antioxidant capacity and suppressed levels of hepatic thiobarbituric acid reactive substances (TBARS), which is an indicator of the degree of lipid peroxidation. The rats fed purple potato flakes showed reduced linoleic acid oxidation and enhanced activity of the hepatic enzymes Mn-SOD and Cu/Zn-SOD, indicating improved antioxidant status.

Robert *et al.* (2006) showed that the consumption of unpeeled cooked potatoes improved the lipid metabolism and antioxidant status in cholesterol-fed rats. Rats fed a potato-enriched diet for 3 wk showed a significant decrease in plasma cholesterol and triglyceride levels and

decreased hepatic cholesterol levels. Antioxidant status was also improved by potato consumption as levels of cardiac TBARS diminished and the plasma vitamin E/triglyceride ratio improved. A subsequent study showed that feeding rats a potato-based diet for 3 weeks led to a decrease in cholesterol and triglyceride concentrations in triglyceride-rich lipoprotein fractions (Robert *et al.*, 2008). Antioxidant status deteriorated with sucrose consumption and improved with potato consumption. Consumption of complex carbohydrates (provided as cooked potatoes), in combination with antioxidant micronutrients within potatoes, enhanced the antioxidant defence and improved lipid metabolism, as compared with consumption of either starch (complex carbohydrates) or sucrose alone.

A 4-wk feeding trial whereby potato peel powder (PPP) was incorporated into the diet of diabetic rats at 5% and 10% weight of food showed a significant lowering of the plasma glucose levels and drastically reduced polyuria associated with PPP supplementation (Singh *et al.*, 2005). Potato peel powder also decreased the elevated activities of serum transaminases (alanine aminotransferase and aspartate aminotransferase), and nearly normalized the hepatic malondialdehyde and glutathione levels and the activities of specific antioxidant enzymes in the liver of the diabetic rats. Incorporation of PPP in the diet also significantly reduced diabetes-associated hypertrophy in the rats. The observed hypoglycemic effect of potato products in part or whole might be related to their polyphenolic and dietary fiber content (Singh, 2002) or due to the strong antioxidative property of the component/extract examined (Singh and Rajini, 2004).

2.2.6 Minerals

Minerals including potassium (K), phosphorus (P), magnesium (Mg), sulphur (S), chloride (Cl), calcium (Ca), silicon (Si), iron (Fe) and zinc (Zn) are found in notable quantities in potatoes. Potassium (564 mg/g FW), and phosphorus (30 – 60 mg/g FW) are present in relatively greater quantities in potato (Burton, 1989; as cited by Buckenhüskes, 2005).

Zinc, which is critically important to cognitive skills, was found to range in cultivars from 12.5 – 20 µg/g DW (Brown, 2008). Similarly, Fe which is important for various physiological functions in the body, and for

which deficiency is said to be common among impoverished populations, showed significant variation among cultivars (18 – 65 μg/g DW). One study found a relationship between greater Fe levels and red-skinned cultivars (White and Broadley, 2005). A recent study (Andre *et al.*, 2007a) reported wide variability in levels of micronutrients within the Andean native potato germplasm and emphasized the significant contribution that different cultivars could make to the dietary intake of zinc and iron.

Iron (Fe) is found in Fe-sulphur enzymes (e.g., aconitase, fumarate reductase) and other Fe-containing or Fe-activated enzymes (e.g., nicotine adenine dinucleotide, reduced (NADH) dehydrogenase, succinate dehydrogenase, alcohol dehydrogenase, and cyclooxygenases) which are involved in redox reactions in biological systems. Zinc is associated with activity of about 100 enzymes (RNA polymerase, carbonic anhydrase, Cu–Zn superoxide dismutase, etc.) and is also present in Zn-fingers associated with DNA.

Copper is involved in the antioxidant system via its involvement in the enzymes Cu–Zn SOD and ceruloplasmin (Spears and Weiss, 2008). Copper deficiency can decrease the activities of certain non-Cu containing enzymes of the oxidant defense system including catalase and selenium-dependent glutathione peroxidase (Se-GPx) and can also alter other ROS scavengers including metallothionein (Cu and Zn containing protein) (Uriu-Adams and Keen, 2005). Selenium is incorporated into proteins to make selenoproteins, which are important antioxidant enzymes (Levander and Beck, 1997). Selenium is found in glutathione peroxidase, thioredoxins, and selenoprotein P. Available evidence is suggests that Se deficiency can make the body more susceptible to illnesses caused by other nutritional, biochemical, or infectious stresses. Deficiency of selenium has been associated with several conditions like cardiovascular and muscular disorders (Barretto et al., 2008; Zeng & Combs, 2008). The role of selenium supplementation in cancer prevention (Klein et al., 2003; Combs, 2004) and health benefits in HIV infected patients (Pitney et al., 2009) has been suggested. Other studies have reported beneficial effects of selenium supplementation in treatment of specific conditions such as rheumatoid

arthritis, systemic inflammation, burns, and sleep apnoea syndrome (Peretz et al., 1992; Gartner et al., 2001; Dekok, 2005).

As mentioned above, potato could be a potentially rich source of some of the above minerals associated with redox reactions. However, there could be huge variability in their content depending upon cultivar. Studies reporting the mineral composition of potatoes often limit their study to a few minerals. Only one study could be located (Anderson *et al.*, 1999) that reported content of eight minerals of nutritional importance (Ca, Cr, Cu, Fe, K, Mg, P, and Zn) in potato. However, it did not relate these concentrations to the potential nutritional contribution potatoes could make per serving. Extremely limited data is available on Se content of potatoes. To date, no study has related mineral concentrations in potatoes to the dietary contribution that potato could make towards meeting the RDA/AI of minerals. The set of nutrient values denoted by RDA/AI are used for nutritional reporting. However, for the convenience of interpreting nutritional value of a food product by consumers, the food label is characterized by the term daily value (DV; FDA, 2011). Daily value is the measure most commonly used for food labelling purposes.

There is evidence regarding antioxidative properties and other possible health benefits elicited by intake of whole or partitioned potato products. Potato cultivars can vary greatly in their content of phytonutrients and antioxidant capacity measures, and this variation could mean significant nutritional differences with respect to dietary contributions when specific cultivars are chosen for consumption. However, information is lacking on potential dietary contributions of specific potato cultivars.

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III. LINKING STATEMENT

Many studies have investigated concentrations of phytonutrients within potatoes that could be associated with an improved antioxidant status. However, these studies have been typically limited to a selected few antioxidants/phytonutrients without consideration of cultivar differences. No study has comprehensively examined the variation in antioxidant capacity measures and key phytonutrients among a selection of cultivars. There is also a dearth of information regarding how nutrients from different potato cultivars can contribute towards meeting the RDA or AI since food composition tables do not describe cultivar differences, including typical North American-grown cultivars. Similarly, there is limited information regarding the individual contribution of tuber tissues (skin, cortex, and pith) to the total tuber content of phytonutrients and antioxidants. This thesis study examined variations in phytonutrient measures (ascorbic acid, total phenolics, selected phenolic compounds, total carotenoids, total soluble protein, total antioxidant activity, and selected minerals) of Québec-grown potato cultivars (Chieftain, Goldrush, Russet Burbank and Yukon Gold) from the 2008 field season (stored for 7 months). These measures were associated with the potential contribution of the cultivars to the amount of phytonutrients and antioxidants in the human diet on a per serving basis. The study quantified these measures separately in tuber tissues (skin, cortex and pith) and used the unique concept of a mathematically reconstructed virtual tuber (Ortiz-Medina *et al.,* 2009) to estimate the amounts of antioxidants and phytonutrients in one serving (virtual tuber of 150 g FW) and determined the percentage contribution of tuber tissues to the total serving content of these components for each cultivar.

IV. MANUSCRIPT

Quantification of antioxidant capacity and phytonutrients in four Québec-grown potato cultivars

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4.1 Abstract

Four Québec-grown potato (*Solanum tuberosum* L.) cultivars (cvs; Chieftain, Goldrush, Russet Burbank, and Yukon Gold) were examined for selected antioxidant indices and phytonutrient content. Cultivars showed significant variation in content of antioxidant indices, total soluble protein, and 2 of 9 minerals (copper and iron), in one serving (150 g fresh weight). Total antioxidant capacity was greatest in the cvs. Goldrush (pale yellow flesh) and Russet Burbank (white flesh). Cultivar Yukon Gold (yellow flesh) showed the greatest total carotenoids and total soluble protein. Cultivar Chieftain (white flesh) had the greatest caffeic acid and ferulic acid content and was similar to cv. Russet Burbank for greatest iron content. Cultivar Goldrush showed the greatest content of total phenolics, chlorogenic and ascorbic acids and was similar to cv. Chieftain for greatest rutin content. The cultivars varied in their dietary contribution to recommended dietary allowance of ascorbic acid, copper, and iron (on a per serving basis). Periderm (skin) of cultivars contributed significantly to certain antioxidants and phytonutrients in one serving, although this contribution of skin was cultivar-dependent. Potato skin can play an important role in increasing the dietary intake of specific antioxidants and phytonutrients. Consumers are advised to eat the entire tuber, including the skin. Dietary preference of one cultivar over another could result in

significantly improved dietary intake of the above reported antioxidants and phytonutrients. Combinations of cultivars could also improve the nutrient composition of the diet. Selling potatoes under cultivar names would clearly help consumers make informed choices for dietary consumption.

4.2 Introduction

The health-promoting attributes of potatoes towards providing phytonutrients in the human diet have not been sufficiently appreciated (Brown, 2005). Potato cultivars vary widely in concentrations of phytonutrients of nutritional significance (soluble protein, calcium, copper, iron, phosphorous, potassium, zinc) and antioxidant properties (ascorbic acid, carotenoids, polyphenols) (Levander and Beck, 1997; Fraga, 2005; Bückenhuskes, 2005). Wide variations in both hydrophilic antioxidants such as polyphenolic compounds and ascorbic acid as well as lipophilic antioxidants such as carotenoids have also been found in potatoes (Lewis *et al.*, 1998a, 1998b; Lu *et al.*, 2001; Breitbaupt and Bamedi, 2002; Nesterenko and Sink, 2003; Brown, 2005; Eichhorn and Winterhalter, 2005; Shakya and Navarre, 2006). One of the most significant determinants of antioxidant capacity and phytonutrient content in potatoes is cultivar choice (Toledo and Burlingame, 2006), which could affect overall dietary antioxidant and phytonutrient intake. Antioxidant capacity of foods consumed has been associated with the levels of antioxidants in human plasma (Rautiainen *et al.,* 2008). Therefore, antioxidant capacity measures of potatoes could be a potentially useful estimate of the contribution of potato intake towards the antioxidant status of population consuming these potato cultivars.

Distribution of some nutrients has been found to be non-uniform in potato tuber tissues (Hasegawa *et al.*, 1966; Mondy *et al.*, 1987; Ortiz-Medina *et al.,* 2009). Therefore, it is likely that tissues of skin, cortex, and pith differ in their percent contribution towards the total tuber content of antioxidants and phytonutrients. Potatoes are often processed and/or consumed with their peel removed. Peeling is also likely to remove some amount of the outer cortex.

There is limited comprehensive information regarding the antioxidant and phytonutrient content among potato cultivars, especially the ones grown in North America. An extensive literature review showed only two studies reporting a few antioxidant and nutritional indices on North American potato cultivars. Ortiz-Medina (2007) and Ortiz-Medina *et al.* (2009) studied twenty North American and European potato cultivars, for their total soluble protein content. Al-Weshahy and Rao (2009) examined six potato varieties grown in Ontario, for total phenolic compounds, phenolic composition, and antioxidant capacity. There is relatively more information available on Andean potato cultivars (Andre *et al.* 2007a, 2007b; Brown *et al.,* 2007). However, these studies also have not extensively looked at all of the antioxidant and phytonutrient indices of interest. Investigations done by Andre *et al.* (2007a) on 74 genetically diverse potato cultivars reported on a few minerals (iron, zinc, calcium) and antioxidant indices of total phenolic compounds, total carotenoids, vitamin C, and hydrophilic antioxidant capacity. Brown *et al.* (2007) examined 38 varieties of South American potatoes for carotenoid compounds, anthocyanins, and total antioxidant capacity. Xu *et al.* (2009) examined 8 varieties (grown in unspecified locations) for total phenolic compounds, composition of phenolics, and antioxidant capacity. Thus, nutritional indices reported by available studies are very few.

The present study comprehensively quantified indices associated with antioxidant capacity, including ascorbic acid (AA), total antioxidant capacity (TOAC), hydrophilic antioxidant capacity (HAOC), lipophilic antioxidant capacity (LAOC), total phenolic compounds (TP), chlorogenic acid (CGA), caffeic acid (CA), ferulic acid (FA), rutin (RU), total carotenoids (TC), and nine minerals (calcium; Ca, copper; Cu, iron; Fe, magnesium; Mg, phosphorous; P, potassium; K, selenium; Se, sodium; Na, and zinc; Zn) in four Québec-grown potato cultivars (Chieftain, Goldrush, Russet Burbank, and Yukon Gold). This study also addressed the relative extent to which tuber tissues contribute to the phytonutrient content of a "virtual tuber" using the summative method of Ortiz-Medina *et al.* (2009), and used this information to determine the potential dietary contribution of each cultivar on a per serving basis (virtual tuber of 150 g FW). This study

also examined cultivars for their relative capacity to meet the recommended dietary allowance (RDA) or adequate intake (AI) of nutritionally significant phytonutrients.

4.3 Materials and methods

4.3.1 Study design

The design was a randomized block design, where the primary factor (block) was cultivar and the sub-factors were tissues within each cultivar. Five replicates (n = 5) of skin, cortex, and pith from each cultivar were used for quantification of polyphenolic compounds (total phenolic compounds and the phenolics chlorogenic acid, caffeic acid, and ferulic acid, and the flavanoid rutin), ascorbic acid, total soluble protein, and total antioxidant capacity. Three replicates (n = 3) were used for analysis of total carotenoids and minerals. Results were calculated in terms of per gram dry weight (DW) values. Using conversion factors for fresh weight to dry weight (Table A.3) and tuber tissue (skin, cortex, and pith) proportions (Table A.2) for each cultivar, tissue amounts of antioxidants and phytonutrients were estimated and summed to form a virtual tuber using the method of Ortiz-Medina *et al.* (2009).

The above method of Ortiz-Medina *et al.* (2009) is based on the concept that cultivars have different proportions of tuber tissues with unevenly distributed nutrients in each tissue. The technique was modified to adjust the virtual tuber from an arbitray 100 g FW to a more nutritionally useful single serving size of 150 g FW, which is the approximate standard U.S. portion size used for labelling. This latter approach is a more precise and accurate method of determining nutrient content of potato cultivars on a per serving basis compared with previous investigations that used tuber parts (peel only, flesh only, tuber cross section, etc.).

4.3.2 Chemicals

All chemicals, solvents and standards used for HPLC quantification of polyphenolic compounds and ascorbic acid (HPLC grade) and spectrophotometric analysis of total phenolic compounds, total carotenoids,

and total antioxidant capacity, were obtained from either Sigma-Aldrich Chemical Co. (St Louis, MO, USA) or Fischer Scientific Co. (Nepean, ON, Canada). For quantification of total soluble protein, the Coomassie Blue G250 dye reagent was obtained from Bio-Rad (ON, Canada), bovine serum albumin (BSA) standard from Pierce (Rockford, IL, USA). The standard used for mineral analysis (custom made) was obtained from SCP Science (Baie D'Urfé, QC, Canada) for quantification of nine different mineral elements using inductively coupled plasma-optical emission spectroscopy (ICP-OES).

4.3.3 Procurement and treatment of plant materials

Tubers from four Québec-grown potato cultivars (Chieftain, red skin and white flesh; Goldrush, brown skin and pale yellow flesh; Russet Burbank, brown skin and white flesh; and Yukon Gold, white skin and yellow flesh; Figure 1.1) were obtained from the Association des Emballeurs des Pomme de Terre du Québec (AEPTQ). Cultivars were selected for analysis by the Fédération des Producteurs de Pomme de Terre du Québec (FPPTQ) and the AEPTQ on the basis of results of previous studies (Piccolomini *et al.,* 2008a*,* 2008b). All tubers were field grown during the 2008 field season and stored at 10 °C and relative humidity of 92% for 7 months.

The tubers were washed under cold running water and dried overnight in a cool, dark environment. Weights were recorded for each tuber and confidence intervals (CI) for tubers of each cultivar were calculated. For each assay, potatoes were selected from within the CI range. For analyses involving freeze-dried tissues, potato tubers were sectioned into skin (periderm), cortex, and pith using a sharp scalpel and were immediately frozen using liquid nitrogen. They were subsequently lyophilized, homogenised, and stored in a – 80 °C freezer until analysed. Weights of tissues were recorded before and after lyophilisation for subsequent calculation of ratios of fresh weight to dry weight for each tissue. Fresh tuber tissue was used for mineral analysis, and freeze-dried tissue was used for the analyses of AA, CA, CGA, FA, RU, TOAC, TC and TP.

4.3.4 Extraction and quantification of antioxidant compounds and phytonutrients

4.3.4.1 Analysis of total polyphenolic compounds

A modified method (Chirinos *et al.*, 2007) was used to quantify TP using the Folin Ciocalteau (FC) reagent. Fifty mg of homogenized freeze-dried material was mixed with 3.5 mL of 0.1% HCL (v/v) in 90% methanol (extraction buffer) and vortexed at room temperature for 1 h in the dark. This mixture was centrifuged, and the supernatant collected and filtered using 0.45 µm syringe filter (Whatman, Montréal, QC, Canada). Chlorogenic acid was used as a standard for quantification and the results were expressed in chlorogenic acid equivalents (CGAE). Concentrations of working standards ranged between 0.02 to 0.26 mg of CGA per mL. A hundred and fifty µL of extract was diluted by adding 1350 µL of double distilled water (DDW). A hundred and fifty µL of 2N FC reagent was added; the mixture was vortexed for 30 sec and allowed to react at room temperature for 3 min. Thereafter, 300 µL of 1 N sodium carbonate was added to the reaction mixture, vortexed for 30 sec, and the reaction was allowed to proceed for 1 h at room temperature in the dark. The absorbance was measured at 725 nm using a spectrophotometer (Beckman DU 640, Corona, CA). Blank consisted of extraction buffer, DDW, FC reagent, and 1 N sodium carbonate. The R-square value of the standard curves obtained was in the range of 0.97 – 0.99. Five replicates (n = 5) were used for each tissue sample (skin, cortex, and pith) and each replicate was read twice and averaged.

4.3.4.2 Analysis of polyphenolic compounds (chlorogenic acid, caffeic acid, ferulic acid), flavanoid rutin and ascorbic acid using high pressure liquid chromatography

Extraction was done using the modified method of Shakya and Navarre (2006) whereby 50 mg of freeze-dried powder was mixed with 3.0 mL of 90% methanol and vortexed at room temperature for 1 h in the dark. The supernatant extracted was filtered and evaporated using a rotary evaporator. The dried extract was resolubilized in 500 µL of 90% methanol

and injected into a high performance liquid chromatography (HPLC) system (Varian, ON, Canada) for quantification of the polyphenolic compounds CGA, CA, and FA, the flavanoid RU, and the antioxidant AA. These were eluted at 7.9, 8.5, 8.9, 9.2, and 1.2 min, respectively. The column used for separation was a reverse phase HPLC Gemini-NX (5 μm, 100 mm × 4.6 mm) column (Phenomenex Inc., Torrance, CA, USA) equipped with a 4.6 mm × 2.0 mm guard column. The mobile phase used was solvent buffer A (10 mM formic acid, pH 3.5, with 14.8 N NH_4OH) and buffer B (100% methanol with 5 mM HCO_2NH_4). The solvent gradient was as follows: 0 – 1 min 100% buffer A, 1 – 5 min 0 – 30% buffer B, 5 – 6.5 min 30 – 70% buffer B, 6.5 – 8.5 min 70 – 100% buffer B. Standards were reconstituted and injected into the HPLC. Ultraviolet detection was carried out at wavelength of 280 nm to obtain the standard curve of peak area versus concentration. The R – square values obtained for these curves of the five compounds ranged from 0.96 – 0.98. A flow rate of 1.0 mL/min was used and the volume of standards injected was 20 μL. Samples (n = 5) were injected into the machine and each sample was read twice. The run time for each sample was approximately 20 min, so refrigeration was used in the auto sampler to prevent possible degradation of compounds due to high temperature. Manual integration was used to integrate peaks and the concentration of each of these compounds was calculated using equations of peak area versus concentration for each of the standards injected.

4.3.4.3 Total carotenoid analysis

Total carotenoids were extracted according to the modified method of (Andre *et al.*, 2007b). 500 mg of freeze-dried potato powder (n = 3) was weighed and added to a 10 mL test tube to which 5 mL of acetone with 1% BHT (w/v) was added and vortexed for 30 sec. Samples were shaken in the dark at 4 °C for 30 min and then centrifuged at 10,000 x g. Supernatant was collected and extraction with acetone was repeated. The two supernatants were combined, centrifuged again, and filtered. The filtrate was evaporated in a rotary evaporator until only the dried extract remained. The containers were flushed with liquid nitrogen, tightly capped and stored in the – 80 °C freezer until analysed. For analysis, the dried extract was resolubilized in 2

mL of acetone with 1% (w/v) BHT. Concentration was calculated according to the following equation given by Britton (1985):

Total carotenoid concentration (µg/mL) = (A x V)/$A^{1\%}$ x 100

A = Absorbance, V = dilution factor, $A^{1\%}$ = 2500 (absorption extinction coefficient of a 1% carotenoid solution in ethanol for a mixture of carotenoids).

The carotenoid concentrations were calculated in µg per g DW of tissue and further expressed in terms of amounts for one serving (virtual tuber of 150 g FW) for each cultivar (modified from Ortiz-Medina *et al.,* 2009).

