Investigations into the Nutritional and Sensory Potential of Taewa (Māori Potatoes)

A thesis presented in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Nutritional Science

At Massey University

Palmerston North, New Zealand

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Ngāti Ranginui

2015

Dedication

Ki taku whānau toa: Taku Whaiāipo, me aku Tamariki.

He mihi NUNUI to my whaiapo Jasen Wharemate, my LONG-suffering, patient, supportive eternal companion. You complete me honey.

Biiiiiiig hugs to my three children Szharei (14), Asjanae (8) and Jaran (6) who have sacrificed time with me, prayed so I might finish quickly, comforted me when exhausted and put up with my absence, lack of energy and shortened patience while getting this research done. ☺☺☺.

To you my awesome whānau, I dedicate this work.

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Acknowledgements

Ehara taku toa i te toa takitahi, engari he toa takitini.

My success has not come as a result of my efforts alone,

but through the efforts of many.

As this journey has been a lengthy one, there are many to acknowledge and thank -so it's going to take a while....

Firstly I acknowledge and give honour to my Creators and my Saviour. Without them, I would not be here and without their divine guidance, strength and love, I would have given up on myself long ago.

Ki taku whānau toa: My honey Jasen Wharemate and my three children Szharei, Asjanae and Jaran Wharemate. ☺ ☺☺☺ To you I dedicate this work.

Ki tōku whānau whānui: E kore te utu mō ō koutou tautoko. Kāre he kōrero hei whakamārama te hōhonu o tōku aroha mō koutou katoa. Thanks for everything guys –the alternative sleeping venues, the babysitting, helping with the mind-numbing jobs that had to be done, the encouragement, the prayers, the meals I didn't have to cook etc. This finished work is as much yours as it is mine.

My doctoral supervisors Kay Rutherfurd-Markwick, David Thomas, Jane Coad and Chris Cunningham thank you for your expert guidance, support and help. Kay, you have seen me through this right from the start. You have been there through my many ups and downs, struggles and tears. Thank you for not giving up on me, being so understanding, patient and encouraging. You truly are a wahine toa (a champion among women).

To Nick Roskruge and Tahuri Whenua. Although you weren't officially a supervisor Nick –you may as well have been. Thanks for being a huge part in getting me to the end. Apart from being the means through which to get the Taewa, your door and heart has always been open. Hopefully something in here may be of use to you and Tahuri Whenua as a major reason for sticking with this was in the hopes that it might help our people!

For the financial assistance from Massey University, Te Pūmanawa Hauora, Pūrehuroa, IFNHH scholarships and my iwi Ngāti Ranginui. Thank you for the funds and scholarships that have helped keep food on the table, the bills at bay and provided the means through which to go on retreats for the PhD.

HUGE thank you to Sherina Holland for your amazing work with the final thesis editing and checking. You are a legend!

Thanks to the many staff at Massey University who have helped me in different parts of this research: nutrient analysis (Michelle Tamehana, Warwick Johnson and the Nutrition lab staff, in particular Fliss Jackson and Leiza Turnbull); computer or stats analysis and advice (Alison Sefton, Patrick Morel, Matt Levin, Yvonne Parkes, Jonathon Godfrey, Jonathan Marshall); sensory and survey development (BJ Stevenson, John Grigor, Philip Gendall, Brian Wilkinson); somewhere to work and be supported (IFNHH staff, past and present staff at Te Pūmanawa Hauora –in particular Maureen Holdaway, Hope Tupara, Monica Koia and Kay Neho).

Thanks also to other organisations such as Tahuri Whenua, Koanga New Zealand, Te Waka Kai Ora, and volunteers who have been involved in this research through the group discussions, Taewa survey or sensory trial. I hope there is something of benefit to you all in here.

I think that's it. I hope I haven't missed anyone.

KA MAU TE WEHI!!!

Abstract

The term Taewa refers to a collection of at least 18 different potato cultivars belonging to the *Solanum tuberosum* family, which have been cultivated by the Māori peoples of New Zealand for at least 200 years.

Due in part to its economic importance worldwide, the chemical and nutritional composition of today's mainstream potato varieties, and the mechanisms by which composition impacts on their culinary and gastronomic properties, have been extensively researched. However few investigators have studied the nutritional, sensory or potential health properties of Taewa, or which Taewa varieties may be the most preferred for eating. Previous Taewa nutritional research has concentrated on anthocyanin, phenolic or flavonoid content and antioxidant potential, glycoalkaloid content and starch characteristics. The variation in culinary quality and different tuber pigmentation of Taewa suggest that the composition, nutritional and sensory properties of Taewa are diverse and are therefore worthy of investigation.

The first goal of the PhD focused on identifying nutritionally beneficial or commercially viable properties of Māori potatoes. This was carried out by quantifying the macronutrient, selected micronutrient, phenolic and glycoalkaloid components and assessing antioxidant activity (using ORAC and FRAP analysis) of four Taewa varieties (Huakaroro, Karuparera, Moemoe, Tūtaekuri) and comparing them against Nadine, a potato variety commonly available in New Zealand. Analysis was carried out on tuber flesh, tuber skin and whole tuber components over two consecutive harvests. In addition, the effects of 6 months storage at 4^{o}C in 80-90% humidity and par-boiling on the nutrient content were also explored.

The second goal of this research was to ascertain the most popular, commonly eaten and commonly grown Taewa varieties; preferred Taewa cooking and eating practices; the availability of Taewa cultivars across New Zealand and to collate information regarding marketable traits or factors that might affect Taewa consumption. In order to achieve this, group discussions were held with 25 adult participants between 18 to 75 years of age from the Manawatu region. Four key themes emerged from these discussions and were used to develop 20 questions for a larger scale survey from a wider crossection of Taewa consumers.

The third goal of the research aimed to assess two characteristics of nutritional or health value (increased resistant starch in potato boiled then cooled at $4^{o}C$ for 24 h) and antioxidant capacity (by measuring the total phenolic content, DPPH and FRAP potential) in four common Taewa varieties (Huakaroro, Karuparera, Moemoe, Tūtaekuri) using a popular Taewa cooking practice (boiling whole with the skin on) to develop a Taewa product with improved health benefits. Consumer acceptance was then measured by assessing the sensory ratings of 56 adult volunteer subjects.

Results of the nutrient analysis consistently showed all four Taewa had promising nutritional value with regards to a greater nutrient content, greater accumulation of resistant starch, greater total phenolic content and antioxidant capacity compared to Nadine. The nutrients in Taewa likely to be of most biologically significant nutritional value in comparison to Nadine and other more common NZ potato cultivars included the soluble and insoluble fibre content, the minerals potassium, magnesium and iron and the vitamins thiamine, pyridoxine and niacin. All four Taewa (particularly Tūtaekuri) also showed excellent potential with regards to accumulating resistant starch and exhibiting antioxidant potential compared to Nadine.

Commonly eaten Taewa varieties included Tūtaekuri, Pawhero, Peruperu, Moemoe, Karuparera and Huakaroro. These Taewa varieties were also grown and eaten by residents in a greater number of regions across New Zealand than other Taewa varieties. Cooking and eating preferences included boiling them whole, unpeeled and cooked on their own; eating them hot or warm, with the skin on and seasoned with butter, salt and pepper. If destined to be pre-cooked or served cold, it was suggested that Taewa varieties should be waxy so as to hold together better, be purple or buttery-yellow to add interest with regards to visual appeal, be an appropriate size for the intended dish and have a sweet, nutty, buttery or delicate taste.

New Zealanders should be encouraged to both eat and grow Taewa due to their value as a popular inexpensive food of high nutritional quality, their promise as a means through which to develop functional food products with added health benefits and their cultural significance to all New Zealanders as a unique heritage food. Government agencies, those involved in the Potato Industry, research institutions and funding agencies should be encouraged to work with Māori growers, to ensure the increased production and nationwide availability of Taewa and support the development of Taewa-based functional and snack food products in way that will be beneficial to all.

List of Abbreviations

AA	Amino Acid
AO	Antioxidant Activity
ACYN	Anthocyanin
AI	Adequate Intake
Ala	Alanine
AMG	Amyloglucosidase
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists International
Arapy	Arabinose pyranoside
Araf	Arabinose furanoside
Arg	Arginine
Asp	Aspartic Acid
AusNZ EAR	Australian and New Zealand Estimated Average Requirement
AusNZ RDI / AI	Australian and New Zealand Recommended Dietary Intake / Adequate Intake
BOIL	Boiled potatoes
^{0}C	Degrees Celcius
C	Carbon
c16:0	Palmitic Acid
c18:0	Stearic Acid
c18:2n6	Linoleic Acid
c18:3n3	Alpha Linolenic Acid
C24:0	Lignoceric acid
Ca	Calcium
Cl	Chlorine
CS	Chemical score
Cu	Copper
Cy3g E	Cyanidin-3-glucoside equivalent
Cy-gal	Cyanidin-3-galactoside
Cy-glu	cyanidin-3-glucoside
Cys	Cysteine
DF	Dilution Factor

df	Degrees of Freedom
DPPH	2, 2-Diphenyl-1-picrylhydrazyl
ΔE	Absorbance (reaction) read against the reagent blank
EAA	Essential Amino Acid
EB	Eaten Before
Fe	Iron
FW	Fresh weight
FWB	Fresh weight basis
FRAP	Ferric Reducing Antioxidant Power
g	Gram
GAE	Gallic Acid Equivalent
Gal	Galactoside
Glu	Glutamic Acid
Gly	Glycine
GM	Genetically Modified
GOPOD reagent	Glucose oxidase/peroxidase reagent
h	Hour
His	Histidine
K	Potassium
KOH	Potassium Hydroxide
kg	Kilogram
ICP-OES	Inductively Coupled Plasma – Optical Emission Spectrometry
IDF	Insoluble dietary fibre
Ile	Isoleucine
Kj	Kilojoule
L	Litre
LCMS	Liquid chromatography-mass spectrometry
Leu	Leucine
Lys	Lysine
M	Molar
min	Minute
Met	Methionine
Mg	Magnesium
mg	Milligram
ml	Millilitre
Mlv-glu	Malvidin-3-glucoside

mm	Millimetre
mM	Millimolar
Mn	Manganese
MUFA	Monounsaturated Fatty Acids
N	Nitrogen
NaCl	Sodium Chloride
ND	Not Detected
NEB	Never Eaten Before
NM	Nano Meters
NRF	Nutrient Rich Foods Index
NZANS	New Zealand Adult Nutrition Survey (2008-2009)
ORAC	Oxygen Radical Absorption Capacity
P	Phosphorus
Phe	Phenylalanine
PKT group	Potato, Kumara, Taro group
Pro	Proline
PUFA	Polyunsaturated Fatty Acids
Q	Quercetin
RAW	Raw Potatoes Samples
REML	Residual Maximum Likelihood Technique
Rha	Rhamnoside
RH18	Boiled, 24 hour Cooled, Reheated to 18 degrees Celsius Potatoes
RH55	Boiled, 24 hour Cooled, Reheated to 55 degrees Celsius Potatoes
RPM	Revolutions Per Minute
RS	Resistant Starch
RSC	Resistant Starch Content
RDS	Rapidly Digestible Starch
Rut	Rutinoside
SCFA	Short Chain Fatty Acids
SD	Soluble Dietary Fibre
SDS	Slowly Digestible Starch
Se	Selenium
Ser	Serine
SEM	Standard Error of the Mean
SFA	Saturated Fatty Acid
S	Sulphur

TAC	Total Anthocyanin Content
TE	Trolox Equivalents
TFA	Total Fatty Acids
Thr	Threonine
TMAH	Trimethylammonium hydroxide
TMS	Trimethylsilyl Sugars
TPC	Total Phenolic Content
TPTZ	2,4,6-tripyridyl-s-triazine
Trp	Tryptophan
Trolox	6-hydroxy-2,5,7,8-tetramethyl-chroman-2-carboxylic acid
Tyr	Tyrosine
µg	Microgram
µl	Microlitre
Unk	Unknown
UEB	Unsure if Eaten Before
Val	Valine
Vse	Volume of Solvent Extract
V/V	Volume to Volume
W	Weight
Xyl	Xyloside
Zn	Zinc

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CHAPTER 1

LITERATURE REVIEW:

Compositional, Nutritional & Sensory Properties of Taewa

1.1. Introduction to Taewa (Māori Potato)

Varieties of Māori potatoes (collectively termed *Taewa, Peruperu, Rīwai, Parareka* or *Māhētau* depending on the tribal region or dialect of the speaker), relate to a collection of at least eighteen potato cultivars belonging to the *Solanum tuberosum* family, which have been cultivated by the Māori peoples of New Zealand for at least 200 years. The name "Taewa" is suggested to have originated from the transliteration by local Māori, of the name of a Captain Stivers who had visited the northern coast of New Zealand and introduced the potato to some of the locals (Richards, 1993). Arūhe (bracken fern root), kūmara (sweet potato), taro and yam were the chief staple food sources for Māori in pre-European times (Best, 1930; Best, 1931; Hiroa, 1949). Although less favoured, arūhe was depended upon as a reliable, plentiful food source for Māori throughout New Zealand whereas much care, time, and divine homage was invested in the successful cultivation of kūmara since a bountiful crop assured tribal prestige as well as physical and spiritual benefits (Hiroa, 1949).

The timing and details of when Māori first acquired the potato has been a matter of some disagreement due to conflicting records among early New Zealand historians and conversations had with Māori (Best, 1930; Best 1931; Harris and Niha, 1999; Roskruge, 2007). However, what is clear is that Māori were quick to recognise the benefits of the potato as a productive food crop that required less care in storage compared to kūmara, less energy expenditure in food preparation than arūhe, and provided a welcome, sustaining food supply in New Zealand regions where most traditional food crops did not grow well (such as the high-lying regions of the Ureweras or lower regions of the South Island) (Best, 1931; Hiroa, 1949).

Being seasoned agriculturalists, Māori were able to transfer, adapt or invent planting and growing techniques already mastered in kūmara cultivation to successful propagation, production and storage of Taewa (Best, 1931). Although cultivation of Taewa had a high labour component, the plentiful return of Taewa for their labour input ensured the continuation of Taewa production (Roskruge, 2007). So great was Māori success in producing Taewa crops that once established, the potato tuber not only ultimately displaced traditional staple foods as the primary carbohydrate source, but they became an important trade commodity between Māori, European settlers and sea voyagers during the early 1800s (Hargreaves, 1959; Harris and Niha, 1999; Roskruge, 1999; McAloon, 2002). Once-necessary daily hunting, fishing and wild-vegetable or fruit collecting activities also became less of a requirement and eventually, many of these activities were abandoned (Best, 1931; Hiroa, 1949).

With the introduction of higher yielding potato varieties from England and Australia during the latter part of the nineteenth century, Taewa became relegated to the gardens of the marae (region of land surrounding an ancestral house of a number of Māori families linked by genealogy) or were maintained within various whānau (family) or iwi (tribal group of Māori originating from a central ancestor) around New Zealand (Hargreaves, 1959; Hargreaves, 1963; Harris and Niha, 1999). Notwithstanding the replacement by modern cultivars in terms of economic benefit, Taewa have continued to be cultivated by Māori and other Taewa enthusiasts (Roskruge, 1999; McFarlane, 2007; Roskruge, 2007). In addition, seed collections of Taewa are being maintained by the New Zealand Institute of Plant and Food Research in Lincoln, Canterbury, New Zealand.

Taewa exhibit similar physical characteristics to the traditional potatoes of the Andes (*Solanum tuberosum subsp andigena*) with respect to their deep set eyes, irregular shapes and variable tuber pigmentations (see Figures 1.1 and 1.2).

Taewa exhibit a considerable range in variation with regard to plant growth habit (including height, width, density of plant; sprout development; tuber initiation or maturation; pest or frost resistance), vigour and flower colour. Perhaps most importantly with regards to an acceptable food source, Taewa also display diversity with regard to tuber shape, colour, cooked texture and flavour. The flesh type varies greatly when cooked, and ranges from the hard waxy texture (low dry matter content) of Huakaroro and Pāwhero which remain firm when boiled, to the floury texture (high dry matter content) of Karuparera or Tūtaekuri / Urenika which tend to disintegrate when boiled (Harris and Niha, 1999; Te Waka Kai Ora, 2010).

Although Taewa are not among those potato varieties most commonly eaten by New Zealanders today, in recent years there has been a strong demand for commercially produced Taewa within the hospitality industry in New Zealand and more increasingly within the general New Zealand consumer market as well (Roskruge, 2007).

Few investigators have studied the chemical, nutritional or potential health properties of Taewa (anthocyanin, phenolic, flavonoid content or antioxidant potential: Lewis *et al.,* 1998; Lewis *et al.,* 1999; Cambie and Ferguson, 2003; Gould *et al.,* 2006; Philpott *et al.,* 2009; Chong *et al.,* 2013: glycoalkaloid content; Savage *et al.,* 2000; starch characteristics: Singh *et al.,* 2006, Singh *et al.,* 2008a and 2008b), but the variation in culinary quality and tuber pigmentation suggest that the composition and nutritional properties of Taewa may be diverse.

Figure 1.1 A Collection of Some of the Native Potatoes of Peru.

Photo courtesy of Dr Nick Roskruge; Agricultural Scientist, Massey University, Palmerston North, NZ.

Figure 1.2 A Collection of Some of the Taewa varieties of New Zealand.

Photo by Zirsha Wharemate.

In contrast to Taewa, the chemical and nutritional composition of today's mainstream modern potato varieties, and mechanisms by which composition impacts on the culinary and gastronomic properties, has been extensively researched. Furthermore, modern potatoes are the result of 400 years of genetic manipulation to improve yield and cooking quality.

Upon the arrival of Europeans in New Zealand, there appeared to be no evidence of iron pots or metal cooking utensils (Leach, 1982). Instead, Maori cooked food within leaves or baskets such as those made with *harakeke* (NZ flax or *phormium tenax*) either by steaming in hangi (earth-ovens) between freshly cut fern leaves, boiled in a thermal hot pool, boiled in wooden receptacles using heated stones or baked in the hot embers of a fire (Buck, 1949; Best, 1902; Royal and Kaka-Scott, 2013). It is likely that Taewa would also have been cooked in these traditional methods until metal pots, utensils and ovens became available. As discussed in Section 1.2.4.2., there are a number of ways potatoes are processed and cooked in modern-times, thus it is of interest to discover if Taewa are still preferred to be cooked by traditional methods, modern methods, or a combination of both.

One of the marketable qualities that Taewa have is the fact that they are a uniquely New Zealand product, carrying intrinsic cultural and historical value as a heritage food crop. Because of this value, extensive efforts have been made by a number of organisations such as Tahuri Whenua, Koanga NZ Institute and Te Waka Kai Ora to preserve, promote and disseminate Taewa seed crops to growers throughout New Zealand, and to preserve this food source for future generations. Potentially, this quality as a unique taste of New Zealand is one that could be promoted within the hospitality and tourism industries. Recent research has shown that potential markets for fresh Taewa and Taewa-derived products already exist (Roskruge, 2007), and therefore, growing Taewa commerically is a potentially viable enterprise.

1.2. Origin and History of the Potato as a Food

1.2.1. Origin and Classification of the Potato

The modern potato (*Solanum tuberosum L.*) originated from, and was domesticated in, the Andes highlands of South America (Spooner *et al.,* 2005) where the potato has been intimately associated with Andean culture, religion, traditional medicine and used as a food source for over 8,000 years (Brush *et al.,* 1981; Ritter *et al.,* 2008; Lutaladio and Castaldi, 2009).

The name "potato" is a European derived word which came from the Caribbean name for the sweet potato plant *Ipomea batatas*, (which also originated in South America), commonly referred to by the locals as "batata" or "patata" (Burton, 1989). The potato belongs to the *Solanaceae* or nightshade family (the same genus as tomato and eggplant), and was thus classified *Solanum tuberosum*. Its leaves are poisonous, and in addition to this, a potato tuber left too long in the light will begin to turn green. The green substance is chlorophyll which in itself is harmless, however, it may indicate an increased production of harmful glycoalkaloids such as α-solanine and α-chaconine which cause the potato to taste bitter and may cause illnesses in humans ranging from gastrointestinal disturbances at low levels (1-2 mg/kg bodyweight), to neurological disorders at higher levels (3-4 mg/kg bodyweight), to possible death at levels above 5 mg/kg bodyweight (Friedman *et al.,* 1997). Recognition of these facts contributed in part to the initial ill-acceptance of the earlier introduced potato tubers as a food source in Europe and the UK (Burton, 1989).

The potato plant is an herbaceous annual that can grow up to a metre tall (Figure 1.3) and produces tubers which actually arise from swollen stems (Figure 1.4).

Figure 1.3 Huakaroro Potato Plant.

Photo by Zirsha Wharemate

Figure 1.4 **Potato Plant (Osprey) With Tubers.**

Photo courtesy of Dr Nick Roskruge; Agricultural Scientist. Massey University, Palmerston North, NZ.

1.2.2. Migration of the Potato

The potato was introduced into Europe on several occasions during the 16th century, although they were initially deemed fit only for servants or those of a lesser class and treated with mistrust and superstition (Ritter *et al.,* 2008; Lutaladio and Castaldi, 2009). Tubers, from which the modern potatoes (as we now know them) were developed, were also introduced into Europe, but most didn't survive the long-day climate.

However, once potatoes had adapted from the short daylight environment of the Andes, to the longer daylight European environment, they became a well-established and accepted crop (Burton, 1989; Harris, 1999). They were named "Potatoes of Virginia" or distinguished as the "Irish potato" or "white potato" (Burton, 1989).

During the 17th century, potatoes spread into many other parts of the world and selection of tubers most suitable to the environment in which they were being grown led to its successful cultivation and production worldwide by the 19th century.

In fact, dependence on the potato crop and abandonment of other crops in Europe became sufficiently great that failures of successive potato crops due to a late blight caused a famine in Ireland that resulted in around a million deaths during the 1840's (Salaman, 1985). The successful cultivation of the potato in China and India led to these countries becoming the first and third most important potato producers by the second half of the 20th century (Bradshaw and Ramsay, 2009).

Although it is estimated that over 4,000 potato cultivars are currently being grown (Camire *et al.,* 2009), modern cultivars are estimated to represent less than 1% of the available genetic diversity of wild species, as approximately 200 wild potato varieties exist in addition to thousands of primitive species (Rama and Narasimham, 1993; Burlingame *et al.,* 2009; Navarre *et al.,* 2009).

1.2.3. Economic Importance of Potato

Potatoes have now been developed that grow in a vast range of environments (Hawkes, 1990) which not only reflects the potatoes' potential genetic diversity, but also bodes well for their potential as a major world-wide crop, as currently over 160 countries around the world are involved in potato production (Camire *et al.,* 2009). Predictions of worldwide demand for potato to the year 2020 suggest that the global demand for potatoes will increase by 1% per year, and more specifically by 2% per year in developing regions of the world with Sub-Saharan Africa and South Asia both increasing demand by 3% per year (Scott *et al.,* 2000).

Potatoes yield more calories per acre than any other major crop, a quality that is becoming more important with regards to the increasing world population, food shortages, competition for farmland and food price inflation (Navarre *et al.,* 2009). Today, the potato is the fourth most important food crop in the world after rice, wheat and maize, and is the world's number one non-grain food commodity, with an annual production in 2012 estimated to be above 350 million tonnes (FAOSTAT, 2014a). In 2005 for the first time, countries in the developing world (particularly China and India) produced more potatoes than countries in the developed world, and this still remains the case (FAO-IYP, 2008; FAOSTAT, 2014a).

In 2012, New Zealand potato production was estimated to be 550,000 tonnes and besides apples, was New Zealand's top crop commodity. Although New Zealand is not one of the world's leading potato producers, it is one of the top five countries in terms of highest potato yields (FAOSTAT, 2014a).

1.2.4. Uses of Potatoes and Consumption Trends

1.2.4.1. Industrial Uses

While the majority of potatoes are used as a source of human food, the potato does have other uses. An extensive review of the industrial uses of the potato is outside of the scope of this present research, however, these include the use of potato as an animal feed; the extraction of potato starch for use as a food ingredient or for glucose, use in dextrin and alcohol production; the extraction of potato starch amylose for use in edible films in food packaging or providing water resistance to paper; the extraction of potato starch amylopectin for use in strengthening fibres or as sizing agents in papers and textiles, or use as a thickening agent in foods (Jackson, 1962; Rama and Narasimham, 1993; Li *et al.,* 2006; Bradshaw and Ramsay, 2009).

Since the 1990s, potato plant cells have also been used for developing vaccines against bacteria and viruses (Li *et al.,* 2006). A review of medicinal uses of potato-derived products found promising results for the treatment of dyspeptic complaints (using raw potato); weight reduction (using potato protease inhibitor); and protease-induced skin inflammation (using a topical potato protein mixture) (Vlachojannis *et al.,* 2010).

1.2.4.2. Edible Uses

Although potatoes were traditionally cooked as fresh tubers and then consumed after boiling, baking or roasting, since the mid-1800s, potatoes have been processed into a number of edible products to suit the taste, flavour and convenience appeal of the consumer (Kirkman, 2007). From the ancient *chuno* (dehydrated potato) production by the Andean peoples, to the initial processing of potatoes into chips and frozen French fries in the early 1950s, potato processing now extends worldwide and includes products destined for use in a wide variety of forms such as frozen potato products; chilled potatoes; frozen chips (French fries); instant mashed potato; potato crisps; canned potatoes and dehydrated potato products (Kirkman, 2007; Keijbets, 2008). Consumer popularity of pre-prepared, convenience food products (Tillotson, 2002; Sloan, 2009); has fuelled the increasing demand for processed potato products (Agriculture and Horticulture Development Board (AHDB), 2012).

1.2.5. *Potato Consumption*

More than one billion people worldwide eat potatoes, and global potato production exceeds 300 million metric tons (International Potato Centre (CIP), 2014). Potatoes remain an essential crop in Europe, especially in Eastern and Central European countries such as Belarus, Ukraine, Poland, Kazakhstan and the Russian Federation where per capita consumption is still the highest in the world. In 2009, consumption estimates of grams of potato consumed per day were 501 g in Belarus; 365 g in Ukraine; 320 g in Poland; 314 g in Kazakhstan and 312 g in the Russian Federation compared to 286 g in the United Kingdom, 147 g in the United States of America and 146 g in Australia (Food and Agriculture Organisation of the United Nation Statistics (FAOSTATS, 2014b). The 1997 National Nutrition Survey showed that on average, adult New Zealand consumers of potatoes ate 180 g of potatoes (in all forms) per day with males consuming around 219 g per day and females 140 g per day (Russell *et al.,* 1999). However in 2009, estimates of per capita consumption of potato were 148 g per day (FAOSTATS, 2014b). While the consumption of potatoes may be slowly declining in New Zealand and other developed countries such as United Kingdom (AHDB, 2013) and the United States of America (National Potato Council, 2013), potato consumption has been increasing in developing countries, with the most rapid increase over the past few decades occurring in developing countries in southern and eastern Asia (Scott *et al.,* 2000; Bradshaw and Ramsay, 2009; Kearney, 2010; CIP, 2014).

In developed countries, consumption of fresh retail potatoes has dropped significantly, while consumption of processed potato products has risen to account for around 60% of the daily potato consumption (Kirkman, 2007). From 1988 to 2011, the consumption of fresh retail potatoes in the UK dropped from about 50% of the total potato products to 35%, whereas the consumption of frozen, chilled potato products steadily rose from less than 20% to greater than 35% and potato chips (also termed potato crisps) rose from 10% to 15% of the total products during the same period (AHDB, 2013). Between 1970 and 2011 in the United States of America, the contribution of fresh retail potatoes to the total proportion of potato products consumed dropped from 50% to 26%, while contribution of frozen potato products rose from 23% to 44% and chips or shoestring products remained around 14 to 15% of the total potato products (National Potato Council, 2014).

According to a report of factors that affected potato purchasing trends within New Zealand, while potatoes are the biggest selling and most popular vegetable in New Zealand, consumption of fresh retail potatoes has been declining (Horticulture NZ, 2006).

A study carried out between November 2004 and August 2006 found that although 53% of New Zealanders are likely to eat fresh potatoes four times a week, 44% of the New Zealand population has decreased their fresh potato consumption in favour of pasta, rice or convenience foods (Horticulture NZ, 2006). On the other hand, the frozen processed potato industry in New Zealand has experienced significant growth over the last two decades (Potatoes NZ, 2014), with total NZ frozen potato exports increasing in value from $NZ 3.25 million in 1993 to over $NZ 85 million in 2013 (StatsNZ Infoshare, 2014).

1.3. Nutritional Potential of Potatoes

Potatoes are already one of the most commonly eaten vegetables in the developed world, and their consumption has been increasing in developing countries (Section 1.2.5.1), and since potatoes are both abundant and inexpensive, they have the potential to provide excellent nutritional value worldwide (Salaman, 1985; Burton, 1989).

In populations where potato consumption is high (e.g. Europe, North America, New Zealand), potatoes can make an important dietary contribution of carbohydrate, energy, phenolic compounds, ascorbic acid (vitamin C), potassium, manganese as well as moderate contributions of dietary fibre (particularly when skins are also eaten), magnesium, phosphorus, iron and B-vitamins such as folate, niacin, thiamine and pyridoxine (Camire *et al.,* 2009; Freedman and Keast, 2011; Ministry of Health, 2011; Liu, 2013). For developing areas of the world such as Africa, China and India, where there are food security concerns and major micronutrient deficiencies, the carbohydrate, energy and micronutrient value of potatoes provide potential nutritional benefit, particularly in populations where potato consumption has been increasing.

However, due to the fact that a growing percentage of potatoes appear to be destined for use as french fries, wedges, hot chips or potato snacks it is also likely that potatoes are increasingly being consumed in a form that has a much greater contribution from fat, saturated fat, and salt. Estimations of nutrient contributions from potato within the New Zealand diet will be discussed with relation to results from the 2008/09 New Zealand Adult Nutrition Survey (NZANS) in Section 1.3.1 .

1.3.1. Nutrient Potential of the Potato Tuber

The ultimate composition of a potato tuber is dependent on a number of factors, although the innate genetic characteristics associated with each cultivar are thought to be among the most significant (Toledo and Burlingame, 2006). This section will introduce the nutrients that are likely to be found in appreciable quantities in potatoes, the range in levels of those nutrients across potato cultivars and those specific nutrients for which potatoes may be of particular value nutritionally. Other factors affecting nutrient composition of potato tubers will be discussed in more detail in Section 1.4

In 1989, Lisinska and Leszcynski provided a summary of the composition of potato tubers sourced from worldwide data from the previous 100 years. In 2009, Burlingame and others presented a more recent literature review of potato compositional data collated from four Solanum potato species (*S. Tuberosum, S. Brevidens, S. S.acaule and S.commersonii*) originating from countries including Argentina, Korea, Peru, Philippines, Spain, Canada, Italy, India, Greece, Germany, New Zealand and USA. The information presented in Tables 1.1 to 1.9 includes information from two major reviews (Lisinska and Leszcynski, 1989 and Burlingame *et al.,* 2009) of potato nutrient content from modern and native Andean potato cultivars and data on potato nutrient content from modern New Zealand potato cultivars as reported in the sixth edition of The Concise NZ Food Composition Tables (Athar *et al.,* 2003).

These three information sources provide a basis from which to gauge the potential nutrient composition of potatoes as they include a wide range of potato cultivars –both modern and traditional, which have been sourced from around the world as well as New Zealand. However, other sources of information will also be included where relevant.

Potatoes and their products are not generally consumed by humans unless they have been cooked. While the nutrient composition of a raw potato will be affected by post-harvest handling, processing and cooking methods (see Section 1.4), presenting nutrient content in a potato's natural state provides a type of "benchmark" of a cultivar's *potential* nutritional value compared to other cultivars and a means by which changes in nutrient content due to post-harvest handling and processing can be measured and losses minimised. Nutrient content of new or less known potato varieties (such as Taewa) are generally assessed in their natural state prior to their further advancement into the marketing arena.

Additionally, due to the extensive means by which a potato might be processed, cooked or prepared prior to consumption, a thorough investigation of the nutrient composition of the various forms of cooked potatoes was outside of the scope of this thesis.

Thus, nutrient data in the following section will be expressed as the estimated nutrient amount per 100 grams of raw, fresh potato component in an effort to provide comparable information across a range of geographical sources, potato cultivars and time periods.

The 2008/09 NZANS survey provides the basis by which nutrient contributions from potatoes in the current New Zealand diet are estimated. The 2008/09 NZANS survey was carried out from October 2008 to October 2009, collecting information from 4721 New Zealanders aged 15 years and over. In this survey, food items were allocated into food groups in order to estimate nutrient sources. Food items such as mashed, boiled, baked potatoes and kumara, hot chips, crisps, hash browns and wedges, potato dishes (stuffed, scalloped potatoes), taro roots and stalks were allocated into one group- "Potatoes, kumara and taro" (Ministry of Health, 2011) This potato, kumara and taro group will hereafter be referred to as the PKT group in this thesis.

1.3.1.1. Proximate Analysis of Potatoes

In food nutrient analysis, the proximate or Weende analysis is a quantitative method used to determine the major nutrients in food or animal feed. It is also a method used to assist in determining potential end use and tuber quality of a potato variety or a potato crop, as the dry matter and starch content of tubers are two of the prime characteristics used by potato processors to initially evaluate a crop. Proximate analysis partitions the food components into categories by means of common chemical properties and thus, generally includes an estimation of moisture / water; dry matter content; carbohydrate; protein; fat; dietary fibre; and ash content. Often, the potential energy contribution that might be expected to be derived from the energy-providing nutrients will also be calculated.

The dry matter content of potato tubers around the world (including modern cultivars as well as native Andean varieties) ranged from 13.0 to 37.3% on a fresh weight basis with the remaining 62.7 to 87.0% of the potato comprised of water (see Table 1.1 and 1.2). The dry matter content values obtained from analysis of main-crop harvest New Zealand commercial potato varieties between 1990 and 1994 also fit within this range as the percentage dry matter in whole tubers of Ilam Hardy, Rua and White Delight were 18.3%, 19.3% and 22.5% respectively (Genet *et al.,* 1997).

According to Lisinska & Leszczynski (1989), the mean carbohydrate (as starch), protein and lipid content of potato tubers is 17.5%; 2.0% and 0.12% fresh weight respectively. Thus carbohydrate contributes the greatest to the dry matter portion and due to the much lower protein and fat content, is also the main contributor to potential energy from the potato tuber.

As with dry matter content, contributions from carbohydrate, protein, fibre, ash and fat in New Zealand cultivars appears to align closely with the average range for internationally reported potato cultivars (Table 1.1 and Table 1.2).

Based on the Australian and New Zealand Estimated Average Requirement (AusNZ EAR) and nutrient ranges shown in Table 1.1, a 150 g portion of whole, raw potato tuber may have the potential to provide 3 – 8% of an adult's daily energy needs (depending on the physical activity level, weight and health condition of the individual); 2 – 18% of the protein requirements and 2 – 22% of an adult's daily fibre requirement. Processing and treatments involving heat, peeling, and water have varying effects on the resulting availability and digestibility of a raw potato tuber's nutrients (see Sections 1.3.1.2. and 1.4.5.). However, general home-cooking techniques of a comparable cooked portion from the same potato cultivar will generally provide similar, if not slightly higher contribution from the energy, carbohydrate, protein and fibre nutrients relative to that in its raw state. Differences are due in part to the loss of tuber moisture although varietal differences also have an effect (Toma *et al.,* 1978).

Table 1.1 Comparisons of Proximate Nutrients in Whole, Raw Potato Tubers From International and New Zealand Potato Cultivars.

Where daily nutrient requirements are based on Australian and New Zealand Estimated Average Requirement (AusNZ EAR), for adults 19-70 years and the Potential Contribution is the percentage of the nutrient's AusNZ EAR that might be expected to be provided in 100 g of whole, raw potato across the tabulated data. Range = lowest to greatest average nutrient content achieved by the cultivars included in the relevant report.

Component	Units	Lisinska & Leszcynski, 1989.	Burlingame *et al.*, 2009.	Galdon *et al.*, 2012	Combined NZ Cultivars*	NZ Red King*	Daily Nutrient Requirement	Potential Contribution #
		Range (content %)	Range (content %)	Range (content %)	Mean	Mean	AusNZ EAR	% of AusNZ EAR
Energy	kJ /100 g		240 – 423		299	297	8 – 13 MJ [a]	2 – 5%
Moisture	g /100 g	63.2 – 86.9	62.7 – 87.0	70.1 – 78.7	78.5	81.0		
Dry matter	g /100 g	13.1 – 36.8	13.0 – 37.3	22.3 – 29.9	21.5	19.0		
Carbohydrate	g /100 g	8.0 – 29.4 [b]	9.1 – 22.6 [b]	11.3 – 20.5 [b]	15.5 [c]	15.5 [c]		
Protein (total nitrogen x 6.25)	g /100 g	0.7 – 4.6	0.9 – 4.2	0.7 – 2.5	2.4	2.4	37 – 52 g	1 – 12%
Fibre	g /100 g	0.2 – 3.5	0.3 – 3.7	1.6 – 3.0 [d]	1.3 [e]	1.3 [e]	25 – 30 g	1 – 15%
Ash	g /100 g	0.4 – 1.9		0.6 – 0.9	1.2	1.2		
Fat	g /100 g	0.0 – 0.2	0.1 – 0.5		0.1	0.1		

Key: * From The Concise NZ Food Composition Tables 6[th] Ed. Athar *et al.,* 2003; Galdon *et al.,* 2012. N = 10 cultivars from Canary Islands, Spain, 6 grown in two locations; [#] Home-cooking procedures are likely to provide similar, if not increased contributions from energy, protein and fibre and highly digestible carbohydrate from a comparable just-cooked portion of whole potato tuber. [a] For a reference female of 61 kg, reference male of 76 kg, 19 – 70 years of age and light to moderate activity; [b] Represents starch component of carbohydrate only; [c] Available carbohydrate (sum of mono- + disaccharides + oligosaccharides + polysaccharides, excluding fibre); [d] AOAC 991.43 method of determining fibre; [e] Englyst 1988 method of determining fibre.

Table 1.2 Comparisons of Proximate Nutrients in Raw Potato Flesh from Individual NZ Potato Cultivars (on a Fresh Weight basis) to Daily Nutrient Requirements.

Where daily nutrient requirements are based on Australian and New Zealand Estimated Average Requirement (AusNZ EAR), for adults 19-70 years and the Potential Contribution is the percentage of the nutrient's AusNZ EAR that might be expected to be provided in 100 g raw potato flesh across the tabulated data.

Component	Units	Combined NZ cultivars*	NZ Ilam Hardy*	NZ Rua*	NZ Red King*	Daily Nutrient Requirement	Potential Contribution [#]
		Mean	Mean	Mean	Mean	AusNZ EAR	% of AusNZ EAR
Energy	kJ/100 g	291	279	291	291	8 – 13 MJ [a]	2 – 4%
Moisture	g/100 g	78.2	79.1	79.9	79.6		
Dry matter	g/100 g	21.8	20.9	20.1	20.4		
Carbohydrate	g/100 g	15.4 [b]	14.8 [b]	15.5 [b]	15.4 [b]		
Protein (total nitrogen x 6.25)	g/100 g	2.1	2.0	1.8	2.1	37 – 52 g	3 – 6%
Fibre	g/100 g	1.4 [c]	1.6 [c]	1.6 [c]	1.2 [c]	25 – 30 g	4 – 6%
Ash	g/100 g	1.0	0.9	0.8	1.0		
Fat	g/100 g	0.1	0.1	0.2	0.1		

Key: * From The Concise NZ Food Composition Tables 6th Ed. Athar *et al.*, 2003; [#] Home-cooking procedures are likely to provide similar, if not increased contributions from energy, protein and fibre and highly digestible carbohydrate from a comparable just-cooked portion of potato flesh. [a] For a reference female of 61 kg, reference male of 76 kg, 19 – 70 years of age and light to moderate activity; [b] Available carbohydrate (sum of mono- + disaccharides + oligosaccharides + polysaccharides, excluding fibre); [c] Englyst 1988 method of determining fibre.

1.3.1.2. *Carbohydrate Components*

Foods can contain a range of chemically distinct carbohydrates, with an extensive array of metabolic and gastrointestinal properties. These properties, along with the food's biological origin and subsequent processing, can have a significant impact in determining the overall nutritional attributes of the final food matrix prior to consumption. Therefore by selecting for, or manipulating the carbohydrate content and properties within foods, opportunities for developing products with improved health benefits or for people with specific dietary needs (such as diabetics) can be explored.

Starch, sugars and non-starch polysaccharides (cell wall components, dietary fibre) constitute the major carbohydrate fractions of plants. Traditionally, starch-based plant foods such as grains, tubers and legumes have been the major staples in many cultures (Wursch, 1989) and as the primary energy source for many animals, including humans (Guilbot and Mercier, 1985).

Starch is composed of amylose (an essentially linear polymer of α-(1,4)-linked D-glucopyranosyl units with few branches) and amylopectin (large, highly branched polymers consisting of α-(1,4)-linked D-glucopyranosyl units with non-randomly distributed α-(1,6)-D-glucopyranosyl units) which are organised into a semi-crystalline structure (Chung *et al.,* 2011).

The digestibility of dietary starch has been classified in a number of ways. Englyst *et al.* (1992) classified dietary starch on the basis of its relative digestibility by pancreatic amylase, and thus grouped types of starch into rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS). Brown *et al.* (1999) further classified RS into four forms:

RS_1: physically entrapped, inaccessible starch such as is found within whole or partially milled seeds;

RS_2: native granular starch consisting of ungelatinised resistant granules such as is found in raw potato, green banana, some legumes and high-amylose starches;

RS_3: non-granular retrograded starch, generally resulting from food processing applications, such as in cooked and cooled potato, cooked and cooled rice, bread or cornflakes;

RS_4: chemically modified starch, such as etherised, esterified, or cross-bonded starches used in processed foods.

The relative digestibility of starch is important nutritionally for a number of reasons. Firstly, the starch polymers amylose and amylopectin are broken down, initially by salivary amylase in the mouth and then by pancreatic amylase in the small intestine, to maltose and glucose.

Further hydrolysis of maltose and glucose will provide 16 – 17 kJ of energy per gram of glucose. Thus starches that are more digestible will produce more utilisable energy.

Following digestion, the glucose products of starch digestion will affect blood glucose levels and will thus need to be monitored in people with diabetes or with glucose intolerance. Rapidly digestible starches are likely to cause a rapid blood glucose rise and a higher glucose peak but then an earlier and greater fall in glucose. Slowly digestible starch is more likely to cause a lower but more prolonged rise in blood glucose level. Long-term, chronic elevated blood glucose contributes to a number of health problems, including glucose intolerance and type 2 diabetes. Glucose intolerance has become recognised as a core feature of metabolic syndrome and type 2 diabetes (Seidell, 2000), and is a condition in which cells are unable to remove glucose from the blood effectively following a meal, ultimately resulting in an extended hyperglycaemic blood state. Diabetes is characterised by chronic hyperglycaemia resulting from defects in insulin secretion, insulin action, or both following dietary ingestion of carbohydrate, fat and protein (WHO, 1999). Both of these conditions lead to an increased prevalence of circulatory disorders, renal dysfunction, problems with visual acuity and widespread tissue damage (WHO, 1999).

Starch which is unable to be digested by pancreatic amylase in the small intestine (termed resistant starch) will pass into the colon where it can act as a substrate for the production of short chain fatty acids by colonic bacteria. This process not only provides an additional means of energy production for the body, but has also been proposed to assist in increasing the population of beneficial bacteria such as *bifidobacteria* in the large bowel (Cummings *et al.,* 1996; Topping and Clifton, 2001), thus also having the potential to promote bowel health.

Starch occurs in a number of forms that differ in molecular structure, and this and a number of other factors affect the relative digestibility of starch. Some of these factors include:

- Origin of the plant starch (uncooked starches from roots and tubers e.g. potato, are generally less digestible than those from uncooked cereal starches such as wheat, maize, rice (Dreher *et al.,* 1984));
- Type and degree of starch crystallinity (starches with B-type x-ray diffraction pattern crystalline forms are likely to be less digestible (Ring *et al.,* 1988));
- Granule size (larger sized granules are generally less digestible (Dhital *et al.,* 2010));
- Amylose/amylopectin ratio (starches with a greater amylose to amylopectin ratio are less digestible (Leeman *et al.,* 2006));

- Amylose – lipid complex formation (formation of amylose-lauric acid complexes lowers digestibility (Crowe *et al.,* 2010));
- Amylose and amylopectin chain length (Longer chain lengths are less digestible (Jood *et al.,* 1988; Chung *et al.,* 2011)).

Cooking or processes such as milling and grinding, can make less digestible starches more susceptible to hydrolysis by amylase (Dreher *et al.,* 1984). The application of heat (and moisture) during cooking, disrupts starch granules which leads to the breakdown of crystalline forms of starch, the leaching of amylose, and thus allows greater digestibility (Hoover *et al.,* 2001). However, upon cooling, starch polymer chains (mostly amylose) will re-associate as double helices stabilised by hydrogen bonds in a process called retrogradation and become entirely resistant to amylase digestion (Sajilata, 2006). Milling and grinding reduces the starch particle size, and helps remove physical barriers such as fibre, thus allowing easier access to the starch by amylase. Thus, each cooking and processing method can affect the structure of the starch in various ways, and ultimately affect the digestibility of the starch and its nutritive value.