4.3.4.4 Analysis of total soluble protein

A modified method described by Ortiz-Medina *et al.* (2009) was used for quantification of TSP. Bovine serum albumin (BSA) was used as a standard (concentration ranging from 100 µg – 350 µg per mL) and phosphate buffer was used for extraction. Phosphate buffer of pH 7.5 was prepared by mixing 16 mL of 0.2 M NaOH and 84 mL of 0.2 M Na_2HPO_4. Coomasie brilliant blue G250 dye was diluted by mixing 1 mL of dye concentrate with 4 mL DDW. For extraction, 30 mg of freeze-dried potato tissue was vortexed with 1.5 mL of phosphate buffer for 30 min. This was cooled in the fridge for 2 h and then centrifuged. The supernatant was extracted, filtered, and used in the determination of TSP using the protein assay kit (Bio-rad Laboratories, CA, USA). Diluted dye (1600 µL) was added to 80 µL extract and vortexed for 10 sec. This was incubated at room temperature for 10 min and absorbance was read at 595 nm using a spectrophotometer (Beckman DU 640, Corona, CA).

4.3.4.5 Determination of antioxidant capacity

Both hydrophilic and lipophilic antioxidants contribute towards the total antioxidant capacity of the food sample. Total antioxidant capacity was expressed as the sum total of hydrophilic and lipophilic antioxidant capacities. Methods commonly used to estimate antioxidant capacity differ in terms of mechanisms of action (free radical-generating system, molecular target, end point, kinetics). Apparently, results obtained by using one

antioxidant assay protocol do not take into account influence of all relevant parameters (Robards *et al.*, 1999; Frankel and Meyer, 2000; Ghiselli *et al.*, 2000; Pulido *et al.*, 2003).

The present study used the two methods 1,1-diphenyl-2-pierylhydrazyl (DPPH) and Ferric ion Reducing Antioxidant Power (FRAP) to quantify hydrophilic and lipophilic fractions. Ascorbic acid and Trolox (an analogue of vitamin E) were used as standards. Trolox, being amphoteric, can be dissolved in aqueous or organic media and therefore can be used as a standard for both lipophilic and hydrophilic antioxidant quantification (Arnao *et al.*, 2001).

For the above mentioned assays, extraction of the hydrophilic fraction (denoting HAOC) was done using 0.1% (v/v) HCl made in 90% (v/v) methanol (extraction buffer) using the modified extraction method of Teow *et al.* (2007). 50 mg of freeze-dried potato powder was extracted for 1 h in the dark using 3.5 mL of extraction buffer. The mixture was centrifuged and the supernatant extracted and filtered. A modified method by Teow *et al.* (2007) was used for extraction of the lipophilic antioxidant fraction (denoting LAOC). For preparation of the lipophilic extracts, 50 mg of freeze dried potato powder was extracted for 1 h in the dark using 3.0 mL of hexane. The mixture was centrifuged and the supernatant filtered. These extracts were then used for the DPPH and FRAP assays. A modified method described by (Nair *et al.*, 2007) was used to measure the DPPH radical scavenging activity for extracts.

According to the principle of the DPPH method, antioxidant capacity is determined using a stable free radical 1,1-diphenyl-2-pierylhydrazyl (DPPH) (Delaplace *et al.*, 2008). The deep purple colour formed by DPPH dissolved in methanol is lost as the radical reacts with antioxidants present in extracts. The absorbance when measured at a given wavelength negatively correlates to antioxidant capacity of sample. The FRAP assay measures the capability of antioxidants to act as reductants in a redox-linked colorimetric reaction involving reduction of Fe^{3+} -2,4,6-tri-pyridyl-S-triazine to a blue-coloured Fe^{2+} complex at low pH (Chen and Blumberg, 2008). Intensity of colour development is measured spectrophotometrically at 595 nm.

The DPPH solution was prepared by mixing 3.94 mg of DPPH in 100 mL of methanol. Ascorbic acid and Trolox standards were prepared in extraction buffer. To start the DPPH test, 50 µL of extract/standard was mixed with 1.5 mL of DPPH solution, vortexed for 10 sec and incubated at room temperature for 20 min.

A modified method described by Nair *et al.* (2007) was used to measure the antioxidant capacity of extracts using FRAP. The FRAP solution was prepared by mixing the three solutions of 2, 4, 6-tripyridyl-s-triazine (TPTZ; 0.3123 g TPTZ and 0.33 mL HCl made upto 100 mL with double distilled water; DDW), ferric chloride (0.5406 g ferric chloride in 100 mL DDW) and acetic acid buffer (16 mL acetic acid and 3.1 g sodium acetate trihydrate made up to 1000 mL using DDW in the ratio 1:1:10). Ascorbic acid and Trolox standards were prepared in extraction buffer; 50 µL of extract was mixed with 1.5 mL of FRAP solution, vortexed for 10 sec and incubated at room temperature for 6 min.

Absorbance was recorded at 517 nm for DPPH and 595 nm for FRAP assays. The blank consisted of distilled water. The control consisted of FRAP reagent incubated with 50 µL of extraction buffer. Results were expressed in terms of ascorbic acid equivalents (hydrophilic fraction), and Trolox equivalents (TE; hydrophilic and lipophilic fractions, and total antioxidant capacity). Results of FRAP assay, calculated as TE, were further converted to be expressed in $FeSO_4$ units using available conversion factor (Benzie and Strain, 1996). This enabled comparision of the TOAC ranking of these potato cultivars with a published database of 3100 different foods from all over the world (Carlsen *et al.,* 2010).

4.3.4.6 Quantification of minerals

Fresh tissue was used for mineral analysis as described by using inductively coupled plasma-optical emission spectroscopy (ICP-OES) (Anderson *et al.,* 1999). All glassware likely to come in contact with the potato samples was acid washed, by soaking the glassware in a 10% (v/v) solution of concentrated nitric acid for 12 h, washing it several times with DDW and subsequent drying for 48 h in a closed space. All solutions and standards were prepared in acid washed glassware.

One g of fresh tissue (skin, cortex, and pith) was digested in 3 mL of concentrated nitric acid for 48 h under a fume hood. These digestion tubes were moved to a heating block at 108 °C for 24 h for complete tissue digestion. Two mL of digested slurry was transferred to acid washed tubes of 15 mL capacity and diluted to 10 mL using 5% nitric acid. After successful calibration of standard by the ICP-OES equipment, these samples were injected into the machine (Varian MPX, ON, Canada). Minerals were detected at the following wavelengths: Ca, 422.673; Cr 267.716; Cu 324.754; Fe 259.940; K 766.491; Mg 280.270; Na 588.995; Se 207.479; Zn 213.857. Each sample was measured in triplicates (n = 3) and read three times.

4.3.5 Statistical analysis

SAS (Version 9.2) was used for statistical analyses (SAS, 2008). Significance level was set at $p < 0.05$. One way ANOVA was followed by the multiple comparisons Tukey's post-hoc test for difference between cultivars with respect to amounts in one serving. Differences between percentage contribution of tissues within each cultivar towards the content of antioxidants and phytonutrients in one serving (virtual tuber of 150 g FW) was examined. Pearson's correlation was used to determine associations between selected indices of antioxidant capacity measures.

4.4 Results

4.4.1 Differences between cultivars on a per serving (virtual tuber of 150 g FW) basis

4.4.1.1 Total phenolic compounds

The mean TP ranged from 93.85 ±1.47 mg/serving (150 g FW) of cv. Yukon Gold to 122.46 ± 46 mg/serving of cv. Goldrush (Table 4.1; Figure A.1). Goldrush provided significantly greater TP than cvs. Yukon Gold, Russet Burbank (110.45 ± 1.27) and Chieftain (93.85 ± 1.47). There was no significant difference in TP content between Yukon Gold and Chieftain.

4.4.1.2 Analysis of polyphenolic compounds (chlorogenic acid, caffeic acid, ferulic acid), flavanoid rutin and ascorbic acid using high pressure liquid chromatography

The mean CGA in one serving of 150 g FW ranged from 1820 ± 96 µg for cv. Yukon Gold to 9797 ± 451 µg for cv. Goldrush (Table 4.1; Figure A.2). Cultivar Goldrush had significantly greater CGA content than cvs. Russet Burbank (7802 ± 633 µg), Yukon Gold (1820 ± 96 µg), and Chieftain (3951 ± 121 µg). Caffeic acid in one serving of 150 g FW was greater in cv. Chieftain (1843 ± 163 µg) than in cvs. Goldrush (1087 ± 52 µg) and Yukon Gold (567 ± 8 µg) but similar to cv. Russet Burbank (1549 ± 49 µg). Ferulic acid per serving was greater in cv. Chieftain (427 ± 21 µg) compared with cvs. Goldrush (222 ± 22 µg), Russet Burbank (185 ± 6 µg), and Yukon Gold (3176 ± 23 µg). Cultivars Russet Burbank and Goldrush were similar. Chieftain showed significantly greater RU content per serving (659 ± 60 µg) than Goldrush (491 ± 63 µg), Russet Burbank (276 ± 18 µg) and Yukon Gold (1844 ± 11 µg) in 1 serving. Cultivars Russet Burbank and Yukon Gold were similar and cvs. Goldrush and Chieftain were similar in RU content per serving.

Ascorbic acid content per serving ranged from 26.35 ± 0.68 mg for cv. Chieftain to 47.54 ± 1.62 mg for cv. Goldrush (Table 4.1; Figure A.1). Cultivar Goldrush had significantly greater AA content than cvs. Chieftain, Russet Burbank (29.69 ± 1.26 mg) and Yukon Gold (39.85 ± 3.03 mg). No difference was observed between AA content of cvs. Russet Burbank and Chieftain.

The percentage contribution of AA in one serving to the RDA for AA (90 mg; Table A.1) varied from 29.28 ± 0.76% to 44.28 ± 3.36%. Cultivars Goldrush and Yukon Gold showed significantly greater contribution to RDA of AA than cvs. Russet Burbank and Chieftain (Table 4.6; Figure A.1). Ascorbic acid being heat sensitive, its typical losses from different cooking methods was assessed by Love and Pavek (2008). Taking into account the loss factors for two commonly used cooking methods (boiling with peel, 21% loss and mashing, 67% loss), the estimated AA contribution of one serving of each of the four cultivars towards meeting the RDA for AA is shown in Figure A.7.

4.4.1.3 Total carotenoids

Content of TC in one serving ranged from 42 ± 5 µg to 236 ± 23 µg (Table 4.1; Figure A.1). Cultivar Yukon Gold, which has distinctly yellow coloured flesh, was significantly greater in its TC content in one serving than the other cvs. all of which had similar TC content.

4.4.1.4 Total soluble protein

Cultivar Yukon Gold showed significantly greater content of TSP on a per serving basis (1358.67 ± 9.23 mg) than other cvs. Goldrush (1196.11 ± 24.96 mg), Russet Burbank (1033.16 ± 33.64 mg), and Chieftain (1025.77 ± 28.04 mg) (Table 4.1; Figure A.3). Cultivars Russet Burbank and Chieftain were least in their TSP content compared with the other two cultivars. The RDA for protein for adult males aged 19 – 50 is 58 – 63 g (Table A.1). The percentage contribution of one serving of cvs. towards the RDA of protein ranged from 1.77 ± 0.05 to 2.34 ± 0.02% (Table 4.6). This small amount may not be nutritionally significant from a dietary point of view. Despite the low amount of protein, the high biological value of potato protein (Kasper, 2004; cited but not referenced by Buckenhüskes, 2005) may prove to be nutritionally significant. Further, the potato protein shows antioxidant activity and may contribute towards raising the antioxidant capacity of diet (Al-Saikhan *et al.,* 1995).

4.4.1.5 Antioxidant capacity

4.4.1.5.1 Total antioxidant capacity

Total antioxidant capacity (TAOC) expressed in TE was calculated as summation of hydrophilic antioxidant capacity (HAOC) and lipophilic antioxidant capacity (LAOC). Although results obtained by DPPH and FRAP were both expressed in TE, DPPH showed greater TE values than FRAP. Goldrush showed greater TAOC with DPPH (along with Russet Burbank with FRAP) while Chieftain showed the least TAOC with both methods (Tables 4.2 and 4.3; Figures A.4 and A.5)

On a virtual tuber basis, total phenolic compounds showed a strong significant positive correlation with total antioxidant capacity (r = 0.82,

FRAP; r = 0.67, DPPH; Table 4.8). Phenolic compounds are the predominant group of hydrophilic antioxidants found in potatoes (Brown 2005). Given the strong correlation, TP could be used as a predictor of relative TOAC in foods (Teow *et al.,* 2007). The hydrophilic antioxidant ascorbic acid was also strongly positively correlated with TOAC (r = 0.75, DPPH; r = 0.68, FRAP; Table 4.8).

4.4.1.5.2 Hydrophilic antioxidant capacity

Hydrophilic antioxidant capacity obtained using DPPH showed significant differences between all cultivars on a per serving basis with cv. Goldrush (6992.90 ± 60.18 μM) being significantly greater than other cvs. (Table 4.2; Figure A.4). When HAOC was quantified in terms of ascorbic acid equivalents (AAE) using DPPH, cv. Russet Burbank (48.56 ± 1.88 mg) had significantly greater HAOC content than the other three cvs. Cultivars Goldrush (24.79 ± 2.40 mg) and Chieftain (22.64 ± 0.89 mg) were similar and least in the HAOC content per serving.

Quantification by FRAP assay (Table 4.3; Figure A.5) showed that cvs. Russet Burbank (1683.84 ± 24.10 μM TE) and Goldrush (1777.67 ± 31.78 μM TE) were similar and significantly greater in HAOC contents per serving than other cultivars. When HAOC was quantified in terms of AAE using FRAP, Russet Burbank (29.91 ± 0.59 mg) and Goldrush (29.96 ± 0.77 mg) were similar and significantly greater in HAOC content than other cultivars on a per serving basis.

4.4.1.5.3 Lipophilic antioxidant capacity

Troloz equivalent values obtained by using DPPH (Table 4.3; Figure A.4) showed significantly greater LAOC for cv. Goldrush (582.60 ± 25.95 μM) compared with the other cultivars which were all similar and ranged from 390.61 ± 21.65 μM to 497.87 ± 16.21 μM per serving. The TE values using FRAP (Table 4.4; Figure A.5) showed that on a per serving basis, cv. Goldrush (586.94 ± 25.61 μM) was superior in its LAOC to cv. Chieftain (361.28 ± 6.90 μM), and both cvs. Russet Burbank (435.11 ± 15.25 μM) and Yukon Gold (481.57 ± 13.69 μM) which were similar. While carotenoids are the predominant lipophilic antioxidants found in potatoes

(Brown, 2005), there was no correlation found between TC content and LAOC in the present study (Table 4.8).

4.4.1.6 Minerals

Cultivar Russet Burbank was significantly greater in Ca content (11.70 ± 1.10 mg) compared with other three cultivars which were similar for one serving (Table 4.5). However, the percent contribution of Ca in one serving of any of these cultivars to the adequate intake (AI) of Ca (100 mg; Tables 4.6 and A.1) was neglible (0.37 ± 0.11 to 1.17 ± 0.11%).

The Fe content of cv. Russet Burbank (0.95 ± 0.11 mg) was similar to cv. Chieftain (0.60 ± 0.11 mg) and significantly greater than cvs. Goldrush (0.42 ± 0.01 mg) and Yukon Gold (0.53 ± 0.05 mg) (Table 4.5). The percent contribution of Fe in one serving to the RDA for Fe (8 mg for adult males; Table A.1) ranged from 5.25 ± 0.12% to 11.88 ± 1.40% with Russet Burbank (similar to cv. Chieftain) providing significantly greater contribution than the other cvs. (Table 4.6; Figure A.6).

Cultivar Goldrush (0.13 ± 0.00mg) was significantly greater in Cu content per serving cv. than Yukon Gold (0.03 ± 0.00 mg), but similar to cvs Chieftain (0.09 ± 0.01 mg) and Russet Burbank (0.10 ± 0.03 mg) (Table 4.5). The percent contribution of Cu in one serving to the RDA of Cu (900 µg; Table A.1) ranged from 3.33 ± 0.24% to 14.44 ± 0.22 % and was similar for all cvs. (Table 4.6; Figure A.6).

Cultivars had similar K, Mg, Na, P, Zn, Se content per serving (Table 4.5). Cultivars were similar in their percent contribution of these minerals in one serving to their RDA/AI (Table 4.6). The cultivars were similar in their Se content per serving (71 ± 11 – 82 ± 16 µg) with an average Se content of 75 ± 5 µg. The contribution of Se in one serving to the RDA of Se (55 µg; Table A.1) was at least 100 % for all cultivars (129 ± 11 – 149 ± 17%; Table 4.6; Figure A.6).

4.4.2 Differences in contribution of tissues towards total serving (virtual tuber of 150 g FW) content of antioxidants and phytonutrients

The potato skin tissue forms a very small portion of a tuber (0.85 – 3.37% by weight; Ortiz-Medina *et al.,* 2009). Skin is often discarded when

potatoes are consumed or processed. The percentage contribution of skin, cortex, and pith to the antioxidants and phytonutrients in one serving (virtual tuber of 150 g FW) was assessed mainly to examine the relative dietary importance of potato skin as a contributor to antioxidants and phytonutrients in one serving **(**Table 4.7).

4.4.2.1 Total phenolic compounds, total soluble protein, total carotenoids, and ascorbic acid

Contribution to the total serving content of TP, TSP and TC was greater from flesh (cortex and pith), than from skin. The percentage contribution from skin was 2.6 – 13.62% of TP, 0.84 – 2.78% of TSP, 0.76 – 8.43% TC, and 1.79 – 6.39% of AA (Table 4.7). The skin of cv. Russet Burbank contributed significantly greater TP (13.62 ± 0.17%), TSP (2.78 ± 0.18%), and TC (8.43 ± 1.05%) and greater AA (6.39 ± 0.44%) with cv. Chieftain to the total serving content than other cvs. The skin contributions of cvs. Chieftain and Goldrush to one serving were similar for TP, TSP and TC. Cultivar Yukon Gold showed least contribution from skin towards AA in one serving (1.79 ± 0.17%).

4.4.2.2 Polyphenolic compounds (chlorogenic acid, caffeic acid, ferulic acid), flavanoid rutin, and total antioxidant capacity

Cultivars showed a wide variation in how much polyphenolic materials were present in the skin. This affected the contribution of skin to the total serving content of CGA (7.23 ± 0.66% to 34.27 ± 2.05%) (Table 4.7). Skin contribution of CGA towards its total serving content was superior for cvs. Russet Burbank (34.27 ± 2.05%) and Goldrush (31.87 ± 2.14%).

Skin contribution of FA showed a 2-fold difference between the least and highest values (48.43 ± 4.50% to 94.06 ± 0.54%) (Table 4.7). Skin of cvs. Chieftain (92.37 ± 1.01%) and Russet Burbank (94.06 ± 0.54%) contributed greater to the content of FA in one serving than other cvs.

Skin contribution of CA varied widely (48.31 ± 3.01% to 90.43 ± 0.66%) among cvs. Cultivars Chieftain (87.46 ± 1.34%), Goldrush (84.66 ± 0.57%) and Russet Burbank (90.43 ± 0.66%) had similar greater

contributions of skin towards one serving than cv. Yukon Gold (48.31 ± 3.01%; Table 4.7).

Contribution of skin towards total serving content of RU was significantly different for all cvs. Cultivar Goldrush (73.81 ± 2.22%) showed greatest contribution from skin followed by Russet Burbank (37.17 ± 4.06%), Yukon Gold (23.00 ± 1.41%), and Chieftain (7.76 ± 2.04%; Table 4.7).

Cultivar Russet Burbank showed greater contribution from skin (3.48 ± 0.04%, DPPH; 26.39 ± 0.31%, FRAP) towards total serving content of TAOC. Cultivar Yukon Gold showed least contribution of skin towards total serving content of CGA, FA, CA, and TOAC (Table 4.7).

4.4.2.3 Minerals

Cultivars showed less variation in contribution of minerals from skin towards total serving content. While the skin did not generally contribute significant amounts of minerals on a per serving basis, cultivars showed significant variation in content of Fe from skin (4.19 ± 1.80% to 41.47 ± 7.96%) with cv. Russet Burbank showing a greater contribution from skin than other cvs. (Table 4.7).

4.5 Discussion

Cultivars showed significant differences with respect to their total content of phytonutrients as well as their antioxidant capacity indices (Tables 4.1 to 4.5). The TP content of cultivars examined was similar to that reported in Andean and American cultivars by Campos *et al.* (2006) and Reddivari *et al*. (2007), respectively (Table 4.9).

Chlorogenic acid was the predominant phenolic acid present in Québec-grown potato cultivars (Table 4.1) as observed in previous studies (Lewis *et al.,* 1998; Shakya and Navarre, 2006; Reddivari *et al.,* 2007). Coffee is one of the richest sources of CGA with content of 15 – 325 mg per serving (250 ml; Clifford *et al.,* 1976). The potatoes examined in the present study showed CGA levels between 1.82 – 9.80 mg/serving (Table 4.1), i.e., 0.56 – 65% of CGA in one serving of coffee when considering the lowest range of CGA content of coffee. The content of CGA, CA and RU found in

the present study is lower than the high end values reported for the Andean cultivars (Andre *et al.,* 2007b; Table 4.9).

Skins of Québec-grown cultivars showed greater amounts of CGA and CA than reported (Al-Weshahy and Rao, 2009) for 6 cultivars grown in Ontario (Table 4.9). The latter study used a mechanical peeler to separate periderm tissue. Mechanical peelers give thicker layers of peel, often including some cortex tissue, as compared with skin obtained by manual peeling in the present study. Since cortex contains significantly less phenolic compounds than skin, the values for periderm obtained by Al-Weshahy and Rao (2009) was likely lowered due to use of mechanical peelers.