In the potato tuber, starch may contribute from 8 – 29% of the tuber's fresh weight and thus is the major contributor to the total tuber carbohydrate content (Table 1.3). Raw potato starch cannot be digested by humans, so potatoes are generally prepared for consumption by a number of cooking methods involving the application of heat (and moisture) for varying lengths of times, include boiling (with or without the skin), baking, steaming, microwaving or frying. Following cooking, potato starch becomes highly digestible, but upon cooling, a percentage of the potato starch will retrograde and form RS_3 starch. The changes that occur in starch during heating and cooling have a profound influence on the functional properties of foods but are also of significant nutritional importance because they influence starch digestibility in the gastrointestinal tract as previously discussed.

As fibre components are unable to be digested by pancreatic amylase, they do not provide any energy per se. However, increasing dietary fibre provides potential health benefit with regards to maintaining regular laxation (insoluble fibre), delaying gastric emptying, slowing glucose absorption, lowering blood cholesterol and contributing to increased satiety (Wong and Jenkins, 2007; Lattimer and Haub, 2010). Certain fibre components as well as resistant starch may provide additional health benefits by providing substrates for beneficial colonic bacteria (Cummings, *et al.,* 1996; Topping & Clifton, 2001), and thus providing the potential for improved bowel health.

Table 1.3 **Carbohydrate Components of Whole, Raw Potato Tubers (on a Fresh Weight basis) From International and New Zealand Sources.**

Range = lowest to greatest average nutrient content achieved by the cultivars included in the relevant report.

Component	Units	Lisinska and Leszcynski, 1989.	Burlingame *et al.,* 2009.	Combined NZ Cultivars*	NZ Red King*
		Range	Range	Mean	Mean
Starch	g/100 g	8.0 – 29.4	9.1 – 22.6	15.2	15.2
Insoluble fibre	g/100 g		0.4 – 2.5	0.6 #	0.6 #
Soluble fibre	g/100 g		0.9 – 1.2	0.7 #	0.7 #
Total sugars	g/100 g	0.1 – 8.0		0.3	0.3
Sucrose	g/100 g	0.4 – 6.6	0.1 – 1.4	0.1	0.1
Glucose	g/100 g	0.5 – 1.5	0.0 – 0.3	0.2	0.2
Fructose	g/100 g	0.2 – 1.5	0.0 – 0.2	0.1	0.1

Key: * From The Concise NZ Food Composition Tables 6th Ed. Athar *et al.,* 2003; # Determined from an analysis of soluble and insoluble non-starch polysaccharides. Note: Since cooked potato starch is highly digestible, it can be expected that when just cooked, a potato cultivar's available carbohydrate content will include the combined quantity from both the starch and sugars.

Differences in sugar content have been observed both, within the same potato cultivar, and between cultivars (Amrein *et al.,* 2003, Halford *et al.,* 2012b), which can be attributable to inherent genetic attributes, maturity, size, seasonal or agronomic conditions (Halford *et al.,* 2012a and 2012b). Variability in post-storage conditions can also affect sugar content, as storing fresh tubers below 7-10°C causes the accumulation of reducing sugars (Marquez and Anon, 1986; Coffin *et al.,* 1987). Total sugar content in fresh weight potato tubers may range from 0.05 – 8% (Table 1.3), but normally only averages around 0.5% fresh weight (Lisinska and Leszcynski, 1989), so is likely to be of minor nutritive importance in potatoes.

A low reducing sugar content (less than 2% fresh weight of total glucose and fructose content) is preferable in the potato processing industry because reducing sugars and free asparagine can cause the undesirable formation of the carcinogen acrylamide (Amrein *et al.,* 2003), and post-cooking darkening in fried potatoes (Marquez and Anon, 1986; Rodriguez-Saona, 1997; Rama and Narasimham, 1993), thus negatively impacting nutritional quality and sensory acceptability.

The 2008/09 NZANS survey estimated that together, the PKT group contributed 17.0 g of the median usual daily carbohydrate for female adults, 23.9 g for male adults but 33.2 g for 16 – 18 year old males (8.2%, 8.6%, 10.8% of the total dietary carbohydrate intake respectively).

Thus potatoes are likely to provide a significant portion of the daily carbohydrate intake for New Zealand adults, particularly 16 – 18 year old males (Ministry of Health, 2011).

Based on the AusNZ EAR and insoluble and soluble fibre content shown in Table 1.3, 150 g of the Combined NZ potato cultivars may provide 2.0 g of fibre (7-8% of an adult's AusNZ EAR daily fibre requirement). Results from the 2008/09 NZANS survey confirm that potatoes are likely to provide a significant portion of daily fibre requirements as the PKT group contributed 1.9 g of the median usual daily fibre for female adults and 2.7 g for male adults (11.1% and 12.3% of the total dietary fibre intake respectively). Young adults (16 – 18 years) were likely to have an even greater dietary contribution of fibre from the PKT group: 15.6% for males, (3.3 g fibre/day) and 14.9% (2.3 g fibre/day) for females (Ministry of Health, 2011).

1.3.1.3. Protein and Amino Acids

Proteins have a number of functions in the human body including being an integral part of bone, muscle, skin, membranes and other bodily components and as such have a role in growth and maintenance. Proteins also function as enzymes, hormones, antibodies, maintaining fluid and electrolyte balance, and transporting vital substances around the body. When necessary, digestion of protein can also provide 16 – 17 kJ energy per gram of protein.

Proteins are polymers of amino acid units, and twenty commonly occurring amino acids are required to make the proteins that humans need. The human body has the capacity to make most of these amino acids from other substrates, but lacks the enzymes or capacity to make sufficient amounts of nine of the amino acids that are required. These are termed essential amino acids (EAA) as they must be provided in the diet and include histidine (His), isoleucine (Ile), leucine (Leu), lysine (Lys), methionine (Met), phenylalanine (Phe), threonine (Thr), tryptophan (Trp) and valine (Val).

Each food protein has a distinctive amino acid pattern with some containing higher proportions of certain amino acids than others. Some food proteins may have a low amount of one of the essential amino acids (termed a limiting amino acid), and thus the remaining amino acids can only be used at a level to balance the lower one. Wheat and rice proteins are limiting in lysine, whereas pulses are limiting in methionine. On the other hand, whole chicken egg protein is not limiting in any essential amino acid and thus is used as a standard by which to gauge an appropriate pattern for amino acid consumption by humans.

Thus food proteins can be classified based on the ratio of limiting amino acids present in a protein and given a score between 0 to 100 (termed the Chemical Score (CS) or Amino Acid Score), where 100 (highest quality) is assigned to whole egg protein. Protein quality can be further classified based on the digestibility and the availability of the protein. A food protein which contains an amino acid pattern that closely aligns to the pattern required by humans, is easily digestible and is biologically available is regarded as being of high protein quality and high biological value (Lisinska and Leszcynski, 1989).

Previous studies have shown potato protein to have a well-balanced amino acid profile (Galdon *et al.,* 2010), but different cultivars show a range in the available contribution of EAA required for a 70kg human adult (Table 1.4), and a range in CS score (between 57 – 95) when compared to whole egg protein (Kaldy and Markakis, 1972; Lisinska and Leszcynski, 1989; Athar, 2003; Galdon *et al.,* 2010; Peksa *et al.,* 2013). Such CS estimates suggest potatoes are likely to have a greater CS than wheat flour (50) with certain cultivars having a CS greater than rice (75) (Kaldy and Markakis, 1972; Lisinska and Leszcynski, 1989).

The first limiting amino acids found in potato proteins are likely to include the sulphur amino acids methionine and cysteine, however leucine or lysine may also be limiting depending on the cultivar, cultivation conditions and storage conditions used (Kaldy and Markakis, 1972; Markakis, 1975; Lisinska and Leszcynski, 1989; Galdon *et al.,* 2010; Peksa *et al.,* 2013).

When compared to other crop plants, potatoes contain a relatively small amount of protein (2.0–2.5% FW), however in regions of high potato consumption (see Section 1.2.5), they can be an important element of the human diet due to the high quality potato protein (generally about 70% compared to whole egg protein) (Markakis, 1975).

Based on the AusNZ EAR and nutrient ranges of NZ potato cultivars shown in Table 1.1, and the 148g daily per capita potato consumption of New Zealanders (FAOSTATS, 2014b), a 150 g portion of whole potato tuber may have the potential to provide 3.6 g protein (7 – 10% of a NZ adult's daily protein needs) as boiling, microwaving or baking whole potato did not cause significant changes in protein content except when peeled (Toma *et al.,* 1978). Results from the 2008/09 NZANS survey suggest that in general, the contribution of daily protein from potatoes is likely to be somewhat less than 3.6 g/day as the survey found that the PKT group contributed to 3.2% of the total dietary protein intake (3.3 g/day for males and 2.3 g/day for females overall, i.e. 6% of the AusNZ EAR). However for adults 16 – 18 years and females 19 – 30 years, potato protein may provide up to 8 – 9% of their respective AusNZ EAR daily protein requirements (Ministry of Health, 2011).

Table 1.4 **Comparisons of Amino Acid Content of Whole, Raw Potato Tubers (Fresh Weight Content) From International and New Zealand Sources.**

Where Daily Nutrient Requirements are based on the Joint WHO, 2007 Human Essential Amino Acid (EAA) requirements for a 70kg adult and the Potential Contribution is the percentage of the nutrient's EAA that might be expected to be provided in 100 g of whole, raw potato across the tabulated data. Range = lowest to greatest average nutrient content achieved by the cultivars included in the relevant report.

Component	Unit	Lisinska and Leszcynski, 1989.	Galdon *et al*., 2010	NZ Rua flesh[b]	Daily Nutrient Requirements	Potential Contribution
		Range [a]	Range	Mean	EAA	% of EAA
Alanine	mg/100 g	2 – 60	0 – 160	65		
Arginine	mg/100 g	10 – 176	1 – 184	92		
Aspartic Acid	mg/100 g	30 – 214	4 – 129	326		
Glutamic Acid	mg/100 g	18 – 184	3 – 256	226		
Glycine	mg/100 g	<1 – 13	3 – 136	59		
Histidine	mg/100 g	4 – 79	5 – 153	34	700 mg	1 – 22
Isoleucine	mg/100 g	4 – 61	3 – 142	74	1400 mg	<1 – 10
Leucine	mg/100 g	2 – 38	7 – 206	109	2730 mg	<1 – 10
Lysine	mg/100 g	2 – 77	0 – 54	100	2100 mg	0 – 5
Methionine	mg/100 g	2 – 31	0 – 22	28		
Cysteine	mg/100 g	0 – 2	0 – 2	22		
SAA	mg/100 g	2 – 33	0 – 24	50	1050 mg	0 – 5
Tyrosine	mg/100 g	2 – 77	3 – 87	54		
Phenylalanine	mg/100 g	0 – 64	9 – 212	77		
AAA	mg/100 g	2 – 141	12 – 299	131	1750 mg	2 – 17
Proline	mg/100 g	0 – 116	5 – 154	69		
Serine	mg/100 g	4 – 47	2 – 192	74		
Threonine	mg/100 g	4 – 65	3 – 190	69	1050 mg	<1 – 18
Tryptophan	mg/100 g	<1 – 42		26	280 mg	<1 – 15
Valine	mg/100 g	4 – 97	2 – 144	92	1820 mg	<1 – 8

Key: [a] = Converted to fresh weight using 24% dry weight; [b] From The Concise NZ Food Composition Tables 6th Ed. Athar *et al*., 2003. Galdon *et al*., 2010 studied ten cultivars grown in two regions in Tenerife, Spain. EAA = Essential Amino Acids; SAA = Total of Sulphur Amino Acids (Methionine and Cysteine); AAA = Total of Aromatic Amino Acids (Tyrosine and Phenylalanine).

1.3.1.4. *Lipids and Fatty Acids*

In the human body, lipids fulfil a number of functional roles that range from protecting vital organs, providing insulation, transporting fat-soluble vitamins, forming cell membranes, and providing a means of storing energy. If completely metabolised, one gram of fat is able to provide 37kJ of energy. Lipids also contribute to the flavour, mouth-feel and satiating effect of a food. As shown in Table 1.5, linoleic acid makes up 40-53% of the fatty acids in potato tubers, followed by alpha-linolenic 16-30%, palmitic acid 18-20%, stearic acid 4-6% and oleic acid 0.6-5% (Lisinska and Leszczynski, 1989; Dobson *et al.,* 2004).

Essential fatty acids (linolenic acid and alpha-linolenic acid) are a group of lipids which must be supplied in the diet because humans lack the enzymes necessary to create double bonds before the ninth carbon from the omega (methyl) end of these fatty acids. These essential fatty acids act as precursors for other important lipids required in vision, immune function and hormone production. However, as the overall lipid content in potato tubers averages only 0.12% of the fresh tuber weight, (Lisinska and Leszczynski, 1989), the potential nutritional value from potato tuber lipids is not likely to be significant in most cases.

Table 1.5 Fatty Acid Components of Whole, Raw Potato Tubers (on a Fresh Weight basis) From International and New Zealand Sources.

Range = lowest to greatest average nutrient content achieved by the cultivars included in the relevant report.

Component	Units	Lisinska and Leszcynski, 1989.	Dobson *et al.,* 2004	Combined NZ Cultivars*	NZ Red King*
		Range	Range	Mean	Mean
Linoleic Acid (c18:2n6)	% of TFA	40 – 50	46 – 53		
Alpha-Linolenic Acid (c18:3n3)	% of TFA	20 – 30	16 – 24		
Palmitic Acid (c16:0)	% of TFA	20	18 – 20		
Stearic Acid (c18:0)	% of TFA	5	4 – 6		
Oleic Acid (c18:1n9)	% of TFA	1 – 5	1		
Total SFA	% of TFA		30	30	30
Total MUFA	% of TFA		2 – 3	3	3
Total PUFA	% of TFA		67 – 68	67	67

Key: TFA = total fatty acids; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; * From The Concise NZ Food Composition Tables 6th Ed. Athar *et al.,* 2003.

Potatoes in their natural form contain vary little fat, however, results from the 2008/09 NZANS survey suggest that New Zealand adults (particularly males and those aged 15 – 30 years) are frequently eating potatoes in foods associated with high fat, saturated fat and energy. Hot chips, french fries, wedges or kumara chips were reported eaten one or two times a week by over 36% of the participants, and three or more times a week by 7.5% of the participants. Males and those aged 15 – 30 years were more likely to report eating hot chips more than once a week compared to females and adults aged over 30 years. Together, the PKT group contributed to 6% of the total dietary energy (9% in younger males aged 15 – 18 years); 6% of the total dietary fat (6 – 10% in adults aged 15 – 50 years); 6% of the saturated fat (6 – 10% in adults aged 15 – 50 years) and 7% each of the monounsaturated and polyunsaturated fat intake (Ministry of Health, 2011). While hot chips, roast potatoes and potato crisps might be a part of food culture in New Zealand, continued efforts to reduce the frequency of their consumption, reduce the portion size, cooking the potatoes in minimal fat and using unsaturated rather than saturated fats would contribute to healthier outcomes for New Zealanders.

1.3.1.5. Micronutrients (Vitamins, Minerals)

Micronutrients include vitamins and minerals that are most often only required in amounts less than one gram per day, but are necessary for an extensive range of functions. In humans, most must be provided in the diet as the human body either lacks the ability to make them, or is unable to produce them in sufficient quantities for biological needs. A deficiency in a particular micronutrient may lead to problems that range from minor skin inflammation to death, depending on the length and severity of the deficiency. Micronutrient requirements can also change according to geographical location, physiological state and health needs.

The potato tuber is considered to be nutrient rich, partly because it contains a range of essential micronutrients. The quantity of the micronutrients provided in a potato cultivar is extremely variable both within and between potato cultivars due to a number of factors including inherent genetic differences, tuber maturity, cultivation and environmental conditions (Lisinska and Leszcynski, 1989; Burlingame *et al.,* 2009; Galdon *et al.,* 2012; Nassar *et al.,* 2012). However, this variability in quantity across cultivars shows that some potato cultivars have the potential to provide appreciable amounts of certain micronutrients with regards to ensuring sufficient quantity for an adult’s daily requirement (Tables 1.6 and 1.7).

Table 1.6 Selected Vitamin Content of Whole, Raw Potato Tubers (On a Fresh Weight basis) From International and New Zealand Sources.

Where daily nutrient requirements are based on Australian and New Zealand Estimated Average Requirement (AusNZ EAR), for adults 19-70 years and the Potential Contribution is the percentage of the nutrient's AusNZ EAR that might be expected to be provided in 100 g of whole, raw potato across the tabulated data. Range = lowest to greatest average nutrient content achieved by the cultivars included in the relevant report.

Component	Units	Lisinska and Leszcynski, 1989.	Burlingame *et al.*, 2009.	Galdon *et al.*, 2012	Combined NZ Cultivars*	NZ Red King*	Daily Nutrient Requirement	Potential Contribution
		Range	Range	Range	Mean	Mean	AusNZ EAR	% of AusNZ EAR
Vitamin C	mg/100 g	1.0 – 54.0	6.5 – 34.0	9.0 – 43.0	19.0	12.0	30 mg	3 – 180
Thiamine (B1)	mg/100 g	0.0 – 0.2	0.0 – 0.1#		0.1	0.1	0.9 – 1.0 mg	2 – 21
Niacin (B3)	mg/100 g	0.4 – 3.3	0.6 – 2.1#		1.5	0.9	11 – 12 mg	3 – 30
Pyridoxine	mg/100 g	0.2#	0.1 – 0.3#		0.1	< 0.1	1.1 – 1.4 mg	1 – 27
Folic Acid	µg/100 g	5.0 – 33.0	10.3 – 15.3#		15.0	15.0	320 µg	2 – 10

Key: * From The Concise NZ Food Composition Tables 6th Ed. Athar *et al.,* 2003. Galdon *et al.,* 2012 studied ten cultivars grown in two regions in Canary Islands, Spain. # reported as dry weight basis but converted to fresh weight using 24% dry matter content.

Table 1.7 **Selected Mineral Content of Whole, Raw Potato Tubers (per 100g Fresh Weight) From International and New Zealand Sources.**

Where daily nutrient requirements are based on Australian and New Zealand Estimated Average Requirement (AusNZ EAR) or Adequate Intake (AI), for adults 19-70 years and the Potential Contribution is the percentage of the nutrient's AusNZ EAR or AI that might be expected to be provided in 100 g of whole, raw potato across the tabulated data. Range = lowest to greatest average nutrient content achieved by the cultivars included in the relevant report.

Component	Units	Lisinska and Leszcynski, 1989.	Burlingame *et al.,* 2009.	Galdon *et al.,* 2012	Nassar *et al.,* 2012	Combined NZ Cultivars*	NZ Red King*	Daily Nutrient Requirement	Potential Contribution
		Range #	Range	Range	Range	Mean	Mean	AusNZ EAR/AI	% of AusNZ EAR/AI
Potassium	g/100 g	0.3 – 0.6	0.2 – 0.7	0.2 – 0.4	0.1 – 1.7	0.4	0.5	2.8 – 3.8	1.5 – 61
Phosphorus	mg/100 g	28.8 – 144.0	33.0 – 126.0		27.5 – 303.5	33.0	5.0	580	0.8 – 52
Chloride	mg/100 g	10.8 – 192.0				55.0	55.0	NRP	
Sulphur	mg/100 g	9.6 – 96.0				35.0	32.0	NRP	
Magnesium	mg/100 g	10.8 – 52.8	10.8 – 37.6	5.0 – 19.4	3.0 – 244.5	17.0	17.0	255 – 350	0.8 – 96
Calcium	mg/100 g	2.4 – 31.2	1.4 – 27.8 [a]	0.9 – 4.3	0.6 – 109.3	3.0	4.0	840 - 1100	0.1 – 13
Sodium	mg/100 g	0.0 – 79.2	0.1 – 7.7	1.2 – 15.6	0.1 – 50.0	4.0	3.0	460 – 920	0 – 9
Iron	mg/100 g	0.6 – 17.3	0.1 – 10.4	0.7 – 3.2	0.1 – 4.5	0.6	0.6	5 – 8	0.6 – 288
Zinc	mg/100 g	0.2 – 0.5	0.2 – 0.8 [a]	0.2 – 0.4	< 0.1 – 2.9	0.3	0.2	6.5 – 12	0.3 – 38
Copper	mg/100 g	< 0.1 – 0.7	0.1 – 0.2	< 0.1 – 0.1	< 0.1 – 1.8	0.1	0.1	1.2 – 1.7	0.6 – 150
Manganese	mg/100 g	0.1 – 1.9	0.1 – 0.4	0.1 – 0.6	0.1 – 1.4	0.1	0.1	5 – 5.5	0.9 – 28
Selenium	µg/100 g				< 0.1 – 11.5	1.1	0.3	50 – 60	0.02 – 23

Key: * From The Concise NZ Food Composition Tables 6th Ed. Athar *et al.,* 2003; AusNZ EAR/AI = Australian and New Zealand Estimated Average Requirement (Calcium, Phosphorus, Zinc, Iron, Magnesium, Selenium) or Adequate Intake (Copper, Manganese, Sodium, Potassium) for adults 19-30years; # reported as dry weight but converted to fresh weight using 24% dry matter content; NRP =No nutrient requirement provided in the Nutrient Reference Values for Australia and New Zealand (NHMRC, 2006); [a] value was converted to fresh weight from dry weight data; Galdon *et al.,* 2012 studied ten cultivars grown in two regions in Canary Islands, Spain. Nassar *et al.,* 2012 reported on over 100 varieties from countries originating from across Europe, North America, South America and Canada.

Results from the 2008/09 NZANS survey suggested that together, the PKT group made useful contributions of vitamin C (13%), vitamin E (6%), thiamine (5%), niacin equivalents (6%), pyridoxine (10%), iron (6%) and potassium (13%) of the nutrient's intake in the diet of New Zealand adults (Ministry of Health, 2011).

Potatoes have long been known for their significant contribution of Vitamin C or ascorbic acid to the human diet among populations where potato consumption is high. Less well known is the fact that potatoes can also provide significant quantities of thiamine, niacin and pyridoxine and to a lesser extent, folate (Table 1.6). Vitamin C has a number of important physiological roles in the human body, including acting as an electron donor, an antioxidant, being linked to collagen formation, iron absorption, cancer prevention and maintenance of normal nerve function (Love and Pavek, 2008). Thiamine, niacin, pyridoxine and folate are important in energy production, and growth and maintenance due to their roles as co-enzymes in numerous metabolic reactions (Fairfield and Fletcher, 2002; Butt and Sultan, 2011). Thiamine and niacin are involved in energy production from carbohydrate, protein and fat. Thiamine also participates in decarboxylation reactions in nucleic acid synthesis (Butt and Sultan, 2011). Amongst others, pyridoxine is needed in protein metabolism, the conversion of tryptophan to niacin and neurotransmitter formation, whereas folate is a necessary coenzyme in purine and pyrimidine synthesis, erythropoiesis, methionine regeneration and preventing neural tube defects during foetal development (Fairfield and Fletcher, 2002).

With regards to quantity of minerals in the potato tuber, key contributors include potassium (K), phosphorus (P), chlorine (Cl), sulphur (S) and magnesium (Mg) (Table 1.7). Minerals in potatoes found in quantities likely to be of most consequence for human nutrition (K, P, Mg, iron (Fe), zinc (Zn), copper (Cu) and selenium (Se)), play many vital roles in optimal growth, metabolism, and maintenance of health or reproduction. Some of these roles include functions as electrolytes (K, P, Mg); enzyme cofactors or constituents (P, Mg, Fe, Cu, Zn, Se); formation of structural organs such as bones, muscle and teeth (P, Mg, Cu, Se) and as vital elements of the antioxidant defence system (Cu, Fe, Se, Zn) (Soetan, et al., 2010; Nassar et al., 2012; Volpe, 2013). Potassium in particular is likely to be of significant nutritional value when potato is a regular part of a diet due to their significant K content (Storey and Anderson, 2013a). Calcium (Ca), Fe, Cu, Zn, Se and manganese (Mn) are also present in amounts such that if potato cultivars with greater contents of these minerals were selected and eaten as a regular dietary source, they could significantly augment the requirements for Ca (Brown *et al.,* 2012; Volpe, 2013), Fe (Fairweather-Tait, 1983; Brown *et al.,* 2010), Zn (Brown *et al.,* 2011); Cu, Se and Mn (Luis *et al.,* 2011; Nassar *et al.,* 2012).

Reviews of nutrient content within and across potato cultivars from around the world (Tables 1.1 – 1.7), have shown a wide range in levels of individual nutrients occur both between and within cultivars. Certain cultivars have been identified that are able to provide greater than 50% of the recommended daily intake of individual nutrients per 100g of fresh tuber (vitamin C, and minerals K, P, Mg, Fe, Cu) and these cultivars might be targeted for use in populations where there are deficiencies in these nutrients (Lisinska and Leszcynski, 1989; Burlingame *et al.,* 2009; Luis *et al.,* 2011; Nassar *et al.,* 2012).

1.3.2. Phytochemicals

Potatoes are known to contain a number of bioactive phytochemicals (Table 1.8). Phytochemicals are compounds such as phenolics, alkaloids, nitrogen-containing compounds, organosulphur compounds, phytosterols and carotenoids found in grains, fruits and vegetables. Some do not provide any nutrition, but appear to contribute to improved health and the reduction of the development of diseases through their antimutagenic, anticarcinogenic, antioxidant, antibacterial and immunity boosting functions (Liu, 2003; Liu, 2004; Rahal *et al.,* 2014).

More than 5000 individual dietary phytochemicals have been identified in fruits, vegetables, whole-grains, legumes and nuts, although the functions of many of these phytochemicals are yet to be elucidated (Liu, 2013). The most studied groups of dietary phytochemicals with relation to human health include the phenolic compounds (particularly phenolic acids and flavonoids) and the carotenoids (Liu, 2013).

In potatoes, the most abundant phenolic acids are chlorogenic (80-90% of total phenolic content), caffeic, *p*-coumaric, and ferulic acids, with minor amounts of other phenolic acids; while the major flavonoids in potato tubers are quercetin, kaempferol glycoside, kaempferol, catechin and rutin (Lewis *et al.,* 1998; Shakya and Navarre, 2006; Andre *et al.,* 2007; Friedman, 2007; Albishi, 2013).

All potatoes contain small amounts of carotenoids (Brown, 2005), however, amounts range from 50-100 µg/100 g FW in white-skinned, white-fleshed varieties to 2000 µg/100 g FW in yellow and orange fleshed varieties (Brown, 2005). In addition to the phenolic acids, carotenoids and flavonoids mentioned above, potatoes with pink, red, blue or purple coloured skins and flesh also contain varying amounts of anthocyanins (a subgroup of the flavonoid compounds) (Lewis *et al.,* 1998; Brown, 2005; Andre *et al.,* 2007).

Phenolic compounds include subgroups of phenolic acids, flavonoids, stilbenes, coumarins and tannins, some of which have been suggested to reduce the risk of cancer, heart disease and diabetes (Liu, 2013). Carotenoids are classified into hydrocarbons (carotenes) and xanthophylls and have been of interest for their health promoting benefits due to their provitamin and antioxidant functions (Liu, 2013).

Diets rich in phenolic compounds, flavonoids and carotenoids have a vast range of health promoting and disease preventing functions (Rahal *et al.,* 2014), including functions associated with a lower incidence of atherosclerotic heart disease, (Hertog *et al.,* 1993; Wang *et al.,* 1999, McGill *et al.,* 2013), certain cancers, (Knekt *et al.,* 1997; Van Duyn and Pivonka, 2000), macular degeneration and severity of cataracts (Brown *et al.,* 1999), anti-inflammatory, antibacterial, antimutagenic and especially antioxidant functions (Rahal *et al.,* 2014).

Potatoes with coloured skin and flesh (particularly red-fleshed and dark purple-fleshed varieties), are more likely to contain greater amounts of antioxidative phytochemicals (and thus greater overall potential antioxidant activity and greater potential health benefits), than white-fleshed, white-skinned varieties (Lewis *et al.,* 1998; Hamouz *et al.,* 2011; Navarre *et al.,* 2011; Lachman *et al.,* 2012; Hu *et al.,* 2012; Albishi, 2013; Kulen, 2013). Red or purple pigmented potatoes have been suggested to have benefits with regards to lowering blood pressure (Vinson *et al.,* 2012), and cholesterol (Han *et al.,* 2013), protecting against breast cancer (Chong *et al.,* 2009; Thomson *et al.,* 2009), prostate cancer (Reddivari *et al.,* 2010), and colonic cancer (Madiwale *et al.,* 2011), and may have anti-inflammatory benefits (Kaspar *et al.,* 2011).

It has been proposed that the phytochemicals found within a whole food work in conjunction with other nutrients the food contains (such as vitamins, minerals and fibres), to exert these beneficial health effects (Liu, 2004). Thus consumption of the whole food (for example eating the whole potato with the skin on), rather than a single nutrient or phytonutrient in a supplement (such as Vitamin C tablets or an "antioxidant-rich" herbal tea) may provide a greater benefit.

1.3.3. Anti-Nutrients (Glycoalkaloids)

Like most members of the Solanaceae family, potatoes contain glycoalkaloids that can have adverse effects in humans (Section 1.2.1.). In addition to their potential toxic effects, glycoalkaloids are also likely to affect bitterness or the perception of aftertaste in potato samples (Friedman *et al.,* 1997).

In commercial modern potatoes (*Solanum tuberosum*), the major glycoalkaloids are α-chaconine and α-solanine, which are normally present at low concentrations (<10mg glycoalkaloid/100g fresh weight potato), but levels can vary significantly between and within potato varieties (Table 1.9). Varieties with total glycoalkaloid levels above 20 mg/100g fresh weight of the potato are generally considered unacceptable due to the bitterness they impart and their potential for adverse health effects (Shakya and Navarre, 2006). The total glycoalkaloid content in the ten Taewa cultivars analysed by Savage *et al*. (2000) (Table 1.9), was found to be at an acceptable level (below 20mg/100g FW), and lower than the upper range of total glycoalkaloid content reported by Lisinska and Leszcynski, (1989) and Burlingame *et al.* (2009) in their reviews of international cultivars.

Table 1.8 **Selected Phytochemical Content of Whole, Raw Potato Tubers (On a Fresh Weight basis) From International and New Zealand Sources.**

Range = lowest to greatest average nutrient content achieved by the cultivars included in the relevant report.

Component	Units	Lisinska and Leszcynski, 1989	Burlingame *et al.,* 2009.		Navarre *et al.,* 2011	Lewis *et al.,* 1998 (Potato grown in NZ)	
		Range	Range	Mean	Range	Skin Range	Flesh Range
Total phenolic acids	mg/100 g		0.2 – 580.0	74.1	43.2 – 264.0*	55.0 – 624.0	7.3 – 122.9
Caffeic acid	mg/100 g	1.2 – 11.1*	<0.1 – 157.0	<0.1	0.0 – 11.5*	4.0 – 50.0	
Protocatechuic acid	mg/100 g					10.0 – 40.0	5.0 – 20.0
Chlorogenic acid	mg/100 g	2.3 – 9.9*	0 .0 – 144.6	0.3	5.3 – 113.5*	100.0 – 400.0	3.0 – 90.0
Total Flavonoids	mg/100 g				13.7* #	11.0 – 109.4	0.0 – 48.6
Total Anthocyanins	mg/100 g		0.0 – 508.0	41.3		0.0 – 744.7	0.0 – 232.0
Total Carotenoids	mg/100 g		0.0 – 2.7	0.3			
Antioxidant Activity	µg TE/g		43.0 – 892.0	386.6			

Key: * = fresh weight calculated using 24% dry matter content; # = only includes rutin and kaemferol-3-rutinoside; TE = Trolox equivalent. Navarre *et al.,* 2011 N = 50 Potatoes from over fifty genotypes representing cultivars, breeding lines, primitive germplasm and wild species available in North America; Lewis *et al.,* 1998 N = 26 potato cultivars grown in New Zealand, 7 of which were Taewa varieties.

Table 1.9 **Glycoalkaloid Content of Whole, Raw Potato Tubers (On a Fresh Weight basis) From International and New Zealand Sources.**

Component	Units	Lisinska and Leszczynski, 1989		Burlingame *et al.,* 2009.		Savage *et al.,* 2000.
		Range	Mean	Range	Mean	Range
Total Glycoalkaloid	mg/100 g	1.6 – 41.0	7.5	0.1 – 175.0	20.0	3.9 – 14.3
α-Solanine	mg/100 g	0.4 – 3.8		<0.1 – 47.2	5.6	1.5 – 6.4
α-Chaconine	mg/100 g	1.1 – 8.4		0.1 – 64.7	8.5	2.3 – 7.8

Key: Savage *et al.,* 2000 = Data from 10 Taewa cultivars grown in New Zealand.

1.3.4. Nutrient Density and Satiating Value of Potatoes

A nutrient dense food is one which contains a wide range of nutrients per unit energy of the food. With the rising cost of food, choosing foods that are nutrient dense, while at an affordable cost is of benefit to all consumers, but particularly in those population groups where there are food security concerns.

American researchers have devised a Nutrient Rich Foods (NRF) Index which measures the nutrient density of foods or diets and is defined as the ratio of a selected nutrient per calorie of food energy. The NRF9.3 is an index based on US dietary guidelines and regulatory structures that suggest encouraging the consumption of 9 nutrients (protein, fibre, vitamins A, C, E, calcium, iron, potassium and magnesium) and discouraging the consumption or limiting of 3 nutrients (saturated fat, added sugar, sodium), (Drewnoski and Fulgoni, 2008; Fulgoni *et al.,* 2009).

When coupled with food prices, indexes such as these are able to assist consumers in making the best nutritional choices within their budget constraints. In terms of nutrients per unit cost, potatoes and vegetables are amongst the foods that provide high nutrient density combined with good value for money (Drewnoski, 2010).

While the nutritive value of a meal containing potato depends to a large extent on the other components that are cooked or served with them, and on the method of preparation, the potato itself is a healthy option due to the range of nutrients it contains, its high energy and low fat and sodium content, and the feeling of satiety it engenders (Anderson *et al.,* 2013).

Holt *et al.* (1995) studied the potential satiating effects of 38 isoenergetic servings (1000kJ) of commonly eaten foods. Subjects (n = 11-13) were assigned to one of six food category groups (fruits, bakery, snacks, breakfast cereals, protein-rich, or carbohydrate rich). During each testing session, subjects were given one of the 4-9 foods in their assigned food category to eat and were then asked to rate the satiety of that food every 15min over the following 2hour period. After the 2hours, subjects were allowed to eat freely from a standard range of foods and drink (over an unspecified time), and the amount was recorded. Satiety was measured by comparing the subject's satiety rating of the test foods to the reference food (white bread) and by recording the amount of food eaten following the test period.

Of the 38 different foods, boiled potato received the highest satiety rating of all the foods measured including that of brown or white rice, brown or white pasta and wholemeal bread. Additionally, the amount of *ad libitum* consumption of the standard foods following the test period was negatively correlated with high satiety ratings, thus further supporting the potatoe's satiating effect (Holt *et al.,* 1995). Another study also confirmed the satiating effect of potato, as it was found that a meal comprised of a potato (providing 50g of carbohydrate) served with a 150g pork steak had a greater satiating value than a similar meal served with white pasta or white rice instead of potato (Erdman *et al.,* 2007).

Based on the results from the 2008/09 NZANS survey perhaps New Zealand might also adopt an NRF index system to encourage the consumption of potato in healthier forms rather than the high fat, high salt forms currently being consumed by many New Zealanders (see Section 1.3.1.4). Potatoes NZ currently provide many educational and advertising resources regarding the nutritional benefits of potatoes, including the satiating effect of baked potatoes and providing recipes for other healthy potato meal options (Horticulture New Zealand, 2013) but perhaps these resources need to be better publicised and more widely circulated.

1.3.5. Potato Products with Improved Nutritional Value

The increasing consumption of potato in developing areas of the world such as China, India and Sub-Saharan Africa has significant benefits with regard to world food security and reducing the prevalence of malnutrition (Camire *et al.,* 2009). However, the increased consumption of processed potato products over fresh potato, and the way in which potato products are often consumed (deep fried French fries; high salt wedges with sour cream; high salt, high fat cold potato chips/crisps) in much of the developed world tends to be less healthy (Haase, 2008).

As discussed in Section 1.3.1.4. New Zealand adults (particularly males and those aged 15 – 30 years) frequently consume potatoes in less healthy forms. With the growing worldwide epidemics of obesity, diabetes and other diet-related diseases, (Seidell, 2000; Wild *et al.,* 2004; Wang and Lobstein, 2006; Kelly *et al.,* 2008; Finucane *et al.,* 2011), a return to less processed, natural foods (such as a home-cooked baked potato sourced from the garden) has been encouraged, as has the development of natural products designed to provide or promote health benefits (Katan and DeRoos, 2004; Nugent, 2005; Herrero *et al.,* 2006).

Consumer demand for convenient, novel or functional foods with improved flavour, nutritional and health properties (Camire *et al.,* 2009), has driven an increase in research into the development of pre-prepared, functional foods with improved sensory acceptability (Charalampopoulos *et al.,* 2002; Bech-Larsen and Grunert, 2003; Menrad, 2003; Verbeke, 2005; Bech-Larsen and Scholderer, 2007; Siro *et al.,* 2008).

Due to their high current rate of consumption, acceptability as a nutrient rich food source and versatility with regards to potential product applications, potatoes are excellent candidates to use to develop functional food products. Two potential applications of how functional food products might be applied to potatoes includes the manipulation of resistant starch in cooked then cooled potato products and the inherent antioxidant phytochemicals available in coloured potato varieties.

As previously discussed in Section 1.3.1.2, when cooked potatoes are subjected to a period of cooling, the digestibility of the starch decreases due to retrogradation of starch to form RS_3, and slowly digestible starch (SDS) so the glycaemic effect of the cooked and cooled potato is reduced compared to a potato consumed soon after cooking (Pi-Sunyer, 2002; Fernandes *et al.,* 2005; Leeman *et al.,* 2005; Tahvonen *et al.,* 2006; Mishra *et al.,* 2008). Repeated cycles of cooling and reheating appear to further increase RS and SDS content of the potatoes (Berry, 1986; Sajilata, 2006).

Thus manipulating the starch component content through different processing techniques could produce potato products with variable digestibility that could suit consumers requiring easily digestible, low allergenic, low cost, nutrient and energy rich products (such as a base for infant weaning foods or other food formulations) (Lisinska and Leszcynski, 1989) or for consumers requiring products with a greater content of slowly or indigestible starch (such as diabetics, or for athletes needing a slow-releasing energy source).

Akin to this consumer interest in food products boasting potential health benefits, there have been a number of recent research studies (discussed previously in Section 1.3.2), which have looked into the potential health benefits of coloured potato varieties due to their higher content of potential antioxidant compounds. Demand for purple-fleshed potatoes is increasing in Korea, where they are considered a functional food (Jang and Song, 2004), and demand for speciality potato varieties (coloured flesh, fingerling varieties) have also increased in America (Voss *et al.,* 1999).

Research into the potential of edible products developed from highly coloured potato tubers have included making colourful potato chips/crisps (Devaux *et al.,* 2009), using extracted anthocyanin from red-fleshed potatoes as natural colourants for juices and beverages (Rodriguez-Saona, 1999), using processed potato flakes from purple coloured flesh varieties (Nayak *et al.,* 2011a), or potato flour from purple coloured flesh varieties (Nayak *et al.,* 2011b) in colourful extruded snacks boasting health benefits. Singh *et al*. (2009) investigated the potential of using ungelatinised potato flours from four Taewa varieties (Huakaroro, Karuparera, Moemoe, Tūtaekuri) in extruded snacks. They found that blending 25% Taewa potato flour with 75% corn flour produced good quality expanded snacks.

The starch and dry matter content and tuber skin and flesh colour inherent in each Taewa cultivar impacted on the cooked colour, textural and rheological characteristics of the extruded snacks. Potato flour from the purple-skinned, purple fleshed Tūtaekuri variety produced darker and tougher extruded snacks, likely due to the higher starch and dry matter content and the dark purple skin and flesh colour (Singh *et al.,* 2009).

Blueberries are regarded as one of the richest food sources of antioxidant phytochemicals (Veliogu *et al.,* 1998; Hu *et al.,* 2012), and have a greater total anthocyanin content (TAC) (138 – 385mg cyanidin-3-glucoside equivalent (Cy3g E) per 100g FW) than red or purple-fleshed potatoes (11 – 174mg Cy3g E per 100g FW) (Reyes *et al.,* 2005; Hu *et al.,* 2012). With improved acceptance of less-common potato tuber colourings, red and purple fleshed potato varieties may also have as much potential as blueberries with regards to benefits from antioxidant phytochemicals due to the fact that potatoes are a staple food that can be produced in bulk, are consumed by a greater population base across the world; are much less expensive on a fresh weight basis; plus they have a longer shelf life and do not require refrigeration (Hu *et al.,* 2012).

1.4. Factors Affecting Nutritional Value

The composition of a potato tuber is dependent on a number of factors, although the innate genetic characteristics associated with each cultivar are thought to be among the most significant (Toledo and Burlingame, 2006). Other factors known to influence potato chemical composition include the geographic growing location, soil type and climate (Knuthsen *et al.,* 2009), agronomic factors such as fertilizer or pesticide use (Klein *et al*., 1982; Turakainen *et al.,* 2004; Lombardo *et al.,* 2012), the impact of potato pests or diseases (Burton *et al.,* 1992; Lambert *et al.,* 2005) and age or maturity at harvest (Lombardo *et al.,* 2012).

Once a potato tuber is harvested, there are a number of other factors such as post-harvest management or storage conditions which can impact on the nutritional value of the tubers (Singh *et al.,* 2007 and 2008b). In addition, processing or preparation techniques (van Marle *et al.,* 1997; Kala and Prakash, 2001; Decker and Ferruzzi, 2013), can affect the actual quantity of the nutrient that is present at the time the potato is eaten. Finally, at the time of consumption, factors such as the bioavailability of the nutrient, or other foods eaten in conjunction with the potato, can influence how well the nutrient is able to be utilised for nutritional or health benefits.

An in-depth discussion of all factors that might affect the nutritional value of potatoes is outside the scope of this PhD research, but a summary of some of the major factors that might impact on nutritional value (genetic variation, cultivation, storage, processing) are presented in relation to selected nutrients or compounds likely to be of most relevance to the nutritional or health benefits of potatoes. The impact of cooking, cooling and processing on starch and fibre has been discussed previously in Section 1.3.1.2. The nutrients and compounds that will be discussed include reducing sugars; protein quality; selected vitamins (vitamin C, thiamine, pyridoxine and niacin); selected minerals (K, Ca, Fe, Zn, Mg, Mn and Cu); antioxidative phytochemicals and the glycoalkaloid anti-nutrients.

1.4.1. Distribution of Nutrients Within Potato Tubers

The potato tuber is an underground, modified, fleshy stem protected by the skin or periderm. Inside the periderm layer is the cortex (0.3-1.0 cm thick), while the medullary region is situated inside the vascular ring/phloem (Figure 1.5). The tuber skin or flesh colour depends on the concentration of anthocyanin (pink, red, blue, purple) or carotenoid (yellow to orange) concentration.

The distribution pattern of nutrients within potato tubers varies considerably as shown in Figure 1.6. However, the area in which the nutrients may be found is not constant throughout tuber development and changes occur with regards to where the nutrient might be found and how quickly a nutrient might accumulate as the tuber matures. For example, dry matter or "solid" content will increase during the growing season but the maximum quantity will be reached at different times depending on the potato variety and the environmental conditions under which it was grown (Lisinka and Leszcynski, 1989).

Figure 1.5 Cross-section of Karupoti Potato Tuber.

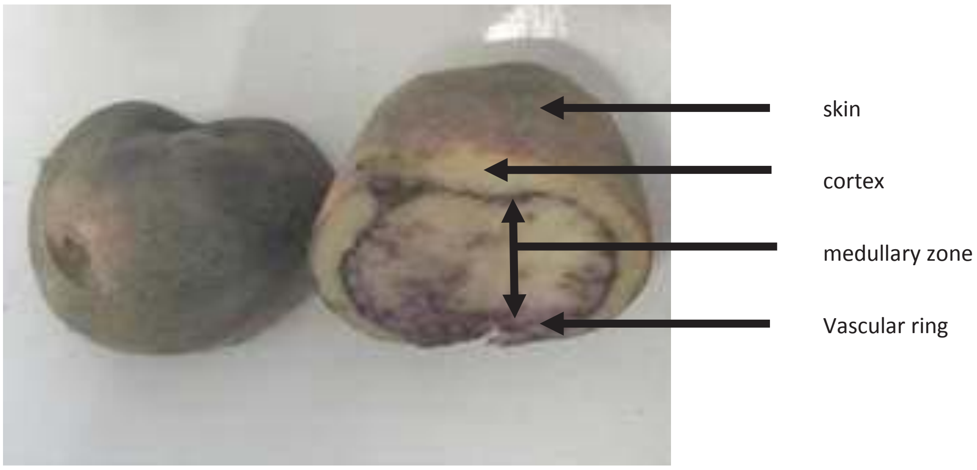


Photo by Dr Nick Roskruge; Agricultural Scientist, Massey University, Palmerston North, NZ.

As shown in Figure 1.6, starch (a), is concentrated primarily in the medullary region whereas vitamins (b) and alkaloids (c) can be found within the medulla or skin but to differing degrees. Sugars, proteins and amino acids (d) are primarily located within the vascular ring. Fats (e) are primarily found within the cortex whereas crude fibre (f) is generally found in the skin. Minerals and organic acids (g) may be found within the skin or cortex and phenolic compounds (h) within the skin, vascular ring and inner medulla.

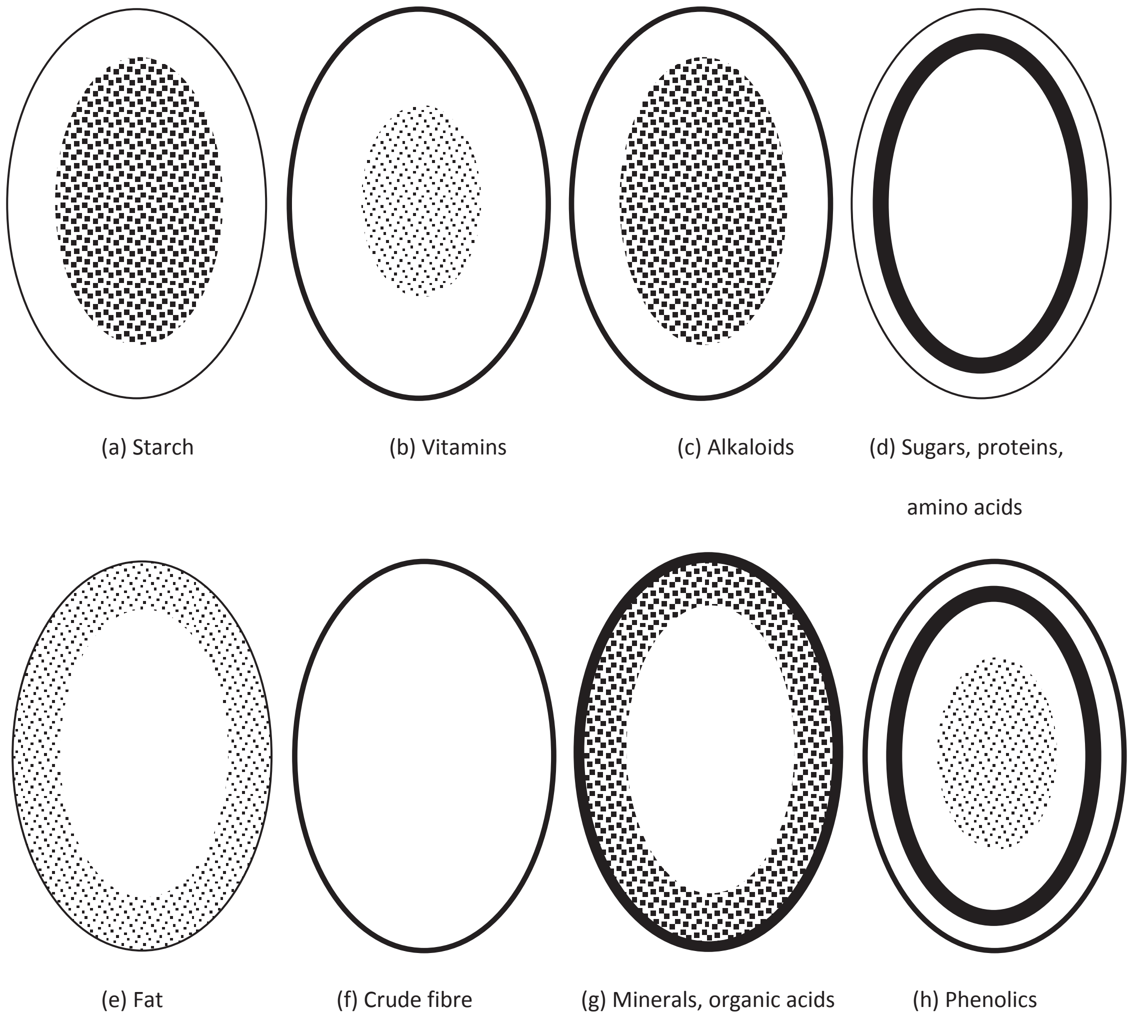
Due to the distribution of important nutrients throughout the tuber flesh as well as the tuber skin, maximum nutritional value is obtained by cooking and consuming a cooked potato with the skin on rather than peeling off the skin. Cooking a potato with the skin left on may provide some protection against thermal degradation of heat-sensitive compounds and will help prevent loss of water-soluble compounds such as the water-soluble vitamins, and amino acids due to water-leaching. Additionally, the potato skin contains the majority of a tuber's fibre and mineral content as well as some phenolic compounds that may provide antioxidant benefits.

However, an exception to leaving the skin on prior to cooking or consumption would occur when the skin or flesh of the potato has an increase in green colouring as this can indicate an accumulation of glycoalkaloid production and consumption could potentially have detrimental health effects (Friedman *et al.,* 1997).

Figure 1.6 General Distributions of Nutrients within Potato Tubers.

(Adapted from Rastovski *et al.,* 1987)

Where shaded areas represent the general distribution of nutrients within a potato tuber; (a) = starch; (b) = vitamins; (c) = alkaloids; (d) = sugars, proteins and amino acids; (e) = fat; (f) = crude fibre; (g) = minerals and organic acids; (h) = phenol compounds



1.4.2. Genetics

Numerous studies of potato cultivars grown under the same environmental, agronomical and geographical region have demonstrated that considerable variation in nutrient composition exists between potato cultivars (see Tables 1.1 to Table 1.8).

This genetic diversity in chemical composition enables researchers to select for cultivars which possess desirable characteristics and traits that align with a particular end use (such as fresh table variety vs processed or French fry vs potato crisp) and could potentially impact on production costs (such as higher yield or increased pest resistance).

Potato cultivars have been identified that have higher potassium, iron or magnesium content (Luis *et al.,* 2011; Nassar *et al.,* 2012); higher thiamine (Goyer and Haynes, 2011); or pyridoxine content (Mooney *et al.,* 2013)); better protein quality (Peksa *et al.,* 2013), greater vitamin C content or potential antioxidant activity (Albishi *et al.,* 2013) compared to others.

Screening nutrient content across cultivars grown within a certain geographical area could be used to select cultivars that might target specific population nutrient deficiencies within the same region and thus have a greater potential for nutritional value if used as part of their regular diet. Cultivars with greater reducing sugar (Halford *et al.,* 2012b) or glycoalkaloid content could also be avoided so as to prevent poisoning from toxic compounds.

1.4.3. Cultivation and Agronomical Factors

By studying the effect of agronomical factors on potato nutrients or anti-nutrients during potato cultivation, information can be gathered that can assist growers to produce tubers with the maximum nutritional benefit (greater vitamin, mineral, antioxidant content, improved protein quality) while minimising accumulation of anti-nutrients like glycoalkaloids.

Differences in mineral content have been observed between potatoes grown organically compared to those conventionally grown. Griffiths *et al*. (2012) found that copper and magnesium content were higher but iron content was lower in organically grown potatoes. A study of 21 Andean cultivars grown under controlled or drought conditions found that water depletion did not significantly affect the mineral content in the majority of the cultivars tested and some were able to maintain good yield stability as well as high mineral content (Lefevre *et al.,* 2012).

Mineral content is also dependent on the soil and environmental characteristics of a region, since the geographic origin of a potato can be determined based on the profile of the trace minerals it contains (Augustin, 1975; Anderson *et al.,* 1999). Nitrogen fertilisation and tubers grown in a sandy rather than loamy type soils appear to enhance nitrogen and protein content, although this is variable across cultivars (Augustin, 1975).

A study of 54 potato clones found that tubers harvested at a mature stage, late in the growing season had higher amounts of thiamine than when harvested at a young stage early in the season (Goyer and Haynes, 2011). Thiamine levels also appear to increase in tubers with increased nitrogen fertilisation and when grown in loamy soil (Augustin, 1975).

Environment and location have also been shown to affect anthocyanin content, as higher altitude localities with lower average daily temperature during the potato growing season appeared to improve anthocyanin content in eight red and purple-fleshed varieties grown in the Czech Republic (Lachman *et al.,* 2012), and areas with greater likelihood for drought stress appeared to increase anthocyanin content and antioxidant activity in 13 Czech cultivars (Hamouz *et al.,* 2011). However, Hu *et al*. (2012) found that 11 cultivars grown in Canada under the same soil type and production practices over two years had differences in total phenolic and anthocyanin content, suggesting that environmental conditions (higher rainfall and higher temperatures) may also effect phenolic and anthocyanin content.

Stress conditions during the growing season (e.g. increased pest infestation, tuber injury, light exposure or disease) can also increase glycoalkaloid levels as glycoalkaloid compounds are part of a plant's naturally occurring defence mechanisms against pests and intense grazing species (Stark and Love, 2003).

1.4.4. Storage

As potatoes need to be stored for extended periods in order to enable a year-long supply, storage is an important issue for the potato industry. Post-harvest conditions such as storage temperature, humidity, damage to the tuber, light or heat degradation can impact on potato nutrient content and thus studying effects of different post-harvest conditions can provide potato growers, manufacturers and the general population information regarding the best storage practices for nutrient retention and optimal potato quality and shelf-life .

Studies have shown that storage at 4^{o}C prevents tubers from sprouting, but storing potatoes at temperatures around 4^{o}C-7^{o}C and in a higher CO_2 to O_2 atmosphere can cause an increase in reducing sugar concentration due to the breakdown of starch (Kumar *et al.,* 2004; Halford *et al.,* 2012a). Goyer and Haynes (2011) found that storage for 1 - 3 months at 7^{o}C caused an increase in thiamine content in some of the 54 potato clones studied, and suggested that increasing the concentration of thiamine in some potato cultivars by manipulating the storage temperature may be feasible.

Reducing the storage time appears to be of benefit in optimising vitamin C content. Research has shown that 2 months storage at 4^{o}C reduces the vitamin C levels by 24%, 4 months storage reduces levels by 45% and 7 months storage results in 52% lower vitamin C levels (Kulen *et al.,* 2013).

However, increasing storage time up to 8 months appeared to slightly increase thiamine levels, increase pyridoxine levels, slightly decrease niacin levels, but caused significant loss (17-40%) in folate in potatoes stored at 3-7^{o}C (Augustin *et al*., 1978). In a study of a high carotenoid-accumulating *Solanum phureja* cultivar with two lower carotenoid-accumulating *Solanum tuberosum* species, storage at 4^{o}C for 9 months caused different changes in the quantity of the relative carotenoid components, but only slightly decreased the total carotenoid content of the three cultivars (Morris *et al.,* 2004), suggesting that total carotenoid content in potato tubers may be relatively stable under these conditions.

The effect of storage temperature on phenolic content appears to be largely cultivar dependant, as storing tubers at 4^{o}C increased total anthocyanin content in some cultivars, but decreased it in others (Lachman *et al*., 2012). Kulen *et al*. (2013) found that the total phenolic content of tubers with pigmented flesh stored at 4^{o}C increased after each 2, 4, 6 and 7 month time points compared to white or yellow-fleshed varieties. However, other studies have found no significant difference in total phenolic content in 8 potato genotypes stored at 4^{o}C or 20^{o}C for 110 days (Blessington *et al.,* 2010).

During storage, glycoalkaloid levels can become elevated after exposure to light (associated with tuber greening), infection with tuber rot organisms, or due to sprouting (Stark and Love, 2003), therefore it is of both nutritional and health benefit to store potatoes away from the light and remove any sprouts before cooking.

1.4.5. Processing (Cooking, Cooling, Reheating)

As potatoes are generally not eaten raw, it is important to understand the effects of different cooking and processing methods on the nutritional content of the potato. Processes to convert the tuber into an edible form (cooking, extraction of starch, extrusion, chipping, freezing, frying) will each impact the nutrient content and thus nutritional value of the final potato product consumed.

As vitamin C, pyridoxine, thiamine, niacin and folate are all water soluble, any cooking process that involves heat and/or water is likely to cause vitamin losses from the potatoes due to the destruction of tissue or leaching out into water (Finglas and Faulks, 1984).

Comparative nutrient analysis of the potato flesh from the New Zealand Rua potato cultivar (in raw, boiled, microwaved and baked potato flesh), showed negligible (<1%) difference in macronutrient contribution following cooking. However, compared to raw flesh, boiled potato flesh had a less vitamin C (-25%); niacin (-25%); potassium (-25%) and manganese (-15%) and baked potato flesh had less iron (-47%) (Athar, 2003). With regards to mineral and dietary fibre content, baking, roasting and frying do not appear to negatively affect the mineral or dietary fibre content in the potato, whereas mineral and dietary fibre losses may be evident after boiling (Finglas and Faulks, 1984). Keeping the skin on during the cooking process and minimising the cooking time, temperature and volume of water used in cooking can help minimise losses.

There are conflicting reports regarding the impact of cooking on levels of potato phenolic compounds. It has been suggested that differences in results may be due to an inherent variability in type and quantity of phytochemical compounds between different varieties, the types of compounds contributing to the phytochemical measurement, chemical changes within the potato material or phytochemical compound itself due to the cooking process causing differences in phytochemical compounds able to be measured and varying sensitivities of detection methods for the different phytochemical compounds (i.e. free versus bound phenolic compounds) (Nayak *et al.,* 2011a).

Faller and Fialho (2009) found that the phenolic content detected was lower following boiling, microwave baking and steaming. However the recovery of polyphenols was greater in boiled rather than microwave baked or steamed potatoes, and greater antioxidant capacity was detected after all three processes. Perla *et al*. (2012) also found that boiling, microwaving and baking decreased total phenolics, and boiling and heat processing decreased the carotenoid content of potatoes (Burmeister *et al.,* 2011).

Blessington *et al*. (2010) found no difference in total phenolic content between raw and boiled potatoes but greater levels were detected in baked, fried or microwaved potatoes. Xu *et al*. (2009) found no significant difference in antioxidant capacity due to heat treatment processes (boiled, baked, microwaved) in eight potato cultivars and Natella *et al*. (2010) also found that the total antioxidant capacity of potato was not significantly affected by boiling, pressure cooking or microwaving. However, Lachman *et al*. (2012) found that boiling led to a greater detection in anthocyanin content in 5 red and purple-fleshed cultivars compared to uncooked, microwave baked and roasted potato. Burgos *et al*. (2013) found a greater detection of total phenolics and that antioxidant activity had increased but caffeic acid levels had decreased in boiled compared to raw purple-fleshed potatoes native Andean potatoes.

Household cooking techniques (boiling, baking, frying), do not appear to affect the glycoalkaloid content of potatoes (Friedman and Lewis, 2009), therefore efforts to reduce glycoalkaloid accumulation should focus on storing potatoes away from light and removing tuber sprouts, green skin or flesh prior to cooking.

1.5. Impact of Nutrient Composition on Potato Quality Assessment and Sensory Acceptance

Apart from its nutritional value (Sections 1.3 and 1.4), various components of a potato's chemical composition help determine its most suitable end use (fresh vs processed); how it performs when it is cooked (chipping colour, mealy vs waxy); and it's acceptability to consumers (taste, flavour, texture, tuber skin and flesh colour, absence of toxic compounds) (Sharma, *et al.,* 1959; Burton, 1989; Friedman and Dao*,* 1992; Thybo *et al.,* 2006; Thygensen *et al.,* 2001; Kaur *et al.,* 2002; Van Dijk *et al.,* 2002a).

1.5.1. Relationship of Potato Composition to Assessment of Potato Quality, End Usage and Sensory Attributes.

Potato tuber quality and acceptance is assessed on factors relating to chemical composition (dry matter content, starch content, specific gravity, reducing sugar content, nutritional value, anti-nutrient content, phytochemical content), physical tuber characteristics (external tuber shape, size, appearance, absence of disease or defects) and culinary preference (flavour, texture, appearance, cooking performance) (Westermann *et al.,* 1994; Stark and Love, 2003).

Potato processors use the dry matter content as one of the initial key characteristics on which to evaluate each crop's suitability for purpose (Lisinska and Lesczynski, 1989; Stark and Love, 2003). Since starch generally makes up about 70% of the total dry matter content in potatoes, and is heavier than water, starch is the primary determinant of potato tuber density, (tuber specific gravity). Thus tuber starch content, tuber dry matter content, tuber total solids content, and tuber specific gravity are terms used interchangeably when describing tuber baking and processing quality (Burton, 1989; Stark and Love, 2003; Vreugdenhill *et al*., 2011).

In processing, potatoes with high dry matter content (20% or greater); high starch content (13% or greater) and specific gravity of 1.080 or higher are preferred (Stark and Love, 2003), and are most suitable for the manufacture of dehydrated food products, stock feed and for the production of fried foods (Gray and Hughes, 1978; Cacace *et al.,* 1994; Pardo *et al.,* 2000; Rama and Narasimham, 1993).

This is because the higher the dry matter content, the less fat uptake occurs because there is less water for the fat to replace. High tuber starch content also helps to ensure products have an acceptable texture and keeps production costs down by limiting the amount of raw product needed and the cooking time required (Stark and Love, 2003). For the home consumer, high dry matter, high starch potato varieties are usually those suited for dry heat-baking end uses such as roasting, baking with the skin on, wedges and mashing, as they have a relatively dry, mealy, fluffy texture when cooked (Stark and Love, 2003).

Potatoes with a low to medium starch content are often preferred for fresh potato consumption due to their firm, waxy texture following cooking (Haase, 2008). When boiled, potatoes with high dry matter often fall apart, whereas low dry matter content varieties tend to hold together. Thus low dry matter content varieties are more suited for boiling, making salads, or inclusion in casseroles and soups (Stark and Love, 2003).

Protein content in tubers is another important element in the evaluation of potato quality (Mitrus *et al.,* 2003) as some potato cultivars have been found to have a high quality protein (chemical amino acid score of 80 or higher compared to whole egg protein) (Kaldy and Markakis, 1972; Lisinska and Leszcynski, 1989; Peksa *et al.,* 2013).

1.5.2. Texture

As discussed previously, a potato cultivar with a high dry matter content, low sugar content and high starch content is positively associated with being floury when cooked and with increased mealiness (Burton, 1989). In turn, this chemical combination will affect textural perception, suitability for the processing industry and ultimately, consumer acceptance.

1.5.3. Flavour and Aftertaste Perception

Lipid content, (Galliard, 1973; Petersen *et al.,* 1998); volatile and non-volatile flavour components (Jensen *et al.,* 1999; Petersen *et al.,* 1999; Ulrich *et al.,* 2000; Blanda *et al.,* 2010; Morris *et al.,* 2010); sugar and nucleotide content (Beksan *et al.,* 2003; Jansky, 2008); phenolic content (Mondy, 1971; Nayak *et al.,* 2011a); reducing sugar content (Stark and Love, 2003) and glycoalkaloid content (Friedman and Dao, 1992; Friedman, *et al.,* 1997; Savage *et al.,* 2000) are all factors likely to affect both flavour and aftertaste perception in potatoes.

Cooking processes will cause degradation of compounds (such as lipids, amino acids and sugars) that will contribute to the aroma and flavour perception of the cooked potato. As the temperature increases, so will the number of volatile constituents detected (Ulrich *et al.,* 2000). Taste and flavour are major contributors to food preference and choice (Drewnoski, 1997; Dressler and Smith, 2013), thus being aware of those compounds that may positively or negatively impact on taste and flavour acceptance is important in product development.

Ulrich and colleagues analysed the basic odourant compounds and their accompanying sensory attributes (shown in brackets) of the boiled potato aroma in three potato genotypes. Diacetyl (buttery, sweet, caramel); hexanal (green); octan-2-one (mushroom, earthy); 2,6-dimethylpyrazine (nutty, warm); 2-methyl-5-isopropylpyrazine/2-ethyl-6-methylpyrazine (nutty, warm, chemical); 3-ethyl-2,5-dimethylpyrazine (nutty, earthy, herbaceous); 2-ethyl-3,5-dimethylpyrazine (roasty, coffee-like); methional (cooked potato) and phenylacetaldehyde (flowery) formed the basic aroma of the boiled potatoes.

Methional (formed from the heat degradation of methionine), diacetyl, and the five pyrazine compounds (formed from amino acids and sugars in Maillard and Strecker reactions) were recognized as positive character impact compounds (provided the most important aroma contribution). A number of dienal compounds (formed by the degradation of unsaturated fatty acids such as linolenic acid) were also detected that imparted off-flavour components (Ulrich *et al.,* 2000). In-depth analysis of the compounds that might affect flavour or aftertaste perception in cooked potatoes was outside of the scope of this thesis but could be developed in future studies.

1.5.4. Appearance

Reducing sugar or asparagine content (Marquez and Anon, 1986; Rodriguez-Saona and Wrolstad, 1997; Amrein *et al.,* 2003), the presence of anthocyanins (Voss *et al.,* 1999; Jemison *et al.,* 2008; Leksrisompong, 2012), and carotenoids (Burgos *et al.,* 2009; Bradshaw and Bonierbale, 2010), may contribute to the appearance of the potato tubers either prior to, or subsequent to cooking. Thus some of these compounds may influence whether a potato variety will be purchased (white-skinned, white fleshed potatoes are generally more accepted and familiar compared to coloured potatoes) and may affect consumer acceptability with regards to colour of the potato product when boiled, baked or fried. A number of unfavourable changes in colour can occur in potatoes as a result of chemical reactions between tuber constituents.

For example, the development of a greyish colour in tuber flesh after boiling or baking, known as after-cooking darkening, is caused by a reaction between chlorogenic acid and iron (Stark and Love, 2003). Peeled and cut potatoes can develop a reddish-brown discolouration on the surface which is caused by the oxidation of polyphenol compounds such as catechol by polyphenol oxidase (Stark and Love, 2003). Potatoes destined for fried potato products should also be low in reducing sugar content to prevent formation of dark-coloured compounds associated with “burned” food that are the result of Maillard reactions between reducing sugars (glucose and fructose) and amino acids such as asparagine (Stark and Love, 2003).

1.6. Food Choice and the Value of a Food

Apart from the key driver of hunger, people select and prepare the food they eat for a variety of reasons and in highly personal ways. These food choices are often based on behavioural, cultural or social determinants rather than the nutrients or health benefit the food may contain. Food choices may be based on biological determinants such as taste, hunger and appetite; social determinants such as culture, family, peers and meal patterns; physical determinants such as access, education, skills (e.g. cooking) and time; economic determinants such as cost, income, availability; psychological determinants such as mood, stress, guilt. Attitudes, beliefs and knowledge about food can also affect food choice (European Food Information Council, 2005).

Using the potato as an example of a typical food item, rather than eating it because it contains around 18g of carbohydrate energy, little fat, is a good source of potassium and vitamin C and contains antioxidants that may provide health benefits, it is more likely that a potato will be chosen for consumption due to other factors which are likely to include:

- it looked, smelled and tasted good when it was obtained and when it was cooked and eaten (sensory influences, (Drewnoski, 1997; Dressler and Smith, 2013));
- it was eaten during childhood, others have used it, it has satisfied requirements previously and not caused any adverse effects (familiarity, (Kratt *et al.,* 2000));
- parents, family, friends and others in the community use and eat it (ethnic or traditional influences, (Furst *et al.,* 1996; Devine *et al.,* 1999; Pieniak *et al.,* 2009));
- it is a food item used and accepted within family or other social gatherings or is a food consumed at social events, food that is shared, or a food used to show hospitality or as part of social customs (social factors, (Clayton, 1978; Fisher and Birch, 1999; Hendy and Raudenbush, 2000; Hendy, 2002; Wardle *et al.,* 2005));

- it is something enjoyable to eat, associated with an emotional connection or holds value (emotional, cultural, spiritual value), (Furst *et al.,* 1996; Connors *et al.,* 2001; Leigh Gibson, 2006));
- and it is easy to obtain at the supermarket whenever required for an agreeable cost (availability and economic considerations, (Glanz *et al.,* 1998)).

In many cultures, food is laden with meaning and forms a major form of social exchange (Rozin, 1996). For example, the factors that might convince a mother to breastfeed her infant are likely to incorporate social, emotional, spiritual and cultural expectations or influences that impart a stronger stimulus than the physical act of her providing nourishment to her child.

1.6.1. Sensory

Sensory perception involves the chemical detection of taste (via sweet, bitter, salty, sour and umami receptors), the chemical detection of odours and flavours, as well as the oral perception of texture, temperature and sometimes pain or irritation (Delwiche, 2004). From birth, a human infant can detect flavours within breast milk (Menella *et al.,* 2001), and during the introduction of foods at weaning, the perceived "taste" and flavour have major influences on food choice (Drewnowski, 1997; Birch, 1999; Dressler and Smith, 2013; Ventura and Worobey, 2013). A food's appearance also has an impact on whether it will be purchased initially and then eaten once it is cooked.

A food's texture, or its pleasure or hedonic impact during and after consumption will determine whether a food will be savoured or discarded after the initial tasting and influence the likelihood of being eaten again in the future (Clydesdale, 1993; Drewnowski, 1997; Clark, 1998; Leksrisompong *et al.,* 2012). Certain foods are preferred for consumption at varying temperatures, depending on individual preference, previous exposure to it, the environment in which it is being eaten and the preparation method used (Stroebele and DeCastro, 2004). For example French fries are usually preferred to be eaten hot, whereas a cold potato salad may be the preferred accompaniment for barbequed meat on a hot summer's day.

1.6.2. Nutritional Information

A number of studies have shown that providing favourable nutritional information can positively influence consumer willingness to consume, purchase or to try novel foods (Pelchat and Pliner, 1995; Kozup *et al.,* 2003; Luckow *et al.,* 2006; Baixauli *et al.,* 2008).

Provision of information has been shown to influence hedonic ratings, even when a product is well known. Before having subjects evaluate a new brand of coffee, Olson and Dover, (1978) gave information to one group of participants that emphasized that the coffee had no bitterness, while the control group received no information. The subjects were then asked to evaluate the bitterness of the coffee which had been prepared using 50% more ground coffee than specified by the package directions. Consumers who received the bitterness information (coffee is not bitter) rated the coffee as being less bitter than did the control group (no information).

Freedman and Connors (2011) tested the effect of nutritional label information on the purchasing behaviour of College students. They measured baseline sales of selected products over a 6 week period. They found that products tagged as healthy had higher sales compared to identically priced similar non-tagged products.

A review of the consumer's use of nutritional labels (Drichoutis *et al.,* 2006), suggested that nutritional label use influences valuations and perceptions of the product, and thus affects purchasing behaviour mainly because consumers want to avoid the negative nutrients in food products. The study also suggested that health claims on the front of the package create favourable judgements about a product and that the effects can be magnified if combined with an information campaign to educate consumers (Drichoutis *et al.,* 2006).

For example, a study of company brand success in relation to bran cereal products (Martin, 1990), found that the only company who was able to increase sales further during a downturn in bran cereal purchases was a company that did an intensive marketing campaign about the acceptable flavour of a their bran cereal. It was found that 40% of those who had not tried it before, believed that it would taste nice and 84% of the subjects who did try it, rated it favourably (Martin, 1990).

However, there is often a taste-nutrition trade off as nutritionally modified foods may be perceived as having inferior sensory properties compared to conventional products (Deliza and MacFie, 1996). Therefore, consumers may prefer the immediate gratification offered by a tasteful product rather than the long term health benefits of a nutritious product (Drichoutis, *et al.,* 2006).

1.6.3. *Familiarity / Previous Exposure*

Familiarity with a food (having seen, heard about, or eaten the food before), as well as the number of repeated exposures to having eaten a food, can all affect food choice. Evaluations of familiar foods have been shown to be generally more positive than evaluations of unfamiliar foods (Raudenbush and Frank 1999). Repeated exposure to products, and repeated exposure to nutritional and favourable information concerning the products has been shown to have a significant positive effect on the "overall liking" of juices containing probiotic culture (Luckow *et al.,* 2006). Aaron *et al*. (1994) found that prior attitudes towards products significantly affected hedonic responses. Consumers (n=101) were asked to fill out a questionnaire about use, attitude and beliefs in relation to full or reduced fat spreads and were then asked to rate liking attributes of novel spreads labelled as reduced fat or full fat. The sensory and hedonic ratings showed that consumers gave significantly greater ratings to the type of spread they already had a positive attitude towards.

The studies by Luckow *et al.* (2006) and Aaron *et al*. (1994) show that repeated exposure and a previous attitude towards a food can affect sensory acceptance, and thus impact on food choice. Thus, in relation to potatoes, prior exposure or a previous attitude towards a type of potato cultivar may influence sensory acceptance of a new potato product using cultivars unfamiliar to the consumer.

1.6.4. *Emotional, Social, Spiritual, Cultural Value of Food*

Food choice can also be affected by the perception of emotional comfort a food provides (Leigh Gibson, 2006), the social connections or environments a food is linked to (Clayton, 1978; Hendy and Raudenbush, 2000; Hendy, 2002; Wardle *et al.,* 2005) and the values (such as cultural, familiarity, spiritual, economic) it might hold or are associated with (Furst *et al.,* 1996; Connors *et al.,* 2001).

As discussed in Sections 1.2.1. and 1.2.2. the 2,000-plus years of history of careful cultivation by the Andean peoples and the impact of the introduction of potatoes into areas where they had not been previously grown, has played a role in history with the potato being a significant a life-providing food source. As one might expect, the potato holds great prominence within Andean livelihood, well-being, religion and culture. Potatoes are used for healing and medicinal purposes, as a trade commodity, in cultural traditions including marriage and special ritual ceremonies and practices accompany the planting and harvesting of potatoes (Stephenson, 2012).

Maintaining the genetic biodiversity and continued cultivation of the many native cultivars of Andean potatoes is particularly important to many Andean peoples, insomuch that they have taken on a protective role as *Papa Arariwas* or Guardians of the Potato (Stephenson, 2012).

The introduction and establishment of potato into Europe and other parts of the world, caused a population growth in Europe, abandonment or displacement of previously important food crops (i.e. grains, wheat in France; arūhe and kumara for Māori in New Zealand, change of grain staples of Asians when immigrating to developed countries that have greater potato consumption), a decrease in physical activity for early New Zealand Māori.

For Māori, hauora (overall wellbeing and health) incorporates a holistic worldview in which ultimate wellbeing requires a balance of taha wairua (spiritual), taha hinengaro (emotional, psychological), taha whānau (family and social) as well taha tinana (physical) aspects (Durie, 1998). Māori also have a deep connection to the whenua (land) as Māori custom and tradition denotes that life originated from the association of Rangi, the Sky father and Papatūānuku, the Earth mother. As such, Rangi, Papatūānuku and their children are revered as Ātua (Gods). With regards to food, those Ātua of chief prominence include Tāne Mahuta (the Father of mankind and God of all living things within the forest), Tangaroa (the God of all living things within and surrounding the sea and bodies of water), Rongo-mā-tāne (the God of cultivated foods such as kūmara and Taewa) and Haumia-tiketike (the God of uncultivated foods such as āruhe).

Similarly to other traditionally eaten foods such as kūmara, shellfish, tuna (fresh-water eel), tītī (muttonbird) and karengo (sea-weed), the act of growing, harvesting and eating Taewa is not just about providing food, physical exercise nor simply a means of supporting the economic survival of the whānau.

For Māori, cultivating Taewa was and still is, very much a community and family affair that helps to strengthen the links between themselves, their tupuna (ancestors), their whenua (land), and their Ātua (gods) (Roskruge, 1999; McFarlane, 2007). In addition, the practice of serving Taewa to whānau or manuhiri (visitors or guests) incorporates social and spiritual aspects such as whanaungatanga (kinship, family relations); manaakitanga (hospitality, kindness); whakapapa (genealogy and creation) and tikanga (customs and habits) (Roskruge, 1999).

Due to the ease with which Taewa can be cultivated throughout New Zealand, growing Taewa could provide New Zealanders, with a number of health-related benefits. As it has for Māori in the past, growing Taewa may enable people to re-establish traditional values in growing food for the family and community, thus promoting pride in this accomplishment, skills in self-reliance, sustainable practice, working together for the benefit of many, and re-connecting with the land. Further to this, growing Taewa may also help to address food security concerns whilst providing cheap, nutritional food for the family. For the modern Māori, the physical activity involved in the soil preparation, planting, maintenance, and harvesting of Taewa not only has the obvious benefits of providing a form of exercise but may evoke historical and cultural reminders that their pre-colonial ancestors were a people that were physically active and mobile, thus encouraging them to do the same.

For Māori, Taewa are regarded as taonga (treasure, holds special importance and value) and are "some of the most deeply treasured Māori foods available to us today" (Te Waka Kai Ora, 2010). Given the many cultural, historical, spiritual, social and emotional connections that Māori have for Taewa, these factors are likely to have a significant influence on the decision and desire for Māori to eat them.

1.6.5. Availability / Accessibility of Products

Accessibility, availability, convenience and economic considerations also influence food choice (Glanz *et al.,* 1998). For example, whether or not a food is easily accessible, quick and easy to prepare, within the financial means of the consumer or is convenient for the time available to cook and eat, are all factors influencing food choice. Foods that are commonly accessible (extent to which a food can be obtained when needed), or available (quantity of the food available in any environment, at any given time) within a region or country will affect what foods consumers from that region or country are able to choose to eat and will eat.

Economic considerations such as the cost or convenience of a food, can impact on food choice and lead to the purchase and consumption of a less-preferred, lower nutrient value food product. In an exploratory study of 83 women, aged 18–64 years from similar income backgrounds, researchers found that price and personal preference were the major factors influencing their grocery shopping and food consumption habits. Where cost was the foremost factor, this emphasis often meant compromising on taste and quality, for many of the women (Dressler and Smith, 2013).

Glanz *et al*. (1998) examined the self-reported importance of taste, nutrition, cost, convenience and weight control on dietary choices. Responses from a North American national sample of 2,967 adults indicated that taste followed by cost were the most important influences on the participant's food choices. However, the importance placed on the various factors also dictated the types of foods consumed, and certain populations were more likely to rate factors higher than others. For example the importance of cost and convenience was rated higher by younger respondents and those on a lower income, whereas the importance of nutrition was rated higher by older respondents and women (Glanz *et al*., 1998). Thus lifestyle, gender, age and income are also likely to impact on food choice.

With regards to potatoes, these studies show that the accessibility, availability, price of a potato cultivar or convenience in being able to obtain, cook and eat a potato will have an impact on whether it will be eaten. Additionally, there may be differences in potato consumption or preference in potato cultivar or potato product depending on an individual's lifestyle, gender, age and income.

1.7. Reference Materials and Research Goals

Little is known about the chemical composition or nutritional potential of Taewa, but great variation in culinary quality and tuber pigmentation occur between varieties, so nutrient composition may be as diverse as their appearance. Although there may be as many as 18 known Taewa varieties, four Taewa varieties, (*Solanum tuberosum* L. cv. Huakaroro, Karuparera, Moemoe, Tūtaekuri), were chosen to provide a reference basis for potential nutritional values and product development of Taewa. These were chosen based on their availability, familiarity and range of culinary quality and tuber pigmentation (see Table 1.10 and Figure 1.7).

Nadine was chosen as the reference modern variety as it represents a commonly available modern cultivar often used by New Zealand consumers and is easily accessible year-round in New Zealand supermarkets. Table 1.10 describes the tuber physical characteristics of the five cultivars analysed and Figure 1.7 gives a visual representation of the five chosen cultivars.

Table 1.10 Tuber Physical Characteristics of the Five Potato Cultivars Investigated.

Potato Cultivar	Skin Colour	Flesh Colour	Density	Tuber Shape & Size	Cultivation	Eye Depth
Huakaroro	Yellow, often splashed with pink, covered in numerous small brown dots	Creamy yellow	Hard, Waxy	Knobbly, slightly elongated, large tuber	Commonly grown, heavier yield	Very deep
Karuparera	Dark purple, creamy yellow around eyes	White	Floury	Slightly elongated, medium tuber	Commonly grown	Medium
Moemoe	Mottled yellow and red	Creamy yellow with purple flecks around the vascular ring	Waxy	Round to slightly elongated, medium tuber	Commonly grown, good yield	Deep set
Tūtaekuri	Dark purple	Dark purple with occasional white flecks	Floury	Elongated	Most commonly grown	Deep set
Nadine	White	White	Waxy	Slightly elongated, large tuber	Commonly grown, modern variety	Very shallow

Note: Information for this table was gathered from notes on experimental potato samples used throughout this research as well as information regarding Taewa varieties provided in Roskruge, 1999 and Harris and Niha, 2006.

Figure 1.7 Visual appearance of the five potato tuber varieties analysed in this thesis.

Huakaroro / Karoro / "White Māori"

Karuparera / Kanohi Parera

Moemoe / Muimui / Nga Toko

Tūtaekuri / Urenika

Nadine

Photos by Dr Nick Roskruge; Agricultural Scientist, Massey University, Palmerston North, NZ.

The overall goals of this PhD research project were threefold:

1. To survey the nutritional and chemical composition of four Māori potato cultivars and compare these with a commonly-used modern potato cultivar, Nadine, with an emphasis on identifying commercially viable or nutritionally beneficial properties of the Māori potatoes.

As discussed in Sections 1.2 and 1.3, potatoes are not only popular, commonly eaten in significant quantities around the world, but also have a high nutritional and potential health promoting properties. However, there are large differences in the quantity of various chemicals and nutrients between potato cultivars. Thus, Chapter 2 will aim to identify the macronutrient, selected micronutrient, phytochemical and anti-nutrient components of four Taewa varieties; (Huakaroro, Karuparera, Moemoe, Tūtaekuri), and compare them against Nadine, a potato variety commonly available to the average New Zealand consumer. The effects of par-boiling and storage on the nutrient content will also be briefly explored in order to begin assessing the relative nutritional value of Taewa.

2. To investigate common practices with regards to Taewa cooking and consumption among those familiar with Taewa in order to ascertain the most popular varieties, cooking methods and factors influencing Taewa consumption.

Research shows that taste, familiarity, convenience and preparation methods may be more important influences on food choice than health considerations or nutritional value (Section 1.6). Little is known about current or historical cooking and dietary habits relating to Taewa, nor which Taewa varieties are preferred. Thus qualitative and quantitative techniques will be used to consolidate, expand or discover information from current Taewa eaters that could be incorporated into the development of future edible Taewa products. Factors that will be explored will include the preferred Taewa cultivars for eating; preferred methods of cooking and eating Taewa; availability of Taewa cultivars across New Zealand and other marketable traits or factors that that might affect Taewa consumption or have potential for future Taewa product development. These will be discussed in Chapters 3 and 4.

3. To incorporate the characteristics of nutritional or health value found in the Taewa with familiar and popular Taewa cooking practices so as to develop a Taewa product with improved health benefits. Then to measure the potential consumer acceptance of that product by sensory evaluation by subjects both familiar and unfamiliar with Taewa.

As discussed in Section 1.3.1.2, cooked, then cooled potatoes may have improved health benefits due to the increased ratio of resistant starch (that is unable to be digested) relative to the digestible starch. This is of great benefit to those who may need to monitor blood glucose levels by choosing foods lower in digestible glucose, and can contribute to bowel health by acting as a metabolic substrate for beneficial colonic bacteria. Potatoes with highly coloured tuber skin or flesh are likely to have greater phenolic content and thus greater beneficial antioxidant content (Section 1.3.2). Chapter 5 will examine the effects of cooking and cooling the four Taewa varieties which have varying flesh and skin colourings, and then compare the potential resistant starch content and antioxidant potential of these four varieties in comparison to the Nadine variety.

Taewa are not among the potato varieties that are most commonly eaten in New Zealand, those most commonly eaten include Nadine, Draga, Frisia (waxy varieties); Rua, Desiree, Karaka, Moonlight (general purpose varieties); Ilam Hardy, Agria, Fianna and Red Rascal (floury varieties), (Horticulture NZ, 2006; Horticulture NZ, 2013). Hence, in order to assess the potential acceptability of Taewa products amongst the general New Zealand population, a sensory evaluation trial of boiled, 24-hour cooled potatoes will be undertaken in order to assess the acceptability of potential potato products that may have potential health benefits as well as to compare the acceptance of Taewa varieties to a commonly eaten variety (Nadine). These results will be discussed in Chapter 6.

CHAPTER 2

Investigation of the Nutrient Composition of Four Taewa and One Modern Potato Variety

2.1. Introduction

In comparison to the modern potato purchased in the supermarkets today, Taewa have undergone minimal selective breeding or genetic modification techniques as Māori have preferred to maintain the inherent genetic qualities of each Taewa variety and instead sought to improve crop qualities through agronomical practices such as quality seed selection, different fertilisation, irrigation and pest management techniques, timing of planting and harvesting (Roskruge and Anderson, 2010; McFarlane, 2007; Fandika, 2010).

As described in Section 1.4, a number of factors can have significant effects on potato tuber nutrient composition (Burlingame *et al*., 2009; Rivero *et al*., 2003a and 2003b; Lachman *et al*., 2005) even when agronomic conditions are controlled (Galdon *et al*., 2010). However, inherent genetic qualities related to the potato variety are a major determinant for a potato variety's tuber nutrient composition (Burton, 1989). Thus the nutrient screening of a range of different cultivars can help identify cultivars that may have advantages for a specific processing purpose or exhibit desirable contribution of a particular nutrient.

2.1.1. Determination of Nutritional Value of Taewa

The proximate analysis estimates the moisture/water, dry matter, carbohydrate, protein, fat, dietary fibre, ash and often energy content in a food or animal feed and is a method used to assist in determining potential end use and tuber quality of a potato variety or a potato crop (Section 1.3.1.1.). Experiment One of this chapter will discuss the proximate analysis results of four Taewa and Nadine potato varieties in order to qualify the major nutrient profile of the tubers and suggest potential end uses of the varieties based on their dry matter and expected starch content. The nutritional value of the tubers will then be further quantified in Experiment Two by assessing the quantity of various essential micronutrients such as the essential amino acids, fatty acids, and selected vitamins and minerals.

Potatoes are a rich source of phytochemicals, many of which can add to the nutritional value of the tuber through health-promoting effects as described in Section 1.3.2. However, as described in Section 1.3.3, bitter, potentially toxic compounds called glycoalkaloids are also found in potatoes. Experiment Three describes the investigation of the phenolic, flavonoid, anthocyanin and glycoalkaloid content that was carried out on the Taewa and Nadine tubers in order to survey for potential health-promoting or anti-nutritional factors.

As described in sections 1.4.4 and 1.4.5., storage conditions and processing are factors that can have an important effect on the nutritional value of the final potato product prior to its actual consumption by humans. Experiment Four presents results of nutrient analysis of the four Taewa and Nadine tubers which had been subjected to various post-handling, storage and processing scenarios in order to provide an estimate of potential for changes in nutrient composition.

Results from these studies will provide a preliminary basis by which the nutritional value of this group of tubers might be compared with regards to other potato tubers such as the Nadine cultivar, already present on the New Zealand market. Should the tuber composition analyses find the nutritional value of the Taewa to match or exceed what is contained in the commonly-available Nadine variety, it is hoped that this might provide impetus for further investigation into the potential marketability, crop production and nutritional value of these traditional cultivars.

2.2. Experiment One: Proximate / Macronutrient Analysis

2.2.1. Aim

The aim of this experiment was to screen the potato tuber macronutrient composition of four Taewa varieties; Huakaroro, Karuparera, Moemoe, Tūtaekuri against Nadine, a potato variety commonly available to the average New Zealand consumer in order to begin assessing the relative nutritional value of Taewa.

2.2.2. Materials and Methods

2.2.2.1. Potato Samples

Tubers of four traditional New Zealand *Taewa* cultivars (*Solanum tuberosum L*. cv. Huakaroro, Karuparera, Moemoe, Tūtaekuri) were procured from several local central and lower North Island sources in New Zealand at three different harvesting periods (July 2004, July 2005, July 2007 harvests). One modern potato cultivar (*Solanum tuberosum L.cv* Nadine) was purchased during the same harvest periods for each year from Foodstuffs (NZ) Ltd, (New World supermarket, Palmerston North, NZ).

It should be noted that due to the limited availability and donation arrangements under which the Taewa were provided, procuring the four Taewa varieties from only one, or the same locations each harvest year was not possible and information on the exact location, soil type, or growing conditions were not always available, but is presented when known. The limited quantity available also limited the number of repetitive trials and replicate assays that were able to be performed. Nutrient analysis from one composite sample is common practice in feed estimations, however, in order to obtain a more definitive estimation of each nutrient, multiple observations are recommended. As such, Taewa nutrient values presented in this research should be regarded as a preliminary estimation of what was present in the sample of the Taewa analysed each year, rather than a definitive presentation of the nutrients that the specified Taewa cultivar would provide.