The present study quantified FA content (Table A.5), which was not quantified in the Andean cultivars (Andre *et al.,* 2007a, b). Greater amounts of CGA, CA and FA were found in potato skin compared to European cultivars (Leo *et al.,* 2008) (Table 4.9). This could have been due to differences in extraction solvents (90 % methanol was used in the present study, while 80 % methanol was used by Leo *et al.,* 2009). Also different ratios of solvent to solid (unspecified by Leo *et al.,* 2009) or difference of cultivars (Toledo and Burlingame, 2009) could have contributed to the study differences. Cultivars having yellow flesh were shown to have lower CGA content (Ševčík *et al.,* 2009). Results of the present study support this latter finding as cv. Yukon Gold (having yellow flesh) had lesser content of CGA than the other cvs. Im *et al.* (2008) reported phenolic content in 1 g DW of cv. Yukon Gold (i.e., 143 ± 5 to 356 ± 39 µg CGA and 45.5 ± 1.7 to 93.3 ± 3.2 µg CA). The content of CGA and CA in cv. Yukon Gold tested in the present study was significantly lower than these (Table A.5). Navarre et *al.* (2011) reported phenolic contents in 1 g DW of cvs. Russet Burbank (i.e., 630 ± 170 µg CGA, 116 ± 43 µg CA and 3.70 ± 1 µg RU) and Chieftain (i.e., 794 ± 180 µg CGA, 87 ± 36 µg CA, and 43.1 ± 5 µg RU). The content of CGA and CA in cv. Russet Burbank in the present study was significantly lesser than these, while RU was greater (Table A.5). The content of CGA and RU in cv. Chieftain in the present study was lesser than these while CA was similar. Reasons for these differences could involve

season length, environment and genotype (Huang *et al.,* 2007; Rio Segade *et al.,* 2008; Rodriguez-Amaya *et al.,* 2008; Andre *et al.,* 2009).

The AA content of cultivars were similar to studies reported previously (Finlay *et al.,* 2003; Love *et al.,* 2003; Andre *et al.,* 2007b; Leo *et al.,* 2008). The present study reported significant differences in white fleshed cultivars (cvs. Chieftain and Russet Burbank) with regard to content of CGA and TP. This latter result is concert with the recent findings of Navarre *et al.* (2011) which showed that white fleshed cvs. can vary significantly in their TP and CGA content.

The tested cultivars of the present study showed TC content similar to the values reported by Brown *et al*. (2008). Cultivar Yukon Gold showed significantly greater TC content than other pale fleshed cvs, which supports the positive association between intensity of the yellow of tuber flesh and amounts of TC previously suggested by Brown *et al.* (1993) and Gross (1991). Content of TC was lesser than that in Andean potato cultivars examined by Andre *et al.* (2007a, b) likely owing to the greater variety of Andean cultivars examined; some with intense yellow flesh. Total carotenoid content was less than that reported by Muller *et al.* (1997) and Delaplace *et al*. (2008) (Table 4.9). Differences in growing location, genotype and year may also account for differences seen in TC content (Toledo and Burlingame, 2006; Reddivari *et al.,* 2007a; Burlingame *et al.,* 2009a, b). Poor correlations found between lipophilic antioxidant capacities and carotenoid content in this study could indicate presence of other lipophilic components, such as tocopherols (Kurilich *et al.*, 2002; Teow *et al.,* 2007) which merits further investigation. Possibly, radicals used in the DPPH and FRAP assays may not be effective in detecting the antioxidant capacity of lipophilic antioxidants such as carotenoids, and that assays such as ABTS or ORAC may be required to better assess the radical scavenging capacity of carotenoid compounds (Teow *et al.,* 2007).

The content of TSP was lesser than that reported by Delaplace *et al.* (2008) and Ortiz-Medina *et al.* (2009) (Table 4.9). Protein content of cultivars in the present study would have likely deteriorated during the lengthy storage period (7 months) prior to analysis (Delaplace *et al.,* 2008). Other reasons for the observed difference would have likely been cultivar

difference, and location of growth (Toledo and Burlingame, 2006; Reddivari *et al.,* 2007a; Burlingame *et al.,* 2009a, b).

The present study showed TOAC values using DPPH were similar to those reported by Hale *et al.* (2003) (Table 4.9). These were greater than values observed by Nara *et al.* (2006), Reddivari *et al.* (2007a), and Delaplace *et al.* (2008). When quantified in terms of ascorbic acid equivalents (AAE) using DPPH, HAOC values were greater than those observed by Lachman *et al.* (2008). When TAOC was expressed in $FeSO_4$ units using available conversion factors (Benzie and Strain, 1996), the cultivars showed TOAC between 13.94 - 18.96 mmol $FeSO_4$/100 g FW (Table 4.5), greater than the mean of the plant-based food group (11.57 mmol $FeSO_4$/100 g) examined by Carlsen *et al.* (2010). Total antioxidant capacity as reported by Halvorsen *et al.* (2006), i.e., 0.062 – 0.966 mmol $FeSO_4$/100 g FW was significantly lesser than that observed in the present study. A possible reason for the relatively high TOAC in the present study might be because sum of HAOC and LAOC was used to calculated TOAC (Pulido *et al.,* 2003), whereas other studies generally estimated only the hydrophilic fraction. Other reasons could be due to differences in climate or growing conditions for potatoes, season or growth period, and storage time (Finlay *et al*., 2003; Brown *et al.,* 2008; Andre *et al.,* 2009; Reddivari *et al.,* 2007a).

A major portion of TAOC on a per serving basis was contributed by HAOC (Tables 4.2 and 4.3; Figures A.4 and A.5). This could be due to the relatively smaller amounts of lipophilic carotenoids found in potato tubers as opposed to larger quantities of hydrophilic antioxidant compounds including TP, CGA, CA, RU, and AA (Brown, 2005). These results are in agreement with other studies suggesting that the majority of antioxidants found in potato are of hydrophilic nature. In the present study, cv. Chieftain showed greater amounts of CA (along with brown skinned cv. Russet Burbank), FA, and RU (along with cv. Goldrush) than other cvs. This supports the observation that red skinned cultivars contain greater amounts of phenolic acids than white skinned ones (Lewis *et al.*, 1998a). The TAOC measured by DPPH was greater for cv. Russet Burbank than for cv. Chieftain (both white fleshed) (Table 4.2). Similarly, the white fleshed cv.

Russet Burbank showed significantly greater TAOC measured by FRAP than white fleshed Chieftain (Table 4.2). These results do not support the findings of Reddivari *et al.* (2007a) who demonstrated that different cultivars with similar flesh color did not show significant differences in antioxidant capacities, irrespective of skin color. However, these results support the findings of a recent study (Navarre *et al.,* 2011) wherein white fleshed cultivars were reported to vary significantly in TOAC measured by ORAC assay.

Mixtures of phytochemicals have been demonstrated to function more effectively towards improving antioxidant status than isolated phytochemicals (DeGraft Johnson, 2007). Antioxidant capacity measurements can reflect the synergistic interactions between redox molecules within biological tissues and foods. The antioxidant capacity of foods consumed by individuals (measured by FRAP) has been found to be a valid and reproducible determinant of the human plasma FRAP measurements (Rautiainen *et al.,* 2008). Antioxidant capacities of foods consumed by a population could therefore indicate the antioxidant status of that population based on food intake (Rautiainen *et al.,* 2008). It is therefore conceivable that intake of specific potato cultivars with relatively greater antioxidant capacity could lead to improved antioxidant status in a population eating substantial amounts of potato.

Cultivars also varied greatly in their relative contributions of skin to the total serving content of certain antioxidants and phytonutrients (Table 4.7). Therefore, cultivar appears to be a determining factor for the relative nutritional contribution of skin for certain nutrients and phytochemicals. This latter evidence indicates that inclusion of potato skin of certain cvs. in the diet might increase the intake of certain key nutrients and polyphenols.

The present study reports the amounts of eight minerals of nutritional significance. Similarities and differences between current and previous findings have been outlined in Table 4.9. Factors likely responsible for the differences in content of minerals between studies may include cultivar differences, fertilization methods and manuring (Srikumar and Ockerma, 1990; Toledo and Burlingame, 2006). Selenium concentrations were markedly greater than found in published studies on potato (Table 4.9), even

where Se fertilization was practiced (Cuderman *et al.,* 2008). For example, cv. Desiree tubers were dramatically increased in Se content by spraying sodium selenate solution as a foliar feed (10 mg/l). Well-watered control plants had tubers that contained 117 ng/g DW (0.12 µg/g DW) Se while the tubers from Se-fertilized plants had 1101 ng/g DW (1.1 µg/g DW) Se (> 9-fold increase). By comparison, cultivars in the present study (1.9 ± 0.12 to 2.1 ± 0.14 µg/g DW Se; Table A.6) had significantly greater Se than both control or fertilized Desiree. Factors that likely account for this difference are the Se content of soil and fertilizers (Stadlober *et al.,* 2001), and the form in which Se is present in soil. For example, the selenate form (anion) is absorbed by plants more effectively than the selenite form (anion) (Ylaeranta, 1983*a, b*).

A unique method used in this study was the use of a mathematically constructed virtual tuber to estimate the amount of antioxidants and phytonutrients on per serving (virtual tuber of 150 g FW) basis as calculated summatively from tissue concentrations quantified separately in skin, cortex and pith. Each potato cultivar has a relatively characteristic tuber shape (e.g., round, oval, etc.) and size at maturity (Netherlands Catalogue of Potato Varieties 1997; Anonymous, 2007). Similarly, the tissues forming the tuber (skin, cortex, and pith) are relatively different in proportion and moisture content for each cultivar. There is increased recognition of the fact that distribution of antioxidants and phytonutrients may not be uniform throughout the tuber. For example, protein was present in different concentrations in skin, cortex and pith (Ortiz-Medina *et al.,* 2009). Previous investigations have either sampled the whole tuber, a cross section, or a part of the tuber (flesh only). In view of the differences in proportions of tuber tissues across cultivars, the latter sampling techniques do not reveal uneven tissue distribution and therefore are inaccurate methods for estimating the total amount of a nutrient in the tuber (Ortiz-Medina *et al.,* 2009). The present study used a more reliable estimate by compartmentalizing the potato tuber into tissues. It first quantified components of interest separately in skin, cortex and pith and thereafter estimated the total amount in one tuber of 150 g FW. This is the first study to use this concept originally developed by Ortiz-Medina *et al.* (2009) to comprehensively quantify,

among potato cultivars, the amounts of antioxidants and phytonutrients in one serving and contributions of tissues to total serving content.

According to the nutritional labelling guidelines (Codex Alimentarius, 2007), one serving (virtual tuber of 150 g) of potato would need to provide 22.5% or 45% contribution towards the RDA for AA (90 mg; Table A.1) to meet the requirements for a "source" or "high source" respectively. Considering losses in ascorbic acid with cooking using estimated values by Love and Pavek (2008), one serving of cv. Goldrush is closer to meeting the requirements for a "source" and "high source" when mashed and boiled with peel, respectively (Figure A.7). Nutritional contribution of mineral amounts in one serving towards RDA/AI of most minerals was relatively small. However, all cultivars met the percent RDA for Se in a single serving (129 ± 11% to 149 ± 17%). Phytates found in plant foods form complex with minerals such as zinc and iron, reducing their bioavailability in the human body. However, potatoes could possibly have better bioavailability for those minerals compared with plant foods that have significantly higher phytic acid content (Camire *et al.*, 2009).

Cultivar could be an essential factor in determining the contribution of certain phytonutrients and antioxidants in populations consuming potatoes as a food staple. Thus, certain cultivars have more potential to meet the dietary requirement of certain nutrients than others. Furthermore, depending on cultivar, skin can be an important part of the tuber contributing substantially to dietary intake of certain phytonutrients and antioxidants. This information when disseminated systematically among consumers could potentially encourage improved nutritional practices and eventually improve dietary intake of nutrients in the population without drastically changing potato eating practices (Andre *et al.,* 2007a).

Table 4.1: Amounts of antioxidants (total phenolic compounds; TP, chlorogenic acid; CGA, caffeic acid; CA, ferulic acid; FA, rutin; RU, ascorbic acid; AA, and total carotenoids; TC) and total soluble protein (TSP) in one serving (virtual tuber of 150 g FW).

Potato Cultivars	**Amounts per serving (150 g)**			
	TP (mg)**	**CGA (µg)****	**CA (µg)****	**FA (µg)****
Chieftain	93.85 ± 1.47^{c}	3951 ± 121^{c}	1843 ± 163^{a}	427 ± 21^{a}
Goldrush	122.46 ± 1.07^{a}	9797 ± 451^{a}	1087 ± 52^{b}	222 ± 22^{c}
Russet Burbank	110.45 ± 1.27^{b}	7802 ± 633^{b}	1549 ± 49^{a}	185 ± 6^{c}
Yukon Gold	97.50 ± 4.59^{c}	1820 ± 96^{d}	567 ± 8^{c}	317 ± 22^{b}
Overall Mean	106.07 ± 6.52	5843 ± 1808	1262 ± 279	288 ± 54

Potato Cultivars	**Amounts per serving (150 g)**			
	RU (µg)**	**AA (mg)****	**TC (µg)***	**TSP (mg)****
Chieftain	659 ± 60^{a}	26.35 ± 0.68^{c}	42 ± 5^{b}	1025.77 ± 28.04^{c}
Goldrush	490 ± 63^{a}	47.54 ± 1.62^{a}	63 ± 7^{b}	1196.11 ± 24.96^{b}
Russet Burbank	276 ± 18^{b}	29.69 ± 1.26^{c}	50 ± 8^{b}	1033.16 ± 33.64^{c}
Yukon Gold	184 ± 11^{b}	39.85 ± 3.03^{b}	236 ± 23^{a}	1358.67 ± 9.23^{a}
Overall Mean	402 ± 107	35.86 ± 4.84	98 ± 46	1153.43 ± 78.90

Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; **n = 5; *n = 3). Results are expressed as mean ± SE. Means having the same letters in each column are not significantly different from each other.

Table 4.2: Antioxidant capacities (hydrophilic antioxidant capacity, HAOC; lipophilic antioxidant capacity, LAOC; total antioxidant capacity, TOAC; percentage contribution of HAOC and LAOC to TAOC) in one serving (virtual tuber of 150 g FW) obtained using 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay.

Cultivars	HAOC (µM TE)	LAOC(µM TE)	TAOC (µM TE)	% contribution to TAOC		HAOC (mg AAE)
				HAOC	LAOC	
Chieftain	5316.05 ± 20.97^{d}	390.61 ± 21.65^{c}	5706.65 ± 32.94^{d}	93.16 ± 0.35^{ab}	6.84 ± 0.32^{ab}	22.64 ± 0.89^{c}
Goldrush	6992.90 ± 60.18^{a}	582.60 ± 25.95^{a}	7575.49 ± 65.45^{a}	92.31 ± 0.32^{b}	7.69 ± 0.32^{a}	24.79 ± 2.40^{c}
Russet Burbank	6522.94 ± 47.21^{c}	497.87 ± 16.21^{b}	7020.80 ± 58.70^{c}	92.91 ± 0.19^{b}	7.09 ± 0.17^{a}	48.56 ± 1.88^{a}
Yukon Gold	6806.01 ± 41.20^{b}	431.96 ± 13.70^{bc}	7237.97 ± 35.40^{b}	94.03 ± 0.20^{a}	5.97 ± 0.19^{b}	36.89 ± 1.64^{b}
Overall Mean	6409.48 ± 377.06	475.76 ± 41.91	6885.23 ± 409.10	93.10 ± 0.36	6.90 ± 0.36	33.22 ± 6.00

Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Results are expressed as mean ± SE. Means having the same letters in each column are not significantly different from each other.

Table 4.3: Antioxidant capacities (hydrophilic antioxidant capacity, HAOC; lipophilic antioxidant capacity, LAOC; total antioxidant capacity, TOAC; percentage contribution of HAOC and LAOC to TAOC) in one serving (virtual tuber of 150 g FW) obtained using ferric ion reducing antioxidant power (FRAP) assay.

Cultivars	HAOC (µM TE)	LAOC(µM TE)	TAOC (µM TE)	% contribution to TAOC		HAOC (mg AAE)
				HAOC	LAOC	
Chieftain	1225.66 ± 33.29^{c}	361.28 ± 6.90^{c}	1586.93 ± 33.69^{d}	77.21 ± 0.58^{ab}	22.80 ± 0.57^{ab}	19.56 ± 1.02^{c}
Goldrush	1777.67 ± 31.78^{a}	586.94 ± 25.61^{a}	2364.62 ± 26.24^{a}	75.18 ± 1.03^{b}	24.82 ± 1.03^{a}	29.96 ± 0.77^{a}
Russet Burbank	1683.84 ± 24.10^{a}	435.11 ± 15.25^{b}	2118.95 ± 35.56^{b}	79.48 ± 0.46^{a}	20.52 ± 0.45^{b}	29.91 ± 0.59^{a}
Yukon Gold	1515.14 ± 17.09^{b}	481.57 ± 13.69^{b}	1996.72 ± 21.94^{c}	75.89 ± 0.56^{b}	24.11 ± 0.55^{a}	24.59 ± 0.41^{b}
Mean	1550.58 ± 121.16	466.23 ± 47.25	2016.81 ± 162.43	76.94 ± 0.95	23.06 ± 0.95	26.01 ± 2.49

Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Results are expressed as mean ± SE. Means having the same letters in each column are not significantly different from each other.

Table 4.4: Total antioxidant capacity (TOAC) obtained using ferric ion reducing antioxidant power (FRAP) assay converted from Trolox equivalents to mmol of $FeS0_4$/100 g units (Halvorsen *et al*., 2006).

Cultivar	**Total Antioxidant Capacity (mmol of $FeSO_4$/100 g)**
Chieftain	13.94 ± 0.89^{d}
Goldrush	18.96 ± 0.76^{a}
Russet Burbank	15.22 ± 0.72^{c}
Yukon Gold	17.17 ± 0.47^{b}
Mean	16.32 ± 1.10

Using conversion factors mentioned by Halvorsen *et al*. (2010), total antioxidant capacity obtained by using FRAP (Table 4.3) as converted to $FeSO_4$ units. Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Results are expressed as mean ± SE. Means having the same letters are not significantly different from each other.

Table 4.5: Amounts of the minerals (calcium; Ca, copper; Cu, iron; Fe, potassium; K, magnesium; Mg, sodium; Na, phosphorous; P, selenium; Se, and zinc; Zn) in one serving (virtual tuber of 150 g FW).

Cultivars	**Ca (mg)**	**Cu (mg)**	**Fe (mg)**	**K (mg)**
Chieftain	3.70 ± 1.13[b]	0.09 ± 0.01[ab]	0.60 ± 0.11[ab]	403.01 ± 37.80[a]
Goldrush	4.34 ± 0.52[b]	0.13 ± 0.00[a]	0.42 ± 0.01[b]	364.59 ± 22.34[a]
Russet Burbank	11.70 ± 1.10[a]	0.10 ± 0.03[ab]	0.95 ± 0.11[a]	332.17 ± 34.39[a]
Yukon Gold	5.83 ± 0.40[b]	0.03 ± 0.00[b]	0.53 ± 0.05[b]	413.13 ± 23.30[a]
Overall Mean	6.39 ± 1.82	0.09 ± 0.02	0.63 ± 0.11	378.23 ± 18.57

Cultivars	**Mg (mg)**	**Na (mg)**	**P (mg)**	**Se (µg)**	**Zn (mg)**
Chieftain	23.93 ± 1.72[a]	0.66 ± 0.07[a]	63.14 ± 3.60[a]	71 ± 11[a]	0.50 ± 0.03[a]
Goldrush	23.70 ± 0.68[a]	1.13 ± 0.18[a]	59.00 ± 1.82[a]	73 ± 15[a]	0.40 ± 0.01[a]
Russet Burbank	18.46 ± 1.56[a]	1.39 ± 0.15[a]	60.23 ± 0.91[a]	82 ± 16[a]	0.43 ± 0.09[a]
Yukon Gold	22.05 ± 0.67[a]	1.22 ± 0.23[a]	43.87 ± 0.72[a]	73 ± 9[a]	0.44 ± 0.04[a]
Overall Mean	22.04 ± 1.26	1.10 ± 0.16	56.56 ± 4.32	75 ± 5	0.44 ± 0.02

Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Results are expressed as mean ± SE. Means having the same letters in each column are not significantly different from each other.

Table 4.6: Percent contribution of nutrients (total soluble protein; TSP, ascorbic acid; AA, calcium; Ca, iron; Fe, zinc; Zn, magnesium; Mg, phosphorous; P, selenium; Se, potassium; K, and sodium; Na) in one serving to RDA/AI for adult males (age 19 – 50; Table A.1)

	TSP	AA	Ca	Cu	Fe	Zn
Chieftain	1.77 ± 0.05^{c}	29.28 ± 0.76^{b}	0.37 ± 0.11^{b}	10.00 ± 0.97^{ab}	7.50 ± 1.32^{ab}	4.55 ± 0.32^{a}
Goldrush	2.06 ± 0.04^{b}	52.82 ± 1.80^{a}	0.43 ± 0.05^{b}	14.44 ± 0.22^{a}	5.25 ± 0.12^{b}	3.64 ± 0.05^{a}
Russet Burbank	1.78 ± 0.06^{c}	32.99 ± 1.40^{b}	1.17 ± 0.11^{a}	11.11 ± 3.64^{ab}	11.88 ± 1.40^{a}	3.91 ± 0.84^{a}
Yukon Gold	2.34 ± 0.02^{a}	44.28 ± 3.36^{a}	0.58 ± 0.04^{b}	3.33 ± 0.24^{b}	6.63 ± 0.74^{b}	4.00 ± 0.32^{a}
Mean	1.99 ± 0.14	39.84 ± 5.37	0.64 ± 0.18	9.72 ± 2.33	7.82 ± 1.43	4.03 ± 0.19

	Mg	P	Se	K	Na
Chieftain	5.98 ± 0.43^{a}	9.02 ± 0.51^{a}	129 ± 11^{a}	8.57 ± 0.80^{a}	0.04 ± 0.00^{a}
Goldrush	5.93 ± 0.17^{a}	8.43 ± 0.26^{a}	133 ± 15^{a}	7.76 ± 0.48^{a}	0.08 ± 0.01^{a}
Russet Burbank	4.62 ± 0.39^{a}	8.60 ± 1.56^{a}	149 ± 17^{a}	7.07 ± 0.73^{a}	0.09 ± 0.01^{a}
Yukon Gold	5.51 ± 0.17^{a}	6.27 ± 0.10^{a}	132 ± 17^{a}	8.79 ± 0.50^{a}	0.08 ± 0.02^{a}
Mean	5.51 ± 0.31	8.08 ± 0.62	136 ± 9	8.05 ± 0.39	0.07 ± 0.01

Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Results are expressed as mean ± SE. Means having the same letters in each column are not significantly different from each other.