For each 2004, 2005 and 2007 harvesting period, up to 10 kg of freshly harvested tubers from each of the five cultivars were stored in the dark, in a chiller at 5^{o}C with 80-90% humidity control. In 2004 and 2005, around 5 kg were allocated for analysis on newly-harvested potatoes and the remainder for analysis after 6 months storage. Unfortunately, the effects of 6 months storage was unable to be completed on the 2005 harvest due to a freezer malfunction. The potatoes destined to represent newly-harvested samples were freeze-dried and stored as described below within two months from initial harvesting.

Up to 5 kg of uniformly sized tubers destined for analysis were selected from each cultivar. Each potato was individually washed, dried, weighed and numbered. Where separate skin and samples were to be analysed, the skin and eyes were removed for each individual potato, weighed and frozen in liquid nitrogen. These became the tuber skin samples.

The remaining flesh was weighed, sliced 3-4 mm thin and frozen in liquid nitrogen. These became the designated tuber flesh samples. The skin and flesh samples were separately placed in plastic zip-lock bags, freeze dried and sublimed under vacuum at 25^{o}C until dry. Samples destined for analysis as whole potatoes were weighed, sliced, frozen and then freeze-dried as for tuber flesh samples except the skin and eyes were not removed. The contents of each freeze-dried bag were then put into foil bags, flushed with nitrogen until the air was removed, vacuum-pack sealed, labeled, then dry-stored until required.

Due to the difference in size between cultivars, the number of whole potatoes required for sufficient dried skin sample analysis differed (approximately 45 Tūtaekuri *cf* approximately 10 Huakaroro, Karuparera, Moemoe and Nadine) but approximately 4-5 kilograms of fresh weight potato from each cultivar was required for each stage.

One to two days prior to nutrient analysis, the vacuum-packed skin or flesh samples from each cultivar were ground to a fine powder of approximately 1-2 mm granular size using a Breville coffee and spice grinder (CG2B, made in China). Ground samples were mixed uniformly and stored in a plastic, zip-lock bag in a dry, cool, dark environment until required for analysis.

2.2.3. Analytical Techniques

2.2.3.1. %Moisture and %Dry Matter

The proximate composition of the potatoes was determined using the Association of Official Analytical Chemists International (AOAC) methods (AOAC, 1995). To estimate the moisture and dry matter contribution of the original fresh weight potato material, a sample of the original fresh potato material was weighed, then the moisture removed by oven dehydration at 105^{o}C overnight as described in the AOAC methods 930.15 and 925.10.

2.2.3.2. Carbohydrate Content

In proximate analysis, carbohydrate content (also sometimes referred to as the nitrogen-free extract) is not directly determined but is normally calculated by difference as shown in the equation below:

Total Carbohydrate or Nitrogen-free extract (g/100 g FW) =

100 – (g Moisture + g Ash + g Fibre + g Crude Fat + g Crude Protein per 100 g FW)

Carbohydrate content determined in this way will principally comprise of starch and sugars.

2.2.3.3. Crude Protein Estimation

Nitrogen content was obtained by applying the Leco, total combustion method as described in AOAC method 986.06. The crude protein content of the food is then calculated using the equation:

Crude protein content (g/100 g FW of food) = N content (g/100 g FW of food) x 6.25

2.2.3.4. Total Dietary Fibre

Total dietary fibre was determined using the enzymatic-gravimetric method (AOAC 991.43) and due to the very low lipid content (< 1%), the Taewa and Nadine samples did not require initial fat extraction.

2.2.3.5. Ash Content

The proximate ash content was determined as described in the AOAC method, 942.05.

2.2.3.6. Total Lipid Content

Crude lipid was extracted by hydrochloric acid hydrolysis, followed by Mojonnier ether extraction as described in the AOAC method, 954.02.

2.2.3.7. Gross Energy Content

The gross energy value of the potato material was estimated in kJ/100 g, using bomb calorimetry (Leco AC350, Leco Corporation, St Joseph, MI, USA).

As all proximate analysis nutrients except moisture, dry matter and carbohydrate are estimated using freeze-dried potato material, in order to present the results as they would be in the original fresh potato material, the dry weight nutrient content (g/100 g) is multiplied by the percentage of the total dry matter content in the original fresh food sample as follows:

Nutrient content of food (g /100 g fresh weight of food) =

Nutrient content (g/100 g dry weight of food)x

% total dry matter content of original fresh food

This was applied to the protein, dietary fibre, ash, fat and energy estimations presented

2.2.3.8. Limitations of Proximate Analytical Methods

Estimation of carbohydrate analysed by the method described in 2.2.3.2. is subject to error as it will also include non-carbohydrate components such as lignin, organic acids, tannins and waxes. In addition, any errors in the estimation of ash, crude protein, fibre and crude fat will also be included in the estimation of carbohydrate.

The estimate of crude protein content is of limited value in human nutrition without an estimation of the actual digestibility of the protein or the supply of essential amino acids.

However, an estimation of crude protein is needed in order to calculate the carbohydrate difference mentioned previously and also provides an initial crude estimation of the relative protein content within each potato variety and within the two tuber components. Both estimation of carbohydrate by difference and crude protein are standard practice in preliminary analysis of feed and food components (FAO CDR, 2014).

2.2.3.9. Degree of Replication and Limits of Uncertainty

With the exception of the carbohydrate estimation which was calculated by difference, duplicate observations of each nutrient within the proximate analysis were measured on dried samples from one composite sample comprised of many tubers for each potato cultivar and for each respective harvest period.

Nutrient analysis was performed in an IANZ accredited laboratory, according to IANZ accredited protocols to ensure accuracy of the analysis being undertaken and validity of replicate measurements.

2.2.4. Experiment One: Results

2.2.4.1. Presentation of Results

Note that the aim of the research presented in this chapter was to provide a preliminary basis by which the overall nutritional value of Huakaroro, Karuparera, Moemoe and Tūtaekuri tubers might be estimated with regards to other potato tubers already present on the New Zealand market, rather than to provide a definitive nutrient composition of Taewa by analysing multiple samples of the same variety in different locations, stages of development or growth environments.

In three harvesting periods, (2004, 2005, 2007 July harvests) four traditional Taewa potato tuber varieties (Huakaroro, Karuparera, Moemoe, Tūtaekuri) together with a common New Zealand modern commercial variety, (Nadine) were analysed concurrently to determine their major tuber flesh, tuber skin or whole potato tuber nutrient composition.

2.2.4.2. Results of Proximate Analysis

Results of the tuber flesh and tuber skin proximate analyses which were carried out on the four Taewa varieties and Nadine tubers from the 2004 and 2005 harvests are shown in Table 2.1, while results of the whole tuber proximate analysis which was carried out on these same varieties, but on the 2007 harvest are shown in Table 2.2. Unless otherwise stated, results within both tables are expressed in fresh weight (FW) for the raw potatoes.

Water was the major constituent in all varieties tested, and in all tuber components with a 69 – 83% moisture range found in the Taewa flesh (*c.f.* 86% in Nadine flesh), a 72 – 84% range found in Taewa skin (*c.f.* 85 – 88% in Nadine skin) and a 75 – 77% moisture range found in the whole, raw Taewa tubers (*c.f.* 85% in whole Nadine tubers). Percent dry matter content in Taewa tuber flesh ranged between 17 – 31%, whereas Taewa tuber skin had a slightly lower range of 16 – 28% (*c.f.* Nadine flesh 14 – 15% and Nadine skin 12 – 15%) and 23 – 25% in whole, raw Taewa tubers (*c.f.* 15% in whole, raw Nadine).

Table 2.1 Proximate Analysis of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 and 2005.

Results represent an average of duplicate observations in each harvest year. Uncertainties of measurements were: moisture / dry matter (± 2%); dietary fibre (± 6%); protein (± 2.9%); fat (± 3%); ash (± 4%) and gross energy (± 1%).

Potato Cultivar	Year	Water	Dry Matter	Carbohydrate	Dietary Fibre	Protein	Fat	Ash	Energy
		Average nutrient values in g/100 g FW potato							kJ/100 g
Potato Flesh									
Huakaroro	2004	77.0	23.0	18.2	1.5	2.1	0.4	0.9	368.1
	2005	72.6	27.4	22.0	1.5	2.1	0.4	1.3	438.2
Karuparera	2004	79.2	20.8	16.5	1.6	1.6	0.2	0.9	327.2
	2005	76.2	23.8	20.1	1.1	1.4	0.3	1.0	382.3
Moemoe	2004	76.7	23.3	19.4	1.4	1.5	0.4	0.7	372.7
	2005	73.8	26.2	21.5	1.5	1.8	0.3	1.1	426.9
Tūtaekuri	2004	82.6	17.4	11.8	1.7	2.4	0.7	0.8	281.2
	2005	68.8	31.2	25.8	2.0	1.8	0.5	1.1	501.7
Nadine	2004	86.3	13.7	10.5	1.0	1.4	0.2	0.6	219.4
	2005	85.5	14.5	11.5	0.9	1.3	0.2	0.6	242.7
Potato Skin									
Huakaroro	2004	80.3	19.7	13.8	2.4	2.0	0.5	1.0	
	2005	77.2	22.8	13.3	5.0	2.3	0.6	1.7	ND
Karuparera	2004	80.0	20.0	14.1	2.4	1.7	0.7	1.1	
	2005	81.1	18.9	11.7	3.9	1.7	0.4	1.3	ND
Moemoe	2004	81.0	19.0	13.6	2.5	1.6	0.4	0.9	
	2005	81.3	18.7	10.5	4.0	2.3	0.5	1.4	ND
Tūtaekuri	2004	84.0	16.0	9.6	2.4	2.7	0.8	0.9	
	2005	72.4	27.6	13.8	8.8	2.9	0.7	1.5	ND
Nadine	2004	85.4	14.6	8.8	2.3	2.1	0.5	1.0	
	2005	88.2	11.8	5.2	2.4	2.6	0.4	1.2	ND

Key: kJ = kilojoules, ND = Not determined.

Table 2.2 **Proximate Analysis of Whole, Raw Tubers from Four Taewa and Nadine Varieties Harvested in 2007.**

Results represent an average of duplicate observations

Potato Cultivar	Year	Water	Dry Matter	Carbohydrate	Dietary Fibre	Protein	Fat	Ash	Energy
		Average nutrient values in g/100 g FW potato							kJ/100 g
Whole Tuber									
Huakaroro	2007	75.1	24.9	19.1	1.7	2.8	0.3	1.0	423.4
Karuparera	2007	74.9	25.1	20.4	1.6	1.7	0.3	1.1	427.7
Moemoe	2007	75.2	24.8	19.3	1.9	2.3	0.3	1.0	423.5
Tūtaekuri	2007	77.4	22.6	16.4	2.3	2.3	0.4	1.2	388.1
Nadine	2007	84.8	15.2	11.3	1.3	1.6	0.3	0.8	260.9

Key: kJ = kilojoules.

Carbohydrate was the major dry matter constituent of the whole potato tuber (73 – 81% of the dry matter), the flesh (68 – 86%) and also the skin (44 – 72%) for all five varieties of potato tested. Taewa carbohydrate content varied between 11.8 g – 25.8 g/100 g FW in raw tuber flesh (*c.f.* 10.5 – 11.5 g in Nadine flesh), 10.5 – 14.1 g in tuber skin (*c.f.* 5.2 – 8.8 g in Nadine skin) and 16.4 – 20.4 g/100 g FW in the whole tuber (*c.f.* 11.3 g in whole, raw Nadine).

Huakaroro (2.8 g/100 g), Moemoe and Tutaekuri (2.3 g/100 g each) had the greatest whole tuber protein while Karuparera and Nadine shared similar values (1.7 g and 1.6 g/100 g respectively). Crude protein content of Taewa flesh ranged from 1.4 g – 2.4 g/100 g FW flesh (*c.f.* 1.3 – 1.4 g Nadine flesh) and Taewa skin ranged from 1.6 – 2.9 g/100 g FW skin (*c.f.* 2.1 - 2.6 g Nadine skin).

Dietary fibre content per 100 g FW in Taewa tuber skin ranged from 2.4 – 8.8 g (*c.f.* 2.3 – 2.4 g Nadine skin) and Taewa tuber flesh ranged from 1.1 – 2.0 g/100 g FW (*c.f.* 0.9 - 1.0 g Nadine flesh). Tūtaekuri had the greatest (2.3 g) and Nadine the least (1.3 g) dietary fibre content per 100 g FW whole tuber and ranged from 1.6 – 1.9 g/100 g FW for the remaining three Taewa varieties. Ash content ranged from 0.9 – 1.7 g/100 g FW in Taewa tuber skin (*c.f.* 1.0 – 1.2 g in Nadine skin), compared to 0.7 – 1.3 g/100 g FW in Taewa tuber flesh (*c.f.* 0.6 g in Nadine flesh). Whole tuber ash content achieved a similar range across the five varieties with 0.8 g/100 g FW in Nadine and 1.0 – 1.2 g/100 g FW in the Taewa.

Across all five varieties, the total crude fat content in grams of fat per 100 g FW of the tuber component had a range of 0.2 – 0.7 g in the tuber flesh; 0.4 – 0.8 g in the tuber skin and 0.3 – 0.4 g in the whole tuber. The potential energy (kJ) provided per 100 g was 388 kJ – 428 kJ in whole Taewa tuber and 280 kJ – 502 kJ/100 g of Taewa tuber flesh (*c.f.* 261 kJ/100 g whole Nadine tuber and 219 – 243 kJ/100 g Nadine flesh).

2.2.5. Experiment One: Discussion

2.2.5.1. Comparison of the Proximate Composition of Taewa with Nadine

In all five varieties, the major fresh weight proximate nutrients in order of decreasing contribution were water: 68.8 – 88.2%; carbohydrate 5.2 – 25.8% (most of which would be in the form of starch); either protein (1.3 – 2.9%; greater in whole tuber and tuber flesh); or fibre (0.9 – 8.8%; greater in tuber skin); followed by ash (0.6 – 1.7%); and lastly fat (0.2 – 0.8%).

2.2.5.1.a. Dry matter

All Taewa varieties had greater dry matter content than Nadine for each of the tuber components (skin, flesh, whole tuber). The review of worldwide data on potato nutrient composition by Burlingame *et al.* (2009), noted that some of the differences in nutrient composition reported were likely to be related to differences in water content between the varieties. In this study, a lower percentage water content (69-84%), and hence greater dry matter percentage content (16-31%) in the four Taewa, correlated with larger quantities of carbohydrate, protein, fat, fibre and energy contribution than in Nadine when compared on a fresh weight basis. Thus differences in water content and therefore dry matter content are also likely to be significant factors and influencing differences in nutrient composition observed between Taewa and Nadine.

2.2.5.1.b. Carbohydrate

Starch is the major carbohydrate tuber component and the second most abundant constituent in potato tuber composition. Fibre also comes under the category of carbohydrate but in proximate analysis, fibre is usually analysed separately. Thus the carbohydrate estimation in Tables 2.1 and 2.2 will mostly represent starch. Starch is mostly concentrated in the tuber flesh and hence a greater carbohydrate composition is expected in the flesh compared to the skin. Analysis of starch content was not carried out as part of the initial nutrient analysis but was carried out later as part of the analysis on resistant starch content (Chapter Five of this thesis).

In all tuber components, all four Taewa had greater carbohydrate content than Nadine. As might be expected (due to the relative dry matter content and the tuber component being analysed), Tūtaekuri flesh from the 2005 harvest recorded the greatest carbohydrate contribution for all varieties and tuber components at 25.8 g/100 g FW and Nadine skin in the 2005 harvest had the lowest carbohydrate contribution of 5.2 g/100 g FW (Table 2.1).

2.2.5.1.c. Protein

Similar ranges of crude protein content per 100 g FW potato were found between the Taewa and Nadine varieties as well as between all tuber components (1.3-2.9 g protein per 100 g FW potato component). However, compared to our reference potato Nadine, protein content in the Taewa was slightly greater (1.4 – 2.9 g in Taewa *cf* 1.3 – 2.6 g/100 g FW in Nadine).

2.2.5.1.d. Dietary Fibre

With regards to all tuber components each of the Taewa varieties had similar or greater dietary fibre content compared to Nadine, with Tūtaekuri having the greatest dietary fibre content per 100 g FW of all five varieties. The Tūtaekuri fibre content was 1.7 – 2.0 g/100 g FW in flesh *(cf* 0.9 – 1.6 g); 2.4 – 8.8 g/100 g FW in skin (*cf* 2.3 – 4.0 g) and 2.3 g/100 g FW in whole tuber (*cf* 1.3 – 1.9 g). As shown by these values, dietary fibre was greater in the tuber skin compared to the tuber flesh or whole tuber component in all varieties.

2.2.5.1.e. Ash

Ash content contributed only about 1% of the fresh weight in all tuber components and across all varieties. Ash was only very slightly higher in tuber skin compared to tuber flesh in all five varieties.

2.2.5.1.f. Crude Fat

When consumed on their own, potato tubers have very low lipid content (Lisinska and Leszczynski, 1989; Burlingame *et al.*, 2009). The results of this analysis support this as all tuber varieties, and all tuber components had less than 1% fat.

2.2.5.1.g. Energy

Energy estimation was carried out on the whole tuber and the tuber flesh only due to the fact that potato tuber skin generally provides only a minimal contribution to the overall energy. The protein and fat content of Taewa is minimal, thus the potential Taewa potato tuber energy will mostly be derived from the starch carbohydrate.

Taewa tubers compare favourably with Nadine as a dietary source of energy. Taewa tuber flesh had 281-501 kJ/100 g FW while Nadine flesh had 219-243 kJ/100 g FW. Whole Taewa tubers had 388-428 kJ/100 g FW while whole Nadine tubers had 261 kJ/100 g FW. Of the four Taewa varieties, both the lower (2004 flesh and 2007 whole tuber) and upper (2005 flesh) limit in potential energy was recorded in the Tūtaekuri variety. This pattern likely reflects the difference in dry matter found in Tūtaekuri within the respective harvest years (discussed further in Section 2.2.5.1.h.).

2.2.5.1.h. Notable Differences in Nutrient Composition Between Harvest Years

When comparing the nutrient composition of the four Taewa varieties across harvest years, Tūtaekuri was the variety that most often recorded an outlying value (highest or lowest value of the four Taewa varieties), while Huakaroro, Karuparera and Moemoe tended to be similar in composition. Tūtaekuri achieved both the lowest (17.4 g/100 g FW, flesh; 16.3 g/100 g FW, skin in 2004) and highest (31.2 g/100 g FW, flesh; 27.6 g/100 g FW, skin in 2005) dry matter content of the Taewa cultivars. Thus the upper and lower limit nutrient pattern in Tūtaekuri is likely related to the difference in water content of Tūtaekuri (82.6% in 2004; 68.8% in 2005). The effect of a higher water content (and thus low dry matter content) is also reflected in the results of the whole tuber analysis in 2007, with Tūtaekuri having the lowest dry matter content of the four Taewa varieties (22.6 g/100 g FW, Tūtaekuri compared to 24.8 – 25.1 g in the other three Taewa) and consequently the lowest carbohydrate and energy content of the Taewa.

The lower dry matter content of Tūtaekuri in 2004 and 2007 compared to 2005 is interesting in that Tūtaekuri is usually regarded as a cultivar that often breaks up and "mushes" when boiled (Harris and Niha, 1999), a characteristic usually linked to those cultivars with high dry matter content (Burton, 1989). These results confirm that significant differences (up to twofold or more) in nutrient composition are possible from year to year within the same cultivar which may be attributable to differences in seasonal or agronomical conditions between the harvest years (Wills *et al*., 1984; Camire *et al*., 2009; Knuthsen *et al*., 2009).

It might be expected that with the almost two-fold greater dry matter content in Tūtaekuri from the 2005 harvest, that the greater protein content would also be found in the 2005 harvest. However, the greatest protein content (2.4 g vs 1.8 g/100 g FW) was recorded in the 2004 harvest, not in the 2005 harvest as expected.

It is unclear as to the reason for this greater protein content in Tūtaekuri flesh in 2004, however, it could be a combination of genetic factors in Tūtaekuri coupled with different fertilisation regimes, environmental stresses or other agronomic conditions (Rexen 1976; Lisinska and Leszcynski, 1989; Mitrus *et al.*, 2003; Ozturk 2010).

In a study by Lehesranta *et al.* (2007), the effects of fertility management methods, crop protection practices and rotational designs on the protein profiles of potato tubers were studied. Apart from inherent differences between cultivars, only organic fertilisation practices caused a significant difference in potato protein composition. Organic fertilisation caused an increase in expression of stress-related proteins compared to mineral fertilisation, whereas increased nitrogenous fertilisation caused an increase in protein content in potato tubers (Lehesranta *et al.*, 2007).

If the increased protein content in Tūtaekuri had been related to growing conditions, or fertilisation protocol, a similar occurrence of greater protein during the 2004 harvest would have been expected in the other three Taewa varieties as they were grown under the same conditions as Tūtaekuri. One possibility is that the growing conditions in 2004 caused a greater stress response and thus increased protein content in Tūtaekuri compared to the other three Taewa, implying that the change is due to genetic differences between varieties.

Seasonal differences were also observed in skin fibre content, as except for Tūtaekuri which had an almost four-fold increase, an almost two-fold increase in skin fibre content in the Taewa varieties occurred in the 2005 harvest compared to the 2004 harvest. Again, these differences may have been in relation to different agronomical conditions between the harvest years.

2.2.5.2. Comparison of the Nutrient Composition of Taewa with Other NZ and International Potato Cultivars

In 1989, Lisinska and Leszcynski provided a summary of the nutrient composition of potato tubers sourced from data from the previous 100 years. In 2009, Burlingame and others presented a more recent report of their findings from a literature review of potato compositional data collated from four Solanum potato species (*S. Tuberosum, S. Brevidens, S. S.acaule and S.commersonii*) originating from several countries including Argentina, Peru, Spain, Canada, Italy, India and USA (Burlingame *et al.*, 2009). A summary of some of the results from these two works are presented in Table 1.1 and Tables 1.3 – 1.9.

Proximate composition of Taewa (total percentage of moisture, dry matter, carbohydrate, protein, fat, fibre, ash) for all Taewa potato varieties in this study were in accordance with the ranges reported by Lisinska and Leszczynski, (1989) and Burlingame *et al.* (2009), falling into one or both of the nutrient ranges for whole, raw potato tubers reported in these reviews (see Table 1.1). The proximate compositions of Taewa tubers were also similar to that found in modern New Zealand cultivars reported in the Concise NZ Food Composition Tables (Athar *et al*., 2003) (see Table 1.1 for whole, raw tubers; see Table 1.2 for tuber flesh only).

Thus, results of this preliminary nutrient analysis suggest the whole tuber macronutrient compositions of all four Taewa varieties are comparable to potatoes commonly consumed in New Zealand as well as those from around the world. However, with respect to the New Zealand cultivars, (Nadine analysed in 2007 and the Red King or Combined NZ cultivars presented in the Concise NZ Food Composition Tables), Huakaroro, Moemoe, Karuparera and Tūtaekuri appear to have potential for greater carbohydrate and fibre content.

This research shows that whole Taewa tubers are potentially a good source of energy, comparing favourably with Nadine and other NZ cultivars, with 388 kJ – 428 kJ provided per whole Taewa tuber and 280 kJ – 502 kJ per 100 g of Taewa tuber flesh. In addition, the energy content in kJ/100 g FW whole raw potato in Huakaroro, Karuparera and Moemoe may match or exceed the greatest energy content recorded by Andean cultivars (423 kJ/100 g FW) in the Immilla negra *(S. tuberosum ssp. Andigenum)* cultivar (Jimenez *et al.*, 2009).

2.2.5.3. Summary of Nutritional Value of Taewa Macronutrients

A higher dry matter content is desirable with regards to potential nutritional value due to the greater relative amount of available nutrients per fresh weight of tuber. Thus due to their overall greater dry matter content and potentially available nutrients per fresh weight of Taewa tuber, the four Taewa are likely to have a greater nutrient density of energy, carbohydrate, protein, dietary fibre, ash (minerals) and fat compared to Nadine. The four Taewa also appear to compare favourably with other NZ varieties in this regard (see Tables 1.1. and 1.2.). The macronutrients that may be of particular interest in Taewa compared to Nadine or other NZ cultivars include the carbohydrate, energy and dietary fibre content.

Cooked potatoes are a good source of carbohydrate and thus energy. The Australian and New Zealand estimated energy requirements for the reference sedentary male (76 kg) or reference sedentary female (61 kg) aged 19-30 years are 10.8 MJ and 8.1 MJ respectively (NHMRC, 2006).

According to the 6^{th} edition of the NZ Food Composition tables, 100 g of boiled New Zealand Rua flesh provides approximately 341 kJ (Athar *et al*., 2003), thus an average portion of boiled, Rua potato flesh (150 g) would provide around 5% and 6% of the energy requirement for a sedentary reference male and female respectively. Assuming boiled Taewa flesh has a comparable energy content to boiled Rua flesh (as raw Taewa flesh has with raw Rua flesh), it would be expected that the four Taewa would contribute similar, if not greater amounts of the daily energy requirement for the reference male and female.

The Australia and New Zealand nutrient reference values for an adequate intake of dietary fibre for a 19-30 year old adult is 30 g/day (NHMRC, 2006). 100 g of boiled Rua flesh provides 1.7 g of fibre (Athar, 2003), thus an average portion (150 g) of boiled Rua flesh would contribute close to 9% of the NZ recommended daily fibre intake. All of the four Taewa varieties had similar fibre content in the raw tuber flesh to raw Rua flesh (1.1 - 2.0 g in Taewa *cf* 1.6 g in Rua), although raw Tūtaekuri flesh (1.7-2.0 g) had slightly greater fibre content than raw Rua flesh. Hence it would be expected that fibre content in boiled Taewa flesh would be comparable to boiled Rua flesh. In addition, Taewa are normally cooked whole and eaten with the skin on, thus the contribution of dietary fibre from Taewa would most likely be even greater.

With regards to macronutrient nutritional value, the four Taewa varieties Huakaroro, Moemoe, Karuparera and Tūtaekuri show potential for a greater nutritional value to Nadine and a comparable, if not greater nutritional value to other modern NZ cultivars.

Consumption of Taewa cooked with the skin on and without the addition of salt or fat should be encouraged in order to highlight the benefits of their low fat, but concentrated carbohydrate source of energy and dietary fibre content that would likely provide greater than 10% of an adult's recommended daily fibre intake.

2.3. Experiment Two: Micronutrient Analysis

2.3.1. Aim

The aim of this experiment was to further assess useful nutritional benefits of Taewa by analysing the micronutrient composition and primary constituents of carbohydrate, protein and fats. Again this was done on four Taewa varieties (Huakaroro, Karuparera, Moemoe and Tūtaekuri) and Nadine (a modern New Zealand potato variety).

This was achieved by performing nutrient analysis to estimate and qualify the sugar content; the amino acid and essential amino acid composition; the relative contribution of insoluble and soluble fibre components; the presence of 10 minerals (K, P, Mg, Ca, Na, Fe, Zn, Cu, Mn, Se); the contribution of essential fatty acids and the quantity of selected vitamins (C, B1, B6, Folic Acid, Niacin). Except where stated, analysis was carried out on all five varieties at three different harvesting periods and on three different components of the potato tuber (the whole tuber, the tuber flesh and the tuber skin).

2.3.2. Materials and Methods

2.3.2.1. Potato Samples

Nutrient analysis for this experiment was carried out on the same composite potato materials prepared and used in Experiment 1. The preparation of potato components for nutrient analysis is described previously in Section 2.2.2.1.

2.3.2.2. Chemical Reagents and Standards

All reagents and standards used were of analytical grade and procured from local New Zealand suppliers such as Biolab Scientific Ltd, Global, Pure Science Ltd.

2.3.3. Analytical Methods

2.3.3.1. Monosaccharide and Disaccharide analysis (Gas Chromatography)

2.3.3.1.a. Potato Sample Preparation

As developed for potato samples by Dr Ian Andrews of Massey University.

60-100 mg dried, ground potato sample was weighed into a glass 15 mL centrifuge tube (with screw cap).

5 mL of 80% ethanol was added to the tube, capped and then mixed well on a vortex mixer to suspend the sample uniformly (samples that required initial dissolving had 1 mL water added to the sample first, were mixed thoroughly using a vortex mixer and then had 4 mL absolute ethanol added and then remixed). Samples were heated for 5 min in a waterbath at 80^{o}C to extract soluble sugars, cooled, and then 5 mL 80% ethanol was added to make 10 mL total. Samples were centrifuged at 3000rpm (x 1942 *g*) for 5 min in a benchtop centrifuge (Heraeus Labofuge 400R, Germany) and the supernatant was used directly for the assay.

2.3.3.1.b. Preparation of trimethylsilyl (TMS) Sugars

As developed for potato samples by Dr Ian Andrews of Massey University.

0.05 mL of xylitol internal standard (10 mg/mL) and 0.4 mL of sample supernatant prepared above were added sequentially into a 1 mL glass screw-cap vial. At the same time a control (0.45 mL 80% ethanol) and sugar standards (glucose, fructose, galactose, sucrose, maltose and lactose) were prepared (0.1 mL of 10 mg/mL standard added to 0.35 mL 80% ethanol). Each sample, control and standard was placed in a heating block and the ethanol carefully evaporated off under a stream of air or nitrogen to obtain a glassy syrup. 0.05 mL of TMS reagent (1:1, v/v mixture of TMS-imidazole in dry pyridine) was added to each and if necessary, samples were heated at 50^{o} to dissolve sugars. 0.2 mL of Hexane was then carefully added, and the samples mixed using a vortex mixer. The samples were allowed to separate into layers (or where necessary, samples were transferred to a microfuge tube, fitted with autosampler vial inserts and centrifuged. 2µL of the samples prepared above were injected into a Hewlett Packard 5890 Gas Chromatograph fitted with a ZB-1 (Phenomenex, Zebron, 100% polydimethylpolysiloxane) capillary column (30 m x 0.25 mm x 0.5 µm). Samples were run using Nitrogen as the carrier gas (2 mL/min constant flow) and an oven programme of 160^{o}-300^{o}C at 10^{o}C/min until the temperature reached 300^{o}C.

2.3.3.2. Total Sugar Estimation by Phenol-Sulphuric assay

This method was an adaptation of the methods described by Dubois *et al*. (1956) and Immers (1964). Samples prepared as in 2.3.3.1.a. above were diluted tenfold with water and 0.4 mL duplicates were added into clean round-bottom glass test tubes, (150 mm x 18 mm internal diameter). 0.4 mL glucose standards (100 µg/mL or 200 µg/mL) and a 0.4 mL water reagent blank were prepared. In a fumehood, 0.4 mL of 5% phenol (aqueous) was added to the prepared tubes and mixed using a vortex mixer. 2.4 mL concentrated sulphuric acid was added quickly and directly into the sample at the bottom of the tube and then the tubes were heated in a boiling waterbath at 100^{o}C for 5 min to ensure uniform reaction. Once cooled, the absorbance of the solution in the tubes was read at 490 nm against the reagent blank.

Where the sample was strongly coloured (such as with Tūtaekuri samples), it was necessary to use controls without phenol and subtract these from the test sample absorbance. Standards were also subjected to the same treatment, such that standards were prepared with and without phenol.

For the controls without phenol, 0.4 mL water was substituted for the phenol (0.8 mL total volume of water in the control used for measuring against Tūtaekuri). Total sugar was expressed as grams of sugar (glucose) per 100 g of fresh weight potato sample.

2.3.3.3. Fibre Components

Total dietary fibre, insoluble dietary fibre and soluble dietary fibre were determined using the enzymatic-gravimetric method (AOAC 991.43).

2.3.3.4. Amino Acid Analysis

Amino acid (AA) analysis includes an estimation of the amino acids present in whole protein as well as free amino acids. Eighteen amino acids: histidine (His), isoleucine (Ile), leucine (Leu), lysine (Lys), methionine (Met), cysteine (Cys), tyrosine (Tyr), phenylalanine (Phe), threonine (Thr), tryptophan (Trp), valine (Val), alanine (Ala), arginine (Arg), aspartic acid (Asp), glutamic acid (Glu), glycine (Gly), proline (Pro) and serine (Ser) were determined in the freeze-dried potato material described earlier (Section 2.2.2.1.). All amino acids except Cys, Met and Trp were analysed by hydrolysis with 6M hydrochloric acid followed by HPLC separation (AOAC 994.12). Cysteine and methionine were analysed using performic acid oxidation, followed by HPLC separation (AOAC 994.12), while Tryptophan was analysed using alkaline hydrolysis followed by HPLC separation (AOAC 988.15).

2.3.3.5. Fatty Acid Analysis

Fatty acid determination by the conversion of non-volatile fatty acid compounds into volatile fatty acid methyl esters (FAMES) was carried out on dried potato samples using the procedure developed by Sukhija and Palmquist (1988).

The fatty acids tested in this research included:

Saturates: *all cis*: c4:0, c6:0, c8:0, c10:0, c11:0, c12:0, c13:0, c14:0, c16:0, c17:0, c18:0, c20:0, c21:0, c22:0, c23:0, c24:0.

Monounsaturates: *all cis:* c14:1n5, c15:1n5, c16:1n7, c17:1, c18:1n9, c20:1n11, c22:1n9, c24:1n15 and c18:1-*trans* elaidic acids.

Di/Polyunsaturates: *all cis:* c18:2n6, c18:2-*trans* linoelaidic, c18:3n3, c18:3n6, c20:2n6, c20:3n6, c20:3n3, c20:4n6, c20:5n3, c22:2n6, c22:6n3 acids.

Where there were no, or <1 mg fatty acid per 100 g fresh weight potato material detected in all cultivars, the results were not included in the tables unless specifically mentioned.

2.3.3.6. Mineral Analysis

Zinc (Zn), copper (Cu) and manganese (Mn) were measured by nitric/hydrochloric acid digestion followed by Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) analysis; selenium was determined by sample digestion with aqueous trimethylammonium hydroxide (TMAH) at 90^oC followed by ICP-MS determination. Potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca), sodium (Na) and iron (Fe) were analysed using nitric/hydrochloric acid digestion, followed by Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) determination. Mineral analysis was carried out on freeze-dried samples (see Section 2.2.2.1. for material preparation) by AgResearch Ltd, Palmerston North, New Zealand.

2.3.3.7. Selected Vitamins

Based on general estimations of vitamin content in potato tubers (Lisinka and Leszczynski, 1989), the consumption of potatoes in New Zealand (Horticulture NZ, 2006; Ministry of Health, 2011), and thus their potential nutritional value, selected vitamins were chosen to be analysed in the potato tubers in this trial. These included Vitamin C, Vitamin B1 (Thiamine HCl), Vitamin B6 (Pyridoxal Phosphate), Folic Acid and Niacin.

Analysis of all Vitamins was carried out by AsureQuality New Zealand, Auckland, New Zealand. Vitamin C was measured using the liquid chromatography and fluorescence detection method (Dodson *et al*., 1992); Thiamine by HPLC (European Committee for Standardisation (CEN), 2001); Vitamin B6 by HPLC (Olds *et al*., 1993; Bitsch and Möller, 1989); Folic Acid by Optical Biosensor Based Immunoassay (Indyk *et al*., 2000) and Niacin by HPLC (Woollard, 1984).

2.3.3.8. Limits of Uncertainty

Uncertainties of measurements for nutrients tested as part of the analyses described in Section 2.3 are as follows: Insoluble dietary fibre, soluble dietary fibre (±6%); sugars(±5%); histidine (±6.9%); isoleucine (±5.56%); leucine (±4.96%); lysine (±6.23%); methionine (±6.58%); cysteine (±6.8%); tyrosine (±4.54%); phenylalanine (±4.74%); threonine (±10%); tryptophan (±6.52%); valine (±5.73%); alanine (±5.07%); arginine (±5.81%); aspartic acid (±5.18%); glutamic acid (±4.4%); glycine (±5.68%); proline (±5.87%); serine (±6.59%); fatty acids (± 5%); vitamin C (±11.64%); vitamin B1 (±15.42%); vitamin B6 (±16.48%); niacin (±15.42%); folate (±9.77%).

2.3.4. Experiment Two: Results

Results of the analysis of various micronutrients which were analysed on tuber flesh and tuber skin (2004 and 2005 harvests) and whole tuber (2007 harvest) for four Taewa varieties and Nadine are shown in Table 2.3 (Carbohydrate constituents); Tables 2.4 and 2.5 (Amino acid analysis); Table 2.6 (Fatty acid analysis); Table 2.7 (Mineral Analysis) and Table 2.8 (Vitamin Analysis). Unless otherwise stated, results within all tables are expressed in fresh weight (FW) for the raw potatoes.

2.3.4.1. Analysis of Carbohydrate Constituents

The ratio of disaccharide to monosaccharide content in potato flesh ranged from an almost 1:1 ratio in Huakaroro and Karuparera, to around half of the monosaccharide content in Moemoe and Tūtaekuri and very minimal disaccharide (0.02:1) in Nadine. Total sugar content in Taewa flesh ranged from 0.4 – 4.5 g/100 g FW (*c.f.* 1.2 – 1.5 in Nadine flesh). Total sugar content in whole tubers ranged from 0.4 – 1.3 g/100 g FW in whole Taewa tubers (*c.f.* 1.5 g in whole Nadine tubers).

A greater percentage (56-89%) of the total dietary fibre in the raw tubers was contributed by insoluble fibre compared to soluble fibre for each of the tuber components. Insoluble fibre in the whole tuber ranged from 0.9 g – 1.6 g/100 g FW in whole Taewa tubers (*c.f.* 0.9 g in whole Nadine) and 0.7 – 1.2 g/100 g FW in Taewa flesh (*c.f.* 0.7 g in Nadine flesh), but was greater in tuber skin (2.0 – 7.7 g/100 g FW in Taewa skin, *c.f.* 2.0 g in Nadine skin). Soluble fibre content was similar between all components with 0.6 – 0.8 g in whole Taewa (*c.f.* 0.4 g in whole Nadine); 0.3 – 0.8 g/100 g FW in Taewa flesh, (*c.f.* 0.2 – 0.3 g in Nadine flesh) and 0.3 – 1.1 g/100 g FW in Taewa skin, (*c.f.* 0.3 – 0.4 g in Nadine skin).

Table 2.3 **Carbohydrate Constituents of Raw Tuber Flesh, Skin and Whole Tuber from Four Taewa Varieties and Nadine over Three Harvest Years.**

Results represent an average of duplicate observations for each harvest year

Potato Cultivar	Harvest	Disaccharide: Monosaccharide Ratio	Total Sugars	Insoluble Fibre	Soluble Fibre
			Average nutrient values in g/100 g FW potato		
Potato Flesh					
Huakaroro	2004	0.9	1.6	0.8	0.7
	2005	0.9	2.4	1.1	0.4
Karuparera	2004	0.8	0.4	0.9	0.7
	2005	0.8	0.6	0.7	0.3
Moemoe	2004	0.5	1.4	0.9	0.5
	2005	0.4	1.9	1.0	0.5
Tūtaekuri	2004	0.5	2.1	1.2	0.5
	2005	0.5	4.5	1.2	0.8
Nadine	2004	<0.1	1.2	0.7	0.3
	2005	<0.1	1.5	0.7	0.2
Potato Skin					
Huakaroro	2004	ND	ND	2.0	0.4
	2005			4.5	0.5
Karuparera	2004	ND	ND	2.0	0.4
	2005			3.4	0.5
Moemoe	2004	ND	ND	2.1	0.6
	2005			3.5	0.6
Tūtaekuri	2004	ND	ND	2.0	0.3
	2005			7.7	1.1
Nadine	2004	ND	ND	2.0	0.3
	2005			2.0	0.4
Whole Tuber					
Huakaroro	2007	ND	0.6	1.1	0.6
Karuparera	2007	ND	0.4	0.9	0.7
Moemoe	2007	ND	0.5	1.2	0.7
Tūtaekuri	2007	ND	1.3	1.6	0.8
Nadine	2007	ND	1.5	0.9	0.4

Key: ND = not determined.

2.3.4.2. Amino Acid Analysis

Results of the amino acid content derived from potato tuber flesh or skin (2004 and 2005 harvest) and whole potato (2007 harvest) are shown in Tables 2.4 and 2.5 respectively. This estimation includes free amino acids and amino acids derived from protein hydrolysis. The essential amino acids (EAA) included in the calculation in these tables include the nine essential amino acids for adults; His, Ile, Leu, Lys, Met, Phe, Thr, Trp and Val as well as Arg which is considered an essential amino acid for babies and young children.

Note Tryptophan was not determined (ND) in the 2005 harvest or 2007 harvest and thus will not be included in the EAA determination for these two years. In decreasing order of contribution, the four major amino acids found in all components of the potato tuber, for all varieties included Aspartic acid, Glutamic Acid, Leucine and Lysine. The EAA contribution of the nine essential amino acids ranged from 442 – 682 mg/100 g FW in Taewa flesh (*c.f.* 348 – 416 mg in Nadine flesh); 474 - 907 mg/100 g FW in Taewa skin (*c.f.* 510 – 539 mg in Nadine skin) and 910 - 988 mg/100 g FW in whole Taewa (*c.f.* 620 mg in whole Nadine). On a per weight basis, the tuber skin generally contained more EAA than tuber flesh and all Taewa varieties had almost 1.0 g of EAA in the whole tuber compared to 0.6 g in whole Nadine tubers.

2.3.4.3. Fatty Acid Analysis

As described earlier (Section 2.3.3.5), a range of fatty acids were detected in the tuber flesh and skin of the four Taewa varieties and Nadine in 2004 and 2005 (Table 2.6). Where there were no, or less than 1 mg fatty acid per 100 g fresh weight potato material detected in all cultivars, the results of the individual fatty acids were not included as a separate fatty acid in the tables but depending on their degree of unsaturation, were included within the saturated fatty acids (SFA), monounsaturated fatty acid (MUFA) or polyunsaturated fatty acids (PUFA) totals. The major potato tuber flesh and skin fatty acids detected in the four Taewa and Nadine varieties included the SFA: palmitic acid (c16:0) and stearic acid (c18:0); and the essential PUFA: linoleic acid (c18:2n6) and linolenic acid (c18:3n3). Thus PUFAs are the major contributors to the total fatty acid (TFA) content providing 57 – 73% of the total fatty acids in the tuber flesh and 44 – 73% in the tuber skin across the five potato varieties. The contribution of the essential fatty acids linoleic acid (c18:2n6) and alpha-linolenic acid (c18:3n3) in tuber flesh ranged from 61 – 117 mg/100 g FW in Taewa flesh (*c.f.* 28 – 40 mg in Nadine flesh); 71 - 132 mg/100 g FW in Taewa skin (*c.f.* 53 – 76 mg in Nadine skin) and 44 - 72 mg/100 g FW in whole Taewa (*c.f.* 35 mg in whole Nadine).

Table 2.4 **Amino Acid Content of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine over Two Harvest Years.**

Results represent a single observation in each harvest year.

Potato Cultivar	Harvest	EAA mg/100 g FW	Arg#	His#	Ile#	Leu#	Lys#	Met#	Cys	Tyr	Phe#	Thr#	Trp#	Val#	Ala	Asp	Glu	Gly	Pro	Ser
			Nutrient values in mg/100 g FW potato																	
Potato Flesh																				
Huakaroro	2004*	644	70	42	60	108	96	21	6	57	76	65	21	84	58	415	368	60	56	64
	2005	682	73	39	67	119	106	32	34	63	85	69	ND	92	61	366	355	68	61	70
Karuparera	2004*	508	71	34	46	76	77	16	12	53	56	49	12	69	42	343	263	44	45	41
	2005	442	63	26	42	69	66	22	25	46	54	42	ND	58	36	242	216	40	39	40
Moemoe	2004*	530	49	36	52	88	79	34	5	56	60	51	13	69	48	308	269	49	46	52
	2005	578	72	34	57	94	88	29	30	57	68	57	ND	79	48	330	265	54	58	56
Tūtaekuri	2004*	729	130	48	67	110	96	36	21	67	68	66	18	90	62	530	321	56	48	59
	2005	607	80	36	60	103	94	29	33	52	67	61	ND	78	53	271	267	55	51	57
Nadine	2004*	426	56	24	39	63	58	27	12	38	49	42	10	59	34	285	256	34	31	35
	2005	348	41	20	31	59	50	19	20	30	41	39	ND	48	32	240	234	34	27	36
Potato Skin																				
Huakaroro	2004*	581	50	37	60	102	91	20	16	54	69	60	14	78	59	355	230	58	54	57
	2005	705	61	44	75	131	108	31	33	64	89	77	ND	89	69	349	270	74	76	71
Karuparera	2004*	557	54	40	55	92	88	19	9	51	64	57	16	73	53	305	215	53	54	50
	2005	518	49	32	55	91	77	24	28	47	66	54	ND	69	50	236	195	52	54	50
Moemoe	2004*	489	37	35	51	84	76	24	19	45	55	51	15	61	51	334	223	49	51	50
	2005	666	63	45	69	113	102	32	32	58	80	69	ND	94	63	495	249	64	69	64
Tūtaekuri	2004*	826	116	54	80	136	114	41	19	71	80	78	23	104	82	611	319	71	68	74
	2005	907	87	57	95	165	139	38	39	74	107	96	ND	123	95	425	290	90	87	85
Nadine	2004*	523	40	34	53	89	75	32	17	47	60	56	13	71	56	531	337	48	42	49
	2005	539	45	37	54	97	85	22	25	49	60	66	ND	72	59	721	392	54	51	56

Key: 2004* = estimation of EAA includes Tryptophan; EAA = Sum of Essential Amino Acids (Arg, His, Ile, Leu, Lys, Met, Phe, Thr, Trp, Val); Arg = Arginine; His = Histidine; Ile = Isoleucine; Leu = Leucine; Lys = Lysine; Met = Methionine; Cys = Cysteine; Tyr = Tyrosine; Phe = Phenylalanine; Thr = Threonine; Trp = Tryptophan; Val = Valine; Ala = Alanine; Asp = Aspartic acid; Glu = Glutamic acid; Gly = Glycine; Pro = Proline; Ser = Serine. # = One of the essential amino acids. ND = Not determined. Limits of uncertainty: EAA = 6.28; His = ±6.9; Ile =±5.56; Leu = ±4.96; Lys =±6.23; Met = ±6.58; Cys = ±6.8; Tyr = ±4.54; Phe = ±4.74; Thr = ±10; Trp = ±6.52; Val = ±5.73; Ala = ±5.07; Arg = ±5.81; Asp = ±5.18; Glu = ±4.4; Gly = ±5.68; Pro = ±5.87; Ser = ±6.59.

Table 2.5 **Amino Acid Content of Whole, Raw Potato Tuber from Four Taewa Varieties and Nadine.**

Results represent a single observation.

Potato Cultivar	Harvest	EAA mg/100 g FW	Arg#	His#	Ile#	Leu#	Lys#	Met#	Cys	Tyr	Phe#	Thr#	Trp#	Val#	Ala	Asp	Glu	Gly	Pro	Ser
			Nutrient values in mg/100 g FW potato																	
Whole Tuber																				
Huakaroro	2007	981	128	54	96	160	151	47	45	92	122	96	ND	128	79	657	449	87	86	98
Karuparera	2007	988	129	55	96	161	152	47	45	93	123	97	ND	129	80	662	452	88	87	99
Moemoe	2007	977	127	54	95	159	150	46	45	92	122	96	ND	127	79	654	447	87	86	98
Tūtaekuri	2007	910	118	50	89	148	140	43	42	85	113	89	ND	118	73	610	416	81	80	91
Nadine	2007	620	81	34	60	101	95	30	28	58	77	61	ND	81	50	415	283	55	55	62

Key: EAA = Sum of Essential Amino Acids (Arg, His, Ile, Leu, Lys, Met, Phe, Thr, Trp, Val); Arg = Arginine ; His = Histidine; Ile = Isoleucine; Leu = Leucine; Lys = Lysine; Met = Methionine; Cys = Cysteine; Tyr = Tyrosine; Phe = Phenylalanine; Thr = Threonine; Trp = Tryptophan; Val = Valine; Ala = Alanine;; Asp = Aspartic acid; Glu = Glutamic acid; Gly = Glycine; Pro = Proline; Ser = Serine. # = One of the essential amino acids. ND = Not determined. Limits of uncertainty: EAA = 6.28; His = ±6.9; Ile =±5.56; Leu = ±4.96; Lys =±6.23; Met = ±6.58; Cys = ±6.8; Tyr = ±4.54; Phe = ±4.74; Thr = ±10; Trp = ±6.52; Val = ±5.73; Ala = ±5.07; Arg = ±5.81; Asp = ±5.18; Glu = ±4.4; Gly = ±5.68; Pro = ±5.87; Ser = ±6.59.

Table 2.6 **Fatty Acid Analysis of Raw Tuber Flesh, Skin and Whole Tuber from Four Taewa and Nadine.** Results represent single observations for each harvest year.

Potato Cultivar	Harvest	TFA	SFA	MUFA	PUFA	c16:0	c18:0	c18:2n6	c18:3n3	C24:0
		Fatty Acid mg/100 g FW potato								
Potato Flesh										
Huakaroro	2004	123.7	53.7	ND	70.0	16.4	37.3	44.3	25.8	ND
	2005	136.8	33.1	4.9	98.8	23.9	6.7	71.8	26.5	ND
Karuparera	2004	74.5	19.4	ND	55.0	14.6	4.9	36.4	18.6	ND
	2005	107.9	25.2	3.8	78.9	17.9	5.3	54.3	24.1	ND
Moemoe	2004	103.6	42.4	ND	61.2	14.4	28.0	36.7	24.5	ND
	2005	124.4	30.2	3.9	90.3	21.5	6.3	63.0	26.7	ND
Tūtaekuri	2004	115.4	47.6	ND	67.8	16.7	30.9	46.4	21.4	ND
	2005	161.0	38.4	5.5	117.1	29.5	6.0	88.1	28.3	ND
Nadine	2004	45.1	17.2	ND	27.9	7.4	9.8	20.4	7.5	ND
	2005	55.3	13.3	2.3	39.7	9.8	2.4	27.8	12.2	ND
Potato Skin										
Huakaroro	2004	133.1	47.0	ND	86.1	18.6	28.4	44.9	41.2	ND
	2005	190.6	53.0	6.0	131.6	30.3	9.9	83.1	44.3	7.4
Karuparera	2004	96.0	24.7	ND	71.3	18.8	5.9	41.1	30.2	ND
	2005	133.7	37.1	4.9	91.7	22.3	6.6	53.5	34.1	4.5
Moemoe	2004	131.2	48.9	ND	82.3	18.1	30.9	42.4	39.9	ND
	2005	155.8	43.6	5.3	106.9	25.0	7.4	65.3	37.2	6.9
Tūtaekuri	2004	118.5	37.3	ND	81.2	19.8	17.5	51.9	29.3	ND
	2005	149.8	65.2	11.5	73.1	36.4	8.6	51.2	14.7	13.2
Nadine	2004	73.3	19.9	ND	53.4	13.1	6.9	34.5	18.9	ND
	2005	121.6	40.6	5.1	75.8	20.4	4.8	48.5	25.8	7.8
Whole Tuber										
Huakaroro	2007	101.6	27.9	11.3	62.4	19.3	5.1	45.7	15.9	1.3
Karuparera	2007	72.9	21.6	7.6	43.7	14.2	4.5	27.9	15.3	1.0
Moemoe	2007	100.8	29.6	7.1	64.1	20.8	5.2	43.3	20.0	1.4
Tūtaekuri	2007	124.4	30.9	21.2	72.3	23.1	3.5	50.6	20.2	2.0
Nadine	2007	73.7	14.0	24.7	34.9	10.8	1.6	26.2	8.7	0.7

Key: TFA = Total Fatty Acids; SFA = Saturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids; c16:0 = palmitic acid; c18:0 = stearic acid; c18:2n6 = linoleic acid; c18:3n3 = alpha-linolenic acid; C24:0 = lignoceric acid. ND = below detection limit. Note: Differences in certain individual fatty acids between years are likely due in part to the increase in sensitivity of the gas chromatographic technique used in 2005 compared to 2004.

2.3.4.4. Mineral Analysis

The mineral content of ten elements: potassium (K); phosphorus (P); magnesium (Mg); calcium (Ca); sodium (Na); iron (Fe); zinc (Zn); copper (Cu); manganese (Mn) and selenium (Se) were estimated in the five potato tuber varieties (Table 2.7).

Of the ten minerals estimated in this research, potassium (K), content provided the greatest contribution to the total ash content in all five potato varieties and in all tuber components (43 – 57% in tuber flesh; 42 – 50% in tuber skin; 45 – 50% in whole tuber). The potassium content in tuber flesh ranged from 0.4 – 0.6 g/100 g FW in Taewa flesh (*c.f.* 0.2 – 0.3 g in Nadine flesh); 0.4 – 0.7 g/100 g FW in Taewa skin (*c.f.* 0.5 g in Nadine skin) and 0.5 g/100 g FW in whole Taewa (*c.f.* 0.4 g in whole Nadine). Phosphorus (P) and magnesium (Mg) were the next two major contributors to the ash content in all tuber components for all five varieties.

Table 2.7 Mineral Analysis of Raw Tuber Flesh, Skin and Whole Tuber from Four Taewa Varieties and Nadine over Three Harvest Years.

Results represent single observations in each harvest year and except where indicated, are expressed in mg/100 g FW potato

Potato Cultivar	Harvest	K	P	Mg	Ca	Na	Fe	Zn	Cu	Mn	Se*
		Nutrient values expressed as mg/100 g FW									µg/100 g FW
Potato Flesh											
Huakaroro	2004	424.0	36.4	18.1	7.2	3.5	0.5	0.4	0.2	0.1	<0.5
	2005	576.6	73.7	23.9	7.8	1.4	0.5	0.5	0.2	0.1	<0.5
Karuparera	2004	462.7	29.4	15.4	5.5	5.1	0.3	0.3	0.1	0.1	<0.5
	2005	421.5	50.0	16.7	5.3	1.2	0.3	0.2	0.1	0.1	<0.5
Moemoe	2004	363.0	28.3	14.6	5.0	3.5	0.4	0.5	0.1	0.1	<0.5
	2005	472.8	63.9	21.7	5.1	1.4	0.4	0.3	0.1	0.1	<0.5
Tūtaekuri	2004	448.3	34.4	19.1	10.4	8.7	0.5	0.4	0.1	0.1	<0.3
	2005	491.6	63.9	22.5	9.8	1.9	0.4	0.3	0.2	0.2	<0.6
Nadine	2004	286.8	33.7	19.0	3.3	0.4	0.3	0.4	0.1	0.1	<0.3
	2005	239.1	24.9	15.1	3.7	0.8	0.3	0.3	0.1	0.1	<0.3
Potato Skin											
Huakaroro	2004	496.3	33.5	19.5	13.1	3.2	6.5	0.8	0.2	0.3	<0.4
	2005	710.1	66.7	29.6	24.0	1.3	4.8	0.6	0.2	0.2	<0.6
Karuparera	2004	585.9	33.1	19.1	13.6	4.5	2.1	0.3	0.2	0.2	<0.4
	2005	553.4	41.3	21.2	16.3	1.1	2.9	0.3	0.1	0.1	<0.4
Moemoe	2004	465.6	27.6	16.8	10.7	2.8	2.2	0.5	0.1	0.2	<0.4
	2005	594.7	51.6	26.7	21.3	1.0	4.4	0.3	0.2	0.2	<0.4
Tūtaekuri	2004	430.7	35.0	19.4	24.3	7.0	5.8	0.5	0.2	0.6	<0.3
	2005	676.3	52.0	30.6	35.4	2.0	5.5	0.5	0.2	0.2	<0.7
Nadine	2004	476.8	36.1	26.1	8.3	0.2	0.5	0.5	0.1	0.1	<0.3
	2005	509.0	17.4	23.9	14.2	0.7	1.9	0.3	0.1	0.2	<0.3
Whole Tuber											
Huakaroro	2007	482.6	53.3	25.4	6.1	1.3	1.0	0.5	0.3	0.2	2.0
Karuparera	2007	537.6	46.1	23.8	5.6	1.7	0.9	0.3	0.1	0.1	0.5
Moemoe	2007	505.9	32.9	18.7	8.6	2.0	1.8	0.4	0.2	0.2	0.5
Tūtaekuri	2007	518.5	35.4	21.7	14.8	3.5	2.1	0.4	0.1	0.2	0.7
Nadine	2007	369.2	27.3	19.3	2.7	0.8	0.4	0.3	0.1	0.1	0.3

Key: K = Potassium; P = Phosphorous; Mg = Magnesium; Ca = Calcium; Na = Sodium; Fe = Iron; Zn = Zinc; Cu = Copper; Mn = Manganese; Se* = Selenium expressed in µg/100 g FW.

Whole tuber and tuber flesh from the Taewa varieties are likely to provide 5 – 10 mg/100 g FW of Calcium (Ca) compared to 3 – 4 mg in Nadine, with Tūtaekuri likely to provide the most Ca (10.4 mg in flesh; 14.8 mg/100 g FW in whole Tūtaekuri). Calcium was found to be more concentrated in the potato skin (10 – 35 mg in Taewa skin and 8 – 14 mg/100 g FW in Nadine skin). Sodium (Na) and iron (Fe) are likely to contribute less than 10 mg/100 g FW in the potato varieties tested irrespective of the tuber component. In all varieties and tuber components, Zinc (Zn), copper (Cu), manganese (Mn) and selenium (Se) most often provided less than 1 mg of each mineral per 100 g fresh weight.

2.3.4.5. Selected Vitamins

Based on their composition or potential nutritional value in potatoes, the vitamins chosen to be analysed in the potato tubers included Vitamin C, Vitamin B1 (Thiamine HCl), Vitamin B6 (Pyridoxal Phosphate), Folic Acid and Niacin. Results of the selected vitamin analyses in whole, raw tubers (2007 harvest) for the four Taewa and Nadine varieties are shown in Table 2.8.

Per 100 g of whole, raw fresh weight Taewa tuber, Vitamin C content ranged from 7.5 – 13.8 mg, (*c.f.* 11.9 mg in Nadine); Niacin from 1.7 – 2.1 mg, (*c.f.* 0.7 mg in Nadine); Vitamin B1 from 0.1 – 0.5 mg (*c.f.* 0.1 mg in Nadine); Vitamin B6 from 0.2 – 0.4 mg (*c.f.* 0.1 mg in Nadine) and Folic Acid from 3.0 – 4.5 µg/100 g (*c.f.* 1.4 µg in Nadine).

Table 2.8 Vitamin Analysis of Raw Whole Tuber from Four Taewa Varieties and Nadine.
Results represent single observations in the 2007 harvest year.

Potato Cultivar	Harvest	Vit C	Niacin	Vit B1	Vit B6	Folic Acid
		mg/100 g FW	mg/100 g FW	mg/100 g FW	mg/100 g FW	µg/100 g FW
Whole Tuber						
Huakaroro	2007	13.7	2.0	0.5	0.4	3.8
Karuparera	2007	13.8	1.7	0.1	0.2	4.5
Moemoe	2007	9.1	1.8	0.1	0.2	3.5
Tūtaekuri	2007	7.5	2.1	0.1	0.2	3.0
Nadine	2007	11.9	0.7	0.1	0.1	1.4

Key: Vit = vitamin; C = ascorbic acid; B1 = Thiamine HCl; B6 = Pyridoxal Phosphate.

2.3.5. Experiment Two: Discussion

2.3.5.1. Comparison of the Micronutrient Composition of Taewa with Nadine

2.3.5.1.a. Carbohydrate Constituents (Monosaccharide and Disaccharide Analysis; Total Sugar Analysis; Insoluble and Soluble Fibre

The disaccharide and monosaccharide free sugar content in potato flesh is mostly made up of the non-reducing sugar sucrose and the reducing sugars glucose and fructose (Lisinska and Leszcynski, 1989). Analysis of the relative disaccharide to monosaccharide ratio suggests that there are differences in the proportions of disaccharides and monosaccharides between the Taewa cultivars as well as between the Taewa and Nadine cultivars. Huakaroro and Karuparera appear to have an almost equal (0.8-0.9 : 1) disaccharide to monosaccharide ratio, whereas Moemoe and Tūtaekuri appear to have half the amount of disaccharides to monosaccharides (0.4-0.5 : 1) and Nadine has mostly monosaccharides (0.02 : 1).

Across all five varieties, tuber flesh was found to have 0.4-4.5% of total sugar per 100 g FW and 0.4-1.3% total sugar per 100 g FW in whole, raw tubers. Total sugar content is likely to contribute to only 0.5% per 100 g FW whole tuber. However a difference of 0.05 – 8% total sugar content between cultivars has been observed both within the same cultivar and between cultivars (Lisinska and Leszcynski, 1989; Amrein *et al*., 2003, Halford *et al*., 2012b). This may be attributable to inherent genetic attributes, maturity, size of the tuber, seasonal or agronomic conditions (Halford *et al*., 2012a; Halford *et al*., 2012b). Thus the high sugar content of raw Tūtaekuri flesh in 2005 (4.5 g) compared to raw Tūtaekuri flesh in 2004 (2.1 g) and whole, raw Tūtaekuri in 2007 (1.3 g) may be due to the higher % dry matter content of Tūtaekuri flesh in 2005 compared to the other two years (higher dry matter would contribute to a higher contribution of dry matter components), or a difference in tuber characteristics, seasonal or agronomic conditions between the years.

Low reducing sugar content (low glucose and fructose content) and total sugar content is desirable nutritionally with regards to the reduced potential for the formation of the carcinogen acrylamide which can occur when potato tubers are baked or fried at high temperatures such as in the cooking of French fries (Amrein *et al*., 2003). As these four Taewa varieties have low sugar content (1.3% or less), a lower reducing sugar ratio compared to Nadine, combined with the fact that they are not consumed regularly suggests concerns with regards to potential acrylamide accumulation from Taewa consumption are unwarranted.

The contribution of insoluble fibre to total fibre was greater than the soluble fibre contribution for each of the tuber components (56-89% *cf* 19-44%) with the highest insoluble to soluble ratio found in tuber skin (82-89% *cf* 11-18%) for all varieties. This greater contribution of insoluble fibre is expected, as the content of insoluble carbohydrate components is normally around two thirds of the total fibre component (Cummings, 1981), with the greater ratio of insoluble to soluble fibre components found in the skin or outer coatings of plants (Rodriguez *et al*., 2006).

For all tuber components, the greatest insoluble and soluble fibre content was found in the Tūtaekuri cultivar (insoluble/soluble fibre: 1.2 g / 0.8 g per 100 g FW in tuber flesh; 7.7 g / 1.1 g per 100 g FW in tuber skin and 1.6 g / 0.8 g per 100 g FW in whole tuber) while the lowest soluble and insoluble fibre content was most often found in Nadine (insoluble/soluble fibre: 0.7 g / 0.2 g per 100 g FW in tuber flesh; 2.0 g / 0.3 g per 100 g FW in tuber skin and 0.9 g / 0.4 g per 100 g FW in whole tuber).

From a human health perspective, increasing dietary insoluble and soluble fibre is a potential health benefit with regards to maintaining regular laxation and providing substrates for beneficial colonic bacteria (Cummings, *et al.,* 1996; Topping & Clifton, 2001). As mentioned previously, the greater insoluble, soluble and overall total fibre content of Taewa combined with the usual practice of eating cooked Taewa whole (with skin) suggests these four Taewa (particularly Tūtaekuri), may have up to twice the fibre content of Nadine and other NZ varieties (Tables 1.3, 2.2 and 2.3) if an equal portion of potato was eaten, and therefore substitution of Taewa for a modern potato variety could have potential health benefits.

2.3.5.1.b. Amino Acids Analysis

Differences in quantity of the total essential amino acids (His, Ile, Leu, Lys, Met, Phe, Thr, Trp, Val, Arg) and individual amino acids between varieties and within tuber materials seemed to follow a similar pattern to the total protein content recorded. For example, Tūtaekuri recorded the greatest tuber flesh (2.4 g *cf* 1.4-2.1 g) and skin (2.7 g *cf* 1.6-2.1 g) protein content in 2004, the greatest tuber skin protein content in 2005 (2.9 g *cf* 1.7-2.6 g) and generally the greater individual amino acid content recorded in those respective years and tuber materials. Tūtaekuri also had the greater total essential amino acid (EAA) content of all varieties and in all tuber components except for the whole tuber where Huakaroro, Karuparera and Moemoe had slightly greater EAA (977 mg -988 mg/100 g FW *cf* 910 mg in Tūtaekuri and 620 mg in Nadine).

Markakis (1975) showed that on the basis of the amino acid profile, potato protein has a high nutritional value as the calculated protein quality was about 70% of that of whole egg protein, which is considered the 'gold standard'. It was also found that potatoes provide a good source of lysine but certain cultivars have low contents of methionine and cysteine, leucine or lysine and varied depending on the cultivation conditions and storage (Kaldy and Markakis, 1972; Markakis, 1975; Lisinska and Leszczynski, 1989; Galdon *et al*., 2010; Peksa *et al*., 2013). Thus cultivars with a higher EAA content, as well as a greater content of the limiting essential amino acids will have greater potential nutritional value.

Based on the human requirements for the essential amino acids (mg/day) proposed by the Joint World Health Organisation (2007), an average portion (150 g) of whole Taewa potato from the four Taewa varieties may contribute 4-5% more of the daily requirement for the sulphur amino acids (SAA), methionine and cysteine; 2-3% more of Leucine and 3-4% more of Lysine for an adult of 70 kg (Table 2.9) compared to Nadine, and even greater for young children or teenagers who require less EAA per kilogram of weight (Table 2.10) but have a greater need for protein due to their greater rate of growth.

Due to the apparent protein quality of potatoes, it has been suggested that potatoes may have potential applications as a base for introductory weaning foods or in formulating infant food products (Lisinska and Leszczynski, 1989). Thus assuming the whole, raw Taewa EAA content is comparable to that following cooking or processing, then including one of these Taewa varieties into such products could be of particular benefit for infants and children.

The greater percentage EAA contribution from the Taewa tubers compared to Nadine is likely due to the greater estimated EAA content (910 – 988 mg/100 g FW whole Taewa tuber *cf* 620 mg/100 g FW Nadine tuber; see Table 2.5.) and protein content (1.7 – 2.8 g/100 g FW whole Taewa tuber *cf* 1.6 g/100 g FW Nadine tuber; see Table 2.2.) in the Taewa compared to Nadine.

Table 2.9 **Percentage Essential Amino Acid Contribution (mg/day) for 70 kg Adult from 150 g Whole, Raw Tuber from Four Taewa Varieties and Nadine.**

Based on an average of duplicate observations on whole, raw tuber in the 2007, or tuber flesh from the 2004 harvest year.

Potato Cultivar	His	Ile	Leu	Lys	Met	Cys	SAA	Tyr	Phe	AAA	Thr	Trp*	Val
	Essential Amino Acid (EAA) in mg/150g FW potato												
Whole Tuber													
Huakaroro	12%	10%	9%	11%			13%			18%	14%	11%	11%
Karuparera	12%	10%	9%	11%			13%			19%	14%	6%	11%
Moemoe	12%	10%	9%	11%			13%			18%	14%	7%	10%
Tūtaekuri	11%	10%	8%	10%			12%			17%	13%	10%	10%
Nadine	7%	6%	6%	7%			8%			12%	9%	5%	7%

Key: EAA = Essential Amino Acids; His = Histidine; Ile = Isoleucine; Leu = Leucine; Met = Methionine; Cys = Cysteine; SAA = Met + Cys; Tyr = Tyrosine; Phe = Phenylalanine; AAA = Tyr + Phe; Thr = Threonine; Trp = Tryptophan; Val = Valine; Ala = Alanine; * From 2004 tuber flesh results; # From Protein and Amino Acid Requirement in Human Nutrition, (Joint WHO, 2007). Note that Arginine was not included in WHO report so not included here as an EAA.

Table 2.10 **Potential Essential Amino Acid Contributions of 150 g Whole, Raw Tuber from Four Taewa Varieties and Nadine for Humans of Selected Age and Weight.**

Based on an average of duplicate observations on whole, raw tuber in the 2007, or tuber flesh from the 2004 harvest year.

Potato Cultivar		His	Ile	Leu	Lys	Met	Cys	SAA	Tyr	Phe	AAA	Thr	Trp	Val
		Essential Amino Acid (EAA) in mg/150 g FW potato												
Whole Tuber														
Huakaroro		81	144	240	227	71	68	138	138	183	321	144	32*	192
Karuparera		83	144	242	228	71	68	138	140	185	324	146	18*	194
Moemoe		81	143	239	225	69	68	137	138	183	321	144	20*	191
Tūtaekuri		75	134	222	210	65	63	128	128	170	297	134	27*	177
Nadine		51	90	152	143	45	42	87	87	116	203	92	15*	122
Age Group	**Weight (kg)**	**#Human EAA Requirements in mg/day for the selected age groups and weight**												
Child 1-2y	11.5	173	311	621	518			253			460	265	74	414
Child 3-10y	21	252	483	924	735			378			630	378	101	609
Child 11-14y	45	540	990	1980	1575			765			1350	810	216	1305
Child 15-18y	66.5	732	1397	2793	2195			1064			1862	1131	299	1862
Adult	70	700	1400	2730	2100			1050			1750	1050	280	1820

Key: EAA = Essential Amino Acids; His = Histidine; Ile = Isoleucine; Leu = Leucine; Met = Methionine; Cys = Cysteine; SAA = Met + Cys; Tyr = Tyrosine; Phe = Phenylalanine; AAA = Tyr + Phe; Thr = Threonine; Trp = Tryptophan; Val = Valine. * From 2004 tuber flesh results; # From Protein and Amino Acid Requirement in Human Nutrition, (Joint WHO, 2007). Note that Arginine was not included in WHO report so not included here as an EAA.

2.3.5.1.c. *Fatty Acid Analysis*

The total fatty acid content (TFA) across the five varieties ranged from 45-161 mg/100 g FW in tuber flesh; 73-191 mg/100 g FW in tuber skin and 50-105 mg/100 g FW in the whole tuber. However, within each tuber component, Nadine had the lowest quantity of the individual fatty acids and thus also the classes of fatty acids they belonged to (SFA, MFA, PUFA, TFA) (Table 2.6).

Of the five varieties, Nadine had the lowest total quantity (often less than half) of the two essential fatty acids (EFA), linoleic acid (c18:2n6) and linolenic acid (c18:3n3) in each tuber component and in all harvest years compared to the four Taewa varieties. However, minimal differences in total fat were found between varieties, harvest years or tuber components (range of 0.2-0.8 g/100 g FW all tuber components) (Tables 2.1 and 2.2), thus the differences in linoleic acid and linolenic acid between the Taewa and Nadine is likely to be of little nutritional consequence.

2.3.5.1.d. *Mineral Analysis*

Due to low intakes of vegetables, fruits, whole grains, milk and milk products, K and Ca were two nutrients that were highlighted as being of public health concern for both adults and children in the 2010 Dietary Guidelines for Americans (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). Similar, low intakes of fruit and vegetable consumption or low intakes of K, Ca, Fe and Zn were also apparent in adults and children in other countries including the UK, Australia and New Zealand (Magarey, 2001; Henderson *et al*., 2003; Parnell *et al*., 2003; Grant *et al*., 2007; Ministry of Health, 2011).

Potatoes are known to have a high content of K and highly variable levels of Ca, Fe and Zn between potato cultivars (Lisinska and Leszcynski, 1989; Burlingame, 2009; Galdon *et al.*, 2012; Nassar *et al*., 2012), and likely to be a major dietary source of K in a number of countries including America (Storey and Anderson, 2013a; Weaver, 2013); the UK (Henderson *et al*., 2003) and New Zealand (Parnell *et al*., 2003; Ministry of Health, 2011). Although potatoes in general are not considered to be a rich source of Mg (Volpe *et al*., 2013; Brown *et al*., 2012) or Fe (Brown *et al*., 2010), researchers have suggested that certain varieties of potatoes have significant Mg and Fe content such that they would be of significant nutritional value (Brown *et al*., 2010; Brown *et al*., 2012).

In addition, a study of the Fe availability in potatoes carried out in rats, found the Fe to be of moderate availability, and likely be enhanced by the rich source of vitamin C in potatoes (Fairweather-Tait, 1983). Thus it was of interest to see what range of minerals might be found in Taewa, and whether the mineral content might be of potential use with regards to improving low mineral intakes in New Zealand.

Nadine had the lowest individual mineral content of the five varieties. When compared on an equal fresh weight basis, all four Taewa varieties were better K sources than Nadine with 363 – 577 mg K / 100 g FW of Taewa tuber flesh (*c.f.* 239 - 287 mg in Nadine flesh); 431 – 710 mg K / 100 g FW Taewa tuber skin (*c.f.* 477 - 509 mg in Nadine skin) and 483 – 538 mg K / 100 g FW whole tuber (*c.f.* 369 mg in Nadine). Thus Taewa may be excellent sources of K and an average portion (150 g) may provide 24 – 29% of its Australian and New Zealand Estimated Average Requirement (AusNZ EAR) and be among the vegetables recommended for population groups showing lower potassium intake (NZ females 11-18 years; NZ females of Pacific ethnicity 11-18 years), (Parnell *et al*., 2003; Ministry of Health, 2011).

Tūtaekuri and Huakaroro had the greatest potential value in terms of providing higher Ca and Fe content of the five tuber varieties. They achieved 7 – 10 mg Ca and 0.4 – 0.5 mg Fe per 100 g FW tuber flesh (*c.f.* 3 – 6 mg Ca and 0.3 – 0.4 mg Fe in the other varieties); and 24 – 35 mg Ca and 5 – 6.5 mg Fe per 100 g FW tuber skin (*c.f.* 8 – 21 mg Ca and 0.5 – 2.9 mg Fe in the other varieties). However, as Australian and New Zealand adults are estimated to require 840 mg Ca/day on average (NHMRC, 2006), but potatoes in general only have 1-31 mg Ca /100 g FW (Lisinska and Leszcynski, 1989; Burlingame *et al*., 2009) and these Taewa only contained minimal amounts of Ca (6-15 mg Ca/100 g FW whole tuber) neither potatoes in general or these Taewa potatoes on their own are likely to be of major nutritional consequence in providing adequate calcium. However adding milk and cheese to Huakaroro and Taewa potato products such as in mashed potato would substantially augment the calcium content.

Depending on the bioavailability of the Fe in Taewa, an average portion (150 g) of whole tuber from the four Taewa varieties (particularly Tūtaekuri with 2.1 mg Fe/100 g FW whole tuber) may provide 17-40% or greater of the AusNZ EAR for Fe in infants, children and non-pregnant adults compared to 8% from whole Nadine and thus including these Taewa, particularly Tūtaekuri, may help provide an inexpensive means for improving iron contribution in the diet. This is important, as in New Zealand, Fe is one of the minerals of particular concern among women, adolescent females and children.

The most recent Adult National Nutritional Survey estimated 34% of New Zealand females (15-18 years) and 15% of women (31-50 years) had inadequate intakes of Fe (Ministry of Health, 2011). Inadequate intakes of Fe were found in 6.6% of New Zealand children (5-14 years) but were more likely to be found among children of Pacific ethnicity (15%) or menstruating females (44%) (Parnell *et al*., 2003). Studies of New Zealand infants (6-23/24months) in Auckland between 1999–2002, (Grant *et al*., 2007) and urban South Island children between 1998-1999 (Soh *et al*., 2004) suggested that 14% and 29% of New Zealand infants may be Fe deficient or have suboptimal Fe status respectively.

Within the three harvest years recorded, Huakaroro achieved the greatest P and Mg whole tuber content (53 mg P: 9% of AusNZ EAR; 25 mg Mg: 8-10% of AusNZ EAR); tuber flesh content (74 mg P; 24 mg Mg) and the greatest P tuber skin content (67 mg); whilst Tūtaekuri achieved the greatest Mg skin content (31 mg) of all five varieties per 100 g FW tuber component.

The AusNZ EAR for Mg in women 19-70 years is 255-265 mg/day and for men 19-70 years is 330-350 mg/day (NHMRC, 2006). Although Mg is unlikely to be a nutrient of concern in Australia or NZ, an average portion of whole, Taewa tubers may provide 5-15% of the adult AusNZ EAR for Mg. An average portion (150 g) of whole Huakaroro tuber may provide twice the EAR of Mg required for Australian and NZ women and men 19-70 years (14-15% women; 11-12% men) compared to Nadine or Moemoe (7% women; 5-6% men) and thus Taewa (particularly Huakaroro and Tūtaekuri) show greater potential in providing Mg in the diet.

Minimal tuber compartmental, varietal, or harvesting differences occurred with respect to Zn, Cu, Mn and Se content within and between the five varieties. All varieties are likely to provide less than 1 mg of each mineral per 100 g fresh weight tuber, although in 2007, whole Huakaroro tuber recorded 2 µg/100 g FW Se compared to 0.3-0.7 µg/100 FW in the other four varieties and all Taewa varieties were more likely to contain greater amounts of these respective minerals than Nadine. While the estimated prevalence of inadequate Zn or Se intake is generally low in New Zealand, it may be of some concern in certain New Zealand population groups (Zn in males aged 71+ years and females of Pacific ethnicity 11-14 years; Se in children 9-13 years and females 15-18 years).

An average portion (150 g) of whole Taewa (in particular Huakaroro) may provide 3.8-11.5% of the adult AusNZ EAR for Zn and 1.5-7.5% of the 9-13 years child and 15-18 years female AusNZ EAR for Se.

An average portion of these Taewa may also provide 8.8-37.5% and 2.7-6% of the adult AusNZ EAR for Cu and Mn respectively. Thus greater consumption of Taewa may provide particular benefit with regards to these minerals.

2.3.5.1.e. Vitamin Analysis

Of all the vitamins analysed in whole raw tubers (vitamins C, Niacin, B1, B6 and Folic Acid), Taewa varieties achieved the greatest vitamin content. There was an at least two-fold difference between the highest and the lowest content of the vitamins in each case. With respect to the relevant nutrient's AusNZ EAR for adults 19-30 years, an average portion (150 g) of whole Taewa may provide 40-69% of vitamin C (*cf* 60% in Nadine; greatest in Huakaroro and Karuparera); 26-49% of vitamin B6 (*cf* 14% in Nadine; greatest in Huakaroro), 22-27% of Niacin (*cf* 9% in Nadine; greatest in Tūtaekuri and Huakaroro); 11-61 % of Vit B1 (*cf* 14-17% in Nadine; greatest in Huakaroro); but minimal folate (1-2% from all varieties).

Daily per capita potato consumption in 2009 has been estimated at 300-500g in parts of Europe and close to 150 g in New Zealand, USA and Australia (FAOSTATS, 2014b). In 2002, tubers such as potatoes, kūmara and taro contributed to 6% of the dietary sources for folate in NZ children (Parnell *et al*., 2003) and in 1997 contributed to around 6-9% folate for NZ adults (Russell *et al*., 1999). Results from the 2008/09 NZANS survey suggested that together, the PKT group contributed to 13% of the vitamin C; 6% of the vitamin E; 5% of the thiamine; 6% of the niacin equivalents; and 10% of the pyridoxine intake in the diet of NZ adults (University of Otago and Ministry of Health, 2011).Therefore by including Taewa cultivars among those potatoes eaten by the general New Zealand public, Taewa also show the potential to be of benefit with regards to vitamins C, B1, B6, niacin and possibly folate.

2.3.5.2. Notable Differences in Nutrient Composition Between Cultivars or Harvest Years

2.3.5.2.a. Between Cultivars

As was discussed in Section 2.3.5.1., two-fold or greater nutrient differences between cultivars most often occurred between a Taewa variety and Nadine. However differences in nutrient content (likely due to the inherent genetic variation) also occurred between Taewa varieties.

With respect to nutrients of most nutritional value, the greater insoluble and soluble fibre and Fe content of Tūtaekuri and the greater vitamin B1 and B6 content of Huakaroro are the most likely to have a potential nutritional impact and thus could be targeted for further research to determine the extent of the differences between these and other cultivars currently used in NZ.

2.3.5.2.b. Between Years

The observed two-fold or greater difference in nutrient content between harvest years but within the same variety is likely due to seasonal or agronomical conditions as previously discussed (Section 2.2.5.1.h). A difference in the fatty acid components was evident between the 2004 and 2005 harvest years with relation to fatty acids with a carbon chain greater than 18 (see Table 2.6). It is likely that an increase in sensitivity in the gas chromatographic technique, resulting in lower detection levels is responsible for this. For longer chain fatty acids, minute amounts (<1.0 mg fresh weight) of c20:0, c20:4n3, c22:0) and small amounts (<1 – 5 mg fresh weight) of c24:0 were able to be detected in the assays following stage 1, 2004 (as shown in the effects of 6 months storage on fatty acid content, Table 2.19 and 2005 fatty acid analyses, Table 2.6). A difference in mineral content between harvest years was found in this research with a higher phosphorus and magnesium content per 100 g FW being recorded in tuber flesh and skin across all four Taewa varieties in 2005 compared to 2004 but as phosphorus and magnesium deficiency are not currently a nutrient of concern in NZ, such changes are likely to be of minimal nutritional consequence.

Notable differences in fatty acid content between 2004 and 2005 were also found, however since the potato tubers contained minimal fat (less than 1% fat), any differences in fatty acid contribution are of minimal nutritional consequence.

2.3.5.3. Comparison of Nutrient Content of Taewa with Other NZ and International Potato Cultivars

2.3.5.3.a. Carbohydrate Constituents

The nutrient content for whole, raw tubers from Taewa cultivars fell within the ranges for total sugars, insoluble fibre and soluble fibre reported in potato cultivars from around the world (Lisinska and Leszcynski, 1989; Burlingame *et al*., 2009) and in NZ (Athar, 2003) (see Table 1.3). However, the insoluble fibre content of whole Tūtaekuri, Moemoe and Huakaroro tubers was double that of other NZ cultivars reported, suggesting twice the potential benefit from fibre constituents as previously discussed in Section 1.3.5.1.a.

Total sugar content in whole raw Tūtaekuri (1.3 g/100 g FW) was near the top end of the range (0.08 – 1.39 g/100 g FW) reported by Lisinska and Leszcynski (1989) and 4 times greater than that reported in other New Zealand varieties (0.3 g/100 g FW), however due to the minimal energy contribution of sugars to the overall energy content of the tuber (about 5.6% of energy contribution in Tūtaekuri), this is of minor nutritional importance.

2.3.5.3.b. Amino Acids and Fatty Acids

The amino acid content in whole, raw Taewa tubers (Table 2.5) generally fell within the ranges of cultivars from around the world as presented by Lisinska and Leszcynski (1989) and Galdon *et al*. (2010) (Table 1.4), with the exception of lysine, methionine, cysteine, tyrosine, aspartic acid and glutamic acid, with the content of these amino acids being greater in all Taewa compared to the ranges reported from international cultivars. It should be noted that the amino acid content presented in this research represents the combination of the amino acids digested in the tuber protein as well as any free amino acids present in the tuber component, whereas that reported by Lisinska and Leszcynski, 1989 only represented free amino acids. Hence it would be expected that the amino acid content presented in this research would be greater. However, the content of these six amino acids were also greater in Taewa compared to that reported for 10 Spanish tuber varieties (Galdon *et al*., 2012). The amino acid content in the Taewa flesh was comparable to that reported in the flesh of the NZ Rua potato variety except for glutamic acid and aspartic acid, which were greater in all Taewa compared to Rua.

Contributions of the four major fatty acids (linoleic, alpha-linolenic, palmitic and stearic acids) to the total fatty acid content within the whole tuber of the four Taewa varieties (Table 2.6) closely aligned with those ranges reported in the literature (Lisinska and Leszcynski, 1989; Dobson *et al*. 2004, Table 1.5). Total saturated, monounsaturated and polyunsaturated fatty acid content of the Taewa also aligned with values reported in the combined NZ cultivars and the NZ Red King cultivar (Athar, 2003, Table 1.5). Thus with regards to amino acid and fatty acid content, Taewa are comparable to other international and NZ cultivars.

2.3.5.3.c. Minerals

Large differences in mineral content ranges have been found between potato cultivars throughout the world (Lisinska and Leszcynski, 1989; Burlingame, 2009; Galdon *et al.*, 2012; Nassar *et al*., 2012) (Table 1.7). Thus it is not surprising that the whole tuber mineral content of all four Taewa varieties (Table 2.7) fell within the reported ranges.

Taewa were lower in K, Mg and Fe content than the upper ranges reported by Lisinska and Leszcynski, 1989; Burlingame, 2009; and Nassar *et al*., 2012 which included reports of both modern and native Andean cultivars. However, with respect to K and Mg, all four Taewa varieties had higher content than those reported in 10 Spanish potato varieties (Galdon *et al*., 2012), and compared to modern NZ cultivars reported by Athar *et al*. (2003), whole tubers from all Taewa varieties appear to have greater content of K, Mg and Fe. Of the minerals analysed in this study, those likely to be of most nutritional value in the Taewa include K, Mg and Fe (Section 2.3.5.1.d.).

2.3.5.3.d. Vitamins

Taewa have been identified as having comparable or greater nutritional value than Nadine with regards to vitamin C, vitamin B6, niacin and vitamin B1. Compared to international (Lisinska and Leszcynski, 1989; Burlingame, 2009), and New Zealand cultivars (Athar, 2003), vitamins B6, B1 and niacin content in whole Taewa (Table 2.8) are near to or greater than the upper range reported for international cultivars and comparable or greater than those reported in other NZ cultivars (Table 1.6). Thus, Taewa may be of particular nutritional value with regards to vitamins B6, B1 and niacin.

2.3.5.4. Summary of Nutritional Value of Taewa Micronutrients

Based on the discussions in Sections 2.3.5.2 and 2.3.5.3, the nutrients likely to be of most biologically significant nutritional value in Taewa compared to Nadine and other NZ cultivars include insoluble fibre content, the minerals K, Mg and Fe and the vitamins B1, B6 and niacin. However, Taewa are also comparable to other NZ cultivars with regards to all essential amino acids; the essential fatty acids linoleic and alpha linolenic acid; the minerals P, Ca, Na, Zn, Cu, Mn and Se and the vitamins folate and vitamin C, thus these nutrients are also likely to be of high nutrient value due to the high consumption of potatoes eaten per capita in New Zealand. However, as all of these estimations are based on raw tuber, it would be of benefit to examine the levels of these nutrients after cooking (See experiment 4 of this chapter).

2.4. Experiment Three: Phytochemical and Anti-Nutrient Analysis

2.4.1. Aim

The aim of this experiment was to examine the presence and quantity of certain phytonutrient components in order gauge health-promoting or toxic potential of the four Taewa varieties: Huakaroro, Karuparera, Moemoe and Tūtaekuri against Nadine, a modern potato variety commonly available to the average New Zealand consumer. This was achieved by performing analyses to estimate and identify certain phenolic, flavonoid, anthocyanin and glycoalkaloid components. Except where stated, analyses were carried out on all five varieties at two different harvesting periods and on the tuber flesh and the tuber skin components.

2.4.2. Materials and Methods

2.4.2.1. Potato Samples

In two harvesting periods, (2004, 2005 July harvest) four traditional Taewa potato tuber varieties (Huakaroro, Karuparera, Moemoe, Tūtaekuri) together with a common commercial variety (Nadine) were analysed concurrently to determine certain phytochemical tuber flesh and tuber skin components. Nutrient analysis for this experiment was carried out on the same composite potato materials prepared and used in Experiment 1. The preparation of potato components for nutrient analysis is described previously in Section 2.2.2.1.

2.4.2.2. Reagents and Equipment

All reagents used in this experiment were of analytical grade and except where stated, were procured from local NZ suppliers e.g. Biolab Scientific Ltd, Global, Pure Science Ltd.

2.4.3. Analytical Methods

2.4.3.1. Phytochemical Analysis

2.4.3.1.a. Sample Preparation

Freeze-dried samples (Section 2.2.2.1.) were ground using a Breville coffee and spice grinder (CG2B, made in China) in a darkened room. Ground samples were kept in zip-locked plastic bags and then stored together in foil bags until analysis.

Ground freeze-dried potato samples (0.5 g sample for Tūtaekuri flesh and skin; Karuparera skin, Moemoe skin and 1.0 g for Nadine flesh and skin; Huakaroro flesh and skin; Karuparera flesh, Moemoe flesh) were accurately weighed into 50 mL, aluminium foil-covered falcon tubes in a darkened room. Polyphenols within the potato sample were then extracted in 15 – 25 mL of solvent mixture (80:20:5 ratio of absolute ethanol; MilliQ water and 99% formic acid). The potato and solvent were mixed using an Ultraturrex LabServ Homogeniser (D500 Series, Germany) at 10,000 rpm for 1 min. Samples stood for 30 min before being centrifuged (Sorvall Evolution RC centrifuge (Kendro Laboratory Products, Newton, Connecticut, USA)) at 3000 rpm (1942 *g*) for 10 min. 2-3 mL of the resulting supernatant was filtered into 3 mL dark brown, screw-capped glass vials using 0.45 µm PTFE filters and stored at -20^{o}C for ORAC, FRAP and polyphenol analysis.

2.4.3.1.b. HPLC analysis of Polyphenols

Phenolic (PH), flavonoid (FLV) and anthocyanin (ACN) concentration in potato flesh and skin samples were determined by reversed-phase HPLC with photodiode array (PDA) detection. PH, FLV and ACN concentrations were calculated as cyaninidin 3-O-galactoside (C3GAL) equivalents using an authentic standard of C3GAL (Extrasyntese, Genay, France) of known concentration. Phenolic compounds detected at 280 nm included the major potato phenolic compound, chlorogenic acid, and compounds that would also fit within the flavonoid (catechin, epicatechin, procyanidins, phloridzin-xyloside, phloridzin) and anthocyanin (cyanindin-3-galactoside) categories. Another major potato phenolic compound, caffeic acid was detected at 370 nm and this was added into the total phenolic content.