Table 4.7: Percent contribution of nutrients (total soluble protein; TSP, ascorbic acid; AA, calcium; Ca, iron; Fe, zinc; Zn, magnesium; Mg, phosphorous; P, selenium; Se, potassium; K, and sodium; Na) in one serving to daily value (DV)

	TSP	AA	Ca	Cu	Fe	K
Chieftain	2.05 ± 0.04^{c}	43.92 ± 0.93^{c}	0.37 ± 0.11^{b}	4.50 ± 0.63^{ab}	3.33 ± 1.11^{ab}	11.51 ± 0.98^{a}
Goldrush	2.39 ± 0.05^{b}	79.23 ± 1.93^{a}	0.43 ± 0.05^{b}	6.50 ± 0.29^{a}	2.33 ± 1.87^{b}	10.42 ± 1.64^{a}
Russet Burbank	2.07 ± 0.03^{c}	49.48 ± 2.48^{c}	1.17 ± 0.11^{a}	5.00 ± 0.55^{ab}	5.28 ± 2.00^{a}	9.49 ± 2.01^{a}
Yukon Gold	2.72 ± 0.04^{a}	66.42 ± 2.11^{b}	0.58 ± 0.04^{b}	1.50 ± 0.28^{b}	2.94 ± 0.09^{b}	11.80 ± 1.69^{a}
Mean	23.07 ± 1.58	59.76 ± 8.06	0.64 ± 0.18	4.38 ± 1.05	3.47 ± 0.64	10.81 ± 0.53

	Mg	Na	P	Se	Zn
Chieftain	5.98 ± 0.43^{a}	0.03 ± 0.00^{a}	6.31 ± 0.38^{a}	101.43 ± 14.22^{a}	3.33 ± 0.27^{a}
Goldrush	5.93 ± 0.17^{a}	0.05 ± 0.00^{a}	5.90 ± 0.55^{a}	104.29 ± 13.61^{a}	2.67 ± 0.05^{a}
Russet Burbank	4.62 ± 0.39^{a}	0.06 ± 0.01^{a}	6.02 ± 1.45^{a}	117.14 ± 10.02^{a}	2.87 ± 0.74^{a}
Yukon Gold	5.51 ± 0.17^{a}	0.05 ± 0.01^{a}	4.39 ± 0.08^{a}	104.29 ± 11.18^{a}	2.93 ± 0.29^{a}
Mean	5.51 ± 0.32	0.05 ± 0.01	5.66 ± 0.43	106.79 ± 3.52	2.95 ± 0.14

Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Results are expressed as mean ± SE. Means having the same letters in each column are not significantly different from each other.

Table 4.8: Percent contribution of skin to total serving (virtual tuber of 150 g FW) content of antioxidants (total phenolic compounds; TP, chlorogenic acid; CGA, caffeic acid; CA, ferulic acid; FA, rutin; RU, ascorbic acid; AA, total carotenoids; TC, and total antioxidant capacity, TAOC) and phytonutrients (total soluble protein; TSP, calcium; Ca, iron; Fe, zinc; Zn, magnesium; Mg, phosphorous; P, selenium; Se, potassium; K, and sodium; Na).

Cvs	TP	CGA	CA	FA	RU	AA	TC*
Chieftain	11.68 ± 0.19^{b}	25.11 ± 1.72^{b}	87.46 ± 1.34^{a}	92.37 ± 1.01^{a}	7.76 ± 2.04^{d}	6.12 ± 0.23^{a}	5.30 ± 0.36^{b}
Goldrush	11.61 ± 0.41^{b}	31.87 ± 2.14^{ab}	84.66 ± 0.57^{a}	79.93 ± 2.48^{b}	73.81 ± 2.22^{a}	4.15 ± 0.41^{b}	5.16 ± 0.23^{b}
Russet Burbank	13.62 ± 0.17^{a}	34.27 ± 2.05^{a}	90.43 ± 0.66^{a}	94.06 ± 0.54^{a}	37.17 ± 4.06^{b}	6.39 ± 0.44^{a}	8.43 ± 1.05^{a}
Yukon Gold	2.61 ± 0.21^{c}	7.23 ± 0.66^{c}	48.31 ± 3.01^{b}	48.43 ± 4.50^{c}	23.00 ± 1.41^{c}	1.79 ± 0.17^{c}	0.76 ± 0.07^{c}
Mean	9.88 ± 2.47	24.62 ± 6.11	77.72 ± 9.87	78.70 ± 10.57	35.44 ± 14.13	4.61 ± 1.07	4.91 ± 1.58

Cvs	TSP	TOAC (DPPH)	TOAC (FRAP)	Ca	Cu	Fe
Chieftain	2.32 ± 0.07^{b}	2.29 ± 0.04^{c}	23.91 ± 0.60^{b}	5.44 ± 2.19^{ab}	3.07 ± 0.82^{a}	4.19 ± 1.80^{b}
Goldrush	1.96 ± 0.05^{b}	2.55 ± 0.02^{b}	20.97 ± 0.45^{c}	11.29 ± 1.30^{a}	4.79 ± 0.51^{a}	18.83 ± 3.76^{b}
Russet Burbank	2.78 ± 0.18^{a}	3.48 ± 0.04^{a}	26.39 ± 0.31^{a}	7.37 ± 1.18^{ab}	6.71 ± 1.97^{a}	41.47 ± 7.96^{a}
Yukon Gold	0.84 ± 0.02^{c}	0.85 ± 0.01^{d}	6.37 ± 0.81^{d}	3.45 ± 0.46^{b}	4.05 ± 0.66^{a}	5.00 ± 0.77^{b}
Mean	1.98 ± 0.41	2.29 ± 0.54	19.41 ± 4.49	6.89 ± 1.67	4.66 ± 0.77	17.37 ± 8.71

Table 4.8 continued.

Cvs	K	Mg	Na	P	Se	Zn
Chieftain	2.57 ± 0.44^{bc}	2.20 ± 0.27^{b}	2.83 ± 0.93^{b}	1.35 ± 0.55^{a}	1.55 ± 0.18^{a}	3.19 ± 0.87^{ab}
Goldrush	3.01 ± 0.16^{ab}	3.14 ± 0.15^{a}	16.11 ± 3.18^{a}	1.48 ± 0.04^{a}	1.51 ± 0.36^{a}	3.11 ± 0.23^{ab}
Russet Burbank	3.98 ± 0.10^{a}	3.32 ± 0.24^{a}	16.11 ± 1.20^{b}	1.60 ± 0.20^{a}	1.80 ± 0.77^{a}	4.58 ± 0.45^{a}
Yukon Gold	1.46 ± 0.06^{c}	1.48 ± 0.05^{b}	1.23 ± 0.41^{b}	0.83 ± 0.02^{a}	1.07 ± 0.16^{a}	0.97 ± 0.27^{b}
Mean	2.76 ± 0.52	2.54 ± 0.43	9.07 ± 4.08	1.32 ± 0.17	1.48 ± 0.15	2.96 ± 0.74

Differences were tested between cultivars for percentage contribution of antioxidant/phytonutrient towards their content in one serving. Tukey's post-hoc test was used ($p < 0.05$; $n = 5$; *$n = 3$). Results are expressed as mean ± SE. Means having the same letters in each column are not significantly different from each other.

Table 4.9 Correlation coefficients between selected antioxidant indices.

	Total antioxidant capacity		**Lipophilic antioxidant capacity**		**Hydrophilic antioxidant capacity**	
	DPPH	**FRAP**	**DPPH**	**FRAP**	**DPPH**	**FRAP**
Total Phenolics	0.67 Significant	0.82 Significant				0.83 Significant
Total Carotenoids			- 0.155 non significant	0.1572 non significant		
Chlorogenic Acid	0.43 P > 0.05	0.66 Significant			0.37 non significant	0.68 Significant
Ascorbic Acid	0.75 Significant	0.68 Significant			0.74 Significant	0.57 significant

Pearson's correlation was tested between selected antioxidants and antioxidant capacities quantified using DPPH and FRAP. Significance level is set at $P < 0.05$. Results are expressed as correlation coefficients followed by whether the association was significant or not.

Table 4.10 Comparing the results of the present study to the available literature. See note below table*

Component Quantified	Present study		Reported literature		
	Amount Reported	**Tuber part**	**Amount reported**	**Tuber Part**	**Reference and study group**
Total Phenolic Compounds (CGAE)	93.85 ± 1.47 – 122.46 ± 1.07 mg/150 g FW	Virtual tuber	61.5 – 505.5 mg/150 g FW	Cross section	Campos *et al.* (2006); 15 andean cvs.
		Virtual tuber	33.15 – 187.5 mg/150 g FW	Whole tuber	Reddivari *et al*. (2007a); 320 cvs. from Texas Potato Variety Development Program
Chlorogenic acid	51 ± 5 – 262 ± 32 µg/g DW	Virtual tuber	174 ± 63 – 12746 ± 5898 µg/g DW	Whole tuber	Andre *et al.* (2007b); 23 native Andean cvs.
	5.1 – 26.2 mg/100 g	Virtual tuber	47 ± 5 – 92 ± 5 mg/100 g DW	Whole tuber	Leo *et al.* (2008); 4 European cvs.
	0.53 – 5.01 mg/g DW	Skin	0.78 ± 0.01 – 2.79 ± 0.12 mg/g DW	Skin	Al-Weshahy and Rao (2009); 6 Canadian cvs.
Caffeic Acid	16 ± 2 – 54 ± 5 µg/g DW	Virtual tuber	9 ± 3 – 143 ± 46 µg/g DW	Whole tuber	Andre *et al.* (2007b); 23 native Andean cvs.

Table 4.10 continued.

Component Quantified	Present study		Reported literature		
	Amount Reported	**Tuber part**	**Amount Reported**	**Tuber part**	**Reference and study group**
Caffeic Acid	1116 – 3323 µg/g DW	Skin	0.26 ± 0.01 – 0.72 ± 0.29 mg/g DW	Skin	Al-Weshahy and Rao (2009); 6 Canadian cvs.
	1.6 ± 0.2 – 5.4 ± 0.5 mg/100 g DW	Virtual tuber	5 ± 0.3 – 12 ± 1 mg/100 g DW	Whole tuber	Leo *et al.* (2008); 4 European cvs.
Ferulic Acid	0.49 ± 0.14 – 1.25 ± 0.25 mg/100 g DW	Virtual tuber	0.6 ± 0.1 – 3.9 ± 0.4 mg/100 g DW	Whole tuber	Leo *et al.* (2008); 4 European cvs.
Rutin	5 ± 1 – 19 ± 3 µg/g DW	Virtual tuber	7 ± 2 – 191 ± 34 µg/g DW	Whole tuber	Andre *et al.* (2007b); 23 native Andean cvs.
Ascorbic Acid	26.35 ± 0.68 – 47.54 ± 1.62 mg/150 g FW	Virtual tuber	16.5 – 45 mg/150 g FW	Whole tuber	Love *et al.* (2003); North American cvs. and breeding lines
			27 – 54 mg/150 g FW	Whole tuber	Finlay *et al.* (2003); Six European cvs. and breeding lines
			Up to 22.8 mg/150 g FW	Whole tuber	Andre *et al.* (2007b); 23 native Andean cvs.

Table 4.10 continued

Component Quantified	Present study		Reported literature		
	Amount Reported	**Tuber part**	**Amount reported**	**Tuber Part**	**Reference and study group**
Ascorbic Acid	26.35 ± 0.68 – 47.54 ± 1.62 mg/150 g FW	Virtual tuber	16.5 mg/150 g FW	Whole tuber	Chu *et al.* (2002); 1 unspecified cvs.
	77.29 ± 10.20 – 127.07 ± 9.34 mg/100 g DW	Virtual tuber	48 – 101 mg/100 g DW	Whole tuber	Leo *et al.* (2008); 4 European cvs.
Total carotenoids	42 ± 5 – 236 ± 23 µg/150 g FW	Virtual tuber	123 – 4029 µg/150 g FW	Whole tuber	Brown *et al.* (2008); 13 crosses made at USDA
		Virtual tuber	675 µg/150 g FW	Flesh	Muller *et al*. (1997); 1 unspecified cv
	1.23 ± 0.08 – 6.61 ± 0.26 µg/g DW	Virtual tuber	2.83 ± 0.63 – 36.21 ± 1.47 µg/g DW	Whole tuber	Andre *et al.* (2007a); 74 Andean cvs.
			1.78 – 54.78 µg/g DW	Whole tuber	Andre *et al.* (2007b); 23 native Andean cvs.
	0.95 ± 0.01 to 7.09 ± 0.35 µg/g DW	Flesh	13.5 – 18.3 µg/g DW	Flesh	Delaplace *et al.* (2008); 2 unspecified Belgian cvs.

Table 4.10 continued

Component Quantified	Present study		Reported literature		
	Amount Reported	**Tuber part**	**Amount reported**	**Tuber Part**	**Reference and study group**
Total soluble protein	21.94 ± 0.82 to 37.91 ± 0.52 mg/g DW	Flesh	92.1 – 115.1 mg/g DW	Flesh	Delaplace *et al.* (2008); 2 unspecified Belgian cvs.
	36.11 ± 2.08 – 48.66 ± 0.64 mg/g DW	Skin	107.03 – 123.6 mg/g DW	Skin	Ortiz-Medina *et al.* (2009); 3 cvs. grown in New Brunswick
	32.84 ± 1.02 – 37.91 ± 0.52 mg/g DW	Cortex	47.14 – 61.57 mg/g DW	Cortex	
	21.94 ± 0.82 – 29.86 ± 0.49 mg/g DW	Pith	48.47 – 66.04 mg/g DW	Pith	
Total antioxidant capacity (DPPH)	5706.65 ± 32.94 – 7575.49 ± 65.45 µmol TE/150 g FW	Virtual tuber	6300 – 133800 µmol TE/150 g FW	Whole tuber	Hale, (2003); 100 U.S grown cvs.
	167.38 ± 32.16 – 202.69 ± 20.43 µmol TE/g DW	Virtual tuber	88 – 95 µmol TE/g DW	Flesh	Delaplace *et al.* (2008); 2 unspecified Belgian cvs.

Table 4.10 continued

Component Quantified	Present study		Reported literature		
	Amount Reported	**Tuber part**	**Amount reported**	**Tuber Part**	**Reference and study group**
TOAC (DPPH)	253.77 ± 3.82 – 310.79 ± 4.23 µmol TE/g DW	Skin	20.72 µmol TE/g DW	Skin	Nara *et al.* (2006): Japanese cv.Toyoshiro
	153.08 ± 1.50 – 183.22 ± 1.74 µmol TE/g DW	Flesh	7.03 µmol TE/g DW	Flesh	
HAOC (DPPH)	66.41 ± 17.38 – 129.82 ± 10.32 mg AAE/100 g DW	Virtual Tuber	14.35 – 19.47 mg AAE/100 g DW	Whole tuber	Lachman *et al.* (2008): 4 cvs. grown in Czech republic
TOAC (FRAP)	13.94 ± 0.89 – 18.96 ± 0.76 mmol $FeSO_4$/100 g FW	Virtual tuber	0.062 – 0.966 mmol $FeSO_4$/100 g FW	Flesh	Halvorsen *et al.* (2006): TOAC of commonly consumed foods in U.S
Calcium	0.11 ± 0.03 – 0.31 ± 0.04 mg/g DW	Virtual tuber	0.27 – 1.09 mg/g DW	Whole tuber	Andre *et al.* (2007a); 74 Andean cvs.
	0.11 ± 0.03 – 0.31 ± 0.04 mg/g DW	Virtual tuber	0.36 – 0.53 mg/g DW	Cross Section	Anderson *et al.* (1999); American cvs. (unspecified)
	3.70 ± 1.13 – 11.7 ± 1.10 mg/150 g FW	Virtual tuber	9.8 ± 6.06 mg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish cvs.

Table 4.10 continued

Component Quantified	Present study		Reported literature		
	Amount Reported	**Tuber part**	**Amount reported**	**Tuber Part**	**Reference and study group**
Copper	0.84 ± 0.14 – 3.53 ± 0.21 mg/kg DW	Virtual tuber	4.26 – 5.6 mg/kg DW	Cross section	Anderson *et al.* (1999); American cvs. (unspecified)
	0.03 ± 0.00 – 0.13 ± 0.00 mg/150 g FW	Virtual tuber	0.29 ± 0.11 mg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish cvs.
Iron	0.01 ± 0.00 - 0.03 ± 0.00 mg/g DW	Virtual tuber	29.87 – 157.96 µg/g DW	Whole tuber	Andre *et al.* (2007a); 74 Andean cvs.
	7.18 ± 0.46 to 20.07 ± 9.05 mg/kg DW	Flesh	37 mg/kg DW	Flesh	Burgos *et al.* (2007); 49 native Andean cvs.
			34.95 – 40.58 mg/kg DW	Cross section	Anderson *et al.* (1999); American cvs. (unspecified)
	0.42 ± 0.01 – 0.95 ± 0.11 mg/ 150 g FW	Virtual tuber	1.11 ± 0.74 mg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish cvs.

Table 4.10 continued

Component Quantified	Present study		Reported literature		
	Amount Reported	**Tuber part**	**Amount reported**	**Tuber Part**	**Reference and study group**
Potassium	8.88 ± 2.01 – 11.82 ± 2.45 mg/g DW	Virtual tuber	20.90 – 21.26 mg/g DW	Cross Section	Anderson *et al.* (1999); American cvs. (unspecified)
	332.17 ± 34.39 – 413.13 ± 23.30 mg/150 g FW	Virtual tuber	846 ± 0.392 mg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish cvs.
Magnesium	0.49 ± 0.04 – 0.70 ± 0.07 mg/kg DW	Virtual tuber	1.17 – 1.20 mg/g DW	Cross Section	Anderson *et al.* (1999); American cvs. (unspecified)
	18.46 ± 1.56 – 23.93 ± 1.72 mg/150 g FW	Virtual tuber	31.29 ± 4.66 mg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish potato cvs.
Sodium	0.66 ± 0.07 – 1.39 ± 0.15 mg/150 g FW	Virtual tuber	11.56 ± 6.93 mg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish potato cvs.
Phosphorous	43.87 ± 0.72 – 63.14 ± 3.60 mg/150 g FW	Virtual tuber	71.84 ± 16.65 mg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish potato cvs.
	1.23 ± 0.17 – 1.85 ± 0.12 mg/g DW	Virtual tuber	2.51 – 2.59 mg/g DW	Whole tuber	Anderson *et al.* (1999); American cvs. (unspecified)

Table 4.10 continued

Component Quantified	Present study		Reported literature		
	Amount Reported	**Tuber part**	**Amount reported**	**Tuber Part**	**Reference and study group**
Selenium	71 ± 11 – 82 ± 16 µg/150 g FW	Virtual tuber	9 ± 10 µg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish cvs.
	1.9 ± 0.1 – 2.1 ± 0.1 µg/g DW	Virtual tuber	0.181 µg/g DW	Whole tuber	Spallhoz *et al.* (2008); Unspecified cvs. from Bangladesh
Zinc	0.01 ± 0.00 – 0.02 ± 0.00 mg/g DW	Virtual tuber	12.6 – 28.83 µg/g DW	Whole tuber	Andre *et al.* (2007a); 74 Andean cvs.
	7.31 ± 0.38 to 15.84 ± 2.49 mg/kg DW	Flesh	8 – 20 mg/kg DW	Flesh	Burgos *et al.* (2007); 49 native Andean cvs.
	0.40 ± 0.01 – 0.50 ± 0.03 mg/150 g FW	Virtual tuber	0.61 ± 0.12 mg/150 g FW	Whole tuber	True *et al.* (1978); 9 Irish cvs.

*Note: All values in literature reported in fresh weight have been modified to 150 g FW (one serving of potato) for the purpose of comparision with the present study.

V. SUMMARY AND CONCLUDING REMARKS

There were significant differences found in content of certain phytonutrients and antioxidants in the four Quebéc-grown potato cultivars on a per serving basis. Significant differences also occurred between cultivars with respect to contribution of skin to total serving content of certain antioxidants and phytonutrients. Cultivars also differed in their percentage contribution of certain nutrients in one serving to the RDA/AI. Therefore, all three of the original hypotheses are accepted.

Findings of this thesis indicate that cultivar is a significant determinant of nutrient content in potatoes, which supports the contention that intake of one potato cultivar versus another could potentially make the difference between nutrient adequacy and deficiency in potato-rich diets (Burlingame *et al.,* 2009). These results support the concept of selling potatoes under cultivar names to enable better informed consumers to chose nutritionally appropriate cultivars for dietary consumption. Although cultivars did not vary with regard to their Se content per serving, it is important to note that all cultivars met the RDA of Se by more than 100 %. Selenium-deficient populations have been found in many parts of the world (Hincal, 2007; Spadoni *et al.,* 2007; Iqbal *et al.,* 2008). Many efforts have been undertaken previously to enhance Se status of populations such as improving the Se content of soil and cultivated foods (Varo and Koivistoinen, 1988). In this study, the four cultivars examined could be used as an excellent dietary source of Se in order to alleviate Se deficiency in populations. There may be other potato cultivars that show greater Se concentrations than the four cultivars identified in this study. Future studies could be undertaken to identify cultivars that could be used for Se supplementation in deficient populations.

Results also indicate that cultivar affects the contribution of certain antioxidants/phytonutrients in skin to one serving of potato. Since potato skin could be an important contributor of certain antioxidants/phytonutrients in diet, the results support the practice of eating of potato skin.

Parameters like polyphenolic compounds, carotenoids, and antioxidant capacity of cultivars have mostly been reported in units that do

not give information regarding the potential dietary contribution of these components, e.g., reporting antioxidant content on a dry weight (DW) basis. Previous investigations that examined cultivars for their phytonutrient and/or antioxidant content used parts of potato tubers for quantification, e.g., cross section, peel only, or flesh. This is the first study that uses the concept of virtual tuber (Ortiz-medina *et al.,* 2009) to precisely quantify antioxidants and phytonutrients in tissues, and then uses these summatively to calculate their amounts in one serving of potato, and further tissue contributions to the quantity of phytonutrients/antioxidants in one serving. The results of this study, reported on a per serving basis, are likely to be more precise and nutritionally applicable than previous studies. The present study shows how cultivar content of key phytonutrients in a typical serving of 150 g FW can contribute towards meeting the RDA/AI for various nutrients.