2.4.3.2. Antioxidant Potential (ORAC and FRAP)

The Oxygen Radical Absorption Capacity (ORAC) assay measures antioxidant activity. The assay used was based on the method by Ou *et al.* (2001). The absorption capacity of the potato tuber extract was expressed as Trolox equivalents (TE) in mmol/g of potato sample on a fresh weight basis. All solutions were used on the day of preparation and all determinations performed in triplicate. The method used to determine FRAP in extracted potato tuber samples was based on the protocol described by Benzie and Strain (1996), with minor modifications by Deighton *et al*. (2000). The antioxidant capacity was expressed as Trolox equivalents (TE) in mmol/g of potato sample on a dry weight basis of the freeze-dried sample initially and then converted to a fresh weight basis. All solutions were used on the day of preparation and all determinations were performed in triplicate.

2.4.3.3. *Anti-Nutrient Analysis: Glycoalkaloid Components*

Analysis of glycoalkaloid content in the 2004 harvest of the five potato cultivars was carried out by the NZ Institute for Crop and Food Research Ltd (McCallum *et al*., 2005) by liquid chromatography-mass spectrometry (LCMS). Results are expressed on a fresh weight basis per 100 g potato sample.

2.4.4. *Experiment Three: Results*

Results of phytochemical analyses of phenolic, flavonoid, anthocyanin, antioxidant potential and levels of the anti-nutrient glycoalkaloid compounds, α-chaconine and α-solanine in potato flesh and skin samples from four Taewa (Huakaroro, Karuparera, Moemoe and Tūtaekuri) and one modern potato variety (Nadine) measured over two consecutive harvests (2004 and 2005) are presented in Tables 2.11 – 2.15.

2.4.4.1. *Phytochemical Analysis*

The phytochemical analysis presented is not a comprehensive identification of all compounds and their precise concentration, but rather presents an idea of the array of compounds that might be present and how they might compare between the Taewa and Nadine varieties. Additionally, the total phenolic content might provide some idea of the potential antioxidant capability of the various potato samples. The total phenolic content of the Taewa were 2 – 50 times greater than Nadine in flesh (20-523 mg total phenolics / 100 g FW Taewa flesh *cf* 6-10 mg total phenolics / 100 g FW Nadine flesh) and 1 – 8 times greater in skin (98 - 970 mg total phenolics /100 g FW Taewa skin *cf* 73-132 mg total phenolics /100 g FW Nadine skin). Of the five cultivars, Tūtaekuri had the greatest total phenolic content in both skin and flesh, whereas Nadine had the lowest, Huakaroro, Karuparera and Moemoe had similar total phenolic contents, however, these were approximately twice that of Nadine (Table 2.11).

Many flavonoid quercetin derivatives were detected in the potato extracts when measured at 370 nm, including: quercetin-rutinoside, -galactoside, -xyloside, - arabinose pyranoside, -arabinose furanoside, - rhamnoside and an unknown quercetin derivative. The total flavonoid content shown in Table 2.12 includes quercetin and its derivatives as well as “other flavonoid” compounds detected at 370 nm. Again Tūtaekuri had the greatest total flavonoid content of the five cultivars (21-37 mg/100 g FW flesh; 59-79 mg/100 g FW skin), whereas Huakaroro, Moemoe, Karuparera were similar in content (0.16-0.27 mg/100 g FW flesh; 0.8-10.8 mg/100 g FW skin) to Nadine (0.12-0.13 mg/100 g FW flesh; 0.6-3.6 mg/100 g FW skin).

Table 2.11 **Contribution of Selected Phenolic Components in Raw Tuber Skin and Flesh from Four Taewa Varieties and Nadine in Two Harvest Years.**

Based on an average of triplicate assays of extracts from composite raw tuber skin and flesh samples for the 2004, 2005 harvests. Measured against standards at 280nm.

Potato Cultivar	Harvest	Caffeic Acid	Chlorogenic	Epicatechin	Procyanidin	Phloridzin-xyl	Phloridzin	Other Phenolics	Total Phenolics*
		Data presented as means in mg/100 g FW							
Potato Flesh									
Huakaroro	2004		4.9	0.4	7.9			8.5	21.6
	2005		4.5	0.3	16.7			6.4	27.9
Karuparera	2004		5.2	0.5	6.8			7.7	20.2
	2005		5.0	0.6	14.4			7.5	27.5
Moemoe	2004		10.5	0.3	7.4			15.3	33.5
	2005		11.0	0.3	18.9			13.5	43.7
Tūtaekuri	2004		111.0	0.7	19.1			392.2	523.0
	2005		68.6	0.0	16.2			212.3	297.1
Nadine	2004		0.8	0.3	2.6			2.1	5.8
	2005		3.1	0.2	2.0			4.7	10.0
Potato Skin									
Huakaroro	2004	1.7	0.0	1.0	19.7	0.1	0.1	75.6	98.1
	2005	7.2	88.4	1.4	65.6	0.1	0.5	115.6	278.8
Karuparera	2004	4.2	37.4	0.0	31.3			85.0	157.9
	2005	0.0	67.3	1.9	47.3			137.4	253.9
Moemoe	2004	2.5	63.6	0.9	22.0	0.6	0.3	88.1	178.1
	2005	0.0	86.9	1.7	67.8	0.0	0.0	151.7	308.1
Tūtaekuri	2004	6.8	181.4	2.5	62.5	93.1	0.6	501.0	847.8
	2005	0.0	144.0	1.7	223.3	90.1	6.3	504.3	969.7
Nadine	2004	2.3	21.5	1.7	18.0			29.2	72.7
	2005	5.6	27.8	11.8	40.3			46.8	132.2

Key: xyl = xyloside; * = includes compounds detected at 280 nm as well as Caffeic acid detected at 370 nm.

Anthocyanin compounds detected in the Taewa included cyanidin-3-glucoside and malvidin-3-glucoside in Tūtaekuri flesh or Karuparera, Moemoe and Tūtaekuri skin (measured at 530 nm) and cyanidin-3-galactoside was also detected in the skins of Huakaroro, Moemoe and Nadine (measured at 280 nm). In addition, “minor” and “other” anthocyanins were able to be detected when measured at 530 nm, particularly in Tūtaekuri suggesting other anthocyanins are also present. Of all five varieties, those that had red to purple colourations in the flesh (Moemoe and Tūtaekuri) and red to purple colourations in the tuber skin (Karuparera, Moemoe and Tūtaekuri) had much higher concentrations of anthocyanins. Tūtaekuri again contained the greatest anthocyanin content, ranging from 43-90 mg/100 g FW flesh; 118-126 mg/100 g FW skin). No anthocyanins were detected in the flesh of Huakaroro, Karuparera or Nadine and less than 0.5 mg/100 g FW flesh was detected in Moemoe. Again minimal anthocyanins were detected in the skins of Huakaroro and Nadine (less than or equal to 1 mg/100 g FW skin) but 3.7-18 mg/100 g FW skin were detected in the skin of Karuparera and Moemoe (Table 2.13).

Table 2.12 Contribution of Selected Flavonoid Components in Raw Tuber Skin and Flesh from Four Taewa Varieties and Nadine in Two Harvest Years.

Based on an average of triplicate assays of extracts from composite raw tuber skin and flesh samples for 2004, 2005 harvests. Measured against standards at 370 nm.

Potato Cultivar	Harvest	Quercetin	Q-rut	Q-gal	Q-glu	Q-xyl	Q-unk	Q-arapy	Q-araf	Q-rha	Other flav.	Total Flavonoids
		Data presented as means in mg/100 g FW										
Potato Flesh												
Huakaroro	2004										0.2	0.2
	2005										0.2	0.2
Karuparera	2004										0.2	0.2
	2005										0.3	0.3
Moemoe	2004											
	2005											
Tūtaekuri	2004	0.4	1.9	6.4	5.4	0.4	19.0		2.2		1.6	37.3
	2005		0.5	2.6	4.8	0.6	11.1				1.8	21.4
Nadine	2004			0.1								0.1
	2005			0.1								0.1
Potato Skin												
Huakaroro	2004			0.4			0.3				0.1	0.8
	2005			0.0			0.0				1.5	1.5
Karuparera	2004		0.2	2.1	0.3	0.3	0.5		0.0		1.9	5.3
	2005		0.5	4.0	0.5	0.3	1.1		0.5		2.5	9.2
Moemoe	2004		0.6	0.3	0.4	0.0	0.0	0.0			0.3	2.3
	2005		0.3	2.5	0.5	0.7	0.8	1.2			5.0	10.8
Tūtaekuri	2004	0.3	3.0	6.4	8.6	1.7	29.9		5.6		3.8	59.3
	2005	0.0	3.5	4.2	14.0	4.8	28.8		10.9		12.7	79.0
Nadine	2004		0.1	0.1		0.2	0.0	0.0	0.0	0.1	0.0	0.6
	2005		0.1	2.4		0.0	0.3	0.2	0.2	0.1	0.4	3.6

Key:* = Q = quercetin; rut = rutinoside; gal = galactoside; xyl = xyloside; unk = unknown; arapy = arabinose pyranoside; araf = arabinose furanoside; rha = rhamnoside. Total flavonoids only include quercetin and quercetin derivatives detected at 370 nm.

2.4.4.2. Assessment of Antioxidant Potential

Based on results which identified the cultivars with the greatest total anthocyanin, flavonoid and phenolic content, it was expected that Tūtaekuri would have the greatest *in vitro* antioxidant capacity. Two measures of antioxidant capacity were used (FRAP; Ferric Reducing Antioxidant Power and ORAC; Oxygen Radical Absorbance Capacity assays) as there are many phenolic compounds with different properties and characteristics. Hence one particular assay may be better at detecting a certain type of antioxidant compound than another and therefore using more than one assay enables a researcher to pick up a wider range of antioxidative compounds. Results of the ORAC and FRAP assays showed that both the flesh and skin extracts of all four Taewa varieties have antioxidant potential. Tūtaekuri displayed the greatest antioxidant potential (Table 2.14), with a 4-10 fold greater capacity to reduce ferric ions in the FRAP assay (1.2-1.4 mM TE/100 g FW in Tūtaekuri flesh; 1.5-2.6 mM TE/100 g FW in Tūtaekuri skin) or protect against peroxyl radicals in the ORAC assay (3.6-5.5 mM TE/100 g FW in Tūtaekuri flesh; 12.3-14.6 mM TE/100 g FW in Tūtaekuri skin) than the other four cultivars.

Table 2.13 **Contribution of Selected Anthocyanin Components in Raw Tuber Skin and Flesh from Four Taewa Varieties and Nadine in Two Harvest Years.**

Based on an average of extracts from composite raw tuber skin and flesh samples for 2004, 2005 harvests. Measured against standards at 530 nm.

Potato Cultivar	Harvest	Cy-gal	Cy-glu	Mlv-glu	Minor	Other	Total Anthocyanins*
		Data presented as means in mg/100 g FW					
Potato Flesh							
Huakaroro	2004						
	2005						
Karuparera	2004						
	2005						
Moemoe	2004					0.4	0.4
	2005					0.3	0.3
Tūtaekuri	2004		1.9	0.8	0.4	86.9	89.9
	2005		1.2	0.7	0.0	41.6	43.5
Nadine	2004						
	2005						
Potato Skin							
Huakaroro	2004	0.3				0.1	0.4
	2005	1.0					1.0
Karuparera	2004			0.4		10.6	11.0
	2005			0.6		17.8	18.4
Moemoe	2004	0.0		0.0		3.7	3.7
	2005	0.9		0.4		12.8	14.1
Tūtaekuri	2004		2.2	0.7	0.6	122.1	125.5
	2005		3.9	0.0	0.0	114.4	118.3
Nadine	2004	0.2					0.2
	2005	0.6					0.6

Key: Cy-gal = cyanidin-3-galactoside; cy-glu = cyanidin-3-glucoside; mlv-glu = malvidin-3-glucoside;* = Includes "minor" and "other" anthocyanins as well as compounds detected at 530 nm as well as cyanidin-3-galactoside detected at 280 nm.

Huakaroro, Karuparera, Moemoe and Nadine had similar antioxidative potential, however, the three Taewa generally had slightly higher values than Nadine. In the potato flesh, the three Taewa achieved 0.2 mM *cf* Nadine 0.1-0.2 mM TE/100 g FW for FRAP and 0.9-1.8 mM *cf* Nadine 0.4-0.5 mM TE/100 g FW for ORAC. In the skin, the three Taewa achieved 0.4-0.9 mM *cf* Nadine 0.2-0.5 mM TE/100 g FW for FRAP and 2.4-5.7 mM *cf* Nadine 2.2-2.4 mM TE/100 g FW for ORAC. Potato extracts from the skins of the potato samples were 2-3 times more effective than flesh extracts at providing anti-oxidative capacity regardless of the cultivar (Table 2.14).

Table 2.14 **Assessment of Antioxidant Potential in Raw Tuber Skin and Flesh from Four Taewa Varieties and Nadine in Two Harvest Years.**

Based on an average of triplicate assays of extracts from composite raw tuber skin and flesh samples for 2004, 2005 harvests. Antioxidant assays expressed as means of mmol of Trolox equivalent/100 g FW; phenolic compounds expressed as means mg/100 g FW.

Potato Cultivar	Harvest	FRAP	ORAC	Total Anthocyanins*	Total Flavonoids	Total Phenolics#
		mM TE/100 g	mM TE/100 g	mg/100 g (530 nm)	mg/100 g (370 nm)	mg/100 g (280 nm)
Potato Flesh						
Huakaroro	2004	0.2	1.0		0.2	21.6
	2005	0.2	1.1		0.2	27.9
Karuparera	2004	0.2	1.0		0.2	20.2
	2005	0.2	1.3		0.3	27.5
Moemoe	2004	0.2	0.9	0.4		33.5
	2005	0.2	1.8	0.3	0.1	43.7
Tūtaekuri	2004	1.4	5.5	89.9	37.3	523.0
	2005	1.2	3.6	43.5	21.4	297.1
Nadine	2004	0.1	0.4		0.1	5.8
	2005	0.2	0.5		0.1	10.0
Potato Skin						
Huakaroro	2004	0.4	2.4	0.4	0.8	98.1
	2005	0.9	4.3	1.0	1.5	278.8
Karuparera	2004	0.6	3.3	11.0	5.3	157.9
	2005	0.7	4.5	18.4	9.2	253.9
Moemoe	2004	0.8	4.5	3.7	2.3	178.1
	2005	0.9	5.7	14.1	10.8	308.1
Tūtaekuri	2004	1.5	14.6	125.5	59.3	847.8
	2005	2.6	12.3	118.3	79.0	969.7
Nadine	2004	0.2	2.2	0.2	0.6	72.7
	2005	0.5	2.4	0.6	3.6	132.2

Key: FRAP = Ferric Reducing Antioxidant Power; TE = Trolox Equivalent; ORAC = Oxygen Radical Absorbance Capacity; * = includes cyanindin-3-galactoside measured at 280 nm; # = includes caffeic acid measured at 370 nm.

2.4.4.3. Anti-Nutrient Analysis: Glycoalkaloid Components

In order to assess the potential anti-nutrient levels in the Taewa, levels of the glycoalkaloids α-chaconine and α-solanine were assayed in the flesh and skin of Huakaroro, Karuparera, Moemoe and Tūtaekuri and compared against the Nadine variety. In potato flesh, levels of α-solanine and α-chaconine were lowest in Huakaroro and Nadine (0.7-0.8 mg α-solanine, 0.9-1.1 mg α-chaconine /100 g FW)and 4-5 times higher in Tūtaekuri and Karuparera (3.5-3.9 mg α-solanine, 3.5-4.6 mg α-chaconine /100 g FW). In potato skin, all four Taewa had 2-3 times higher levels of α-solanine (15.0-24.4 mg *cf* 7.2 mg in Nadine/100 g FW) and 1.5-2 times higher α-chaconine levels(21.4-38.3 mg *cf* 7.2 mg/100 g FW in Nadine). Total glycoalkaloid levels were 7-27 times greater in potato skin than potato flesh (Table 2.15).

Table 2.15 **Contribution of Glycoalkaloid Components in Raw Tuber Skin and Flesh from Four Taewa Varieties and Nadine.**

Based on triplicate assays of extracts from composite raw tuber skin and flesh samples for the 2004 harvest year. Expressed as means mg/100 g on a fresh weight basis

Potato Cultivar	Harvest	α-Solanine	α-Chaconine	Total Glycoalkaloids
		mg/100 g	mg/100 g	mg/100 g
Potato Flesh				
Huakaroro	2004	0.9	1.1	2.2
Karuparera	2004	3.5	4.6	8.2
Moemoe	2004	1.8	1.9	3.8
Tūtaekuri	2004	3.9	3.5	7.5
Nadine	2004	0.7	0.9	1.6
Potato Skin				
Huakaroro	2004	21.9	37.3	60.4
Karuparera	2004	24.4	38.3	63.6
Moemoe	2004	15.0	21.4	36.5
Tūtaekuri	2004	23.4	32.2	56.7
Nadine	2004	7.2	19.2	26.4

2.4.5. Experiment Three: Discussion

As discussed in Section 1.3.2., potatoes are known to contain a number of bioactive phytochemicals. While many phytochemicals do not provide any nutritional value, they appear to contribute to improved health through their proposed roles in disease prevention through their antimutagenic, anticarcinogenic, antioxidant, antibacterial and immunity boosting functions (Liu, 2004; Liu, 2005; Rahal *et al.,* 2014).

Being members of the *Solanaceae* family, potatoes are known to contain glycoalkaloids such as α-chaconine and α-solanine which can have adverse health effects if consumed in large quantities (Section 1.2.1.), or can impart bitter tastes that will affect consumer sensory acceptability (Friedman, 1997). Hence the aim of this experiment was to assess the relative phenolic and glycoalkaloid content as well as the potential antioxidant capacity of Taewa varieties compared to Nadine.

2.4.5.1. Phenolic, Flavonoid and Anthocyanin Content and Potential Antioxidant Capacity of Taewa

All Taewa were found to have greater levels of phenolic, flavonoid and anthocyanin compounds compared to Nadine, in both the flesh and skin samples.

Tūtaekuri in particular had much greater total phenolic content (30-90 and 6-13 times greater in flesh and skin respectively); total flavonoid content (160-300 and 16-130 times greater in flesh and skin respectively); and total anthocyanin content (40-90 and 190-830 times greater in flesh and skin respectively) compared to Nadine. As expected due to the high phytochemical content, Tūtaekuri flesh and skin also had 4-10 fold greater antioxidant capacity than Nadine flesh or skin.

Similar to findings in this research, extractions from raw Taewa skin and flesh have been shown to exhibit variable degrees of phenolic, flavonoid and anthocyanin content and *in vitro* antioxidant activity. As found in this research, the purple-skinned, purple-fleshed variety Tūtaekuri / Urenika showed higher concentrations of phenolic compounds and greater antioxidative potential compared to white-skinned, white-fleshed varieties (Lewis *et al.,* 1998; Gould *et al.,* 2006; Philpott *et al.,* 2009; Chong *et al.,* 2013).

Lewis *et al.* (1998) provided information on the levels of phenolic compounds in tuber flesh and skin components over two consecutive harvest years from 26 potato varieties grown in New Zealand. Seven of these were Taewa varieties and included Urenika (varietal name for Tūtaekuri), Kowiniwini (varietal name for Karuparera) and Moemoe varieties. The content of total phenolics (TPC) found in this PhD research (20-523 mg and 158-970 mg per 100 g FW in Taewa flesh and skin) was higher than that reported by Lewis and colleagues (15-123 mg and 204-534 mg per 100 g FW in Taewa flesh and skin) for these three varieties. The TPC found in Tūtaekuri in this study is also likely to be greater than that determined in fifteen native Andean potato cultivars by Campos *et al*. (2006) (TPC ranged from 64 to 232 mg/100 g FW whole tuber), some of which were red and purple-fleshed cultivars (Campos *et al.,* 2006).

Andre *et al*. (2007) investigated 74 genotypes from among the native Andean cultivars that represented the greatest range of genetic diversity available at the time. They found that TPC ranged from 112 to 1237 mg per 100 g dry weight (about 27 to 297 mg/100 g FW assuming a % dry weight of 24%). Thus Tūtaekuri are likely to align near the higher range reported in these cultivars based on its TPC flesh content.

Similar to findings in this PhD research, other researchers have found that varieties with deeper purple skin and flesh (such as Tūtaekuri) had greater TPC, and TPC were greater in tuber skin compared to tuber flesh (Lewis *et al.,* 1998; Reyes *et al*., 2003; Brown, 2005; Campos *et al*., 2006; Albishi *et al*., 2013).

Albishi *et al*. (2013) reviewed the phenolic content of four modern potato cultivars that included white, yellow or purple skinned and fleshed varieties and found that potato peel rather than potato flesh and purple-fleshed and skinned rather than white or yellow-fleshed and skinned varieties had much greater phenolic content and the highest antioxidant activity.

In tuber skin, Lewis and colleagues (1998) found that the major phenolic acid was chlorogenic acid, followed by caffeic acid and lesser amounts of protocatechuic acid, vanillic acid, *p*-coumaric acid, ferulic acid, sinapic acid, salicylic acid and an unidentified phenolic acid. Lesser amounts of eriodictyol, naringenin, catechin, syringic acid and cinnamic acid were observed. In tuber flesh they found that again the major phenolic acid was chlorogenic acid, however, only small amounts of caffeic acid were present. Tuber flesh contained moderate amounts of protocatechuic acid, *p*-coumaric acid, ferulic acid plus traces of gallic acid, sinapic acid, catechin, epicatechin and eriodictyol (Lewis *et al.,* 1998).

An extensive survey of phenolic compounds was not the goal of this PhD research; however, chlorogenic acid was identified as a major phenolic compound in both tuber skin and flesh, as was procyanidin and also caffeic acid in the skin components. Other phenolics identified included epicatechin, phloridzin xyloside, phloridzin, quercetin and quercetin derivatives (Tables 2.11 and 2.12). Lewis *et al.* (1998) were also able to determine the major anthocyanins in seven Taewa varieties, which had varying degrees of purple pigmentation in the tuber skin or flesh. The major anthocyanin compounds identified included petunidin-3-(*p*-coumaroyl-rutinoside)-5-glucoside (Pt-crg) and malvidin-3-(*p*-coumaroyl-rutinoside)-5-glucoside (Mlv-crg). Of the seven varieties, only Tūtaekuri /Urenika and Karuparera/Kowiniwini contained Mlv-crg.

In this PhD research, malvidin and cyanidin glycosides were detected in Tūtaekuri flesh and skin as well as Karuparera and Moemoe skin, however, other major anthocyanin constituents (Pt-crg) were not identified as these standards were not included, but were likely included within the Total Anthocyanin content. Like other yellow or white fleshed and skinned potato varieties, a much lower content of anthocyanins were detected in Huakaroro and Nadine compared to the purple fleshed or skinned varieties. Cyanidin galactosides were only detected in Huakaroro, Moemoe and Nadine skin samples (Table 2.13). Compared to white-fleshed, white-skinned potato varieties, those with coloured skin and flesh (particularly red-fleshed and dark purple-fleshed varieties), have been found to contain greater amounts of antioxidative phytochemicals (and thus greater overall potential antioxidant activity and greater potential health benefits), (Lewis *et al.,* 1998; Hamouz *et al.,* 2011; Navarre *et al.,* 2011; Lachman *et al.,* 2012; Hu *et al.,* 2012; Albishi, 2013; Kulen, 2013).

This was also found to be the case in this PhD research when comparing the relative antioxidant capacity of Nadine and Huakaroro (yellow or white fleshed and skinned potato varieties) to Moemoe and Karuparera (white-fleshed, light to dark purple skinned) or Tūtaekuri (dark purple skin and flesh). Tūtaekuri had 4 to 8 times greater antioxidant capacity compared to Huakaroro, Moemoe and Karuparera and 5 to 10 times greater antioxidant capacity compared to Nadine (as measured by ORAC and FRAP) (Table 2.14).

Thus with regards to nutritional or health value, substituting consumption of Taewa varieties such as Tūtaekuri for Nadine is likely to provide greater antioxidant benefit. Since the skin of potatoes generally have a greater phenolic content relative to the flesh, it would be advisable to eat the whole potato rather than peeling them. However, as potatoes are not eaten in their raw state, it is of importance to know the effect of cooking treatments on the phenolic and anthocyanin content in potatoes. This will be assessed in Chapter 5 of this research.

2.4.5.2. Glycoalkaloids

As part of the screening process prior to introducing new potato cultivars to the market, anti-nutrient components are measured. This research found that the total glycoalkaloid content of the four Taewa varieties ranged from 2.2-8.2 mg/100 g FW in Taewa flesh and 36.5 – 63.6 mg/100 g FW in Taewa skin, which is 2-8 times greater than Nadine flesh and 1.5-2 times greater than Nadine skin (Table 2.15).

As shown by a number of researchers (Hellenas *et al.*, 1995a; Friedman *et al*., 2003; Savage *et al.,* 2000), glycoalkaloid content appears to vary significantly both between and within varieties. An analysis of 8 modern cultivars grown in the United States (Atlantic, Dark Red Norland, Ranger Russet, Red Lasoda, Russet Burbank, Russet Norkota, Shepody, and Snowden) found a 0.7 – 18.7 mg difference in total glycoalkaloid content per 100 g of fresh, whole potato between these varieties (Friedman *et al*., 2003). Levels of α-chaconine and α-solanine in the whole, fresh weight tubers ranged from 0.5 and 0.3 mg/100 g FW respectively in Russet Norkota, to 11.9 and 6.8 mg/100 g FW respectively in Snowden (Friedman *et al*., 2003). Hellenas and colleagues (1995a) found a total glycoalkaloid range of 5.1 – 22.1 mg/100 g FW in nine Swedish cultivars , then later found a 10 fold variation (6.1–66.5 mg/100 g FW) in total glycoalkaloid content within 300 commercial batches of the same Swedish potato cultivar (Magnum Bolum) grown in the same season (Hellanas *et al*., 1995b).

In a study of 10 Taewa cultivars grown in New Zealand, Savage *et al.,* (2000) found that glycoalkaloid content ranged from 3.9 to 14.3 mg/100 g FW whole potato between Taewa cultivars, with the higher glycoalkaloid content found in cultivars that had purple flesh and skin (most likely Tūtaekuri). Although the glycoalkaloid content of whole Taewa tubers were not analysed in this research, 2.2-8.2 mg/100 g FW of glycoalkaloids were found in Taewa flesh and 36.5 – 63.6 mg/100 g FW in Taewa skin. These levels are likely to be similar to the amounts found by Savage *et al.,* (2000) due to the low glycoalkaloid flesh content found in this research and the minor contribution of the skin to the whole tuber.

Potato varieties with a total glycoalkaloid content of less than 20 mg/100 g FW are considered appropriate for the general market, as this level limits both adverse health effects and unacceptability with regards to perception of bitterness (Shakya and Navarre, 2006). Based on these criteria, the results from this PhD research and from Savage and colleagues (2000), it is likely that the glycoalkaloid content of these Taewa falls within acceptable levels, although varieties such as Tūtaekuri, Huakaroro and Karuparera may be more likely to impart a bitter taste compared to Moemoe and Nadine due to their higher glycoalkaloid content in the tuber flesh or skin as mentioned above. A taste test conducted by Savage *et al*. (2010) on 10 Taewa varieties found that the Taewa were generally well accepted although some (including a variety likely to be Tūtaekuri) were noted to have a slightly bitter after-taste (Savage *et al*., 2010). Thus it is advisable that future Taewa product development involves a sensory trial to assist in the assessment of consumer acceptability of varieties that may be perceived as bitter (carried out in Chapter 6).

2.5. Experiment Four: Effect of Storage and Processing on Nutrient Composition

2.5.1. Aim

To estimate the potential for changes in nutrient composition and quality due to various post-harvest storage or processing scenarios in four Taewa and one modern variety (Nadine) tubers.

2.5.2. Materials

2.5.2.1. 6 Month Stored Potato Tubers

Nutrient analysis for this experiment was carried out on composite potato materials prepared from tubers of four New Zealand Taewa (Solanum tuberosum L., cv. Karuparera, Huakaroro, Tūtaekuri, Moemoe) and one modern potato cultivar (Nadine) from the 2004 harvest as described previously in Section 2.2.2.1. These tubers were stored in the chiller at 5^{o}C with 80-90% humidity control for 6 months. All materials or chemicals used in this experiment were of analytical grade and were as described previously in Section 2.2.2. (Proximate / Macronutrient Analysis); Section 2.3.2. (Micronutrient Analysis) and Section 2.4.2. (Phytochemical and Glycoalkaloid Analysis).

2.5.2.2. Par-boiled Potatoes

Materials were prepared as described by Singh *et al*. (2008a). The tubers of four New Zealand Taewa (Solanum tuberosum L., cv. Karuparera, Huakaroro, Tūtaekuri, Moemoe) and one modern potato cultivar (Nadine) were procured from local sources in New Zealand (2006 harvest). Uniformly sized tubers were selected from each cultivar batch.

2.5.3. Methods

2.5.3.1. Storage

In 2004, up to 5 kg of the tubers were stored in the dark, in a chiller at 5^{o}C with 80-90% humidity control for 6 months in order to determine the effects of 6 month post-harvest storage on the nutritional quality of the tubers. Methods for nutrient analysis of these samples were as described previously in Section 2.2.3. (Proximate / Macronutrient Analysis); Section 2.3.3. (Micronutrient Analysis) and Section 2.4.3 (Phytochemical and Glycoalkaloid Analysis). Note: In Tables 2.16 – 2.25, the red values denote a potential loss and the blue values denote a potential gain in nutrient contribution after 6 months storage (dry weight basis).

2.5.3.2. Par-boiled Potatoes

The method used for par-boiling of potatoes was as described by Singh *et al.* (2008a). Once the potatoes had been par-boiled, they were stored at 4^{o}C until further use. Up to 3 kg of each cultivar was removed from storage on days 0 and 21 since par-boiling and prepared for future nutritional analysis as described for whole potatoes in section 2.2.2.1.

2.5.4. Experiment Four: Results

2.5.4.1. Changes in Nutrient Content Due to Storage

2.5.4.1.a. Macronutrients

Across all varieties and tuber components, the percentage of dry matter appeared to increase by 1-3% with 6 months storage at 4°C (likely due to the loss in moisture and thus relative increase in contribution from dry matter) (see Table 2.16). This increase in dry matter content would have had the greatest impact on the relative ratio of nutrients that are only present in small amounts (protein, ash and fat) and may explain in part the slight increases noted in these three nutrients for some varieties. Overall, 6 months storage did not have a large negative impact on the macronutrients likely to be of most nutritional value in potatoes (dietary fibre, energy) and appeared to increase the total ash content (see Table 2.16) which may result in greater contributions of minerals of nutritional value in potatoes (K, P, Mg, Fe, Zn, Cu, Se).

Table 2.16 Proximate Analysis of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.

6 month results represent an average of duplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value.

Potato Cultivar	Stage	Moisture	Dry Matter	Carbohydrate	Protein	Dietary Fibre	Ash	Fat	Energy
		Nutrient values in g/100 g potato							kJ per 100 g
Potato Flesh									
Huakaroro	**6mth**	75.3	24.7	19.9	2.1	1.5	0.9	0.3	395.3
	change	***-1.7***	***1.7***	***1.4***	***-0.5***	***-0.5***	***0.0***	***-0.3***	***2.0***
Karuparera	**6mth**	77.8	22.2	17.1	2.1	1.5	1.0	0.5	358.8
	change	***-1.4***	***1.4***	***-2.4***	***1.7***	***-0.9***	***0.4***	***1.3***	***41.1***
Moemoe	**6mth**	75.0	25.0	20.7	1.7	1.5	0.8	0.3	400.0
	change	***-1.7***	***1.7***	***-0.3***	***0.3***	***0.1***	***0.4***	***-0.5***	***-1.3***
Tūtaekuri	**6mth**	80.3	19.7	13.7	2.7	1.8	1.0	0.5	340.3
	change	***-2.3***	***2.3***	***1.6***	***0.1***	***-0.6***	***0.6***	***-1.6***	***113.4***
Nadine	**6mth**	84.5	15.5	12.1	1.4	1.1	0.6	0.3	259.4
	change	***-1.8***	***1.8***	***1.2***	***-1.0***	***-0.3***	***-0.5***	***0.6***	***72.6***
Potato Skin									
Huakaroro	**6mth**	77.5	22.5	15.8	2.3	2.7	1.3	0.4	
	change	***-2.8***	***2.8***	***0.1***	***0.1***	***-0.2***	***0.6***	***-0.6***	
Karuparera	**6mth**	77.8	22.2	14.8	2.4	2.9	1.6	0.5	
	change	***-2.2***	***2.2***	***-4.0***	***2.2***	***1.2***	***1.6***	***-1.1***	
Moemoe	**6mth**	77.9	22.1	15.5	1.9	2.9	1.2	0.6	
	change	***-3.1***	***3.1***	***-1.5***	***0.4***	***-0.1***	***0.6***	***0.6***	
Tūtaekuri	**6mth**	81.0	19.0	11.2	3.2	3.1	1.1	0.4	
	change	***-2.7***	***2.7***	***0.2***	***0.4***	***1.7***	***0.3***	***-2.6***	
Nadine	**6mth**	82.6	17.4	10.8	2.3	2.6	1.2	0.5	
	change	***-2.8***	***2.8***	***1.7***	***-0.8***	***-0.5***	***0.1***	***-0.5***	

Key: 6mth = Fresh weight nutrient values after 6 months storage; change = change in nutrient content.

2.5.4.1.b. Micronutrients

The major effects on storing potatoes for 6 months at 5°C appeared to include trends with regards to increasing the total sugar content (Table 2.17); increasing essential amino acid content, noticeably that of cysteine (Table 2.18); increasing the monounsaturated fatty acid content (MUFA), linolenic and lignoceric fatty acids but showed a decrease in stearic and linoleic fatty acids (Table 2.19); a general increase in potassium, iron, copper and selenium but a decrease in phosphorus, magnesium and calcium (Table 2.20).

Within cultivars, the 6 month storage period appeared to positively affect Karuparera with regards to amino acid content (likely due to its higher protein content at 6 months storage) (Table 2.18), but have negative affects with regards to insoluble fibre in Tūtaekuri (Table 2.17); amino acid content in Tūtaekuri and Nadine (Table 2.18); fatty acid content in all varieties except Karuparera (Table 2.19) and mineral content, particularly in Huakaroro, Tūtaekuri and Nadine (Table 2.20).

Table 2.17 Carbohydrate Constituents of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.

6 month results represent an average of duplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value.

Potato Cultivar	Stage	Disaccharide: Monosaccharide Ratio	Total Sugars	Insoluble Fibre	Soluble Fibre
			Nutrient values in g/100 g potato		
Potato Flesh					
Huakaroro	**6mth**	0.5	2.5	0.9	0.6
	change	***-0.4***	***3.2***	***-0.1***	***-0.4***
Karuparera	**6mth**	0.8	2.2	1.1	0.5
	change	***0.0***	***7.7***	***0.3***	***-1.2***
Moemoe	**6mth**	0.4	1.6	1.0	0.5
	change	***0.0***	***0.4***	***0.3***	***-0.2***
Tūtaekuri	**6mth**	0.5	2.3	1.2	0.6
	change	***-0.1***	***-0.1***	***-0.7***	***0.1***
Nadine	**6mth**	0.0	2.9	0.8	0.2
	change	***0.0***	***9.6***	***0.0***	***-0.3***
Potato Skin					
Huakaroro	**6mth**			2.1	0.6
	change			***-1.0***	***0.8***
Karuparera	**6mth**			2.3	0.6
	change			***0.3***	***0.9***
Moemoe	**6mth**			2.2	0.7
	change			***-0.8***	***0.7***
Tūtaekuri	**6mth**			2.7	0.4
	change			***1.5***	***0.2***
Nadine	**6mth**			2.3	0.3
	change			***-0.3***	***-0.2***

Key: 6mth = Nutrient values after 6 months storage; change = change in nutrient content.

Table 2.18 Comparison of Amino Acid Content of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Harvested in 2004 after Storage

6 month results represent an average of duplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value.

Potato Cultivar	Stage	EAA* mg/100 g FW	His#	Ile#	Leu#	Lys#	Met#	Cys	Tyr	Phe#	Thr#	Trp#	Val#	Ala	Arg#	Asp	Glu	Gly	Pro	Ser
			Nutrient values in mg/100 g potato																	
Potato Flesh																				
Huakaroro	**6mth**	673	41	59	110	105	27	34	67	80	65	30	85	64	70	431	419	63	64	72
	change	***-70***	***-16***	***-21***	***-24***	***8***	***17***	***113***	***24***	***-8***	***-19***	***32***	***-19***	***9***	***-20***	***-58***	***100***	***-4***	***15***	***14***
Karuparera	**6mth**	684	44	54	99	100	26	29	73	73	63	31	85	59	107	468	364	57	65	67
	change	***635***	***35***	***21***	***80***	***79***	***39***	***71***	***75***	***60***	***49***	***80***	***54***	***66***	***139***	***455***	***375***	***48***	***75***	***104***
Moemoe	**6mth**	582	40	52	93	92	25	29	63	68	54	23	75	56	59	350	290	55	59	67
	change	***49***	***5***	***-14***	***-7***	***30***	***-44***	***94***	***11***	***17***	***-4***	***36***	***4***	***18***	***26***	***78***	***6***	***11***	***39***	***44***
Tūtaekuri	**6mth**	863	53	76	132	119	31	35	78	82	80	30	106	81	154	643	397	70	67	80
	change	***200***	***-6***	***4***	***43***	***50***	***-54***	***60***	***11***	***26***	***29***	***54***	***18***	***55***	***37***	***226***	***172***	***30***	***63***	***71***
Nadine	**6mth**	452	26	39	68	63	21	24	38	50	43	16	65	47	61	288	302	38	37	45
	change	***-195***	***-5***	***-31***	***-17***	***-18***	***-61***	***69***	***-33***	***-35***	***-30***	***30***	***-17***	***54***	***-13***	***-221***	***76***	***-5***	***18***	***33***
Potato Skin																				
Huakaroro	**6mth**	720	44	67	124	115	28	39	75	87	76	18	94	83	65	400	311	76	78	85
	change	***252***	***10***	***-6***	***37***	***46***	***23***	***95***	***61***	***37***	***33***	***11***	***26***	***70***	***37***	***-23***	***212***	***44***	***74***	***89***
Karuparera	**6mth**	770	51	71	124	115	31	38	75	87	75	23	102	78	90	460	322	74	82	81
	change	***684***	***34***	***45***	***98***	***77***	***48***	***129***	***85***	***74***	***52***	***25***	***99***	***88***	***135***	***547***	***375***	***66***	***104***	***118***
Moemoe	**6mth**	566	42	53	97	89	27	31	52	62	58	16	74	67	48	379	262	58	69	69
	change	***-15***	***6***	***-26***	***-5***	***5***	***-7***	***40***	***-2***	***-11***	***-6***	***-8***	***10***	***35***	***26***	***-43***	***8***	***3***	***44***	***46***
Tūtaekuri	**6mth**	859	52	81	143	121	34	39	74	86	86	25	112	92	119	721	383	80	77	89
	change	***-544***	***-61***	***-65***	***-81***	***-62***	***-72***	***90***	***-47***	***-39***	***-29***	***-6***	***-49***	***-19***	***-82***	***51***	***62***	***-12***	***-13***	***14***
Nadine	**6mth**	531	37	53	89	78	23	31	46	57	55	14	75	60	51	537	357	50	47	60
	change	***-527***	***-21***	***-57***	***-99***	***-65***	***-85***	***57***	***-58***	***-85***	***-69***	***-10***	***-56***	***-38***	***19***	***-551***	***-253***	***-43***	***-18***	***7***

Key: EAA* = Sum of Essential Amino Acids (His, Ile, Leu, Lys, Met, Phe, Thr, Trp, Val, Arg); His = Histidine; Ile = Isoleucine; Leu = Leucine; Lys = Lysine; Met = Methionine; Cys = Cysteine; Tyr = Tyrosine; Phe = Phenylalanine; Thr = Threonine; Trp = Tryptophan; Val = Valine; Ala = Alanine; Arg = Arginine; Asp = Aspartic acid; Glu = Glutamic acid; Gly = Glycine; Pro = Proline; Ser = Serine. # = One of the essential amino acids. ND = Not determined. Limits of uncertainty: EAA = 6.28; His = ±6.9; Ile =±5.56; Leu = ±4.96; Lys =±6.23; Met = ±6.58; Cys = ±6.8; Tyr = ±4.54; Phe = ±4.74; Thr = ±10; Trp = ±6.52; Val = ±5.73; Ala = ±5.07; Arg = ±5.81; Asp = ±5.18; Glu = ±4.4; Gly = ±5.68; Pro = ±5.87; Ser = ±6.59.

Table 2.19 Fatty Acid Analysis of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.

6 month results represent an average of duplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value.

Potato Cultivar	Stage	TFA	SFA	MUFA	PUFA	c16:0	c18:0	c18:2n6	c18:3n3	C24:0
		Nutrient values in mg/100 g potato								
Potato Flesh										
Huakaroro	6mth	94.0	24.9	0.7	70.6	17.5	4.2	41.3	28.5	0.5
	change	***-157.0***	***-132.5***	***3.0***	***-18.5***	***-0.5***	***-145.0***	***-25.0***	***3.5***	***2.0***
Karuparera	6mth	83.5	22.2	0.4	62.2	16.0	3.6	35.5	26.2	0.4
	change	***17.5***	***6.5***	***2.0***	***15.5***	***2.0***	***-7.5***	***-15.5***	***28.5***	***2.0***
Moemoe	6mth	87.5	23.7	0.8	64.6	16.3	4.1	37.3	26.8	0.5
	change	***-95.0***	***-87.5***	***3.0***	***-4.5***	***3.0***	***-103.5***	***-8.5***	***2.0***	***2.0***
Tūtaekuri	6mth	102.0	26.3	1.2	75.8	19.7	3.0	48.5	26.6	0.7
	change	***-144.5***	***-140.0***	***6.0***	***-4.5***	***4.0***	***-162.0***	***-20.0***	***12.0***	***3.5***
Nadine	6mth	41.8	11.1	0.3	31.2	8.2	1.2	20.9	10.1	0.2
	change	***-59.4***	***-54.2***	***2.0***	***-2.2***	***-1.0***	***-63.7***	***-14.0***	***10.8***	***1.5***
Potato Skin										
Huakaroro	6mth	142.8	40.3	1.8	103.1	23.3	6.6	48.2	53.9	4.0
	change	***-40.5***	***-59.5***	***8.0***	***21.5***	***9.0***	***-114.5***	***-13.5***	***30.5***	***18.0***
Karuparera	6mth	116.8	34.4	1.4	83.3	20.8	5.6	39.3	43.1	3.3
	change	***46.0***	***31.5***	***6.5***	***18.5***	***-0.5***	***-4.5***	***-28.5***	***43.0***	***15.0***
Moemoe	6mth	130.9	36.5	2.2	93.9	21.5	5.9	47.7	45.4	4.0
	change	***-98.5***	***-92.5***	***10.0***	***-8.5***	***2.0***	***-136.0***	***-7.5***	***-4.5***	***18.0***
Tūtaekuri	6mth	125.6	36.9	2.4	87.9	22.2	4.3	52.5	34.6	4.9
	change	***-65.5***	***-34.5***	***12.5***	***-35.0***	***-4.5***	***-85.0***	***-42.0***	***2.5***	***26.0***
Nadine	6mth	82.6	24.2	1.8	58.0	14.7	2.8	33.6	23.9	2.8
	change	***-26.5***	***2.5***	***10.5***	***-32.0***	***-5.0***	***-31.0***	***-42.5***	***8.0***	***16.0***

Key: TFA = Total Fatty Acids; SFA = Saturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids; c16:0 = palmitic acid; c18:0 = stearic acid; c18:2n6 = linoleic acid; c18:3n3 = alpha-linolenic acid; C24:0 = lignoceric acid. ND = not detected.

Table 2.20 Mineral Analysis of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.

6 month results represent an average of duplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value.

Potato Cultivar	Stage	K	P	Mg	Ca	Na	Fe	Zn	Cu	Mn	Se*
		Nutrient values expressed as mg/100 g									**µg/100 g**
Potato Flesh											
Huakaroro	**6mth**	436.6	36.4	15.4	5.8	3.9	0.5	0.4	0.2	0.1	0.5
	change	***-73.9***	***-10.8***	***-16.3***	***-8.0***	***0.5***	***0.2***	***0.0***	***0.1***	***-0.1***	***-4.0***
Karuparera	**6mth**	513.0	33.3	18.1	5.2	3.3	1.0	0.4	0.2	0.1	0.4
	change	***83.4***	***8.1***	***7.3***	***-3.4***	***-9.4***	***2.7***	***0.5***	***0.1***	***0.1***	***-5.0***
Moemoe	**6mth**	400.0	29.9	14.8	5.1	4.0	0.4	0.3	0.1	0.1	0.5
	change	***40.0***	***-1.9***	***-3.4***	***-1.0***	***0.9***	***-0.3***	***-0.7***	***0.0***	***0.0***	***-4.0***
Tūtaekuri	**6mth**	478.1	35.2	18.6	9.8	7.2	0.8	0.5	0.2	0.1	2.7
	change	***-146.8***	***-18.6***	***-15.4***	***-9.8***	***-13.5***	***1.1***	***0.2***	***0.0***	***-0.1***	***4.7***
Nadine	**6mth**	271.9	30.7	17.4	3.1	0.8	0.3	0.4	0.1	0.1	0.3
	change	***-338.1***	***-47.8***	***-26.4***	***-3.9***	***2.3***	***-0.2***	***-0.2***	***-0.1***	***-0.2***	***-3.0***
Potato Skin											
Huakaroro	**6mth**	587.5	37.0	20.1	13.2	3.5	2.7	0.5	0.3	0.3	0.7
	change	***93.2***	***-5.3***	***-9.7***	***-7.8***	***-0.9***	***-21.0***	***-1.5***	***0.1***	***-0.2***	***-3.7***
Karuparera	**6mth**	698.9	34.6	4.6	13.7	2.9	12.4	0.4	0.2	0.7	1.2
	change	***218.1***	***-9.8***	***-74.4***	***-6.2***	***-9.5***	***45.6***	***0.2***	***0.2***	***2.3***	***0.5***
Moemoe	**6mth**	602.0	31.0	17.5	12.4	3.2	2.9	0.4	0.2	0.3	1.0
	change	***271.8***	***-5.3***	***-9.4***	***-0.3***	***-0.1***	***1.8***	***-0.8***	***0.0***	***0.1***	***1.4***
Tūtaekuri	**6mth**	484.3	35.9	20.2	24.3	7.2	5.3	0.6	0.2	0.4	3.5
	change	***-91.2***	***-25.1***	***-12.6***	***-20.9***	***-4.6***	***-7.9***	***0.1***	***0.0***	***-1.5***	***8.5***
Nadine	**6mth**	568.7	37.6	27.5	9.1	0.9	0.7	0.5	0.1	0.1	0.3
	change	***6.2***	***-30.6***	***-20.1***	***-4.1***	***3.8***	***0.6***	***-0.4***	***-0.1***	***-0.1***	***-2.0***

Key: K = Potassium; P = Phosphorous; Mg = Magnesium; Ca = Calcium; Na = Sodium; Fe = Iron; Zn = Zinc; Cu = Copper; Mn = Manganese; Se*= Selenium where 6 month results are presented as µg/100 g FW.

2.5.4.1.c. Effect of Storage on Phytochemical, Antioxidant Capacity and Glycoalkaloid Content

Storage for 6 months caused variable effects amongst the phytochemical components. With regards to changes in various phytochemicals, the major trends appeared to include a general increase in total phenolic content (TPC), epicatechin, procyanidin (Table 2.21) and antioxidant capacity (Table 2.24); but a general decrease in total flavonoid content (more likely to be compounds other than the quercetin derivatives listed) (Table 2.22); and anthocyanin content (Table 2.23). 6 months storage also led to increases in glycoalkaloid content (dry weight basis) with increases in both α-chaconine and α-solanine for all varieties and tuber components except Karuparera flesh and α-chaconine in Huakaroro skin (Table 2.25).

The 6 month storage period appeared to affect the five potato cultivars in different ways. The most noticeable trend was the consistent decrease in content of the phenolic, flavonoid and anthocyanin constituents in Tūtaekuri regardless of the tuber component and a general decrease in content of the phenolic, flavonoid and anthocyanin constituents present in Nadine. Huakaroro, Moemoe and Karuparera were more likely to show an increase in phenolic and flavonoid content (Tables 2.21-2.23). The antioxidant capacity of Tūtaekuri also decreased as shown by both the FRAP and ORAC values, but increased in Karuparera, Moemoe and Nadine flesh and Huakaroro skin (Table 2.24).

Glycoalkaloid content generally increased in all cultivars and tuber components; however, Karuparera flesh and Huakaroro skin showed a decrease in glycoalkaloid content (Table 2.25).

Table 2.21 **Polyphenol Analysis (Fresh weight basis) of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.**

6 month results represent an average of duplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value. Measured against standards at 280 nm.

Potato Cultivar	Stage	Caffeic Acid	Chlorogenic	Epicatechin	Procyanidin	Phloridzin-xyl	Phloridzin	Other Phenolics	Total Phenolics*
		Nutrient values in mg/100 g potato							
Potato Flesh									
Huakaroro	**6mth**		3.7	0.6	16.1			7.7	28.1
	change		***-6.1***	***0.7***	***30.9***			***-5.8***	***19.7***
Karuparera	**6mth**		5.7	0.6	14.5		0.1	11.1	32.0
	change		***0.4***	***0.6***	***32.5***		***0.3***	***12.8***	***46.6***
Moemoe	**6mth**		17.0	0.6	10.5			22.9	51.1
	change		***22.9***	***1.1***	***10.4***			***26.1***	***60.6***
Tūtaekuri	**6mth**		49.7	0.0	17.7			179.4	246.9
	change		***-385.3***	***-3.8***	***-19.8***			***-1342.1***	***-1751.0***
Nadine	**6mth**		0.9	0.0	5.6			2.6	9.0
	change		***0.0***	***-2.0***	***16.7***			***1.2***	***15.8***
Potato Skin									
Huakaroro	**6mth**	1.9	36.5	3.3	29.3	0.1	0.2	52.5	121.9
	change	***0.3***	***162.1***	***9.8***	***30.2***	***0.0***	***0.3***	***-150.2***	***50.8***
Karuparera	**6mth**	3.4	40.4	3.5	32.1			88.4	164.4
	change	***-5.8***	***-5.1***	***15.6***	***-11.8***			***-26.7***	***-28.0***
Moemoe	**6mth**	2.9	82.1	1.4	26.3	0.0	0.0	115.1	224.9
	change	***-0.1***	***36.1***	***1.5***	***3.1***	***-3.0***	***-1.7***	***57.0***	***93.0***
Tūtaekuri	**6mth**	8.1	110.5	3.7	71.3	62.9	0.6	331.0	580.0
	change	***1.5***	***-530.5***	***4.3***	***-8.2***	***-239.5***	***-0.4***	***-1330.2***	***-2104.5***
Nadine	**6mth**	2.9	19.4	5.0	25.1			28.7	78.1
	change	***1.1***	***-35.9***	***17.2***	***21.0***			***-34.5***	***-33.4***

Key: xyl = xyloside; * = includes compounds detected at 280 nm as well as Caffeic acid detected at 370 nm.

Table 2.22 Flavonoid Content (Fresh Weight) of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.

6 month results represent an average of duplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value. Measured against standards 370nm.

Potato Cultivar	Stage	Q	Q-rut	Q-gal	Q-glu	Q-xyl	Q-unk	Q-arapy	Q-araf	Q-rha	Other Flav.	Total Flavonoids
		Nutrient values in mg/100 g potato										
Potato Flesh												
Huakaroro	6mth										0.1	0.1
	change										***-0.4***	***-0.4***
Karuparera	6mth										0.6	0.6
	change										***1.8***	***1.8***
Moemoe	6mth	0.5	0.1	0.2		0.1						0.9
	change	***2.1***	***0.6***	***0.7***		***0.3***						***3.7***
Tūtaekuri	6mth	0.0	1.1	2.8	3.3	0.3	8.8		1.5		0.7	18.6
	change	***-2.4***	***-5.4***	***-22.2***	***-14.4***	***-0.4***	***-64.3***		***-5.2***		***-5.9***	***-120.2***
Nadine	6mth										0.0	0.0
	change										***-0.9***	***-0.9***
Potato Skin												
Huakaroro	6mth		0.1	0.5			0.6	0.2	0.1	0.1	0.6	2.3
	change		***0.6***	***0.4***			***1.3***	***0.8***	***0.6***	***0.4***	***1.9***	***6.0***
Karuparera	6mth		0.3	2.3	0.4	1.7	0.6				0.9	6.1
	change		***0.3***	***-0.5***	***0.6***	***5.9***	***0.1***				***-5.4***	***1.1***
Moemoe	6mth		0.3	0.9	0.7	0.4					0.3	2.6
	change		***-1.8***	***-1.0***	***1.0***	***1.7***					***0.0***	***-0.1***
Tūtaekuri	6mth	0.0	2.2	3.7	6.5	1.3	20.1		4.6		2.1	40.3
	change	***-2.0***	***-7.1***	***-20.0***	***-18.6***	***-3.9***	***-77.6***		***-10.0***		***-12.3***	***-151.5***
Nadine	6mth		0.0	0.0		0.0				0.0	0.7	0.7
	change		***-0.7***	***-1.0***		***-1.4***				***-0.6***	***3.9***	***-0.3***

Key:* = Q = quercetin; rut = rutinoside; gal = galactoside; xyl = xyloside; unk = unknown; arapy = arabinose pyranoside; araf = arabinose furanoside; rha = rhamnoside. Total flavonoids only include quercetin and quercetin derivatives detected at 370 nm.

Table 2.23 Anthocyanin Analysis (Fresh weight basis) of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.

6 month results represent an average of triplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value. Measured against standards 530nm.

Potato Cultivar	Stage	Cy-gal	Cy-glu	Mlv-glu	Minor	Other	Total Anthocyanins*
		Nutrient values in mg/100 g potato					
Potato Flesh							
Huakaroro	**6mth**						
	change						
Karuparera	**6mth**						
	change						
Moemoe	**6mth**					0.9	0.9
	change					***2.0***	***2.0***
Tūtaekuri	**6mth**	1.0	0.0	0.4	0.0	40.0	41.4
	change	***5.3***	***-10.7***	***-2.1***	***-2.5***	***-296.1***	***-306.1***
Nadine	**6mth**						
	change						
Potato Skin							
Huakaroro	**6mth**	0.0				0.0	0.0
	change	***-1.4***				***-0.6***	***-1.9***
Karuparera	**6mth**			0.0		9.0	9.0
	change			***-2.2***		***-12.4***	***-14.6***
Moemoe	**6mth**					3.9	3.9
	change					***-1.8***	***-1.8***
Tūtaekuri	**6mth**	1.6	0.0	0.5	0.0	80.3	82.4
	change	***8.4***	***-13.2***	***-1.6***	***-3.7***	***-325.8***	***-336.0***
Nadine	**6mth**	0.0					0.0
	change	***-1.1***					***-1.1***

Key: Cy-gal = cyanidin-3-galactoside; cy-glu = cyanidin-3-glucoside; mlv-glu = malvidin-3-glucoside;* = Includes compounds detected at 530 nm as well as cyanidin-3-galactoside detected at 280 nm.

Table 2.24 Antioxidant/Polyphenol Analysis (Fresh weight basis) of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.

6 month results represent an average of triplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value.

Potato Cultivar	Stage	FRAP	ORAC	Total Anthocyanins*	Total Flavanoids	Total Phenolics#
		mM TE/ 100 g	mM TE/ 100 g	mg/100 g (570 nm)	mg/100 g (370 nm)	mg/100 g (280 nm)
Potato Flesh						
Huakaroro	**6mth**	0.2	1.0		0.1	28.1
	change	***-0.1***	***0.0***		***-0.4***	***19.7***
Karuparera	**6mth**	0.2	1.3		0.6	32.0
	change	***0.1***	***1.1***		***1.8***	***46.6***
Moemoe	**6mth**	0.3	1.5	0.9	0.4	51.1
	change	***0.4***	***2.0***	***2.0***	***1.6***	***60.6***
Tūtaekuri	**6mth**	0.9	3.5	41.4	18.6	246.9
	change	***-3.4***	***-13.6***	***-306.1***	***-120.2***	***-1751.0***
Nadine	**6mth**	0.1	0.7		0.0	9.0
	change	***0.1***	***1.7***		***-0.9***	***15.8***
Potato Skin						
Huakaroro	**6mth**	0.5	3.1	0.0	2.3	123.8
	change	***0.0***	***0.0***	***-1.9***	***6.0***	***52.5***
Karuparera	**6mth**	0.8	3.7	9.0	6.1	167.8
	change	***0.0***	***0.0***	***-14.6***	***1.1***	***-33.8***
Moemoe	**6mth**	0.8	5.4	3.9	2.6	227.8
	change	***0.0***	***0.0***	***-1.8***	***-0.1***	***92.9***
Tūtaekuri	**6mth**	1.6	8.7	82.4	40.3	588.2
	change	***0.0***	***-0.4***	***-336.0***	***-151.5***	***-2103.0***
Nadine	**6mth**	0.3	1.9	0.0	0.7	81.1
	change	***0.0***	***0.0***	***-1.1***	***-0.3***	***-31.2***

Key: FRAP = Ferric Reducing Antioxidant Power; ORAC = Oxygen Radical Absorbance Capacity; TE = Trolox Equivalent; * = Includes cyanidin-3-galactoside at 280 nm; # = includes caffeic acid at 370 nm.

Table 2.25 Contribution of Glycoalkaloid Analysis (Fresh weight basis) of Raw Tuber Flesh and Skin from Four Taewa Varieties and Nadine Tubers Harvested in 2004 after Storage.

6 month results represent an average of duplicate observations (FW basis) but the change in nutrient values are based on the dry weight difference between the stored and the initial value.

Potato Cultivar	Stage	α-Solanine	α-Chaconine	Total Glycoalkaloids
		mg/100 g	mg/100 g	mg/100 g
Potato Flesh				
Huakaroro	**6mth**	1.2	1.5	2.7
	change	***0.2***	***0.4***	***0.5***
Karuparera	**6mth**	1.7	2.1	4.0
	change	***-1.8***	***-2.4***	***-4.2***
Moemoe	**6mth**	2.3	2.5	4.8
	change	***0.5***	***0.6***	***1.1***
Tūtaekuri	**6mth**	4.4	4.0	8.7
	change	***0.5***	***0.5***	***1.1***
Nadine	**6mth**	0.8	1.2	2.0
	change	***0.2***	***0.3***	***0.5***
Potato Skin				
Huakaroro	**6mth**	22.7	36.8	59.6
	change	***0.8***	***-0.4***	***-0.8***
Karuparera	**6mth**	28.7	39.7	69.7
	change	***4.3***	***1.4***	***6.2***
Moemoe	**6mth**	21.5	30.4	52.3
	change	***6.5***	***9.0***	***15.8***
Tūtaekuri	**6mth**	30.1	41.0	71.7
	change	***6.7***	***8.7***	***15.0***
Nadine	**6mth**	10.0	24.9	34.8
	change	***2.7***	***5.7***	***8.4***

2.5.4.2. Effect on Nutrient Content Due to Processing and Cooking Techniques

Potatoes products are most often cooked before they are eaten, thus it is of nutritional interest to determine potential effects of various processing and cooking techniques on Taewa nutrient content.

2.5.4.3. Nutrient Content of Par-boiled Potato

Compared to raw, whole tubers, par-boiling, and par-boiling followed by 21 days storage did not appear to negatively affect the nutrient content with regards to carbohydrate, total sugars, soluble dietary fibre, total protein, total fat or ash content. In addition, slight increases in total dietary fibre and insoluble fibre content (0.2-0.6 g) occurred after par-boiling and storing. However parboiling caused a 2-23% loss in energy value and par-boiling followed by a 21 day storage period caused a 6-18% loss in energy compared to the potential energy available in the raw tubers.

The most significant losses in energy occurred in Moemoe (9-18%) and Tūtaekuri (18-23%), although the energy content in all Taewa varieties was greater than that in Nadine after each par-boiling and storage step (Table 2.26).

The most significant losses in micronutrient content after par-boiling occurred in Vitamin C levels (45-54% loss) and par-boiling followed by a 21 day storage period resulted in a 32-45% loss of Vitamin C regardless of cultivar (Table 2.27). Losses with regards to potassium occurred in Moemoe (5%, 7%) and Huakaroro (1% gain, 16% loss) after parboiling or storing respectively, but were either insignificant or no loss occurred in the other varieties. Calcium content did not appear to be affected by par-boiling, but all Taewa varieties incurred small losses in Ca when stored for 21 days following par-boiling. Losses in iron content were minor after par-boiling and storage in all varieties, except Tūtaekuri which actually increased in iron content upon boiling (3 g after par-boiling and 2.4 g after storage *cf* 2.1 g/100 g FW prior to cooking). Small losses in EAA were also observed after par-boiling (Table 2.27).

Table 2.26 Comparison of Macronutrient Content after Par-boiling and Storage for 21 days at 4°C.

Results are expressed as averages of duplicate assays per 100 g fresh weight, whole potato

NUTRIENT	UNITS	Huakaroro whole, fresh			Karuparera whole, fresh			Moemoe whole, fresh			Tūtaekuri whole, fresh			Nadine whole, fresh			Rua flesh, fresh	
		Raw	PBd0	PBd21	Raw	PBd0	PBd21	Raw	PBd0	PBd21	Raw	PBd0	PBd21	Raw	PBd0	PBd21	Raw	Boiled
MACRONUTRIENTS																		
Moisture	g/100 g	75.1	73.4	73.6	74.9	72.6	73.8	75.2	74.4	76.5	77.4	79.3	78.4	84.8	84.2	84.1	79.9	77
Dry matter	g/100 g	24.9	26.6	26.4	25.1	27.4	26.2	24.8	25.6	23.4	22.6	20.7	21.6	15.2	15.8	15.9	20.1	23
Energy [a]	MJ/100 g	0.43	0.40	0.40	0.42	0.41	0.40	0.42	0.38	0.35	0.39	0.30	0.32	0.26	0.23	0.23	0.29	0.34
Carbohydrate [b]	g/100 g	19.1	20.5	20.6	20.4	21.5	21.0	19.2	19.9	17.8	16.4	14.7	15.5	11.3	11.5	11.7	17.4	18.2
Total Sugars	g/100 g	0.6	0.4	0.6	0.4	0.4	0.2	0.5	0.5	0.5	1.3	1.3	1.0	1.5	2.5	1.9	0.4	0.2
Total DF [c]	g/100 g	1.7	2.2	2.1	1.6	2.2	2.0	1.9	2.2	2.1	2.3	2.2	2.3	1.3	1.7	1.6	1.6	1.7
IDF	g/100 g	1.1	1.5	1.5	0.9	1.5	1.4	1.2	1.5	1.4	1.6	1.5	1.5	0.9	1.3	1.3		
SDF	g/100 g	0.6	0.6	0.6	0.7	0.7	0.6	0.7	0.7	0.7	0.8	0.7	0.8	0.4	0.4	0.3		
Protein	g/100 g	2.8	2.6	2.5	1.7	2.0	1.8	2.3	2.2	2.1	2.3	2.2	2.3	1.6	1.5	1.5	1.8	2.1
Total fat	g/100 g	0.3	0.2	0.3	0.3	0.4	0.2	0.3	0.2	0.3	0.4	0.3	0.4	0.3	0.2	0.2	0.2	0.2
Ash	g/100 g	1.0	1.1	1.0	1.1	1.3	1.2	1.0	1.1	1.1	1.2	1.2	1.2	0.8	0.9	0.9	0.8	

Key: [a] For a reference female of 61 kg, reference male of 76 kg, 19-30 years of age and light to moderate activity; [b] Estimated by difference where carbohydrate = 100 – (% Moisture + % Ash + % Fibre + % Fat + % Protein); Total DF = Total Dietary Fibre; [c] Englyst method of determining fibre; IDF = Insol Dietary Fibre; SDF = Soluble Dietary Fibre;

Table 2.27 Comparison of Micronutrient Content after Par-boiling and Storage for 21 days at 4°C.

Except where stated, results are expressed as averages of duplicate assays per 100 g fresh weight, whole potato

NUTRIENT	UNITS	Huakaroro whole, fresh			Karuparera whole, fresh			Moemoe whole, fresh			Tūtaekuri whole, fresh			Nadine whole, fresh			Rua flesh, fresh	
		Raw	PBd0	PBd21	Raw	PBd0	PBd21	Raw	PBd0	PBd21	Raw	PBd0	PBd21	Raw	PBd0	PBd21	Raw	Boiled
MICRONUTRIENTS																		
Total EFA	g/100 g	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0		
Total EAA	g/100 g	1.1	0.9	ND	1.1	0.7	ND	1.3	0.8	ND	1.0	0.8	ND	0.7	0.5	ND	0.7	
Calcium	mg/100 g	6.1	6.0	4.6	5.6	5.6	4.8	8.6	9.6	7.4	14.8	14.1	13.6	2.7	2.9	2.7	3.0	4.0
Copper	mg/100 g	0.3	0.3	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
Iron	mg/100 g	1.0	0.9	0.7	0.9	0.8	0.7	1.8	1.2	1.1	2.1	3.0	2.4	0.4	0.3	0.3	0.6	0.5
Magnesium	mg/100 g	25.4	25.0	21.4	23.8	25.5	26.0	18.7	17.2	18.9	21.7	23.6	22.0	19.3	18.5	18.7	17.0	
Manganese	mg/100 g	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.1	0.1	0.1	0.1	
Phosphorus	mg/100 g	53.3	54.4	51.4	46.1	55.9	56.2	32.9	33.9	31.1	35.4	34.3	33.4	27.3	25.2	23.8	33.0	32.0
Potassium	mg/100 g	482.6	489.8	405.5	537.6	559.4	535.6	505.9	468.8	479.1	518.5	535.3	511.4	369.2	369.5	374.6	444.0	332.0
Zinc	mg/100 g	0.5	0.5	0.5	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2
Vitamins*																		
Vitamin C	mg/100 g	13.7	7.6	8.6	13.8	6.7	8.3	9.1	4.2	5.0	7.5	4.1	5.1	11.9	6.4	7.2	12.0	9.0
Thiamine	mg/100 g	0.4	ND	ND	0.1	ND	ND	0.1	ND	ND	0.1	ND	ND	0.1	ND	ND	0.1	0.07
Niacin	mg/100 g	2.0	ND	ND	1.7	ND	ND	1.8	ND	ND	2.1	ND	ND	0.7	ND	ND	0.4	0.8
Vitamin B6	mg/100 g	0.4	ND	ND	0.2	ND	ND	0.2	ND	ND	0.2	ND	ND	0.1	ND	ND	0.1	0.07
Folic Acid	µg/100 g	3.8	ND	ND	4.5	ND	ND	3.5	ND	ND	2.9	ND	ND	1.4	ND	ND		

Key: * = Results are based on single observation only; Total EFA = Total Essential Fatty Acids; Total EAA = Total Essential Amino Acids; PBd0 = Parboil Day 0; PBd21 = Parboil Day 21; ND = Not determined.

2.5.5. *Experiment Four: Discussion*

As potatoes need to be stored for extended periods in order to enable a year-long consumer supply, storage is an important issue for the potato industry. Optimal storage conditions are required in order to maintain potato quality (prevention of rotting, sprouting, or accumulation of reducing sugars or glycoalkaloids) as well as to prevent losses of valuable nutrients. Since potatoes are generally eaten in a cooked form it is important to understand the effects of different cooking and processing methods on the nutritional content of the potato. Hence the purpose of this experiment was to examine the potential for changes in Taewa nutrient composition and nutritional value due to various post-harvest storage or processing and cooking scenarios.

Based on the findings in Sections 2.2.5, 2.3.5 and 2.4.5., the nutrients likely to be of most nutritional consequence in Taewa includes:

Nutrients of benefit:

- Energy
- Resistant Starch
- Fibre (includes total, insoluble and soluble fibre)
- Protein (particularly with regards to the essential amino acid (EAA) content and amino acids likely to be limiting in potato ; methionine, cysteine, leucine or lysine)
- Minerals: potassium (K), phosphorus (P), magnesium (mg), iron (Fe), zinc (Zn) and copper (Cu)
- Vitamins: C, thiamine (B1), B6, niacin and folate
- Phytochemicals: Total phenolic content (TPC), flavonoid (FLV), anthocyanin content (ACY) and antioxidant capacity

Nutrients to limit:

- Reducing sugars
- Glycoalkaloids

Hence where analysed, the nutrients listed above will be the main focus of discussion with regards to the impact of storage and processing methods.

2.5.5.1. Nutrient and Phytochemical Changes Due to 6 month Storage

As discussed in Section 1.4.4. post-harvest conditions such as storage temperature, humidity, physical or microbiological damage to the tuber, light or heat degradation can impact on potato nutrient content. In this research five cultivars of potatoes were stored at 5°C for 6 months, in a darkened chiller with 80-90% humidity control.

On a fresh weight basis, energy content (281-373 kJ *cf* 340-395 kJ/100 g FW after storage); total fibre; insoluble fibre; soluble fibre and total protein were unaffected by the 6 month storage period. Slight gains in total protein were noted after storage (0.2-0.3 g/ 100 g FW in tuber flesh and 0.3-0.5 g/ 100 g FW in tuber skin), which translated into slight gains in total EAA as well as the limiting amino acids cysteine, leucine and lysine in both tuber flesh and skin samples. This is of benefit with regards to potentially providing greater than 12-13%; 8-9% and 10-11% of the required cysteine, leucine and lysine contributions for a 70 kg adult in a 150 g portion of whole potato (Section 2.3.5.1.b.).

Despite a general decrease appearing to occur in P and Mg content (as shown by the negative values in the change of the nutrient), these values are based on dry weight content and when compared using fresh weight values, differences in P, Mg, Zn and Cu were negligible. One notable exception to this was the much lower Mg content in Karuparera skin after 6 months storage (5 mg *cf* 19 mg/100 g FW prior to storage). On the other hand, after 6 months storage 10-20% increases in K had occurred across all cultivars and 50% or greater increases of Fe occurred in Karuparera or Tūtaekuri. Both of these mineral increases are of potential nutritional value and could translate to greater than 24-29% or 17-40% of an adult AusNZ EAR for K and Fe respectively.

Variable effects on phytochemical compounds were noted following 6 months storage. Notable differences included a general decrease in TPC, FLV and ACY content in Tūtaekuri. These decreases in phenolic content likely contributed to the lower antioxidant capacity in Tūtaekuri after 6 months storage as shown by the decreased FRAP and ORAC values. In contrast, increases in TPC, FLV and ACY content as well as FRAP and ORAC values were noted in Karuparera and Moemoe flesh. Variable effects of storage on phenolic content have been found in other research. Lewis *et al.* (1999) found that anthocyanin content increased up to 5 months in the New Zealand coloured potato varieties Desirée, Arran Victory, Red flesh and Urenika (Urenika is a varietal name for Tūtaekuri) when stored at 4°C.

Anthocyanin, total phenolic and flavonoid concentration also increased up to 120 days in Desirée tuber skin stored at 4°C but not when stored at 10°C, 18°C or 26°C. Although a 5% loss in weight occurred after 170 days storage, there was no change in ratios of the individual phytochemical compounds or % dry matter (Lewis *et al.*, 1999). Kulen *et al*. (2013) found that the total phenolic content of tubers with pigmented flesh stored at 4°C increased after each 2, 4, 6 and 7 month time point compared to white or yellow-fleshed varieties, however, Blessington *et al.* (2010) found no significant difference in total phenolic content in 8 potato genotypes stored at 4°C or 20°C for 110 days. As cold storage is known to cause the production of sugars from starch, and sugars are an anthocyanin precursor, the increase in sugars may play a part in the increased synthesis of anthocyanins. It is possible that differences in the effects of storage on phenolic content may also be aligned to the inherent genetic differences in the cultivars, change in the physiochemical environment, and presence of metal ions that affect the expression of anthocyanin colour or response of the tuber to disease or injury (Lewis *et al.*, 1999). With regards to storage of Tūtaekuri, results from this study seem to suggest that limiting storage of Tūtaekuri would help retain optimal antioxidant capacity, although Tūtaekuri flesh is still likely to have 5-6 times greater antioxidant capacity than Nadine flesh and 4-5 times greater antioxidant capacity than Nadine skin even after a 6 month storage period.

Although vitamins were not analysed during the 2004 harvest, research shows that reducing storage is of benefit with regards to preventing losses of Vitamin C (Kulen *et al.,* 2013); B6, niacin and folate (Augustin *et al*., 1978); but may improve thiamine content (Augustin *et al*., 1978; Goyer and Haynes, 2011). Starch and sugar are the main components affected by post-harvest metabolism in potato tubers, which will ultimately affect potato cooking, sensory and processing characteristics. Storing potatoes at temperatures around 4°C - 7°C and in a higher CO_2 to O_2 atmosphere can cause an increase in reducing sugar concentration due to the breakdown of starch (Kumar *et al.,* 2004; Halford *et al.,* 2012). Low reducing sugar (less than 2% fresh weight of total glucose and fructose content) and low sugar content in raw potato is preferable for potential use in the potato processing industry so as to minimise the undesirable formation of acrylamide and after-cooking darkening in fried potato products (Marquez and Anon, 1986; Coffin *et al*., 1987; Rodriquez-Saona, 1997; Amrein *et al*., 2003). 6 months storage caused a slight increase in total sugars in Taewa (1.6-2.5 g *cf* 0.4-2.1 g/100 g FW tuber flesh prior to storage) and the ratio of reducing monosaccharide sugars doubled compared to disaccharide sugars in Huakaroro.

Thus, although the reducing sugar content is likely to be lower than 2% after 6 months storage, it appears that limiting the storage time where possible to prevent further increases in reducing sugar content would still be of benefit.

Singh *et al.* (2008b) measured the effects of 6 months storage at 4°C and 80-90% humidity on raw starch physico-chemical and functional characteristics in Huakaroro, Moemoe, Karuparera, Tūtaekuri and Nadine varieties. They found that storage increased the ratio of smaller starch granule sizes, caused a decrease in solubility but increased peak viscosities (Singh *et al*., 2008b). Such changes may have effects on the texture of the cooked potato and relative intestinal digestibility and thus may affect sensory acceptability and ratios of rapidly digestible, slowly digestible or resistant starch components of the cooked tubers. Although the effect of storage on sensory parameters were not measured in this research, an effect of storage was noted with regards to resistant starch accumulation in cooked then cooled potatoes with potatoes that had been stored for greater than 6 months appearing to accumulate greater resistant starch compared to potatoes that had been stored for less than 2 months postharvest (Chapter 5).

During storage, glycoalkaloid levels can become elevated after exposure to light (associated with tuber greening), infection with tuber rot organisms, or due to sprouting (Stark and Love, 2003). Glycoalkaloid content in Taewa flesh and skin slightly increased after 6 months storage (3-9 mg *cf* 2-8 mg/100 g FW tuber flesh prior to storage and 52-72 mg *cf* 37-64 mg/100 g FW tuber skin prior to storage). Total glycoalkaloid levels above 20 mg/100 g fresh weight of the potato are generally considered unacceptable due to the bitterness they impart and their potential for adverse health effects (Shakya and Navarre, 2006). As such, it would be advisable that any potential product involving Taewa skins only (such as in a snack of fried potato skins), be analysed for potential glycoalkaloid toxicity. As previously discussed in Section 2.4.5.2, previous research on Taewa found that glycoalkaloid content ranged from 3.9 to 14.3 mg/100 g FW whole potato between Taewa cultivars (Savage *et al.,* 2000) and thus whole Taewa products are likely to fall within an acceptable range. Although the effect of cooking on glycoalkaloid content was not carried out in this research, household cooking techniques (boiling, baking, frying), do not appear to affect the glycoalkaloid content of potatoes (Friedman and Lewis, 2009), therefore efforts to reduce glycoalkaloid accumulation should focus on storing potatoes away from light and removing tuber sprouts, green skin or flesh prior to cooking.

2.5.5.2. *Nutrient Changes Due to Par-boiling*

Processes to convert the potato tuber into an edible form (cooking, extraction of starch, extrusion, chipping, freezing, frying) will each impact the nutrient content and thus nutritional value of the final potato product consumed.

Overall, par-boiling Taewa tubers whole incurred minimal if any nutrient losses and thus par-boiling Taewa whole appears to have excellent potential for use as a future par-boiled Taewa product that could be marketed as a convenience product with added health benefits (increased resistant starch content as well as increased antioxidant potential compared to white or yellow-flesh, white-skinned potatoes). Par-boiled Taewa could be used in potato salads sold in delicatessens, or used at home as a pre-cooked potato that would only need warming, adding to a potato salad or adding to a recipe requiring cooked potatoes (such as a cheese and potato bake, stir-fry, or stew). Of interest was the fact that Fe content slightly increased after par-boiling in the Tūtaekuri variety. Previous research by Bethke and Jansky, (2008) supports the fact that a reduction in potato tissue disruption helps to reduce mineral losses as peeling, cubing or shredding potato tubers prior to boiling incurred 50% and 75% loss in potassium and around 50% losses for P, Mg, Zn, Mn and Fe (Bethke and Jansky, 2008).

As might be expected, cooking processes that included boiling in water had a major effect on Vitamin C content (45-54% loss due to par-boiling). Although not determined in this experiment, other water-soluble and heat-sensitive vitamins such as Vitamins B6, B1,and niacin are also likely to incur significant losses due to heat destruction or leaching out into water (Finglas and Faulks, 1984). Research suggests that folate may not incur as extensive losses when boiled, as the folate content of raw whole potato was similar to that after boiling for 60 minutes (125.1 and 102.8 µg/100 g FW for raw and boiled potatoes respectively), nor did folate levels decrease if the skin was removed prior to cooking (McKillop *et al*., 2002). It appears that keeping the skin on during the cooking process, and minimising cooking time, temperature and volume of water used during the cooking process can help minimise losses of vitamins (Burgos *et al.,* 2007).

In comparison to processes including chipping, frying or extrusion, par-boiling is likely to be the best option with regards to retaining nutritional value. Par-boiling is likely to not only incur the least loss of valuable nutrients compared to extrusion or frying, but par-boiled potatoes do not have the additional fat and calories that are associated with fried products.

Realistically however, potato snacks such as potato crisps or extruded snacks are potentially a more profitable market than bags of raw, whole potatoes, thus the challenge is to explore various cooking processes which minimise nutrient losses or the addition of fat and salt, and thus maximising health potential. Suggestions of possible options will be explored in Chapter 7.

2.6. Summary and Key Findings of Chapter 2

One of the major goals of this PhD research was to investigate the nutritional composition of four Māori potato cultivars and compare these with the commonly-used modern potato cultivar, Nadine, with an emphasis on identifying, commercially viable, health-promoting or nutritionally beneficial properties of the Māori potatoes.

As discussed in Sections 1.2 and 1.3, potatoes are not only commonly eaten in significant quantities around the world, but also have a high nutritional value and potential health promoting properties. However, there are large differences in the quantity of various nutrients between potato cultivars. Thus, the overall aim of this chapter was to quantify the levels of the macronutrients, selected micronutrients, phytochemical and anti-nutrient components of four Taewa varieties; (Huakaroro, Karuparera, Moemoe, Tūtaekuri), and compare them against Nadine. As potatoes are normally cooked before being eaten, the effects of par-boiling, extrusion processing and storage on the nutrient content was also briefly explored in order to assess how these processes might impact on nutritional composition and thus provide information for future Taewa product development.

A summary of the major findings with regards to the potential nutritional value of four Taewa (Huakaroro, Karuparera, Moemoe and Tūtaekuri are as follows:

- Fresh, raw tubers from these four Taewa (including flesh, skin, whole tuber components) are each likely to be of greater nutritional benefit compared to Nadine due to their higher content of energy; fibre (includes total, insoluble and soluble fibre); protein (particularly with regards to the essential amino acid (EAA) content and amino acids likely to be limiting in potato; methionine, cysteine, leucine or lysine); mineral content (in particular K, P, Mg, Fe, Zn and Cu); the vitamins thiamine (B1), B6, niacin and folate; and with regards to greater potential health benefits from greater phenolic, flavonoid and anthocyanin content as well as greater antioxidant capacity.

- Taewa varieties (particularly Tūtaekuri) are more likely to have greater glycoalkaloid content compared to Nadine, but these levels are still likely to be within acceptable limits (<20 mg/100 g FW). Sensory evaluation is advisable to determine the extent of bitterness perception in Taewa varieties.

- Variation in nutrient content between Taewa cultivars is likely, with Tūtaekuri most often having a greater nutrient and phytochemical content compared to the other three Taewa cultivars measured.

- 6 months storage at 5^{o}C with 80-90% humidity had little or no effect on energy; total fibre; insoluble fibre; soluble fibre levels with slight gains in total protein and total EAA content (as well as the limiting amino acids cysteine, leucine and lysine). Differences in P, Mg, Zn and Cu were negligible; however 10-20% increases in K and 20-50% increases in Fe occurred in Karuparera and Tūtaekuri.

- Storage had variable effects on phytochemical compound levels between cultivars; however, all four Taewa generally had greater phenolic content and antioxidant capacity compared to Nadine. Although a notable decrease in TPC, FLV and ACY content as well as antioxidant capacity occurred in Tūtaekuri following storage. However, despite these decreases, Tūtaekuri is still likely to have 4-6 times greater antioxidant capacity than Nadine.

- Apart from 45-55% losses in Vitamin C, par-boiling incurred minimal if any nutrient losses and thus appears to have excellent potential for use as a par-boiled Taewa product that might be sold as a chilled, pre-cooked, convenience potato product that could be warmed and eaten by the consumer at home, used in a potato salad or in other recipes requiring cooked potatoes. Of interest was the fact that Fe content slightly increased after par-boiling in the Tūtaekuri variety. Retaining the skin during boiling is likely to minimise potential vitamin and mineral losses due to leaching or tissue destruction.

In conclusion, the four Taewa varieties analysed in this research have excellent nutritional value, do not have glycoalkaloid levels of health concern and incur minimal nutrient losses after 6 months storage or par-boiling. Overall, these Taewa have shown the potential to exceed the nutritional value shown by Nadine in all scenarios described in this research thus the use of these Taewa in the diets of New Zealanders should be encouraged as they have the potential to provide nutritional value and health benefits for those who do.

CHAPTER 3

Qualitative Analysis of Usage and Consumption Practices Associated with Taewa using Group Discussions

3.1. Introduction

A comprehensive study into all of the factors that currently influence Taewa consumption is beyond the scope of this PhD research. However, to date there have been no investigations into the usage or cooking and consumption practices associated with Taewa. Therefore, as part of this research, a mixed methods approach has been used which involved initial exploratory qualitative research techniques (facilitated group discussions and one-one interview followed by thematic analysis of recorded transcripts) so as to gather information from regular Taewa consumers regarding their experiences, usage, knowledge, preferences, challenges and values with regards to Taewa. Re-occurring themes or observations gathered from the qualitative analysis were used to provide a basis from which to derive questions for a subsequent quantitative survey (questionnaire) in order to generalize results from a wider population group of Taewa consumers.

By involving those familiar with Taewa, it was hoped that clues might be discovered as to whether there might be specific Taewa varieties or Taewa cooking preferences that might have some marketing advantage for future Taewa product development or that might be better suited for a pre-cooked, cooled Taewa product. With the advent and availability of modern cooking appliances, it was also of interest to see how modern practices may have impacted on traditional cooking and consumption preferences of Taewa.

3.2. Aim

The aims of this study were threefold. To record experiences from regular Taewa consumers to a) identify the range and type of Taewa varieties and cooking practices that might be common, traditional, modern or preferred in the nutritional and non-nutritional usage of Taewa; b) identify information regarding Taewa varieties or cooking practices that may have some marketing advantage for future Taewa product development; and c) identify factors which might have an impact on consumer choice to eat Taewa. In particular, sensory acceptability; cultural, historical or emotional value of different varieties; impact of availability (quantity of Taewa available in any environment, at any given time); accessibility (extent to which Taewa can be obtained when needed) or economic viability were consumer choice factors explored.

3.3. Materials and Methods

3.3.1. Qualitative Methodology

Discussion with the Chairman of the Human Ethics Committee deemed this study to be of low risk and thus only notification of the details for the intended study was required to be lodged with the Massey University Human Ethics Committee, which occurred in October 2010.

During October and November of 2010, invitations to participate in facilitated group discussions regarding the cooking and consumption practices of Taewa were sent out via email distribution lists for Massey University staff and students, Māori iwi (Māori ancestral tribal group), health organisations and church communities. With permission, advertisements seeking volunteer participants for the proposed study were also posted on noticeboards or left at receptions of local marae (Māori ancestral meeting area and village connected with a particular tribe), Māori iwi or community groups.

3.3.1.1. Pre-screening and Gaining of Informed Consent

Prior to acceptance into the study, interested participants were informed that they would be invited to share personal experiences, feelings, practices or recipes relating to the cooking and consumption of Taewa within a closed, facilitated discussion group. Participants were informed that the discussions would be recorded (using an Olympus D-1000 digital voice recorder) and information from the discussion groups would be used to develop survey questions for a subsequent large-scale investigation of current practices in the cooking and consumption of Taewa (see Chapter 4). Individuals were informed that their identity would only be known to the researcher and they would not be identified in subsequent reports unless their written consent was given (see Appendices 3.1 to 3.3 for copy of group discussion participant consent form, information sheet and the advertisement for participation).

3.3.1.2. Group Discussion Protocol

Four facilitated group discussions of 3-7 participants and one individual interview were held between November and December 2010. Each session lasted between 45 – 90 minutes. The purpose of this qualitative research was exploratory: to identify or discover important categories in relation to the usage of Taewa and to generate hypotheses for further research into Taewa potato products.

At the beginning of each group discussion or interview, a *mihi* (welcome), and then introduction to the researcher and aims of the group discussions was given. Participants were asked to read the information sheet regarding the study and any concerns or questions regarding the study were answered. Each participant was asked to sign a consent form in relation to the recording of their voice and the use of any information they provided about their experiences with Taewa. Demographic data including age group, gender, ethnicity(s) and iwi affiliation(s) were also collected following consent being given.

Each group discussion or interview involved two main parts. The first part involved the same open-ended questions (Questions 1 – 4) being posed by the facilitator (Zirsha Wharemate) to each participant one at a time to allow each to express their views and experiences with relation to their habits and interest in eating Taewa.

In the first part, participants were invited to name, or identify with the aid of an identification chart, common Taewa varieties they had eaten, and which of these they preferred to eat (See Appendix 3.4 for Māori Potato Identification Chart). To describe the ways in which they had cooked, or had seen Taewa being cooked, and the cooking methods or practices which they preferred. To share any traditional practices that they knew of, regarding the way Taewa were cooked, the circumstances or occasions in which Taewa might be more likely to be eaten and also any occasions in which Taewa had been used to promote health. In the interest of developing future Taewa products, to be eaten either cold or reheated, the participants were also asked what marketable traits they felt Taewa had or did not have when compared to modern potato varieties.

The second part involved open-ended questions (Questions 5 – 6) posed to the whole group that were designed to allow discussion and exploration of the differences (positive and negative) of using Taewa compared to modern potato varieties.

The groups were asked to identify positive attributes or barriers they felt existed with regards to being able to eat Taewa, such as cultural, historical or emotional value and the impact of availability, accessibility or economic factors. The groups were also asked which Taewa variety they felt might be the best variety cooked then served cold or reheated and their reasons for choosing this one (See Appendix 3.5 for a copy of the discussion protocol).

3.3.1.3. Data Analysis

Transcriptions of the voice-recorded group discussions or interviews were typed out. Comments or points brought up by the participants were then grouped into four main themes of interest which included nutritional uses of Taewa, non-nutritional uses of Taewa, factors affecting Taewa consumption and future edible Taewa developments. Sub-categories relating to each of the four themes were grouped as follows:

- Nutritional Uses Of Taewa
  (Range and type of Taewa varieties eaten, commonly eaten Taewa varieties, range and common cooking methods used, Taewa eating preferences).
- Non-Nutritional Uses Of Taewa
  (Medicinal or healing purposes, other uses)
- Factors Affecting Taewa Consumption
  (Sensory qualities; cultural, historical or emotional value; availability, accessibility or economic viability factors)
- Future Edible Taewa Developments
  (General suggestions for marketing of Taewa or edible products, suggestions for cold or pre-cooked cooled Taewa products)

Results of the analysis are presented and discussed in terms of these four main themes and their sub-categories.

3.4. Results

3.4.1. Participant Demographics

A total of 25 adults between 18 to 75 years of age participated in a group discussion or one-one interview. All participants were living within the Manawatu region of New Zealand at the time of the study but included participants who were affiliated with a total of 22 Māori iwi that originate from ancestral regions within the North and South Islands of New Zealand. 88% of the participants were of Māori descent, 52% were female and 48% had grown Māori potatoes before (See Table 3.1). All participants had previously eaten Taewa on several occasions, which they had either cooked themselves or had seen being cooked.