To the best of our knowledge, despite the small number of cultivars examined, the present study is the most comprehensive in terms of examining the range of antioxidants and phytonutrients among cultivars and tissues. Such comprehensive information can be useful towards identifying potentially major differences in antioxidant and nutrient content in different cultivars. This information on cultivar differences could be considered for inclusion in food composition tables, which otherwise lack cultivar variations while reporting nutritional information (Burlingame *et al.,* 2009). This information could also be used in community nutritional education that focuses on appropriate dietary choices of cultivars in populations consuming these potato cultivars. The cultivar differences in content of antioxidants and phytonutrients exhibited in this study also provide a rationale for taking into account the antioxidant and phytonutrient content of cultivars when potatoes are promoted for consumption (FAO, 2005). These differences could translate to difference between sufficiency and deficiency of a nutrient resulting from the consumption of one cultivar verses another (Burlingame *et al.,* 2009). Therefore, dissemination of information on phytonutrients in specific cultivars should be meticulously and systematically carried out.

Cultivars also vary in their tissue contributions of nutrients towards the total tuber content. This important finding helped to validate the concept

of virtual tuber (Ortiz-Medina *et al.,* 2009). A few studies that have examined tuber tissue differences in antioxidant capacity did so with the objective of screening potato varieties suitable for breeding (Li *et al.,* 2006). Dietary supplements prepared from isolated antioxidants show reduced health benefits compared with a diet rich in fruit and vegetables because, when taken alone, the isolated antioxidants do not seem to show consistency in preventive effects (Liu, 2003). Considering the many antioxidants found in potato cultivars, combinations of appropriate cultivars to be eaten with other foods could increase the diversity of phytochemicals in the diet thereby improving chronic disease prevention. The TAOC takes into account the antioxidant capacity of different individual compounds present in foods along with the result of their potential synergistic interactions in a food system, which has been related to the efficacy of dietary benefits against cancer (Serafini *et al.,* 2002) or inflammation (Szeto *et al.,* 2004; Brighenti *et al.,* 2005). However, since these values are obtained via in vitro tests they must be considered only as potential values, since the real physiological effect is modulated by the bioavailability and functioning of antioxidant compounds within the biological system (Pulido *et al.,* 2003). For this reason, it would be worthwhile in the future to confirm the in *vitro* values given by this study by testing the antioxidative effects of potato extracts using cell culture and in vivo studies.

The cultivars used in this study were harvested during the 2008 field season, and stored by using a conventional storage method for 8 months before they were tested for phytonutrients and antioxidant capacity. Antioxidant capacity has been found to change with time in storage (Delaplace *et al.,* 2008). It would therefore be worthwhile to examine fresh material and changes in content of phytonutrients and antioxidants with storage. Considerable losses in AA (up to 45%) have been observed over 4 months storage (Finlay *et al.,* 2003). Davidek *et al.* (1974) reported a 32 – 70% decrease in AA after only 2 months storage at 8 – 10 °C. Since AA content post-storage would be an important factor determining the dietary intake of AA in populations consuming potatoes (Finlay *et al.,* 2003), it would be worthwhile in the future to examine fresh tubers since AA content changes with storage. The present study reported AA content of raw,

uncooked potato tubers. There is evidence of loss in AA with heat treatment (Love and Pavek, 2003). Although the present study estimated for losses in ascorbic acid using retention factors for different cooking methods established by Pennington and Wilkeling (1997), it is likely that this change may be cultivar dependent (Xu *et al.,* 2009). Future studies should be directed towards investigating cultivar-dependent changes in AA and TAOC with different cooking methods.

Potatoes are cooked in many different forms for consumption. While there is evidence of loss in AA with heat treatment (Love and Pavek, 2003), TOAC has been shown to increase with certain cooking methods (Halvorsen *et al.,* 2006). However, the effects of different methods of cooking on antioxidant capacity and polyphenol bioavailability or antioxidant quantity are not yet clear. Considering this, there are many reasons to study the effects of different cooking methods on changes in phytonutrients present in potato cultivars.

Potatoes are eaten in many different ways, most commonly with skin removed. However, it is not known how much the quantity of antioxidants and phytonutrients are lost when skin is removed from tubers before consumption. The novel suggestion this study makes, is that cultivar could determine the potential loss of health beneficial components when partitioned potato products are used. Potato peels, which are a major portion of processing waste, pose a disposal problem to the processing industry especially because they are prone to rapid microbial spoilage owing to their high moisture content (Schieber and Saldana, 2008). However, their use has shown success in a number of applications. Potato peel extract (PPE) prevented peroxidation of soybean oil through its antioxidation properties, and has been suggested for use as a natural antioxidant in oils, fats and other food products (Zia Ur *et al.,* 2003). It has also been shown to effectively reduce lipid peroxidation in radiation-processed meat (Kanatt *et al.,* 2005). Potato peel supplementation effectively reduced plasma glucose levels and oxidative stress in streptozotocin induced diabetic rats (Singh *et al.,* 2005). The present study showed that potato peels varied widely in their phytochemical content of the four cultivars examined (Table A.4). This suggests that there may be value in selecting peels of one cultivar over

another to prepare antioxidant extracts for the food additives and health applications mentioned above. Since potato peels differ immensely from other agricultural by-products on account of the nutritionally and pharmacologically useful components found in them, a potential pharmaceutical market could be identified for appropriate use of potato peels (Schieber and Saldana, 2008).

The most unique suggestion made by the results of this study is that skin could contribute substantially to dietary intake of certain antioxidants and phytonutrients in certain cultivars. Consumers should therefore be encouraged to eat potatoes with skin. This information when properly disseminated to consumers could encourage the consumption of potato skin, such as in case of cv. Russet Burbank, to maximise the Fe intake. Certain cultivars stand out for their content of polyphenolic compounds (Goldrush and Chieftain), TC (Yukon Gold) and, AA (Goldrush). Potato cultivars rich in lipophilic carotenoids are seen to be poor in hydrophilic antioxidants and vice versa, e.g., cvs. Yukon Gold and Goldrush. Therefore, there may be increased nutritional value in eating two or more cultivars in the same meal, and/or implementing a dietary rotation in the use of cultivars at the household level. Consumers could be educated on the appropriate dietary combinations of cultivars for maximized nutritional benefit, e.g., eating cvs. Goldrush and Yukon Gold together to maximise the dietary intake of CGA and TC. Cultivar combinations could also increase the bioavailability of nutrients from one cultivar on account of the presence of another component in a different cultivar, e.g., eating cvs. Russet Burbank and Goldrush in the same meal may make Fe from the skin of the former more bioavailable owing to the presence of AA in the flesh of the latter. This study primarily suggests consumption of potato skin, and dietary combinations of cultivars for improved nutritional benefits in populations consuming these cultivars.

VI. REFERENCES CITED

Adom, K. K. and Liu, R. H. (2002). Antioxidant activity of grains. Journal of Agricultural and Food Chemistry 50: 6182-6187.

Ahmed, S. S., Lott, M. N. and Marcus, D. M. (2005). The macular xanthophylls. Survey of Ophthalmology 50: 183-193.

Al-Saikhan, M. S., Howard, L. R. and Miller J.C, Jr. (1995). Antioxidant activity and total phenolics in different genotypes of potato (*Solanum tuberosum, L.*). Journal of Food Science 60: 341-343.

Aliyu, A. B., Ibrahim, M. A., Musa, A. M., Ibrahim, H., Abdulkadir, I. E. and Oyewale, A. O. (2009). Evaluation of antioxidant activity of leave extract of Bauhinia rufescens Lam. (*Caesalpiniaceae*). Journal of Medicinal Plant Research 3: 563-567.

Al-Weshahy A. and Rao V. (2009). Isolation and characterization of functional components from peel samples of six potatoes varieties growing in Ontario. Food Research International 42: 1062-1066.

Anderson, K. A., Magnuson, B. A., Tschirgi, M. L. and Smith, B. (1999). Determining the geographic origin of potatoes with trace metal analysis using statistical and neural network classifiers. Journal of Agricultural and Food Chemistry 47: 1568-1575.

Andre, C. M., Ghislain, M., Bertin, P., Oufir, M., Herrera, M. D. R., Hoffmann, L., Hausman, J. F., Larondelle, Y. and Evers, D. (2007a). Andean potato cultivars (*Solanum tuberosum L.)* as a source of antioxidant and mineral micronutrients. Journal of Agricultural and Food Chemistry 55: 366-378.

Andre, C. M., Oufir, M., Guignard, C., Hoffmann, L., Hausman, J. F., Evers, D. and Larondelle, Y. (2007b). Antioxidant profiling of native

Andean potato tubers (*Solanum tuberosum L.)* reveals cultivars with high levels of beta-carotene, alpha-tocopherol, chlorogenic acid, and petanin. Journal of Agricultural and Food Chemistry 55: 10839-10849.

Andre, C. M., Oufir, M., Hoffmann, L., Hausman, J. F., Rogez, H., Larondelle, Y. and Evers, D. (2009). Influence of environment and genotype on polyphenol compounds and in vitro antioxidant capacity of native Andean potatoes (*Solanum tuberosum L.*). Journal of Food Composition and Analysis 22: 517-524.

Anonymous (2007). World catalogue of potato varieties. Potato Library, Agrimedia, pp 253.

Arai, Y., Watanabe, S., Kimira, M., Shimoi, K., Mochizuki, R. and Kinae, N. (2000). Dietary intakes of flavonols, flavones and isoflavones by Japanese women and the inverse correlation between quercetin intake and plasma LDL cholesterol concentration. Journal of Nutrition 130: 2243-2250.

Aqil, F., Ahmad, I. and Mehmood, Z. (2006). Antioxidant and free radical scavenging properties of twelve traditionally used Indian medicinal plants. Turkish Journal of Biology 30: 177-183.

Arnao, M. B., Cano, A. and Acosta, M. (2001). The hydrophilic and lipophilic contribution to total antioxidant activity. Food Chemistry 73: 239-244.

Ascencio, C., Torres, N., Isoard-Acosta, F., Gomez-Perez, F. J., Hernandez-Pando, R. and Tovar, A. R. (2004). Soy protein affects serum insulin and hepatic SREBP-1 mRNA and reduces fatty liver in rats. Journal of Nutrition 134: 522-529.

Augustin, J. (1975). Variations in the nutritional composition of fresh potatoes. Journal of Food Science 40: 1295-1299.

Bamberg, JB and Del-Rio A. (2005). Conservation of Genetic Resources. In: Razdan, M. K., and Mattoo, A. K. (eds.), 2005. Genetic Improvement of Solanaceous Crops Vol.1: Potato. Science Publishers, Inc., Enfield, USA, pp 1-38.

Barretto, J.R., Silva, L.R., Leite, M.E., Boa-Sorte N., Pimentel H., Purificaçao A.C., Carvalho G., Fontes M.I., Amorim T. (2008). Poor zinc and selenium status in phenylketonuric children and adolescents in Brazil. Nutrition Research 28: 208-211.

Battin, E. E. and Brumaghim, J. L. (2009). Antioxidant activity of sulfur and selenium: A review of reactive oxygen species scavenging, glutathione peroxidase, and metal-binding antioxidant mechanisms. Cell Biochemistry and Biophysics 55: 1-23.

Benzie, I. F. F. and Strain, J. J. (1996). The ferric ion reducing ability of plasma (FRAP) as a measure of 'antioxidant power': The FRAP assay. Analytical Biochemistry 239: 70-76.

Bray, G. A. and Popkin, B. M. (1998). Dietary fat intake does affect obesity. American Journal of Clinical Nutrition 68: 1157-1173.

Breitbaupt, D. E. and Bamedi, A. (2002). Carotenoids and carotenoid esters in potatoes (*Solanum tuberosum L.*): New insights into an ancient vegetable. Journal of Agricultural and Food Chemistry 50: 7175-7181.

Brighenti, F., Valtuena, S., Pellegrini, N., Ardigo, D., Del Rio, D., Salvatore, S., Piatti, P., Serafini, M. and Zavaroni, I. (2005). Total antioxidant capacity of the diet is inversely and independently related to plasma concentration of high-sensitivity C-reactive protein in adult Italian subjects. British Journal of Nutrition 93: 619-625.

Britton, G. (1985). General carotenoid methods. Methods in Enzymology 111: 113-149.

Brown, C. R., Edwards, C. G., Yang, C. P. and Dean, B. B. (1993). Orange flesh trait in potato: Inheritance and carotenoid content. Journal of American Society of Horticulture Science 118: 145-150.

Brown, C. R. (2005). Antioxidants in potato. American Journal of Potato Research 82: 163-172.

Brown, C. R., Culley, D., Yang, C. P., Durst, R. and Wrolstad, R. (2005). Variation of anthocyanin and carotenoid contents and associated antioxidant values in potato breeding lines. Journal of the American Society for Horticultural Science 130: 174-180.

Brown, C. R., Culley, D., Bonierbale, M. and Amoros, W. (2007). Anthocyanin, carotenoid content, and antioxidant values in native South American potato cultivars. HortScience 42: 1733-1736.

Brown, C. R. (2008). Breeding for phytonutrient enhancement of potato. American Journal of Potato Research 85: 298-307.

Brown, C. R., Durst, R. W., Wrolstad, R. and De Jong, W. (2008). Variability of phytonutrient content of potato in relation to growing location and cooking method. Potato Research 51: 259-270.

Buckenhüskes, H. J. (2005). Nutritionally relevant aspects of potatoes and potato constituents. In: Haverkort, A.J. and Struik, P.C. (eds.). Potato in Progress: Science Meets Practice. Wageningen Academic Publishers, The Netherlands, pp 17-45.

Burlingame, B., Mouille, B. and Charrondiere, R. (2009a). Nutrients, bioactive non-nutrients and anti-nutrients in potatoes. Journal of Food Composition and Analysis 22: 494-502.

Burlingame, B., Charrondiere, R. and Mouille, B. (2009b). Food composition is fundamental to the cross-cutting initiative on biodiversity for food and nutrition. Journal of Food Composition and Analysis 22: 361-365.

Burton, W. G. (1989). The Potato: 3rd Ed. Longman Scientific and Technical. Harlow, UK, pp 742.

Burgos, G., Amoros, W., Morote, M., Stangoulis, J. and Bonierbale, M. (2007). Iron and zinc concentration of native Andean potato cultivars from a human nutrition perspective. Journal of the Science of Food and Agriculture 87: 668-675.

Camire, M. E., Kubow, S. and Donnelly, D. J. (2009). Potatoes and human health. Critical Reviews in Food Science and Nutrition 49: 823-840.

Campos, D., Noratto, G., Chirinos, R., Arbizu, C., Roca, W. and Cisneros-Zevallos, L. (2006). Antioxidant capacity and secondary metabolites in four species of Andean tuber crops: Native potato (*Solanum* sp.), mashua (*Tropaeolum tuberosum Ruiz & Pavon*), Oca (*Oxalis tuberosa* Molina) and ulluco (*Ullucus tuberosus* Caldas). Journal of the Science of Food and Agriculture 86: 1481-1488.

Canadian Food Inspection Agency (2010). Canadian potato varieties [internet]. Available from: <http://www.inspection.gc.ca/english/plaveg/potpom/var/indexe.shtml> [Accessed February 17, 2011].

Carlsen, M. H., Halvorsen, B. L., Holte, K., Bohn, S. K., Dragland, S., Sampson, L., Willey, C., Senoo, H., Umezono, Y., Sanada, C., Barikmo, I., Berhe, N., Willett, W. C., Phillips, K. M., Jacobs, D. R. and Blomhoff, R. (2010). The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. Nutrition Journal 9: 1-11.

Chen, C. Y. O. and Blumberg, J. B. (2008). In vitro activity of almond skin polyphenols for scavenging free radicals and inducing quinone reductase. Journal of Agricultural and Food Chemistry 56: 4427-4434.

Chirinos, R., Rogez, H., Campos, D., Pedreschi, R. and Larondelle, Y. (2007). Optimization of extraction conditions of antioxidant phenolic compounds from mashua (*Tropaeolum tuberosum Ruiz & Pavon*) tubers. Separation and Purification Technology 55: 217-225.

Chu, Y. F., Sun, J., Wu, X. and Liu, R. H. (2002). Antioxidant and antiproliferative activities of common vegetables. Journal of Agricultural and Food Chemistry 50: 6910-6916.

Chun, O. K., Kim, D. O., Smith, N., Schroeder, D., Han, J. T. and Chang, Y. L. (2005). Daily consumption of phenolics and total antioxidant capacity from fruit and vegetables in the American diet. Journal of the Science of Food and Agriculture 85: 1715-1724.

Clifford, M. N. and Wight, J. (1976). The measurement of feruloylquinic acids and caffeoylquinic acids in coffee beans. Development of the technique and its preliminary application to green coffee beans. Journal of the Science of Food and Agriculture 27: 73-84.

Codex Alimentarius (2007). Food Labeling, 5th ed. WHO and FAO, Rome, pp 38.

Cuderman, P., Kreft, I., Germ, M., Kovacevic, M. and Sibilj, V. (2008). Selenium species in selenium-enriched and drought-exposed potatoes. Journal of Agricultural and Food Chemistry 56: 9114-9120.

Dao, L. and Friedman, M. (1992). Chlorogenic acid content of fresh and processed potatoes determined by ultraviolet spectrophotometry. Journal of Agriculture and Food Chemistry 40: 2152-2156.

Davey, M. W., Van Montagu, M., Inze, D., Sanmartin, M., Kanellis, A., Smirnoff, N., Benzie, I. J. J., Strain, J. J., Favell, D. and Fletcher, J. (2000). Plant L-ascorbic acid: Chemistry, function, metabolism, bioavailability and effects of processing. Journal of the Science of Food and Agriculture 80: 825-860.

Davidek, J., Velisek, J., and Domah A.M.B. (1974). Determination of L-ascorbic and L-dehydroascorbic acids in potatoes. Zeitschrift für Lebensmittel-Untersuchung und-Forschung 154: 18-22.

Davis-Searles, P. R., Nakanishi, Y., Kim, N. C., Graf, T. N., Oberlies, N. H., Wani, M. C., Wall, M. E., Agarwal, R. and Kroll, D. J. (2005). Milk thistle and prostate cancer: Differential effects of pure flavonolignans from Silybum marianum on antiproliferative end points in human prostate carcinoma cells. Cancer Research 65: 4448-4457.

DeGraft-Johnson, J., Kolodziejczyk, K., Krol, M., Nowak, P., Krol, B. and Nowak, D. (2007). Ferric-reducing ability power of selected plant polyphenols and their metabolites: Implications for clinical studies on the antioxidant effects of fruits and vegetable consumption. Basic and Clinical Pharmacology and Toxicology 100: 345-352.

Dekok, H.J. (2005). Case Report: the medical treatment of obstructive sleep apnoea syndrome (OSAS) with selenium. Medical Hypotheses 65: 817-818.

Delanty, N. and Dichter, M. A. (2000). Antioxidant therapy in neurologic disease. Archives of Neurology 57: 1265-1270.

Delaplace, P., Rojas-Beltran, J., Frettinger, P., du Jardin, P. and Fauconnier, M. L. (2008). Oxylipin profile and antioxidant status of potato tubers during extended storage at room temperature. Plant Physiology and Biochemistry 46: 1077-1084.

De Schrijver, R. (1990). Cholesterol metabolism in mature and immature rats fed animal and plant protein. Journal of Nutrition 120: 1624-1632.

Dietary Reference Intakes (2011). Recommended intakes for individuals [internet]. National Academy of Sciences, Institute of Medicine, Food and Nutrition Board. Available from: <http://search.nap.edu/nap-cgi/de.cgi?term=DRI+reports&x=0&y=0> [Accessed February 17, 2011].

Dragsted, L. O., Krath, B., Ravn-Haren, G., Vogel, U. B., Vinggaard, A. M., Jensen, P. B., Loft, S., Rasmussen, S. E., Sandstrom, B. and Pedersen, A. (2006). Biological effects of fruit and vegetables. Proceedings of the Nutrition Society 65: 61-67.

Duthie, G. G., Duthie, S. J. and Kyle, J. A. M. (2000). Plant polyphenols in cancer and heart disease: Implications as nutritional antioxidants. Nutrition Research Reviews 13: 79-106.

Eichhorn, S. and Winterhalter, P. (2005). Anthocyanins from pigmented potato (*Solanum tuberosum L.*) varieties. Food Research International 38: 943-948.

FAO (2005). FAOSTAT, FAO Statistical Databases, IYP 2008 [internet]. Available from: <http://www.potato2008.org/> [Accessed February 17, 2011].

FAO (2009). Press release, 19 June 2009 [internet]. Available from: <http://www.fao.org/news/story/en/item/20568/icode/> [Accessed February 17, 2011].

FDA (2011). Food labelling guide [internet]. Available from: <http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/ucm064928.htm> [Accessed May 8, 2011].

Finlay, M., Dale, B., Griffiths, D. W. and Todd, D. T. (2003). Effects of genotype, environment, and postharvest storage on the total ascorbate content of potato (*Solanum tuberosum L.*) tubers. Journal of Agricultural and Food Chemistry 51: 244-248.

Fraga, C. G. (2005). Relevance, essentiality and toxicity of trace elements in human health. Molecular Aspects of Medicine 26: 235-244.

Frankel, E. N. and Meyer, A. S. (2000). The problems of using one-dimensional methods to evaluate multifunctional food and biological antioxidants. Journal of the Science of Food and Agriculture 80: 1925-1941.

Friedman, M. (1996). Food browning and its prevention: An overview. Journal of Agricultural and Food Chemistry 44: 631–653.

Friedman, M. (1997). Chemistry, biochemistry, and dietary role of potato polyphenols: A review. Journal of Agricultural and Food Chemistry 45: 1523-1540.

Garcia-Closas, R., Berenguer, A., Tormo, M. J., Sanchez, M. J., Quiros, J. R., Navarro, C., Arnaud, R., Dorronsoro, M., Chirlaque, M. D., Barricarte, A., Ardanaz, E., Amiano, P., Martinez, C., Agudo, A. and Gonzalez, C. A. (2004). Dietary sources of vitamin C, vitamin E and specific carotenoids in Spain. British Journal of Nutrition 91: 1005-1011.

Gartner, R., Albrich, W. and Angstwurm, M.W. (2001). The effect of a selenium supplementation on the outcome of patients with severe systemic inflammation, burn and trauma. Biofactors 14: 199-204.

Gaziano, T. A. (2005). Cardiovascular disease in the developing world and its cost-effective management. Circulation 112: 3547-3553.

Ghiselli, A., Serafini, M., Natella, F. and Scaccini, C. (2000). Total antioxidant capacity as a tool to assess redox status: Critical view and experimental data. Free Radical Biology and Medicine 29: 1106-1114.

Graf, E. (1992). Antioxidant potential of ferulic acid. Free Radical Biology and Medicine 13: 435-448.

Gregory, J. F. (1996). Vitamins. Food Chemistry 60: 531-616.

Gross, J. (1991). Pigments in Vegetables: Chlorophylls and Carotenoids. Van Nostrand Reinhold, New York, USA, pp 148-278.

Hale, A. L. (2003). Screening potato genotypes for antioxidant activity, identification of the responsible compounds, and differentiating russet norkotah strains using aflp and microsatellite marker analysis. Ph.D. Thesis, Dissertation Texas A & M University, USA, pp 74-169.

Halliwell, B. and Gutteridge, J. M. C. (1990). Role of free radicals and catalytic metal ions in human disease: An overview. Methods in Enzymology 186: 1-85.

Halvorsen B.L., Carlsen M.H., Phillips K. M, Bohn S.K, Holte K., Jacobs D.R., and Blomhoff (2006). Content of redox-active compounds (i.e. antioxidants) in foods consumed in the United States. American Journal of Clinical Nutrition 84: 95-135.

Han, J. S., Kozukue, N., Young, K. S., Lee, K. R. and Friedman, M. (2004). Distribution of ascorbic acid in potato tubers and in home-processed and commercial potato foods. Journal of Agricultural and Food Chemistry 52: 6516-6521.

Han, K. H., Hashimoto, N., Shimada, K. I., Sekikawa, M., Noda, T., Yamauchi, H., Hashimoto, M., Chiji, H., Topping, D. L. and Fukushima, M. (2006). Hepatoprotective effects of purple potato extract against D-

galactosamine-induced liver injury in rats. Bioscience, Biotechnology and Biochemistry 70: 1432-1437.

Hasegawa, S., Johnson, R. M. and Gould, W. A. (1966). Changes during storage - Effect of cold storage on chlorogenic acid content of potatoes. Journal of Agricultural and Food Chemistry 14: 165-169.

Higdon, J. (2006). Vitamin C [internet]. Corvallis, Oregon, Linus Pauling Institute, Oregon State University. Available from: <http://lpi.oregonstate.edu/infocenter/vitamins/vitaminC/> [Accessed February 17, 2011].

Hincal, F. (2007). Trace elements in growth: iodine and selenium status of Turkish children. Third International FESTEM Symposium, Journal of Trace Elements in Medicine and Biology 21(Suppl 1): 40-43.

Ho, E., Boileau, T. W. M. and Bray, T. M. (2004). Dietary influences on endocrine-inflammatory interactions in prostate cancer development. Archives of Biochemistry and Biophysics 428: 109-117.

Holst, B. and Williamson, G. (2008). Nutrients and phytochemicals: from bioavailability to bioefficacy beyond antioxidants. Current Opinion in Biotechnology 19: 73-82.

Hughes, R.E. (2000). Vitamin C. In: Kiple, K.F. and Ornelas, K.C. (eds.). The Cambridge world history of food. Vol. 2. Cambridge University Press, Cambridge, UK, pp 754-762.

Hyman, L. (1992). Epidemiology of AMD. In: Hampton R.G. and Nelson P.T. (eds.). Age-Related Macular Degeneration. Principles and Practice. Raven Press, New York, USA, pp 1-35.

Im, H. W., Suh, B. S., Lee, S. U., Kozukue, N., Ohnisi-Kameyama, M., Levin, C. E., and Friedman, M. (2008). Analysis of phenolic compounds by

high-performance liquid chromatography and liquid chromatography/mass spectrometry in potato plant flowers, leaves, stems, and tubers and in home-processed potatoes. Journal of Agriculture and Food Chemistry 56: 3341–3349.

Iqbal, S., Gul, K.T., Iqbal, B.M., Akhtar, M. and Sarfraz, R.A. (2008). Determination of selenium content in selected Pakistani foods. International Journal of Food Science and Technology 43: 339-345.

Iwanzik, W., Tevini, M., Stute, R. and Hilbert, R. (1983). Carotinoidgehalt und-zusammensetzung verschiedener deutscher Kartoffelsorten und deren Bedeutung fur die Fleischfarbe der Knolle. Potato Research 26: 149-162.

Jimenez, M. E., Rossi, A. M. and Samman, N. C. (2009). Phenotypic, agronomic and nutritional characteristics of seven varieties of Andean potatoes. Journal of Food Composition and Analysis 22: 613-616.

Kanatt, S. R., Chander, R., Radhakrishna, P. and Sharma, A. (2005). Potato peel extract - A natural antioxidant for retarding lipid peroxidation in radiation processed lamb meat. Journal of Agricultural and Food Chemistry 53: 1499-1504.

Khachik, F., Cohen, L. and Zhao, Z., (1999). Metabolism of dietary carotenoids and their possible role in prevention of cancer and macular degeneration. In: Shibamoto, T. (Ed.). Functional foods (American Chemical Society Symposium Series), Oxford University Press, pp 71-85.

Kikuzaki, H., Hisamoto, M., Hirose, K., Akiyama, K. and Taniguchi, H. (2002). Antioxidant properties of ferulic acid and its related compounds. Journal of Agricultural and Food Chemistry 50: 2161-2168.

Kotikova, Z., Hejtmankova, A., Lachman, J., Hamouz, K., Trnkova, E. and Dvorak, P. (2007). Effect of selected factors on total carotenoid content in

potato (*Solanum tuberosum L.*) tubers. Plant, Soil and Environment 53: 355-360.

Kritchevsky, D., Tepper, S. A., Czarnecki, S. K. and Klurfeld, D. M. (1982). Atherogenicity of animal and vegetable protein. Influence of the lysine to arginine ratio. Atherosclerosis 41: 429-431.

Kurilich, A. C., Jeffery, E. H., Juvik, J. A., Wallig, M. A. and Klein, B. P. (2002). Antioxidant capacity of different broccoli (*Brassica oleracea*) genotypes using the oxygen radical absorbance capacity (ORAC) assay. Journal of Agricultural and Food Chemistry 50: 5053-5057.

Lachman, J., Hamouz, K., Orsak, M. and Pivec, V. (2000). Potato tubers as a significant source of antioxidants in human nutrition. Rostlinna Vyroba 46: 231-236.

Lachman, J. and Hamouz, K. (2005). Red and purple coloured potatoes as a significant antioxidant source in human nutrition - A review. Plant, Soil and Environment 51: 477-482.

Lachman, J., Hamouz, K., Sulc, M., Orsak M. and Dvorak, P. (2008). Differences in phenolic content and antioxidant activity in yellow and purple-fleshed potatoes grown in the Czech Republic. Plant, Soil and Environment 54: 1-6.

Landrum, J. T., Bone, R. A. and Kilburn, M. D. (1996). The macular pigment: A possible role in protection from age-related macular degeneration. Advances in Pharmacology 38: 537-556.

Landrum, J. T., Bone, R. A., Joa, H., Kilburn, M. D., Moore, L. L. and Sprague, K. E. (1997). A one year study of the macular pigment: the effect of 140 days of a lutein supplement. Experimental Eye Research 65: 57-62.

Landrum, J. T. and Bone, R. A. (2001). Lutein, zeaxanthin, and the macular pigment. Archives of Biochemistry and Biophysics 385: 28-40.

Leo, L., Leone, A., Longo, C., Lombardi, D. A., Raimo, F. and Zacheo, G. (2008). Antioxidant compounds and antioxidant activity in "early potatoes". Journal of Agricultural and Food Chemistry 56: 4154-4163.

Levander, O. A. and Beck, M. A. (1997). Interacting nutritional and infectious etiologies of Keshan disease: Insights from coxsackie virus B-induced myocarditis in mice deficient in selenium or vitamin E. Biological Trace Element Research 56: 5-21.

Lewis, C. E., Walker, J. R. L., Lancaster, J. E. and Sutton, K. H. (1998a). Determination of anthocyanins, flavonoids and phenolic acids in potatoes. I: Coloured cultivars of *Solanum tuberosum L*. Journal of the Science of Food and Agriculture 77: 45-57.

Lewis, C. E., Walker, J. R. L., Lancaster, J. E. and Sutton, K. H. (1998b). Determination of anthocyanins, flavonoids and phenolic acids in potatoes. II: Wild, tuberous *Solanum* species. Journal of the Science of Food and Agriculture 77: 58-63.

Li. K., Park E., Lee H., Khu D., Love S., and Lim H. (2006). Evaluation of potato varieties with high antioxidant activities by measuring phenolic acids in different tuber parts. Journal of the Korean Society for Horticultural Science 47:126-131.

Lin, C. C. and Yin, M. C. (2008). Effects of cysteine-containing compounds on biosynthesis of triacylglycerol and cholesterol and anti-oxidative protection in liver from mice consuming a high-fat diet. British Journal of Nutrition 99: 37-43.

Liu, R. H. (2003) Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. American Journal of Clinical Nutrition 78: 517s-520s.

Liu, Y. W., Han, C. H., Lee, M. H., Hsu, F. L. and Hou, W. C. (2003). Patatin, the tuber storage protein of potato *(Solanum tuberosum L.),* exhibits antioxidant activity in vitro. Journal of Agricultural and Food Chemistry 51: 4389-4393.

Love, S. L., Salaiz, T., Shafii, B., Price, W. J., Mosley, A. R. and Thornton, R. E. (2003). Ascorbic acid concentration and stability in North American potato germplasm. Acta Horticulture 619: 87-93.

Love, S. L. and Pavek, J. J. (2008). Positioning the potato as a primary food source of vitamin C. American Journal of Potato Research 85: 277-285.

Lu, W., Haynes, K., Wiley, E. and Clevidence, B. (2001). Carotenoid content and color in diploid potatoes. Journal of the American Society for Horticultural Science 126: 722-726.

Lukaszewicz, M., Matysiak-Kata, I., Skala, J., Fecka, I., Cisowski, W. and Szopa, J. (2004). Antioxidant capacity manipulation in transgenic potato tuber by changes in phenolic compounds content. Journal of Agricultural and Food Chemistry 52: 1526-1533.

Lutaladio, N. and Castaldi, L. (2009). Potato: The hidden treasure. Journal of Food Composition and Analysis 22: 491-493.

Machlin, L. J. (1995). Critical assessment of the epidemiological data concerning the impact of antioxidant nutrients on cancer and cardiovascular disease. Critical Reviews in Food Science and Nutrition 35: 41-50.

McLaughlin, B. (2005). Potatoes: changing production, changing consumption [internet]. Statistics Canada. Available from: <http://dsp-

psd.pwgsc.gc.ca/Collection/Statcan/21-004-X/21-004-XIE2005004.pdf.> [Accessed February 17, 2011].

Brand-Miller JC, Foster-Powell K & Colagiuri S (1996). The G.I. factor. Hodder & Stoughton, Rydalmere, New South Wales, Australia, pp 217.

Moline, J., Bukharovich, I. F., Wolff, M. S. and Phillips, R. (2000). Dietary flavonoids and hypertension: is there a link? Medical Hypotheses 55: 306-309.

Mondy, N. I., Leja, M. and Gosselin, B. (1987). Changes in total phenolic, total glycoalkaloid, and ascorbic acid content of potatoes as a result of bruising. Journal of Food Science 52: 631-635.

Moosmann, B. and Behl, C. (2002). Secretory peptide hormones are biochemical antioxidants: Structure-activity relationship. Molecular Pharmacology 61: 260-268.

Morita, T., Oh-hashi, A., Takei, K., Ikai, M., Kasaoka, S. and Kiriyama, S. (1997). Cholesterol-lowering effects of soybean, potato and rice protein depend on their low methionine contents in rats fed a cholesterol-free purified diet. Journal of Nutrition 127: 470-477.

Müller H. (1997). Determination of the carotenoid content in selected vegetables and fruit by HPLC and photodiode array detection. Zeitschrift für Lebensmittel-Untersuchung und-Forschung 204: 88-94.

Nair, V. D. P., Foster, B. C., Thor Arnason, J., Mills, E. J. and Kanfer, I. (2007). In vitro evaluation of human cytochrome P450 and P-glycoprotein-mediated metabolism of some phytochemicals in extracts and formulations of African potato. Phytomedicine 14: 498-507.

Nara, K., Miyoshi, T., Honma, T. and Koga, H. (2006). Antioxidative activity of bound-form phenolics in potato peel. Bioscience, Biotechnology and Biochemistry 70: 1489-1491.

Navarre, D.A., Pillai, S.S., Shakya, R., Holden, M. J. (2011). HPLC profiling of phenolics in diverse potato genotypes. Food Chemistry (in press).

Nesterenko, S. and Sink, K. C. (2003). Carotenoid profiles of potato breeding lines and selected cultivars. HortScience 38: 1173-1177.

Netherlands Catalogue of Potato Varieties (1997). Boom-planet, B.V. Harlem, The Netherlands, pp 270.

Nijveldt, R. J., Van Nood, E., Van Hoorn, D. E. C., Boelens, P. G., Van Norren, K. and Van Leeuwen, P. A. M. (2001). Flavonoids: A review of probable mechanisms of action and potential applications. American Journal of Clinical Nutrition 74: 418-425.

Olmedilla, B., Granado, F., Blanco, I., Vaquero, M. and Cajigal, C. (2001). Lutein in patients with cataracts and age-related macular degeneration: A long-term supplementation study. Journal of the Science of Food and Agriculture 81: 904-909.

Ortiz-Medina, E. (2007). Potato tuber protein and its manipulation by chimeral disassembly using specific tissue explantation for somatic embryogenesis. Doctoral thesis, Faculty of Graduate Studies and Research, McGill University, pp 152.

Ortiz-Medina, E., Sosle, V., Raghavan, V. and Donnelly, D. J. (2009). A method for intercultivar comparison of potato tuber nutrient content using specific tissue weight proportions. Journal of Food Science 74: S177-S181.

Pennington, J. A. T. and Wilkening, V. L. (1997). Final regulations for the nutrition labeling of raw fruits, vegetables, and fish. Journal of the American Dietetic Association 97: 1299-1305.

Peretz, A., Neve, J., Duchateau, J. and Famaey, J.P. (1992). Adjuvant treatment of recent onset rheumatoid arthritis by selenium supplementation: preliminary observations. British Journal of Rheumatology 31: 281-282.

Piccolomini A., Kubow S., Donnelly D.J., Annamalai A., Riciardi R.R., Nassar A., and Sabally K. (2008a). Unraveling the chlorogenic acid and phenolic content among twelve potato cultivars for improved human health and consumer acceptance. Horticulture Science 43:1222.

Piccolomini A., Kubow S., Donnelly D.J., Annamalai A., Riciardi R.R., Nassar A., and Sabally K. (2008b). Differential antioxidant capacity among twelve potato cultivars. Horticulture Science 43:1082.

Pihlanto, A., Akkanen, S. and Korhonen, H. J. (2008). ACE-inhibitory and antioxidant properties of potato (*Solanum tuberosum* L). Food Chemistry 109: 104-112.

Pitney, C. L., Royal, M. and Klebert, M. (2009) Selenium Supplementation in HIV-Infected Patients: Is There Any Potential Clinical Benefit? Journal of the Association of Nurses in AIDS Care 20: 326-333.

Popkin, B. M., Kim, S., Rusev, E. R., Du, S. and Zizza, C. (2006). Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases. Obesity Reviews 7: 271-293.

Pulido, R., Bravo, L. and Saura-Calixto, F. (2000). Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/antioxidant power assay. Journal of Agricultural and Food Chemistry 48: 3396-3402.

Pulido, R., Hernandez-Garcia, M. and Saura-Calixto, F. (2003). Contribution of beverages to the intake of lipophilic and hydrophilic antioxidants in the Spanish diet. European Journal of Clinical Nutrition 57: 1275-1282.

Rautiainen S., Serafini M., Morgenstern R., Prior R. L., and Wolk A. (2008). The validity and reproducibility of food-frequency questionnaire–based total antioxidant capacity estimates in Swedish women. American Journal of Clinical Nutrition 87: 1247-1253.

Reddivari, L., Hale, A. L., and Miller Jr, J. C. (2007a). Genotype, location, and year influence antioxidant activity, carotenoid content, phenolic content, and composition in specialty potatoes. Journal of Agricultural and Food Chemistry 55: 8073-8079.

Reddivari, L., Vanamala, J., Chintharlapalli, S., Safe, S. H. and Miller Jr, J. C. (2007b). Anthocyanin fraction from potato extracts is cytotoxic to prostate cancer cells through activation of caspase-dependent and caspase-independent pathways. Carcinogenesis 28: 2227-2235.

Reeve, R. M., Hautala, E. and Weaver, M. L. (1969). Anatomy and compositional variation within potatoes II: Phenolics, enzymes and other minor components. American Potato Journal 46: 374-386.

Reyes, L. F., Miller Jr, J. C. and Cisneros-Zevallos, L. (2005). Antioxidant capacity, anthocyanins and total phenolics in purple- and red-fleshed potato (*Solanum tuberosum L.)* genotypes. American Journal of Potato Research 82: 271-277.

Rimbach, G., Fuchs, J. and Packer, L. (2005). Application of nutrigenomics tools to analyze the role of oxidants and antioxidants in gene expression. In: Rimbach, G., Fuchs, J. and Packer, L. (eds.). Nutrigenomics. Taylor & Francis, Boca Raton, Florida, USA, pp 1-12.

Ritter, E., Barandalla, L., Lopez, R. and De Galarreta, J. I. R. (2008). Exploitation of exotic, cultivated *Solanum* germplasm for breeding and commercial purposes. Potato Research 51: 301-311.

Robards, K., Prenzler, P. D., Tucker, G., Swatsitang, P. and Glover, W. (1999). Phenolic compounds and their role in oxidative processes in fruits. Food Chemistry 66: 401-436.

Robert, L., Narcy, A., Rock, E., Demigne, C., Mazur, A. and Remesy, C. (2006). Entire potato consumption improves lipid metabolism and antioxidant status in cholesterol-fed rat. European Journal of Nutrition 45: 267-274.

Robert, L., Narcy, A., Rayssiguier, Y., Mazur, A. and Remesy, C. (2008). Lipid metabolism and antioxidant status in sucrose vs. potato-fed rats. Journal of the American College of Nutrition 27: 109-116.

Rodriguez De Sotillo, D., Hadley, M. and Holm, E. T. (1994). Phenolics in aqueous potato peel extract: Extraction, identification and degradation. Journal of Food Science 59: 649-651.

Salil, G. and Rajamohan, T. (2001). Hypolipidemic and antiperoxidative effect of coconut protein in hypercholesterolemic rats. Indian Journal of Experimental Biology 39: 1028-1034.

Sanchez-Moreno, C., Larrauri, J. A. and Saura-Calixto, F. (1998). A procedure to measure the antiradical efficiency of polyphenols. Journal of the Science of Food and Agriculture 76: 270-276.

Sanchez-Moreno, C., Jimenez-Escrig, A. and Saura-Calixto, F. (2000). Study of low-density lipoprotein oxidizability indexes to measure the antioxidant activity of dietary polyphenols. Nutrition Research 20: 941-953.

SAS (2008). Version 9.2 of the SAS system for windows. SAS Institute Inc, Cary, NC, USA.

Schieber A. and Saldana M.D.A. (2008). Potato Peels: A Source of Nutritionally and Pharmacologically Interesting Compounds – A Review. In: Yee N., and Bussell W.T. (eds.). Potato IV. Food 3, Global Science Books, Ltd., UK, pp 23-29.

Scott, G.J., Rosegrant, M., Ringler, C. (2000). Global projections for root and tuber crops to the year 2020. Food Policy 25: 561-597.

Seddon, J. M., Ajani, U. A., Sperduto, R. D., Hiller, R., Blair, N., Burton, T. C., Farber, M. D., Gragoudas, E. S., Haller, J., Miller, D. T., Yannuzzi, L. A. and Willett, W. (1994). Dietary carotenoids, vitamins A, C, and E, and advanced age-related macular degeneration. Journal of the American Medical Association 272: 1413-1420.

Serafini, M., Bellocco, R., Wolk, A. and Ekstrom, A. M. (2002). Total antioxidant potential of fruit and vegetables and risk of gastric cancer. Gastroenterology 123: 985-991.

Ševčík R., Kondrashov A., Kvasnička F., Vacek J., Hamouz K., Jirušková M., Voldřich M., Čížková H (2009). The impact of cooking procedures on antioxidant capacity of potatoes. Journal of Food and Nutrition Research 4: 171–177.

Shakya, R. and Navarre, D. A. (2006). Rapid screening of ascorbic acid, glycoalkaloids, and phenolics in potato using high-performance liquid chromatography. Journal of Agricultural and Food Chemistry 54: 5253-5260.

Shukla, A., Brandsch, C., Bettzieche, A., Hirche, F., Stangl, G. I. and Eder, K. (2007). Isoflavone-poor soy protein alters the lipid metabolism of rats by

SREBP-mediated down-regulation of hepatic genes. Journal of Nutritional Biochemistry 18: 313-321.

Singh, N. (2002). Studies on the biological activity of potato waste (peel) components for their possible applications. Ph.D. Thesis, University of Mysore, Mysore, India, pp 258.

Singh, R. P. and Agarwal, R. (2002). Flavonoid antioxidant silymarin and skin cancer. Antioxidants and Redox Signaling 4: 655-663.

Singh, N. and Rajini, P. S. (2004). Free radical scavenging activity of an aqueous extract of potato peel. Food Chemistry 85: 611-616.

Singh, N., Kamath, V. and Rajini, P. S. (2005). Protective effect of potato peel powder in ameliorating oxidative stress in streptozotocin diabetic rats. Plant Foods for Human Nutrition 60: 49-54.

Singh, N. and Rajini, P. S. (2008). Antioxidant-mediated protective effect of potato peel extract in erythrocytes against oxidative damage. Chemico-Biological Interactions 173: 97-104.

Singleton, V. L., Orthofer, R. and Lamuela-Raventos, R. M. (1998). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods in Enzymology 299: 152-178.

Spadoni, M., Voltaggio, M., Carcea, M., Coni, E., Raggi, A. and Cubadda, F. (2007). Bioaccessible selenium in Italian agricultural soils: Comparison of the biogeochemical approach with a regression model based on geochemical and pedoclimatic variables. Science of the Total Environment 376: 160-177.

Spallholz, J. E., Boylan, L. M., Rahman, M. M., Katz, D., Robertson, J. D., Zakaria, A. B. M., Khan, A. H., Alauddin, M., Bhattacharjee, M., Sultana, S., Khanam, S. and Choucair, Z. (2008). Selenium content of rice, mixed

plant foods and fish from Bangladesh. Toxicological and Environmental Chemistry 90: 211-220.

Spears, J. W. and Weiss, W. P. (2008). Role of antioxidants and trace elements in health and immunity of transition dairy cows. Veterinary Journal 176: 70-76.

Spielmann, J., Kluge, H., Stangl, G. I. and Eder, K. (2009). Hypolipidaemic effects of potato protein and fish protein in pigs. Journal of Animal Physiology and Animal Nutrition 93: 400-409.

Srikumar, T. S., and Ockerman, P. A. (1990). The effects of fertilization and manuring on the content of some nutrients in potato (var. Provita). Food Chemistry 37: 47-60.

Stadlober, M., Sager, M. and Irgolic, K. J. (2001). Effects of selenate supplemented fertilisation on the selenium level of cereals - Identification and quantification of selenium compounds by HPLC-ICP-MS. Food Chemistry 73: 357-366.

Stushnoff, C., Holm, D., Thompson, M. D., Jiang, W., Thompson, H. J., Joyce, N. I. and Wilson, P. (2008). Antioxidant properties of cultivars and selections from the Colorado potato breeding program. American Journal of Potato Research 85: 267-276.

Subar, A. F., Krebs-Smith, S. M., Cook, A. and Kahle, L. L. (1998). Dietary sources of nutrients among U.S. children, 1989 to 1991. Journal of the American Dietetic Association 98: 537-547.

Sun, J., Chu, Y. F., Wu, X. and Liu, R. H. (2002). Antioxidant and antiproliferative activities of common fruits. Journal of Agricultural and Food Chemistry 50: 7449-7454.

Szeto, Y. T., Kwok, T. C. Y. and Benzie, I. F. F. (2004). Effects of a long-term vegetarian diet on biomarkers of antioxidant status and cardiovascular disease risk. Nutrition 20: 863-866.

Tanaka, T., Kojima, T., Kawamori, T., Wang, A., Suzui, M., Okamoto, K. and Mori, H. (1993). Inhibition of 4-nitroquinoline-1-oxide-induced rat tongue carcinogenesis by the naturally occurring plant phenolics caffeic, ellagic, chlorogenic and ferulic acids. Carcinogenesis 14: 1321-1325.

Tanaka, T. (1994). Cancer chemoprevention by natural products. Oncology Reports 11: 139-155.

Teow, C. C., Truong, V. D., McFeeters, R. F., Thompson, R. L., Pecota, K. V. and Yencho, G. C. (2007). Antioxidant activities, phenolic and beta-carotene contents of sweet potato genotypes with varying flesh colours. Food Chemistry 103: 829-838.

Toledo, A. and Burlingame, B. (2006). Biodiversity and nutrition: A common path toward global food security and sustainable development. Journal of Food Composition and Analysis 19: 477-483.

True, R. H., Hogan, J. M., Augustin, J., Johnson, S. R., Teitzel, C., Toma, R. B. and Shaw, R. L. (1978). Mineral composition of freshly harvested potatoes. American Journal of Potato Research 55: 511-519.

Uriu-Adams, J. Y. and Keen, C. L. (2005). Copper, oxidative stress, and human health. Molecular Aspects of Medicine 26: 268-298.

Valko, M., Rhodes, C. J., Moncol, J., Izakovic, M. and Mazur, M. (2006). Free radicals, metals and antioxidants in oxidative stress-induced cancer. Chemico-Biological Interactions 160: 1-40.

Varo, P. and Koivistoinen, P. (1988). Selenium intake and serum selenium in Finland: effects of soil fertilisation with selenium. American Journal for Clinical Nutrition 48: 324-329.

Vingerling, J. R., Klaver, C. C. W., Hofman, A. and De Jong, P. T. V. M. (1995). Epidemiology of age-related maculopathy. Epidemiologic Reviews 17: 347-360.

White, P. J. and Broadley, M. R. (2005). Biofortifying crops with essential mineral elements. Trends in Plant Science 10: 586-593.

WHO (2003). Diet, nutrition and the prevention of chronic diseases. Report of a joint WHO/FAO expert consultation. WHO Technical Report Series, Geneva, pp 797.

Xu, X., Li, W., Lu, Z., Beta, T. and Hydamaka, A. W. (2009). Phenolic content, composition, antioxidant activity, and their changes during domestic cooking of potatoes. Journal of Agricultural and Food Chemistry 57: 10231-10236.

Yang, C. S., Landau, J. M., Huang, M. T. and Newmark, H. L. (2001). Inhibition of carcinogenesis by dietary polyphenolic compounds. Annual Review of Nutrition 21: 381-406.

Ylaeranta, T. (1983a). Selenium in Finnish agricultural soils. Annales Agriculturae Fenniae, 22: 122-136.

Ylaeranta, T. (1983b). Effect of added selenite and selenate on the selenium content of Italian rye grass (Lolium Multiflorum) in different soils. Annales Agriculturae Fenniae 22: 139-151.

Zeng, H. and Combs Jr., G.F (2008). Selenium as an anticancer nutrient: roles in cell proliferation and tumor cell invasion. *Journal of Nutritional Biochemistry* 19: 1-7.

Zia Ur, R., Habib, F. and Shah, W. H. (2004). Utilization of potato peels extract as a natural antioxidant in soy bean oil. Food Chemistry 85: 215-220.

VII. APPENDIX

Table A.1: Recommended dietary allowance/adequate intake for Adult Males (aged 19 – 50; Dietary Reference Intakes, 2011).

Nutrient	Recommended Dietary Allowance (RDA)	Adequate Intake (AI)
Ascorbic acid (AA)	90 mg	
Calcium (Ca)		1000 mg
Copper (Cu)	900 µg	
Iron (Fe)	8 mg	
Zinc (Zn)	11 mg	
Magnesium (Mg)	400 mg	
Phosphorous (P)	700 mg	
Potassium (K)		4700 mg
Selenium (Se)	55 µg	
Sodium (Na)		1500 mg
Protein (TSP)	58-63 g	

Table A.2: Daily values of nutrients (FDA, 2011)

Nutrient	Daily Value (DV)
Ascorbic acid (AA)	60 mg
Calcium (Ca)	1000 mg
Copper (Cu)	2 mg
Iron (Fe)	18 mg
Zinc (Zn)	15 mg
Magnesium (Mg)	400 mg
Phosphorous (P)	1000 mg
Potassium (K)	3500 mg
Selenium (Se)	70 µg
Sodium (Na)	2400 mg
Protein (TSP)	50 g

Table A.3: Dry matter in a potato cultivar (virtual tuber of 150 g fresh weight).

Tuber Tissues	Potato cultivars			
	Chieftain	**Goldrush**	**Russet Burbank**	**Yukon Gold**
Skin	0.49 ± 0.04	0.63 ± 0.10	0.79 ± 0.09	0.25 ± 0.02
Cortex	12.84 ± 0.19	14.29 ± 0.31	15.80 ± 0.23	12.01 ± 0.09
Pith	20.66 ± 0.39	30.72 ± 0.21	21.40 ± 0.38	29.87 ± 0.29

Table A.4: Ratios of fresh weight to dry weight (FW:DW) for tissues.

Tuber Tissues	Potato cultivars			
	Chieftain	**Goldrush**	**Russet Burbank**	**Yukon Gold**
Skin	5.85 ± 0.19	4.95 ± 0.12	5.26 ± 0.30	5.22 ± 0.16
Cortex	3.97 ± 0.22	3.70 ± 0.10	3.76 ± 0.11	3.39 ± 0.24
Pith	4.65 ± 0.13	3.78 ± 0.41	4.03 ± 0.13	3.61 ± 0.25
Whole Tuber	4.40 ± 0.23	4.01 ± 0.16	4.01 ± 0.20	4.20 ± 0.11

Table A.5: Concentration of antioxidants and phytonutrients in tuber tissues reported on a per unit dry matter basis.

Potato Cultivars	Tuber Tissues	TP (mg/g DW)	CGA (µg/g DW)	CA (µg/g DW)	FA (µg/g DW)	RU (µg/g DW)
Chieftain	**Skin**	22.50 ± 0.22	2035 ± 144	3323 ± 329	811 ± 45	100 ± 23
	Cortex	2.66 ± 0.06	172 ± 6	14 ± 2	2 ± 0	4 ± 1
	Pith	2.36 ± 0.08	36 ± 3	2 ± 0	1 ± 0	7 ± 1
Goldrush	**Skin**	22.56 ± 0.67	5013 ± 516	1462 ± 76	285 ± 34	581 ± 89
	Cortex	2.40 ± 0.03	245 ± 31	5 ± 0	1 ± 0	5 ± 1
	Pith	2.41 ± 0.05	102 ± 11	3 ± 0	1 ± 0	2 ± 0
Russet Burbank	**Skin**	18.98 ± 0.13	3314 ± 127	1769 ± 63	220 ± 9	129 ± 15
	Cortex	2.70 ± 0.12	218 ± 30	6 ± 1	1 ± 0	6 ± 1
	Pith	2.46 ± 0.10	81 ± 4	3 ± 0	1 ± 0	4 ± 1
Yukon Gold	**Skin**	10.30 ± 0.56	527 ± 24	1116 ± 63	610 ± 17	171 ± 7
	Cortex	2.48 ± 0.11	44 ± 3	16 ± 3	2 ± 0	3 ± 0
	Pith	2.18 ± 0.12	39 ± 3	4 ± 0	5 ± 1	4 ± 0
Overall Mean	**Skin**	18.59 ± 2.89	2722 ± 953	1918 ± 487	482 ± 139	245 ± 113
	Cortex	2.56 ± 0.07	170 ± 45	10 ± 3	2 ± 0	5 ± 1
	Pith	2.35 ± 0.06	65 ± 16	3 ± 0	2 ± 1	4 ± 1

Table A.5 continued.

Cultivar	Tissue	AA (mg/g DW)	TC (µg/g DW)	TSP (mg/g DW)	$HAOC^{DPPH}$ (AAE/g DW)	$HAOC^{FRAP}$ (AAE/g DW)
Chieftain	**Skin**	3.20 ± 0.11	5.56 ± 0.60	48.66 ± 0.64	4.48 ± 0.14	10.66 ± 0.49
	Cortex	0.82 ± 0.04	1.56 ± 0.36	36.77 ± 0.56	0.12 ± 0.05	0.60 ± 0.02
	Pith	0.69 ± 0.03	0.95 ± 0.01	25.65 ± 1.01	0.92 ± 0.05	0.32 ± 0.03
Goldrush	**Skin**	3.09 ± 0.22	5.14 ± 0.32	37.08 ± 0.34	6.04 ± 0.10	11.65 ± 0.26
	Cortex	0.74 ± 0.03	1.85 ± 0.40	34.91 ± 0.36	0.60 ± 0.04	0.71 ± 0.02
	Pith	1.14 ± 0.05	1.10 ± 0.09	21.94 ± 0.82	0.40 ± 0.07	0.41 ± 0.02
Russet Burbank	**Skin**	2.39 ± 0.16	5.08 ± 0.22	36.11 ± 2.08	5.39 ± 0.15	10.43 ± 0.17
	Cortex	0.67 ± 0.01	1.55 ± 0.35	32.84 ± 1.02	1.17 ± 0.08	0.74 ± 0.02
	Pith	0.80 ± 0.04	3.00 ± 0.12	22.68 ± 0.95	1.20 ± 0.05	0.47 ± 0.01
Yukon Gold	**Skin**	2.83 ± 0.07	7.20 ± 0.08	46.52 ± 0.50	3.12 ± 0.11	7.05 ± 0.12
	Cortex	0.75 ± 0.05	7.09 ± 0.35	37.91 ± 0.52	0.31 ± 0.04	0.68 ± 0.02
	Pith	1.01 ± 0.09	4.98 ± 0.81	29.86 ± 0.49	1.09 ± 0.05	0.49 ± 0.01
Overall Mean	**Skin**	2.88 ± 0.18	5.50 ± 0.58	42.09 ± 3.21	4.78 ± 0.63	9.95 ± 1.00
	Cortex	0.75 ± 0.03	3.01 ± 1.36	35.61 ± 1.11	0.55 ± 0.23	0.68 ± 0.03
	Pith	0.91 ± 0.10	2.51 ± 0.95	25.03 ± 1.80	0.90 ± 0.18	0.42 ± 0.04

Table A.5 continued.

Cultivars	Tissue	µmol TE/g DW					
		HAOC (DPPH)	LAOC (DPPH)	TAOC (DPPH)	HAOC (FRAP)	LAOC (FRAP)	TAOC (FRAP)
Chieftain	**Skin**	251.89 ± 3.59	18.56 ± 0.78	270.46 ± 3.76	449.88 ± 19.99	21.01 ± 0.86	470.89 ± 19.41
	Cortex	142.66 ± 1.29	10.42 ± 0.46	153.08 ± 1.50	36.68 ± 0.93	10.86 ± 0.45	47.54 ± 0.93
	Pith	162.78 ± 1.19	12.00 ± 0.89	174.74 ± 1.82	25.93 ± 0.92	10.25 ± 0.29	36.17 ± 0.95
Goldrush	**Skin**	291.09 ± 2.55	19.00 ± 0.87	310.09 ± 3.32	490.54 ± 10.51	19.17 ± 0.81	509.71 ± 10.94
	Cortex	154.72 ± 0.92	10.98 ± 0.50	165.70 ± 0.88	40.98 ± 0.63	13.03 ± 0.82	54.01 ± 1.01
	Pith	149.69 ± 1.76	13.47 ± 0.79	163.16 ± 1.83	28.74 ± 0.71	12.65 ± 0.59	41.39 ± 0.54
Russet Burbank	**Skin**	274.90 ± 3.78	35.89 ± 0.73	310.79 ± 4.32	440.55 ± 7.15	35.33 ± 0.84	475.88 ± 6.88
	Cortex	169.03 ± 2.02	11.50 ± 1.04	180.53 ± 1.56	42.36 ± 0.98	10.31 ± 0.70	52.67 ± 1.66
	Pith	169.78 ± 1.37	13.44 ± 0.89	183.22 ± 1.74	31.09 ± 0.36	11.41 ± 0.47	42.50 ± 0.58
Yukon Gold	**Skin**	217.88 ± 2.78	35.90 ± 1.11	253.77 ± 3.82	301.74 ± 4.88	21.81 ± 0.49	323.55 ± 4.93
	Cortex	147.27 ± 0.91	9.50 ± 0.53	156.77 ± 0.91	40.06 ± 0.78	10.52 ± 0.16	50.58 ± 0.82
	Pith	166.84 ± 1.17	10.35 ± 0.39	177.19 ± 1.22	32.14 ± 0.27	11.71 ± 0.40	43.85 ± 0.49
Overall mean	**Skin**	258.94 ±15.87	27.34 ± 4.94	286.28 ± 14.36	420.68 ± 41.10	24.33 ± 3.71	445.01 ± 41.39
	Cortex	153.42 ± 5.77	10.60 ± 0.43	164.02 ± 6.11	40.02 ± 1.21	11.18 ± 0.63	51.20 ± 1.41
	Pith	162.27 ± 4.43	12.32 ± 0.74	174.58 ± 4.20	29.48 ± 1.38	11.51 ± 0.49	40.98 ± 1.68

Table A.5 continued.

Cultivars	Tissues	Ca (mg/kg DW)	Cu (mg/kg DW)	Fe (mg/kg DW)	K (mg/kg DW)
Chieftain	**Skin**	314.56 ± 107.26	5.48 ± 1.38	43.53 ± 14.87	20534.28 ± 2024.99
	Cortex	140.43 ± 70.10	2.74 ± 0.48	20.07 ± 9.05	12434.44 ± 1369.49
	Pith	84.40 ± 16.62	2.46 ± 0.30	15.36 ± 1.55	11281.68 ± 1030.97
Goldrush	**Skin**	756.76 ± 14.85	10.14 ± 0.95	123.59 ± 22.69	17302.07 ± 227.33
	Cortex	115.63 ± 17.15	3.40 ± 0.21	8.32 ± 0.87	9631.59 ± 340.68
	Pith	72.05 ± 8.94	2.56 ± 0.07	7.18 ± 0.46	7031.78 ± 602.68
Russet Burbank	**Skin**	1100.64 ± 215.46	7.11 ± 0.21	484.58 ± 79.70	16638.61 ± 1665.30
	Cortex	385.83 ± 54.22	3.15 ± 0.99	17.27 ± 2.65	9467.93 ± 759.45
	Pith	220.69 ± 28.95	2.20 ± 0.81	13.56 ± 3.35	7898.53 ± 985.22
Yukon Gold	**Skin**	806.11 ± 57.94	4.88 ± 0.57	104.12 ± 7.09	24498.16 ± 805.45
	Cortex	150.40 ± 22.13	0.85 ± 0.18	11.91 ± 3.18	11530.07 ± 1997.56
	Pith	127.73 ± 5.42	0.63 ± 0.01	11.95 ± 0.83	8976.87 ± 184.91
Overall mean	**Skin**	744.52 ± 162.18	6.90 ± 1.18	188.96 ± 100.00	19743.28 ± 1798.91
	Cortex	198.07 ± 63.01	2.54 ± 0.58	14.39 ± 2.64	10766.01 ± 726.83
	Pith	126.22 ± 33.68	1.96 ± 0.45	12.01 ± 1.75	8797.22 ± 918.75

Table A.5 continued

Cultivars	Tissues	Mg (mg/kg DW)	Na (mg/kg DW)	P (mg/kg DW)	Se (mg/kg DW)	Zn (mg/kg DW)
Chieftain	**Skin**	1071.02 ± 126.69	36.31 ± 10.77	1677.30 ± 576.60	2.36 ± 0.36	31.43 ± 7.55
	Cortex	664.87 ± 81.11	19.45 ± 3.27	1655.15 ± 383.67	1.53 ± 0.27	15.84 ± 2.49
	Pith	718.86 ± 32.43	18.90 ± 1.48	1986.17 ± 68.21	2.57 ± 0.28	13.46 ± 0.33
Goldrush	**Skin**	1183.02 ± 86.61	282.75 ± 50.89	1384.79 ± 55.83	1.69 ± 0.51	19.75 ± 1.16
	Cortex	638.57 ± 34.41	28.33 ± 6.16	1692.65 ± 38.09	1.28 ± 0.17	11.47 ± 0.47
	Pith	450.03 ± 5.34	17.85 ± 3.75	1104.74 ± 40.74	1.62 ± 0.28	7.31 ± 0.38
Russet Burbank	**Skin**	762.61 ± 12.53	102.88 ± 20.15	1162.97 ± 85.47	1.77 ± 0.73	24.88 ± 5.80
	Cortex	491.90 ± 41.22	44.32 ± 4.13	1802.53 ± 260.85	1.67 ± 0.39	13.32 ± 2.85
	Pith	470.26 ± 47.18	28.19 ± 3.78	1437.35 ± 319.33	2.46 ± 0.09	9.54 ± 2.01
Yukon Gold	**Skin**	1326.09 ± 17.34	57.79 ± 18.06	1486.20 ± 23.17	3.08 ± 0.55	16.68 ± 3.35
	Cortex	516.83 ± 68.89	18.37 ± 5.60	1154.91 ± 142.10	1.95 ± 0.39	9.91 ± 2.22
	Pith	518.47 ± 6.36	33.04 ± 5.63	990.45 ± 55.42	1.53 ± 0.26	10.47 ± 0.73
Overall mean	**Skin**	1085.69 ± 119.67	119.93 ± 56.02	1427.82 ± 107.10	2.23 ± 0.32	23.19 ± 3.23
	Cortex	578.04 ± 43.18	27.62 ± 5.99	1576.31 ± 143.91	1.61 ± 0.14	12.64 ± 1.28
	Pith	539.41 ± 61.52	24.50 ± 3.68	1379.68 ± 223.28	2.05 ± 0.27	10.20 ± 1.27

Table A.6: Concentration of antioxidants and phytonutrients in one gram of dry weight of a virtual tuber of cultivars tested.

Potato Cultivars	TP (mg)	CGA (µg)	CA (µg)	FA (µg)	RU (µg)	AA (mg)
Chieftain	2.75 ± 0.10	115.89 ± 29.34	54.06 ± 4.29	12.53 ± 2.46	19.33 ± 2.44	0.77 ± 0.10
Goldrush	3.27 ± 0.11	261.88 ± 32.10	29.06 ± 3.51	5.93 ± 1.11	13.10 ± 3.26	1.27 ± 0.09
Russet Burbank	2.95 ± 0.09	208.55 ± 21.79	41.41 ± 6.10	4.95 ± 1.40	7.38 ± 1.91	0.79 ± 0.11
Yukon Gold	2.73 ± 0.21	50.97 ± 4.91	15.88 ± 2.02	8.87 ± 1.83	5.15 ± 1.03	1.12 ± 0.18
Mean	2.93 ± 0.13	159.33 ± 47.05	35.10 ± 8.19	8.07 ± 1.70	11.24 ± 3.17	0.98 ± 0.12

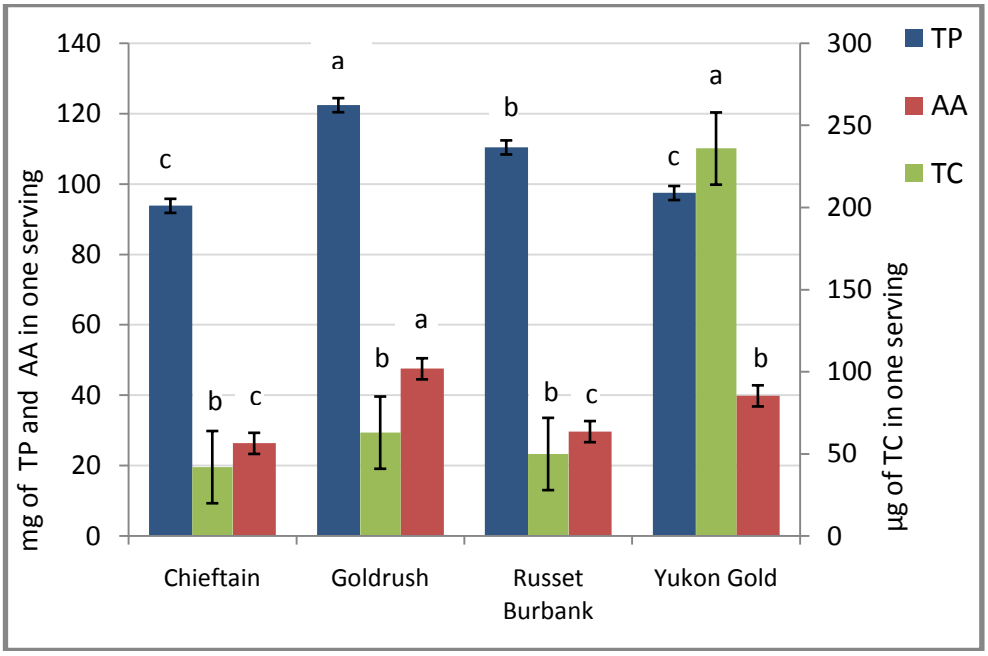
Potato Cultivars	TC (µg)	TSP (mg)	HAOC (DPPH) (µM TE)	LAOC (DPPH) (µM TE)	TAOC (DPPH) (µM TE)	HAOC (DPPH) (mg AAE)
Chieftain	1.23 ± 0.08	30.09 ± 4.87	155.94 ± 29.78	11.46 ± 2.11	167.38 ± 32.16	0.66 ± 0.09
Goldrush	1.68 ± 0.07	31.97 ± 6.09	186.93 ± 23.81	15.57 ± 3.82	202.50 ± 26.47	0.66 ± 0.17
Russet Burbank	1.34 ± 0.12	27.62 ± 5.18	174.36 ± 14.27	13.31 ± 3.78	187.67 ± 29.99	1.30 ± 0.10
Yukon Gold	6.61 ± 0.26	38.05 ± 5.63	190.59 ± 15.30	12.10 ± 1.45	202.69 ± 20.43	1.03 ± 0.04
Mean	2.72 ± 1.30	31.93 ± 2.23	176.96 ± 7.82	13.11 ± 0.91	190.06 ± 8.33	0.91 ± 0.15

Table A.6 continued

Potato Cultivars	HAOC (FRAP) µM TE	LAOC (FRAP) µM TE	TAOC (FRAP) µM TE	HAOC (FRAP) mg AAE	Ca (mg)	Cu (mg)
Chieftain	35.95 ± 4.56	10.60 ± 2.45	46.55 ± 3.73	0.57 ± 0.07	0.11 ± 0.03	0.0026 ± 0.0001
Goldrush	47.52 ± 3.98	15.69 ± 2.01	63.21 ± 8.91	0.80 ± 0.04	0.12 ± 0.04	0.0035 ± 0.0002
Russet Burbank	45.01 ± 2.77	11.63 ± 1.69	56.64 ± 6.38	0.80 ± 0.09	0.31 ± 0.04	0.0027 ± 0.0001
Yukon Gold	42.43 ± 3.61	13.49 ± 1.86	55.91 ± 5.12	0.69 ± 0.04	0.16 ± 0.03	0.0008 ± 0.0001
Mean	42.73 ± 2.49	12.85 ± 1.12	55.58 ± 3.43	0.72 ± 0.05	0.18 ± 0.05	0.0024 ± 0.0006

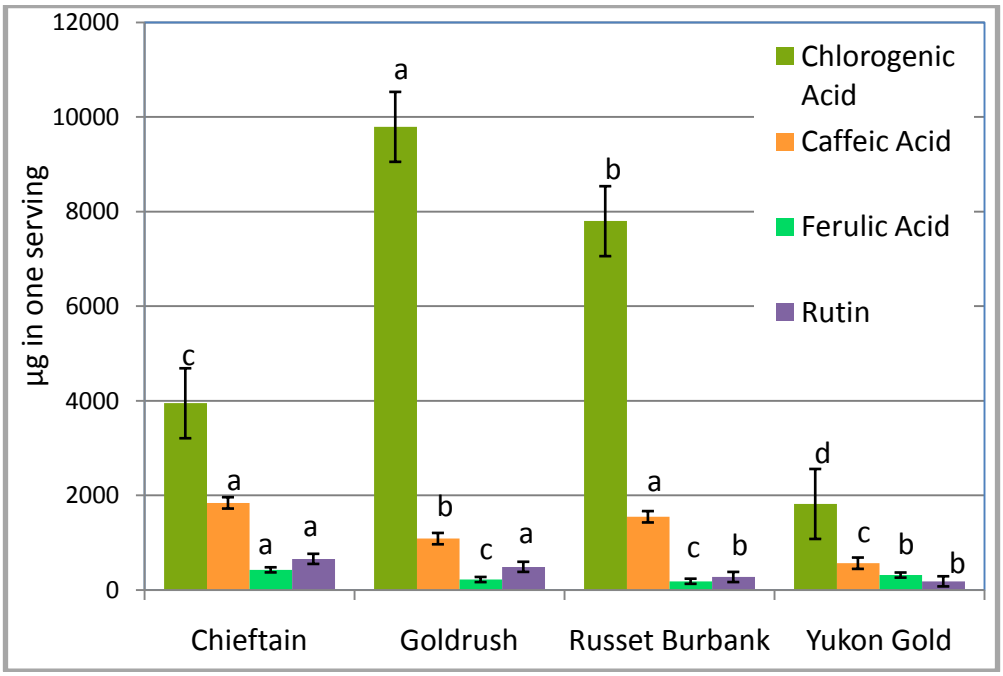
Potato Cultivars	Fe (mg)	K (mg)	Mg (mg)	Na (mg)	P (mg)	Se (mg)	Zn (mg)
Chieftain	0.02 ± 0.00	11.82 ± 2.45	0.70 ± 0.07	0.02 ± 0.00	1.85 ± 0.12	0.0020 ± 0.0001	0.02 ± 0.00
Goldrush	0.01 ± 0.00	9.75 ± 1.04	0.63 ± 0.04	0.03 ± 0.00	1.58 ± 0.19	0.0019 ± 0.0001	0.01 ± 0.00
Russet Burbank	0.03 ± 0.00	8.88 ± 2.01	0.49 ± 0.04	0.04 ± 0.01	1.61 ± 0.21	0.0021 ± 0.0001	0.01 ± 0.00
Yukon Gold	0.02 ± 0.00	11.57 ± 1.97	0.62 ± 0.03	0.03 ± 0.00	1.23 ± 0.17	0.0020 ± 0.0001	0.01 ± 0.00
Mean	0.02 ± 0.00	10.50 ± 0.71	0.61 ± 0.04	0.03 ± 0.00	1.57 ± 0.13	0.0020 ± 0.0000	0.01 ± 0.00

Figure A.1: Variation seen between cultivars in total phenolic compounds (TP), *total carotenoids (TC), and ascorbic acid (AA) in one serving (virtual tuber of 150 g FW).



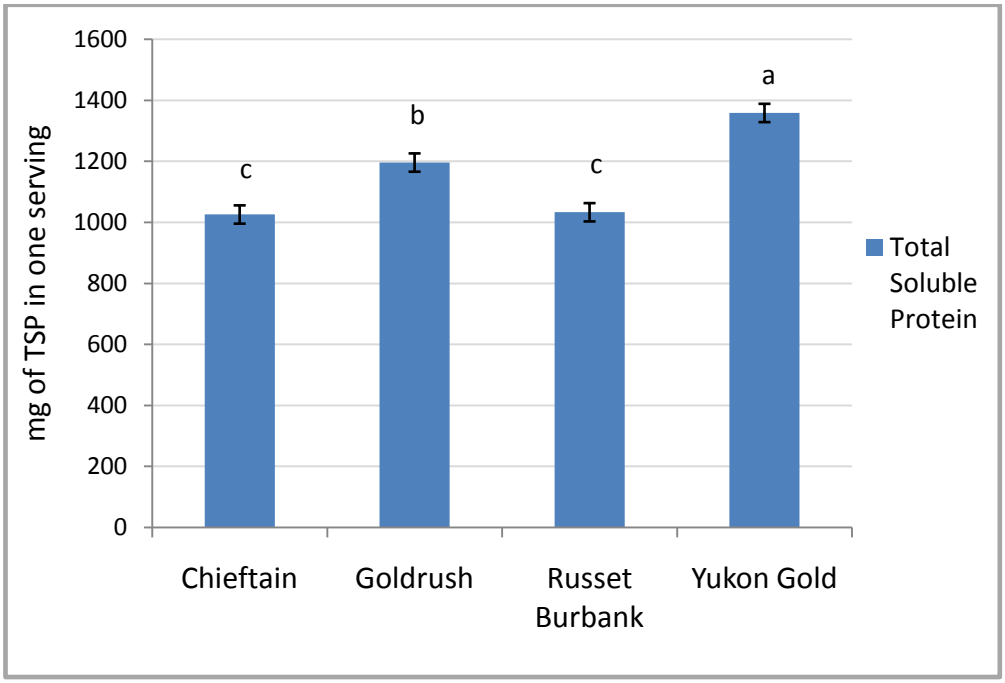
Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; n = 5; *n = 3). Bars represent mean ± SE for each cultivar. Means having the same letters are not significantly different from each other.

Figure A.2: Variation seen between cultivars in selected polyphenolic compounds (chlorogenic acid, caffeic acid, ferulic acid and rutin) in one serving (virtual tuber of 150 g FW).



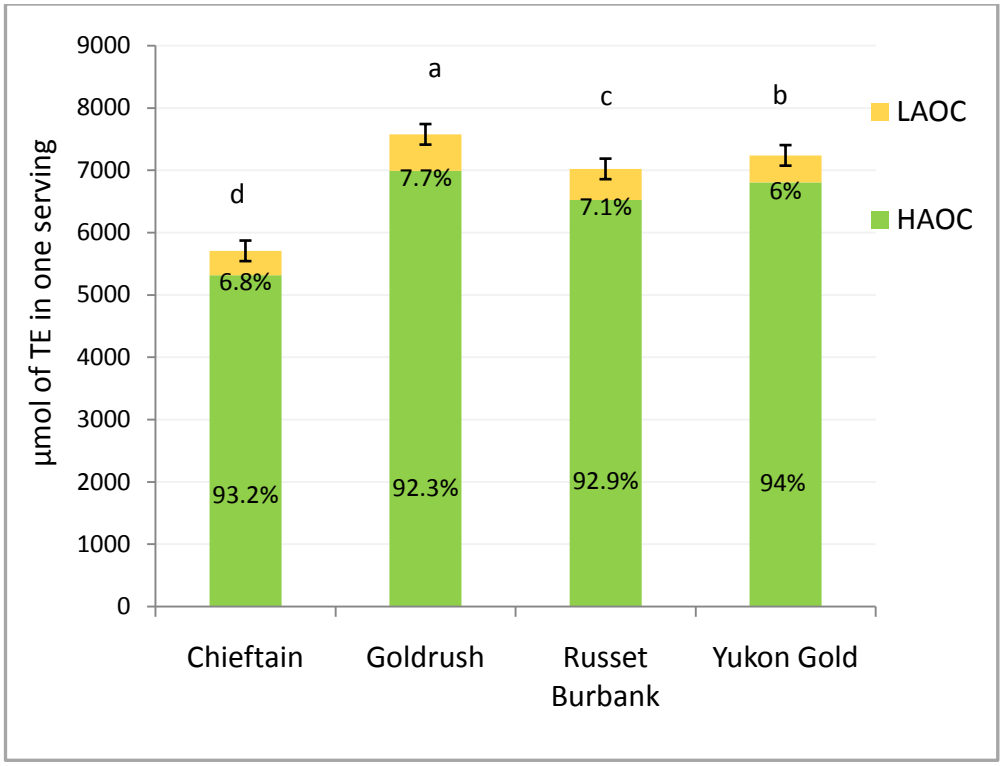
Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Bars represent mean ± SE for each cultivar. Means having the same letters are not significantly different from each other.

Figure A.3: Variation seen between cultivars in total soluble protein (TSP) in one serving (virtual tuber of 150 g FW).



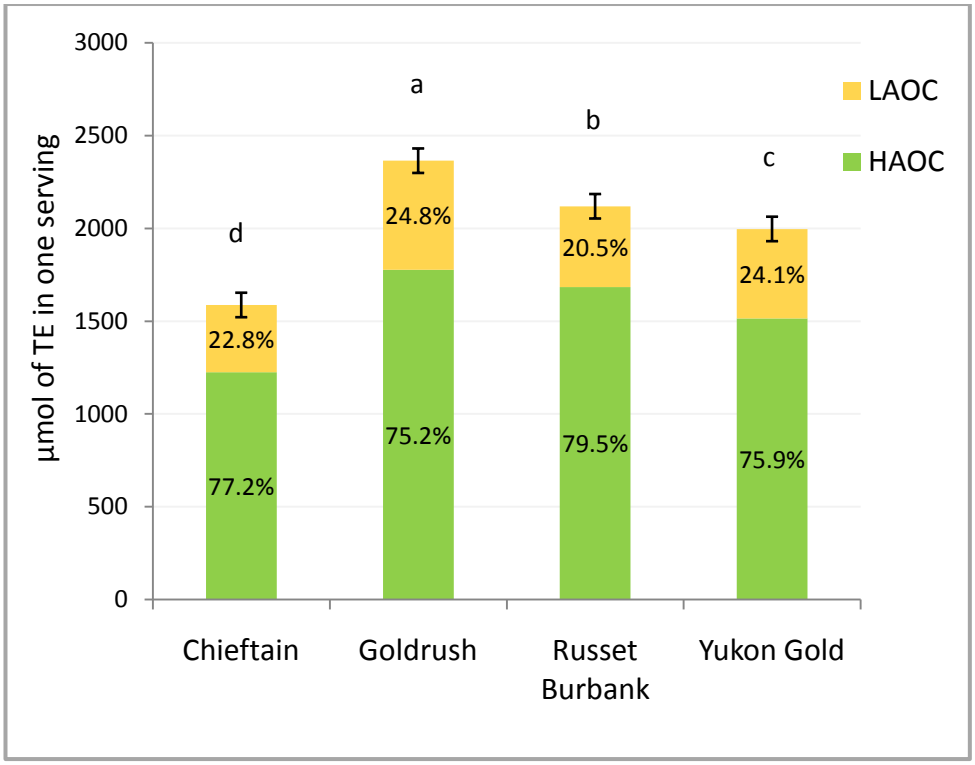
Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Bars represent mean ± SE for each cultivar. Means having the same letters are not significantly different from each other.

Figure A.4: Variation seen between cultivars in total antioxidant capacity (TOAC) using 1,1-diphenyl-2-picrylhydrazyl (DPPH) in one serving (virtual tuber of 150 g FW).



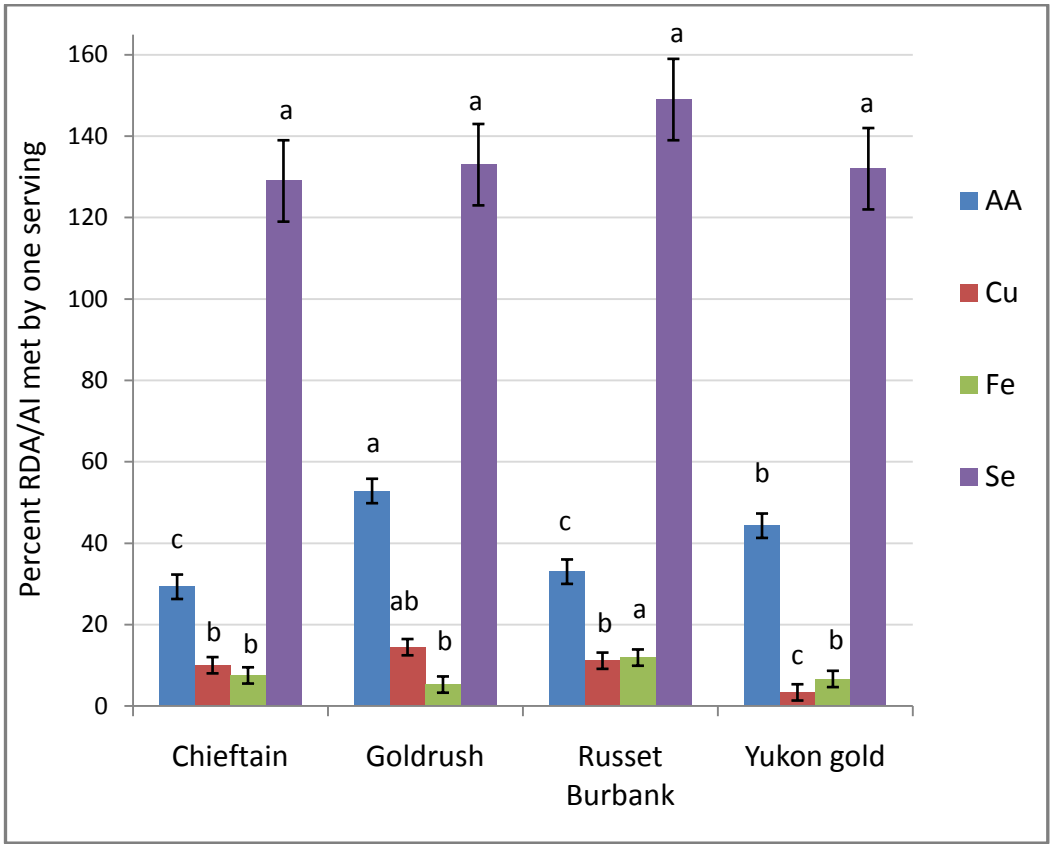
Total antioxidant capacity (TAOC) is represented as sum of hydrophilic antioxidant capacity (HAOC) and lipophilic antioxidant capacity (LAOC) obtained using DPPH. Percentages indicate contribution of HAOC and LAOC towards TAOC. Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Bars represent mean ± SE for each cultivar. Means having the same letters are not significantly different from each other.

Figure A.5: Variation seen between cultivars in total antioxidant capacity (TOAC) using Ferric ion reducing antioxidant power (FRAP) in one serving (virtual tuber of 150 g FW).



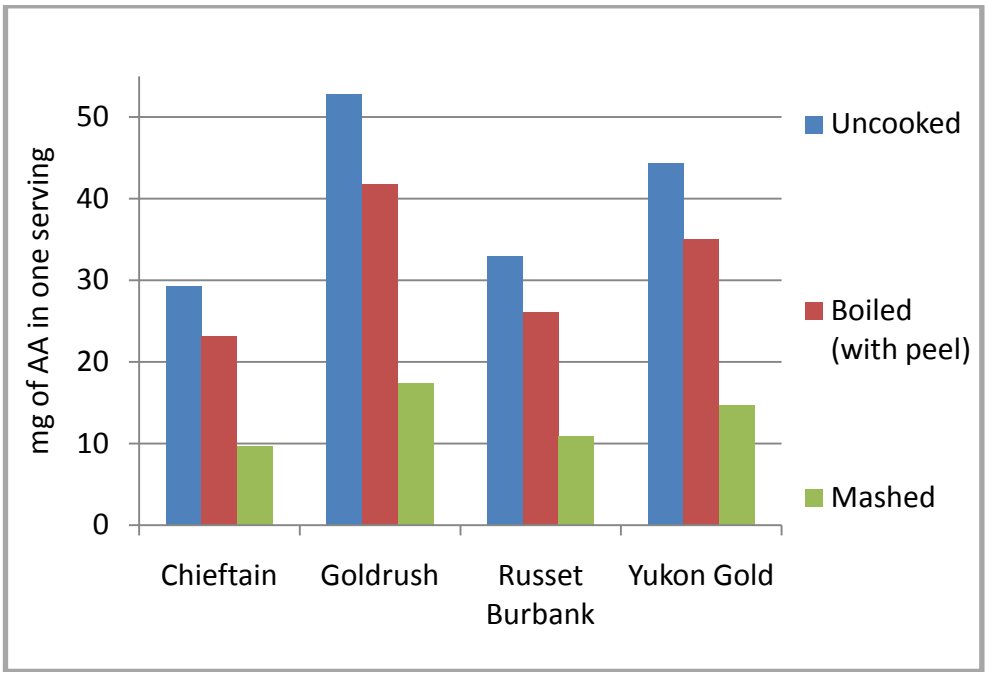
Total antioxidant capacity (TAOC) is represented as sum of hydrophilic antioxidant capacity (HAOC) and lipophilic antioxidant capacity (LAOC) obtained using FRAP. Percentages indicate contribution of HAOC and LAOC towards TAOC. Differences were tested between cultivars for one serving of 150 g virtual tuber using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Bars represent mean ± SE for each cultivar. Means having the same letters are not significantly different from each other.

Figure A.6: Percentage contribution of nutrients (ascorbic acid; AA, copper; Cu, iron; Fe, and selenium; Se) from one serving (virtual tuber of 150 g FW) to recommended dietary allowance (RDA) or adequate intake (AI) of nutrients.



Differences were tested between cultivars for contribution of one serving (virtual tuber of 150 g FW) to the RDA/AI of nutrients using Tukey's post-hoc test ($p < 0.05$; $n = 5$). Bars represent mean ± SE for each cultivar. Means having the same letters are not significantly different from each other.

Figure A.7: Estimated percentage contribution of ascorbic acid (AA) from one serving (virtual tuber of 150 g FW) to recommended dietary allowance (RDA) of AA after estimated cooking losses from boiling and mashing (Love and Pavek, 2008).



Losses factors for AA with two cooking methods (boling with peel and mashing) were used from Love and Pavek (2008), to calculate loss of AA and represent the remaining amounts of AA in one serving of cultivars. Cultivar Goldrush is closer to meeting the requirements for a "source" and "high source" when mashed and boiled with peel, respectively.