Table 3.1 **Demographics of Group Discussion Participants.**

N = 25 (Participants who were involved in either a group discussion or one-one interview)

Group Name	Age Group	Gender	Grown Taewa	Ethnicity	Tribal Affiliation
MD1211	46-55	Male	yes	NZ Maori, NZ European	Te Atiawa nui tonu ki Taranaki, Ngati Tama-Ariki
	36-45	Male	no	NZ Maori, NZ European	Nga Puhi
	46-55	Female	no	NZ Maori	Ngati Pukenga, Te Arawa
	36-45	Female	no	NZ Maori	Nga Puhi, Ngati Whatua
	26-35	Male	yes	NZ Maori	Te Atiawa, Ngai Tahu
	46-55	Female	yes	NZ Maori	Ngai Tamanuhiti, Ngati Te Rangihouhiti, Ngai Tahu, Nga Puhi
MP2311am	36-45	Female	yes	NZ Maori	Nga Puhi, Ngati Hine
	26-35	Male	no	NZ Maori	Te Aitanga a Mahaki
	26-35	Female	no	NZ Maori	Maniapoto, Raukawa, Te Arawa
	36-45	Female	no	NZ Maori, Irish	Ngati Raukawa, Ngarauru
	46-55	Female	yes	White American	
	26-35	Female	no	NZ Maori	Nga Puhi
	36-45	Female	yes	NZ Maori, NZ European	Te Atihaunui a Paparangi
	46-55	Male	yes	NZ Maori	Rangitane, Ngati Raukawa, Ngati Kauwhata
	36-45	Male	no	Chilean	
MP2311pm	56-65	Male	yes	NZ Maori	Nga Puhi
	36-45	Female	no	Indian, Fijian Indian	Gujarati
	18-25	Male	no	NZ Maori	Te Atiawa, Nga Puhi
	26-35	Female	no	NZ Maori	Ngati Porou
	56-65	Female	no	NZ Maori	Ngati Tuwharetoa, Ngati Raukawa, Ngati Kahungunu
	56-65	Male	yes	NZ Maori, NZ European	Ngati Porou
MP3011	36-45	Female	yes	NZ Maori, NZ European	Ngati Ranginui ki Tauranga, Maniapoto
MP2312	66-75	Male	yes	NZ Maori	Te Atiawa, Ngati Hauiti
	66-75	Male	yes	NZ Maori	Ngati Raukawa, Ngati Hauiti, Ngati Tuwharetoa
	66-75	Male	no	NZ Maori	Ngati Hauiti, Ngati Kahungunu

3.4.2. Nutritional Uses of Taewa

3.4.2.1. Range and Type of Taewa Varieties Eaten

Fifteen Taewa varieties were identified by name as having been eaten by at least one of the 25 group discussion participants (see Table 3.2). A purple-skinned; creamy-yellow fleshed variety was eaten by two participants but was unable to be identified conclusively. According to Dr Nick Roskruge, an agricultural scientist from Massey University (Palmerston North, New Zealand), this variety was most likely to have been either Pawhero / Black Kidney / Old Red; Te Māori or Waiporoporo. Additional Taewa varieties may have been eaten by participants familiar with Taewa, but as these were not mentioned during the recorded discussions, they are not listed in Table 3.2.

3.4.2.2. Commonly Eaten Varieties

The Tūtaekuri / Urenika variety was the most commonly eaten Taewa variety as 13 out of 25 participants had eaten it. Other varieties most frequently identified by participants included Moemoe (8), Waiporoporo (7), Huakaroro (6), Karuparera or Kowiniwini (5) and Peruperu (5) (see Table 3.2).

Table 3.2 Frequency with Which Taewa Varieties Were Identified as Having Been Eaten by Group Discussion Participants.

N = 25 (Participants who were involved in either a group discussion or one-one interview)

Taewa Varieties	Times Identified
Tūtaekuri / Urenika	13
Moemoe / Muimui / Nga Toko	8
Waiporoporo	7
Huakaroro / Karoro / "White Māori"	6
Karuparera / Kanohi Parera *or* Kowiniwini / Kaupari	5
Peruperu (Not purple skin & flesh)	5
Te Māori	3
Karupoti	2
Ngaupere or Moemoe type	2
Paraketia / Parareka	2
Purple-skinned, creamy-yellow flesh	2
Wherowhero	2
Kohatuwhero / Red Rock	1
Raupi	1
Uwhi / Uwhiwhero	1
Wakaora	1

Although the majority of the 25 participants were familiar with the names of Taewa varieties they had eaten, some were not, and needed photos of Taewa cultivars to help with identification (Appendix 3.4).

3.4.2.3. Common, Traditional or Modern Cooking Methods of Taewa

Participants were asked how they, or those who had prepared the Taewa, had prepared and cooked the Taewa that had been eaten.

The most common method of cooking used by the participant themselves, or used by a participant's parents or grandparents (22 out of 25 participants), was to boil the Taewa whole, unpeeled in a pot separate from other potatoes, vegetables or meal accompaniments (see Table 3.3).

An explanation of why Taewa were cooked separately is given by one participant (below):

> *"My grandmother used to always cook it (Taewa) separately. She never mixed it with other potatoes or other foods like boil-up or something. It was always cooked separately and her explanation to that was that it had a flavour of its own and that's the treasure of the potato is to have its own flavour".*
>
> (Group Discussions, 2010)

Another participant recalled how he had eaten Taewa as a child, which was a method similar to the traditional hangi-steamed method of cooking food:

> *..."We used harakeke (flax plant –Phormium tenax or Phormium Cookanium) and fern between the stones and the food. It would just sit there. You'd serve yourself basically from the hangi itself. When you finish cooking, take all the covers off, serve it from there.... everything was quite open. 'Cause that was quite a different flavour because the fern added a different taste ... but they always used fresh fern".*
>
> (Group Discussions, 2010)

Nowadays, hangi-cooked Taewa are reserved for special occasions so it is not surprising that the majority of the participants had generally eaten boiled Taewa because this is a relatively quick and easy method of cooking as mentioned by this participant:

> ..."*they (Taewa) are all easy to cook ... cos they're mostly boiled".*
>
> (Group Discussions, 2010)

Another common cooking method, mentioned by 9 participants was adding Taewa to a "boil-up" (a dish which involves boiling meat such as pork bones, bacon bones, mutton flaps and vegetables such as potatoes, kūmara (Māori name for sweet potato), cabbage, puha (sow thistle) or watercress together in one large pot). Baking/roasting Taewa in an oven (mentioned by 7 participants); steaming in a hangi (mentioned by 7 participants); boiled and mashed (mentioned by 6 participants); and fried up as chips the day after cooking (mentioned by 5 participants) were other popular cooking methods mentioned. Non-traditional ways of cooking the Taewa included methods used by 2 participants of American and Indian descent which were, respectively, to incorporate Taewa into pasta or curry.

The frequency of different Taewa cooking methods used by group discussion participants, are listed in Table 3.3.

Table 3.3 Frequency With Which Taewa Cooking Methods Were Identified by Group Discussion Participants. N = 25. (Participants who were involved in either a group discussion or one-one interview).

Taewa Varieties	**Times Selected**
Boiled, whole, on own	22
Incorporated into boil-up	8
Baked or roasted whole or cut, in oven	7
Steamed and smoked whole or cut, in hangi	7
Boiled then mashed with or without skin	6
Leftover cooked Taewa sliced and fried up as chips next day	5
Boiled then used in cold potato salad	3
Boiled, mashed, then incorporated into bread	3
Steamed, whole, on own	3
Leftover cooked Taewa mashed and fried up as *"Bubble and Squeak" next day	2
Boiled, mashed, then incorporated into pasta	1
Boiled, deep fried whole, incorporated into curry	1

Key: *"Bubble and Squeak" is a dish that usually involves frying up leftover mashed or potato pieces with onion, butter and sometimes beaten egg or other leftovers from previous meals.

3.4.2.4. Taewa Eating Preferences

The most traditional and common preferences identified by the group discussion participants for eating Taewa included eating cooked Taewa hot or warm (21 participants); with the skin on (22 participants); with butter (20 participants); and with a type of salt seasoning (20 participants).

Taewa were served alongside other components of the meal (usually meat and other vegetables), but having Taewa often signified an occasion where accompaniments not served on a daily basis (such as rewena bread (bread whereby fermented potato yeast is used as the leavening agent), seafood, smoked fish, puha (sow thistle leaves) or watercress) would accompany the eating of Taewa. Thus having Taewa appeared to be associated with a special occasion.

..."*you can guarantee that when my grandfather cooked it, that there was rewena bread and those sorts of things with it"*

.."*when we have salmon and smoked fish...that's when we'll do that potato dish"* (Participant referring to a dish reserved for Taewa).

(Group Discussions, 2010)

Although boiled Taewa was the most common form of Taewa eaten, boiled Taewa was not the preferred method for eating Taewa among some of the participants. Hangi-cooked (mentioned by 7 participants), and oven-roasted Taewa (mentioned by 3 participants) were preferred and eight participants liked to be more "adventurous" with their methods of cooking as well as less traditional in foods that would accompany the Taewa.

"I'd go for hangi because hangi was very rare"

"I find boiled spuds quite bland. I like to have a tutu (play) around and just do it with anything to see what it's like"

"I like to be adventurous. If someone did spuds in a certain way and it looked nice, I might try that"

(Group Discussions, 2010)

Non-traditional Taewa accompaniments included: Taewa being spread with jam (mentioned by 3 participants); eaten with cream (mentioned by 3 participants); sour cream (mentioned by 2 participants); or chilli, tomato or mint sauce (mentioned by 2 participants each). Others (4 participants), preferred to eat the Taewa on their own without any type of seasoning or accompaniment as expressed by this participant:

"I must be boring because I prefer to keep those (Taewa) just the way they are"

(Group Discussions, 2010)

3.4.3. Non-Nutritional Uses of Taewa

It was of interest to find out whether Taewa tubers had been used for purposes other than for their nutritional benefit. Through posing questions regarding whether Taewa were used for healing, medicinal or other functional properties, it was hoped that other useful properties of Taewa tubers might be discovered.

3.4.3.1. Rongoa

Although a number of the participants mentioned that they knew Taewa had been used as a *rongoa* (a traditional form of Māori healing, medicine or treatment), most were not able to specify which quality or purpose Taewa were used for, or in what manner they were applied (i.e. whether applied topically or taken orally). In most cases, it was the participant's parent, grandparent or people of 'older' generations who used Taewa as *rongoa*.

> *"My big Nanny used to use it for a rub, for rongoa, but I can't remember what for"*.

> *"A poultice (was) made from cold, mashed potato and the potato leaves to draw out pus from sores"*.

> *"My Nanny ... cut then scraped it (the Taewa), put it on my foot when I stood on a nail and it actually drew out the infection"*.

> "*My mother ... used the potato peelings for abrasions or something like that I can't remember. But I know she used it for medicinal purposes. The juice from the boiling of the potatoes ... she would save that and it would be a health drink".*

> *"The leaves of the potato were used".*

> *"My grandmother and my mother used potato for medicinal purposes too. They used to grate the potato and then squeeze all the juice out of it ... I remember my sister being given it. I think it was ... to settle her stomach. And I remember the flesh being used for something else on the skin ... for burns or something like that. I remember my grandmother doing something with the skin when she boiled them and then something that comes out of the skin, she used for medicine or healing. And the other stuff, like for upset stomach for instance, they used to grate and dry it (the potato) and use it as a supplement because sometimes when you have a bad stomach, you can't eat certain things, you have to start slowly to build your stomach up so they used to use that because it's light and it's not heavy for our bodies"*.

"The rangatira (chief) of the man is the head, so (Taewa is) never used on the head".

(Group Discussions, 2010)

Thus, the most common healing or medicinal uses of Taewa tubers appeared to be associated with treating skin injuries, stomach upsets or as a health tonic. The parts of the Taewa tuber that were used included the whole tuber, the tuber flesh (cooked and uncooked) and starch or juices extracted from the tuber. Leaves from the potato plant also appear to have been used.

3.4.3.2. Other Non-Nutritional Uses

Two other non-nutritional uses of Taewa were mentioned by the group discussion participants. Starch extracted from the potatoes was used to starch clothes and there may have been a possibility of using extracted pigments from flowers of the Taewa plant or from Taewa tuber skin flesh (particularly the skin or flesh of Tūtaekuri), for use in dyeing.

"My Nan used them (Taewa) to starch my grandfather's clothes".

"They had different ways they (Taewa) were used, like my Nan used the flowers sometimes for making dye for the curtains. They (the older Māori generation) were just those sort of people they knew what do for different things without having to go into town to buy anything really".

"I've looked at those Taewa and wondered if they'd ever used them for dyeing things. You know, pretty colours aye, the purples and the pinks (of the Taewa)".

(Group Discussions, 2010)

3.4.4. Factors Affecting the Consumption of Taewa

The intention of the second group of questions posed to the group discussion participants was to identify factors which impacted in either a positive or negative manner, on the participant's ability to be able to eat Taewa.

3.4.4.1. Effect of Sensory Qualities of Taewa on Consumption

Sensory qualities of Taewa were frequently mentioned as reasons why Taewa, or a particular variety of Taewa, was preferred or not preferred (see Table 3.4). The Huakaroro (Taewa variety with creamy-yellow skin and flesh) was mentioned most frequently (by 6 participants) as being the preferred variety for eating.

The reasons why Huakaroro was preferred mostly included factors relating to its sensory acceptability such as its taste: *"it's got a nice, quite strong buttery taste"*; its texture: *"... they're not soft, easier to bite into them, (they) don't fall apart"*; and its colour: *"cos they're yellowy, just reminds me of butter on it"* (comments from Group Discussions, 2010).

Table 3.4 Preferred Taewa Varieties for Eating and Reasons for Their Preference.
N = 25 (Participants who were involved in either a group discussion or one-one interview)

Preferred Varieties	Participants	Reasons for Preference
Huakaroro	6	Buttery taste Nice flavour Doesn't need accompaniments Keeps its shape when boiled Waxy Firmer Good texture Doesn't come all mashy Nice to bite into Yellow colour reminds me of butter
Peruperu	3	Tasted nice Tasted beautiful Preferred them cold because of taste Tasted sweet and I can eat lots of them without getting full
Moemoe	2	Nice and tasty Nice cold Keeps its shape when cooked
Waiporoporo	2	Nice taste Dense, waxy potato Like the colour (purple skin, white flesh)

It was interesting that although Tūtaekuri was a variety of Taewa most commonly eaten by the participants (22 out of 25 participants had eaten Tūtaekuri), it did not appear to be the preferred variety for eating if another Taewa variety had also been eaten. Reasons that were stated as to why Tūtaekuri was not preferred included:

> *"Because they're fluffy mush when you cook them".*
>
> *"I don't like the name (Tūtaekuri)".*
>
> *"Eating them cold is yuck"*.
>
> *"They're a lot denser and drier...don't taste as sweet".*
>
> *"Skin's really tough".*

"Skin is really bitter so I had to take the skin off".

"The purple one (Tūtaekuri), was a lot stronger".

"Only recently I've tried Tūtaekuri but I'm not too fussed about them".

(Group Discussions, 2010)

3.4.4.2. Cultural, Historical or Emotional Value

The cultivation, cooking and eating of Taewa appeared to be strongly associated with cultural, historical and emotional values as shown by the comments made by the group discussion participants presented in this section.

3.4.4.2.a. Cultural and Historical Value

Among the participants, particularly those of Māori descent, the eating of Taewa was used as a means of promoting cultural values such as *manaakitanga* (the sharing of food with others, being a good host and giving guests the best you have to offer) or *whanaungatanga* (developing kinship within or between families or others). Cultivating and eating Taewa was also linked with the desire to continue and pass on a traditional practice.

"... for Māori potatoes … we (Māori) value it more, it's really something that's quite special .... we'd hold it back for us, nobody else".

"I like the idea of continuing something that has been a traditional practice. I like the idea of sharing that kind of thing with my kids so that it's something that's familiar with them, not something that was in the past that's not a living practice anymore. Appeal of Taewa is that they come with a story. They have cultural significance, are unique to this country. You can't find exact replicas elsewhere. They have been grown by our own people and have been used by Māori for years".

"... with this Nanny that we lived with, that the Māori potato was definitely something special like even though we had it all the time at her place, it was like a delicacy, a spoil herself thing and she's always said that when people would come over and stuff, it's about manaakitanga (hospitality), having kai(food) available so it's just like how you would say maybe when you'd have guests, you would offer them a biscuit, that she'd have Māori potatoes available there".

"Like you said before, it's a bit of the history (for Māori)".

"My grandfather... had about 20 acres of garden so it was our job to plant and all his kids and grandchildren would go back and do that".

"My grandfather had huge plantations, especially of Māori potatoes ... and just grew them and gave them away, for his family and other families that visited, or people that needed them".

(Group Discussions, 2010)

3.4.4.2.b. Emotional Value

As discussed previously in Section 1.6.4. of this thesis it also appears that in New Zealand, Taewa were highly valued because their cultivation or use was associated with childhood or family memories; special occasions such as Christmas or Matariki (celebration of New Year for Māori); with eating a hangi or with other foods relished but not regularly eaten.

*"When I was growing up.... my Dad's parents, they boiled and roasted them, my grandmother <u>just for me</u>***"***.

"I usually only do them for over the Christmas period. ... Our pakeke (parents, grandparents) ... like having Māori potatoes because it reminds them of their childhood. If we can give them (the Taewa) to them, they like to have them".

"I mostly just have them at special occasions ... mostly in hangi".

"I think if it was just for me, I would choose the Māori potato (over a modern potato) because they have memories attached to them and that makes them nicer".

"... And that it's not available all the time so we treasure those moments and they were special moments for us when those (Taewa) were put on the table. ... Rarity of Taewa made them special. ...With Māori potatoes ... I don't care what the shape or thing is like, it's a delicacy".

"... And that it's not available all the time so we treasure those moments and they were special moments for us when those (Taewa) were put on the table. ... Rarity of Taewa made them special. ...With Māori potatoes ... I don't care what the shape or thing is like, it's a delicacy".

"It's sort of like an absolute treat but it comes with memories of working all those hours in the garden but you know it's just something that you value more".

"I think like the feelings and that it brought back memories, family memories of being together and that it was a special occasion for us when we had them and I can always recall fond memories of how we'd walk in the door and we'd ask what was for dinner and she'd say 'Oh there's Moemoes on the stove' and how excited we used to be and feel about it and not wanting to share them with anybody else. But she would always ring other family members up and they'd come over and we just have fun as a family. We'd sing a lot of music. So those are the sort of feelings that it brought back when I think about Moemoe - as a family coming together to share".

"... And that it's not available all the time so we treasure those moments and they were special moments for us when those (Taewa) were put on the table. ... Rarity of Taewa made them special. ...With Māori potatoes ... I don't care what the shape or thing is like, it's a delicacy".

(Group Discussions, 2010)

3.4.4.3. Impact of Availability, Accessibility or Economic Viability on Taewa Consumption

Group participants were asked to suggest reasons as to why people are not eating Taewa, or are discouraged from eating Taewa. The following headings depict some of the themes that arose from this discussion.

3.4.4.3.a. Barriers Due to Limited Availability or Accessibility

Some participants' comments suggested that they are unable to access Taewa due to lack of awareness of where to purchase them, limited season availability and limited supply.

"Oh very on and off occasions, I've seen them".

"... Probably from about March until July-August, but yeah patchy (Taewa availability season)".

"If they were available all year around and you could get them in the supermarket, I'd go for them more".

"The biggest barrier is just supply. You can't find them when you want them. You want them like when you've got visitors or a 21st but you can't find them ... In some areas there are more people growing them. You've just got to know someone. It's just that availability thing. Te Kuiti ... sell them at the supermarket, but not here. (They sell Taewa) … at the flea market though".

"I do want try other things with it (Taewa), but whenever I try to go to the flea market now, it's not there".

"I was really delighted when you mentioned about the Māori potatoes ... I'd been looking for them (Taewa) for a long time because she (the mother) had a little patch of her own but when she passed away, I don't know what happened to them. Cos when we went back, they were all dug up and gone and so I've never seen any since until ... about a month ago with one of the girls ... at work ... brought some and she had them in a boil up but she didn't want to share the seeds so I thought 'Wow, I've never seen those for so many years'. Trying to find them was a mission so it was really good when you said that you had some that I could get".

(Group Discussions, 2010)

3.4.4.3.b. Barriers Relating to Economic Viability (Loss of Land or Cultivation Knowledge / Production Costs)

Other participants' comments suggested that a lack or loss of land, cultivation knowledge or production costs related to growing Taewa was a barrier to being able to access Taewa.

"I would grow more of them too if they were more readily available. I just like trying different things and so I'd be interested in growing different types if I had more space".

"I'd grow much more than what I've got, but I can only grow what space I've got ... Don't really see much Māori potato on the marae anymore. No-one's growing. We still have gardens now but generally it's not done as much as it used to be done. Gardens used to be full, everybody had a garden and they were always full".

"Cos I know up the coast there's lots of cost in terms of selling it (Taewa). I think it's getting it to Gisborne, they don't really do it and then cos the growers list is small ... it's not on a large scale and expensive. So I think the only place where it's been really successful is when like restaurant franchises buy them in bulk".

"I don't know any one of my cousins that grow the potatoes. Everybody had a garden in our village but not many are gardening these days including potatoes ... I grow them but I'm limited on how much space I've got".

"Barrier to growing Taewa would include their lower yield compared to the Pakeha spuds".

"But that means it's not really available for the everyday person ... Yeah, cos when the ones are available for the everyday person, it's expensive ... But I know that's just got to do with our growing costs. Anything in Ruatoria is so much more expensive because the closest town is Gisborne. That's like two hours. There's the petrol and that sort of thing".

(Group Discussions, 2010)

3.4.4.3.c. Barriers Due to Unfamiliarity / Differences in Taewa Compared to Modern Potatoes

Other suggested barriers to eating Taewa related to the unfamiliarity or difference in characteristics of Taewa compared to the more commonly available modern varieties.

"I think if there's a barrier for people it's because (Taewa are) unfamiliar. So if it's more familiar and people are in the shops actually baking and cooking them and giving them a chance to try it out, then they could try it out without buying it and not knowing how to use it best. Then maybe ... showing different ways of using them and cooking them ... show them they (the Taewa) are just as useful and just as tasty as any other potato ... The kids don't really like the skins on so they'll peel it all off. And there are some that have quite a strong flavour with some of these Taewa so I do take off the skins sometimes".

"Some may want to peel them and modern ones are easy to peel ... Trying to work with the different shapes (of Taewa) might be an aspect (a barrier)".

"They're a bit tricky to clean aye ... The skin is a pain because it's so knotted and you've gotta clean it", (Participant talking about Tūtaekuri).

"I found that the purple one was a lot stronger (in taste / flavour)", (Participant talking about Tūtaekuri).

(Group Discussions, 2010)

3.4.5. Suggestions for Future Developments of Taewa

Participants were asked how they thought future Taewa products might be best marketed or developed.

3.4.5.1. General Marketing of Taewa

When asked about what made Taewa unique, desirable or preferable to other potato cultivars currently on the market, participants' suggestions often involved highlighting the tuber characteristics of Taewa (their variety of colours, shapes and flavour differences) so as to generate interest or sensory appeal. Other suggestions for marketing Taewa included emphasising the potential health benefits due to coloured pigments of the Taewa tubers; providing opportunities to see Taewa being used; or promoting Taewa alongside their cultural and historical background.

A non-Māori participant asked about and tried Māori potatoes seen at a flea market because:

> *"I thought this is really something different ... It was just something that I didn't know about"…*

Upon finding out they were Māori potatoes and being a vegetarian, this participant was keen to experiment with the Taewa. Due to the fact that they were Māori potatoes, the same participant used them in a dish to feed visitors from overseas:

> *"... I would go for Māori potatoes because it would be like something exotic and different'.*
>
> (Same participant; Group discussions, 2010)

Comments from each of the groups suggested that the differences in Taewa (variety of Taewa tuber shapes, colours -particularly colour difference of Tūtaekuri, and tastes) compared to the modern potato varieties would be a good selling point for a potential Taewa product and therefore there was potential to emphasise Taewa tuber characteristics (variety of shapes, colours, flavours):

> *"Moemoe ... complemented the presentation because it was different ... was used in salads because it was a different colour ... Both (Taewa) had different, distinctive flavours".*
>
> *"Market them to show that they're quite unique and they're all these amazing colours and shapes and different flavours and just (the) variety. So they (Taewa) definitely have that over some of the plain ones (potatoes) that are on the market. There's a huge variety of patterns on the skins and colours and there's a slight difference with the taste. I find the commercial ones quite bland".*

> *"I think there's a lot ... going for them that people would be interested in like the colours, the different shapes".*
>
> *"That's why we have it (Tūtaekuri) because it's purple and we like bright colours".*
>
> *"I think I'd try to use the Tūtaekuri because of the colour".*
>
> *"I love the colour (of Tūtaekuri) ... It was absolutely purple ... (I would) add slices (of Tūtaekuri) to green salad because of colour difference. People are always looking for something different to serve. They want to have a dish that people say 'Oh, I want to try that'".*
>
> *"I think the visual thing is part of it. Partly about that and partly about the flavour ... I think all of them (Taewa) if you take the time to think about them, have a different flavour ... The restaurants like them (Tūtaekuri), because visually they look good, so they slice them like on the side of the plate".*
>
> *"I'd buy Māori potatoes if I knew where to buy it. Just because of the taste".*
>
> *"Huakaroro and Moemoe have a taste of their own".*
>
> (Group Discussions, 2010)

Some of the participants knew about the potential health benefits of eating produce with naturally coloured pigments and suggested emphasising the different colours of the Taewa tubers and their potential health benefits as a marketing tool.

> *"There's also the health side, the nutrition. There's a lot of opportunity in marketing especially some of these ones (Taewa) with the antioxidants, different colours, especially this day and age".*
>
> *"If you can get something that's healthy, a lot of people jump at that, so I think that's something people would pick up on, the healthy thing".*
>
> *"Yeah, jump on the health food track. And because it's true, they have a lot of those antioxidants ... You make them trendy and if you make them gourmet".*
>
> *"If I had to choose between a coloured potato and an ordinary potato, I'd go for the coloured one. I think 'Oh it's healthy. It's coloured'".*
>
> (Group Discussions, 2010)

Participants also suggested that a cookbook, recipes, instructions or providing opportunities to see how Taewa could be used would encourage people to try Taewa:

“If there was a cookbook out, I think that people would try them”.

“If you have the gourmet, trendy, healthy cookbook and they were available and the information was easily available you could see them becoming the new hot thing”.

“So if it's more familiar and people are in the shops actually baking and cooking them and giving them a chance to try it out. Then they could try it out without buying it and not knowing how to use it best”.

“Then maybe showing different ways of using them and cook them and maybe show them they are just as useful and just as tasty as any other potato”.

“And in the supermarkets ... they have signs like good for roasting or good for boiling or just the basics just like "good for boiling or use that" and that you can get them at the supermarket. That would help”.

“Then they could have it on the wine-bottle aye like this would go good with this potato”.

“I think the minute people start using it (Taewa), other people see it like at functions and stuff and they realise that 'oh, that’s different’... People are always looking for something different in dinners and stuff ... Recipes and instructions and how to make it and lots of photos ... would help in people knowing what to do”.

Some participants felt that promoting the cultural or historical aspect of Taewa would give added interest in the marketing Taewa.

“If there was a salad bar somewhere saying these are Māori potatoes or something like that then I might be interested in trying something like that”.

“I think there’s also the other aspect like the historical thing like the old style cars it’s got that sort of back ground to it. Just like stories you know like the historical - kept in maara (family gardens) for how many years. That Māori context adds to it, like if it’s grown on the Pa (local village), you’d choose that one because it’s got a bit of background to it”.

“I think maybe just marketing it as a Māori potato would make a bit of difference. If they had Māori potato written on the bag, it would be so much easier and (including) the name, like Peruperu, that's easy to do and as long as it was in one of those see through bags so you can actually see the shape”.

(Group Discussions, 2010)

3.4.5.2. Cold or Pre-cooked Cooled Taewa Products

The suggestions from the Group discussion participants indicated the most appropriate Taewa variety for a cold, pre-cooked Taewa product (such as a potato salad), would be a waxy variety (such as Huakaroro) that has good colour attributes, tastes good cold and has a uniform size. Peruperu and Moemoe were suggested as best fitting all these criteria. It was also suggested that newly harvested (sweeter taste), small-sized Taewa (about the size of a squash ball) might be boiled on low heat or steamed then cut in half to make the most of the colour difference and a sweeter taste.

Table 3.5 summarises the suggestions that were given in response to the question of which Taewa varieties (and why those cultivars) might be best suited to a pre-cooked and cooled Taewa product that was served cold or at room temperature.

Table 3.5 **Suggestions for Potential Cold, Pre-Cooked Taewa Product**.

N = 25 (Participants who were involved in either a group discussion or one-one interview)

Qualities	Suggestions / Reasons for Preference
Texture	Use a waxy variety that doesn't fall apart (Huakaroro)
Flavour	Hangi-flavoured because different to the norm Smaller Taewa are sweeter Removing skins may make more acceptable as can have strong taste
Visual	Colour difference (Use Tūtaekuri or Moemoe) Use more than one coloured Taewa variety at a time Use Taewa of a uniform size
Varieties	Huakaroro (buttery taste) Peruperu (tastes good cold, uniform size, holds its shape) Moemoe (taste good cold, colour difference, holds its shape) Tūtaekuri (colour difference) Te Māori (uniform size, colour)
Method of Cooking	Boil slowly on low heat Steam over boiling water or in a hangi
Size	Use small Taewa whole (look good in salad, are sweeter) Slice Taewa to maximize colour appeal (i.e. red-skinned, yellow-fleshed variety)

3.4.5.3. Other Potential Edible Taewa Products

Other edible Taewa products that were suggested by the participants as having potential for human consumption included potato crisps or hot potato chips (particularly using Taewa with a different tuber flesh to skin colours or with unusual colours such as the purple colour of Tūtaekuri); or using Tūtaekuri flesh to make lavender coloured bread or pasta.

> *"You could slice them (Wherowhero cultivar) really thinly, and you've got the red skin colour and the yellow flesh and just deep fry them as chips and they'd still look good as they'd have the red around the outside".*
>
> *"Even doing them as the other type of chips (hot chips). Like now they do the kūmara chips and they cost three times as much, so yeah even those purple ones (Tūtaekuri) as chips ... when you do chips it seals them (Tūtaekuri) anyway so they don't go fluffy".*
>
> *"You can't go wrong with potato crisps. Yeah when you make it use like orange kūmara and white potatoes and purple potato and then cook them all together and mix them and they just look cool".*
>
> *"She used to slice them (Moemoe or Tūtaekuri) into chips once they were cooked and cooled down and she would sprinkle them over a salad, lettuce salad with carrots ... and it would give a nice colour to the salad".*
>
> *"I reckon it would be quite interesting to see chips of the purple ones (Tūtaekuri) cos I know they do them (purple crisps) in other countries, like the Asian countries".*
>
> *"So I have purple bread or purple pasta just because I find that entertaining. They don't taste any different. It just tastes like normal bread and normal pasta ... When I have people over for dinner they tend to eat less of the purple one (Tūtaekuri) because they say they don't taste as sweet or they're too dry but when you put them into things like bread or pasta, you can't tell the difference in terms of taste or texture. It's just colour ... (The bread) comes out purple, a lovely lavender bread. It's lovely".*
>
> (Group discussions, 2010)

3.5. Discussion

As stated in Marshall and Rossman's *Designing Qualitative Research*, qualitative research is a method of inquiry that enables a researcher "to be able to explore, explain or describe a phenomenon of interest" (Marshall and Rossman, 1999).

Focus groups have been used for a number of years to help define concepts around product development and innovation (Durgee, 1987; Van Kleef *et al.,* 2005; Stewart *et al.,* 2007), and were used by Guerrero and colleagues to define concepts around traditional food products and innovation (Guerrero *et al.,* 2009). Involvement with the indigenous communities and people at the core of potato production, consumption and development has been a key role of The Papa Andina Partnership Program which was an initiative designed to collaborate and disseminate work being done with the native potatoes of Peru (Devaux *et al.,* 2011). Thus focus groups involving participants of Māori ethnicity, those involved in Taewa production or marketing and who were connected to Taewa through more than just their consumption of Taewa were invited to be a part of the group discussions in order to collaborate with those with a particular interest in the future potential and sustainability of Taewa.

The purpose of the qualitative research carried out in this study was to a) identify the Taewa varieties the group had seen, how the potatoes were prepared and cooked and what other foodstuffs they were consumed with; b) identify information regarding Taewa varieties or cooking practices that may have some marketing advantage for future Taewa product development; and c) identify factors which might have an impact on consumer choice to eat Taewa.

Thematic analysis of the group participants' suggestions aligned into four key areas/themes: those relating to nutritional uses of Taewa; those relating to the non-nutritional uses of Taewa; factors affecting the consumption of Taewa; and suggestions for future developments of edible Taewa products.

3.5.1. Nutritional Uses of Taewa

Fifteen Taewa varieties were identified by name as having been eaten by at least one of the 25 group discussion participants. The Tūtaekuri / Urenika variety was the most commonly eaten Taewa variety as 13 out of 25 group discussion participants had eaten this variety.

Other varieties more frequently identified by participants included Moemoe (8/25); Waiporoporo (7/25); Huakaroro (6/25); Karuparera or Kowiniwini (5/25) and Peruperu (5/25). Thus these 5, as well as the Tūtaekuri variety may be among the more commonly known and eaten varieties of Taewa in New Zealand.

One reason why Tūtaekuri may have been identified as commonly eaten is because Tūtaekuri has a distinctive tuber colouring and it is the only Taewa variety that has a dark purple skin as well as deep purple flesh that usually extends throughout the entire tuber.

Thus Tūtaekuri is more easily recognised, whereas the physical characteristics of other varieties may not be as memorable or unique, thus making them less easily identifiable. Although most of the Taewa varieties that were eaten were able to be identified by the group participants, some required the use of a photo board. Thus, a list of common Taewa varietal names as well as a means by which to describe tuber characteristics should be incorporated into the large-scale survey in order to capture, as best as possible, the commonly eaten Taewa varieties (based on frequency of consumption) as well as the range of Taewa likely to be eaten.

Due to the frequency with which Tūtaekuri was mentioned or identified as having been eaten by the group participants, the Tūtaekuri / Urenika variety may be the most commonly eaten Taewa variety, but not necessarily the most preferred variety for eating. Thus a question regarding which Taewa variety is the most preferred for eating and why that variety is the most preferred, should be included in the large survey.

Based on results from these group discussions, it appears that participants incorporated a number of traditional as well as modern influences with regards to the practices of cooking and eating Taewa. Although the more common form of cooking and eating Taewa was to boil the tuber whole and unpeeled; and then to eat hot with the skin on accompanied with butter and salt; it was not necessarily the preferred method for eating Taewa amongst all participants. Group participants preferred a range of dishes and methods of cooking Taewa, including boil-up; baking / roasting; steamed in a hangi; mashed; and fried up as chips the day after cooking. Non-traditional or more modern ways of cooking the Taewa included incorporating Taewa into pasta or curry.

A list of possible options for Taewa preparation and cooking methods, based on those mentioned by the group participants, were included as part of the survey (see Chapter 4) in order to ascertain common Taewa preparation and cooking methods. Additionally, questions regarding preferences for eating Taewa (hot vs cold; skin on or off; condiments or food accompaniments eaten with the Taewa) were posed in order to identify what might be common, preferred, traditional or modern practices in eating Taewa.

3.5.2. Non-Nutritional Uses of Taewa

The most common non-nutritional use of Taewa that was mentioned by the group participants included using parts of the Taewa plant (leaves); or tuber (flesh, skin, juices; cooked or uncooked) for a healing or medicinal purpose. Potato starch was also mentioned as being used to starch clothes or as a supplement to settle an upset stomach. Pigments from flowers of the potato plant or from the tuber skin or flesh may also have been used as a dye.

Raw potatoes have been used traditionally in Europe for gastrointestinal disorders and topical potato preparations as a hot pack for pain or for softening furuncles (Vlachojannis *et al.,* 2010). Boiled potato peelings have also been used as a dressing for burn wounds in India (Subrahmanyam, 1996).

Therefore questions relating to non-nutritional uses of Taewa were incorporated into the larger-scale survey to further consolidate information from the group participants regarding the types of non-nutritional uses of Taewa that may have previously taken place or are in current use.

3.5.3. Factors Affecting Consumption of Taewa

It has been well-established that the factors affecting food preference are multi-faceted and may be influenced by sensory (Drewnoski, 1997; Dressler and Smith, 2013); familiarity (Kratt *et al.,* 2000); ethnic or traditional (Furst *et al.,* 1996; Devine *et al.,* 1999; Pieniak *et al.,* 2009); social (Clayton, 1978; Fisher and Birch, 1999; Hendy and Raudenbush, 2000; Hendy, 2002; Wardle *et al.,* 2005); emotional (Furst *et al.,* 1996; Connors *et al.,* 2001; Leigh Gibson, 2006); or availability and economic considerations (Glanz *et al*., 1998), rather than the physiological need to eat or the nutritional or health implications of what is being eaten.

In line with this, comments from group participants suggest that positive attributes or positive influences relating to the consumption of Taewa often included sensory attributes such as taste, colour or texture qualities of the Taewa, but also the cultural, historical or emotional value that was associated with Taewa. This is not surprising due to the 200+ years of association of Māori in cultivating, eating and supplying Taewa.

Barriers to eating Taewa that were identified, generally involved factors relating to the lack of availability and decreased accessibility to Taewa. These involved a decrease in the number of people either growing, or with the knowledge to grow Taewa, or with the land or economic base required for cultivating, supplying or purchasing Taewa. Unfamiliarity and differences in tuber characteristics were also mentioned as possible barriers to eating Taewa.

Barriers relating to the ability to be able to access Taewa were further explored in the large-scale survey (See Chapter 4). In particular where, or from whom Taewa are being sourced from; whether there are differences in regional availability of Taewa cultivars and the types being eaten or grown throughout New Zealand; and what factors might encourage people to be able to eat Taewa more often.

3.5.4. *Future Developments of Edible Taewa Products*

In terms of potential pre-cooked and cooled Taewa products such as cold potato salad or par-boiled potatoes, a small, newly harvested Taewa (due to the appropriate size and sweeter flavour) waxy Taewa variety that had good colour and taste attributes when cold; was uniform, squash-ball sized; boiled on low heat or steamed then cut in half to make the most of the colour difference were the most common suggestions from the group participants. Moemoe, Peruperu, Huakaroro, Waiporoporo (firm, waxy texture when boiled) or Te Māori (uniform shape) were suggested as having the tuber characteristics to best fit these criteria.

Information from a larger group of Taewa eaters could help gauge possible acceptance of pre-cooked Taewa products with a wider demographic group and corroborate suggestions from the group discussions regarding qualities and types of Taewa varieties that would be more suited to such a product. Thus survey questions focussing on the respondents' likelihood of eating cold, pre-cooked Taewa; the most appropriate Taewa variety(s) to use in a cold, pre-cooked Taewa product and reasons for its use were incorporated (see Chapter 4). Additional information on preferences with regards to eating pre-cooked Taewa (serving temperature, length of time before consumption and possible accompaniments or serving options to compliment the Taewa) were also obtained.

Due to the different tuber characteristics of the Taewa –particularly in terms of the different colours, tastes, shapes and textures, comments from the group participants suggest there might be a number of possibilities with regards to potential Taewa edible products suitable for human consumption. Potato crisps, in particular were suggested as being a product that might be popular and marketable. Other suggestions included cold, pre-cooked potato products, gourmet hot potato chips and speciality breads or pasta. Participants also suggesting incorporating the history of Taewa or New Zealand's ethnic culture in relation to promotion or marketing of Taewa products.

Although Tūtaekuri may have characteristics which are perceived as undesirable by some (such as a stronger taste, a tough skin, tendency to mush when cooked and may be drier than other Taewa varieties), Tūtaekuri's distinctive purple tuber colour makes it unique and different compared to other Taewa or modern varieties.

Therefore it was suggested that using Tūtaekuri tubers for making into hot chips, potato crisps, pasta or bread could help overcome its shortcomings by highlighting its distinctive colour; crisping its skin and overcoming any potential undesirable flavour through the addition of salt, oils or other flavours normally added to or eaten with potato crisps or potato chips.

'*Mi Papa'* (a new brand of high-quality, fresh potatoes for the wholesale market); '*Papy Bum'* (a new native potato chip product); '*Tunta Los Aymaras'* (a brand of high-quality, freeze-dried, native potato); coloured chips made from native potatoes are example of products that have been developed from the native Andean potatoes (Devaux *et al.,* 2009). Thus there may be potential for similar products made from Taewa.

It would be of potential benefit with regards to the development of new Taewa products that survey respondents also have an opportunity to suggest or comment on what they feel might be positive Taewa characteristics, potential Taewa edible products or Taewa recipes that they enjoy, thus the survey should provide opportunities for respondents to make comments as they wish.

Thus suggestions from the group discussions have provided useful information from which to develop and design an appropriate framework for questions to be posed to a larger scale survey of Taewa consumers (see Chapter 4 of this thesis).

CHAPTER 4

Quantitative Analysis of the Cooking and Consumption Practices Associated With Taewa Using a Large Scale Online Survey

4.1. Introduction

Quantitative research involves "explaining phenomena by collecting numerical data that are analysed using mathematically based methods (in particular statistics)" (Aliaga and Gunderson, 1999). It is usually carried out using surveys or experiments that employ close-ended questions, pre-determined approaches and the collection of numerical data (Cresswell, 2002).

The benefit of following qualitative research with quantitative research is that the data (themes and understandings) gathered from exploratory focus groups and individual interviews can be further supplemented, expanded, verified or refuted through the gathering of data on the frequency of the themes from larger numbers of the target population. This helps ensure that the sample data gathered is a more representative cross-section of the target population, allowing more valid generalisations or assumptions to be made (Cresswell, 2002).

Thus, the themes and understandings from group discussion participants (Chapter 3) were used to develop and design an appropriate framework for questions to be posed as a larger scale survey from a wider cross-section of Taewa consumers in order to further consolidate, expand or discover factors that might affect Taewa consumption, or that might be used to aid in the development of future edible Taewa products. The survey was also designed to identify important data on the cooking and consumption practices relating to Taewa, data which is currently lacking in the literature.

The qualitative themes were incorporated into 8 major quantitative goals in this manner:

- Nutritional uses of Taewa
    1. Range of commonly eaten Taewa, preferred Taewa varieties
    2. Preferred preparation, cooking and eating practices associated with Taewa

- Practices relating to the non-nutritional usage of Taewa
    3. Medicinal, healing, functional uses of Taewa

- Factors which might affect the choice to eat Taewa
    4. Sensory acceptability of Taewa varieties
    5. Cultural, historical or emotional value associated with Taewa
    6. Accessibility and availability of Taewa

- Future edible Taewa product development
    7. Suggestions of Taewa varieties or useful traits best suited for cooked and cooled Taewa products with increased resistant starch
    8. Compilation of Taewa recipes for public use.

4.2. Aim

In order to identify factors that might affect Taewa consumption and determine the most appropriate Taewa varieties and Taewa cooking practices for potential Taewa-based products, the aim of this quantitative research was to further validate and consolidate themes and understandings that had arisen from qualitative research (see Chapter 3), through gathering information from a survey of a larger group of Taewa consumers.

It was hoped that the information gathered from these participants would help highlight key factors that might be important in the choice to eat Taewa and suggest suitable pathways for developing potential Taewa products in the future. The survey would also provide important data on the cooking and consumption practices relating to Taewa, data which is currently lacking.

4.3. Materials and Methods

4.3.1. Methods

Discussions with the Chairman of the Human Ethics Committee deemed this study to be of low risk and thus notification of the details for the intended study was lodged with the Massey University Human Ethics Committee in November 2010.

4.3.1.1. Recruitment of Participants

Regular consumers of Taewa were invited to participate in a survey designed to explore Taewa cooking and consumption practices, determine the most appropriate Taewa varieties and Taewa cooking practices for potential Taewa-based products. Survey questions were aligned to eight goals (see Section 4.1). Volunteers (n=209) responded in differing degrees to the 20 questions posed.

Although participation in the survey was open to anyone who had previously eaten Taewa, participation from those of Māori ethnicity, those involved in Taewa production or marketing and who were connected to Taewa through more than just their consumption of Taewa were invited to be a part of the discussions in order to gain a perspective from those with a particular interest in the future potential and sustainability of Taewa.

From December 2010 to February 2011, advertisements for potential survey participants for this study were sent out or posted in areas where there were likely to be high numbers of Māori potato consumers (such as Māori organisations or groups, marae (Māori ancestral meeting area and village connected with a particular tribe) or iwi (Māori ancestral tribal group) authorities, kuia/kaumatua groups, heritage or Māori potato growing enthusiast groups and online Māori or potato growing networking groups).

Advertisements were also sent out through organisational chairmen or managers of suitable groups (such as Tahuri Whenua, Koanga NZ Institute, Te Waka Kai Ora), to their members, who had given approval for release of contact details, or who showed interest in participating in this research.

From February 2011, interested participants were either mailed an information sheet, consent form and the questionnaire forms, or were invited to go to a specific web-link address to access an information sheet and complete an online version of the questionnaire (see Appendices 4.1-4.4 for copy of the survey participant consent form, information sheet and the advertisement for participation).

4.3.1.2. Survey questionnaire

The survey questionnaire (Appendix 4.5) contained a total of 20 questions. An initial series of 15 questions asking the participants about their experiences and preferences with regards to cooking and eating Taewa, was followed by five questions regarding age group, gender, ethnic groups, iwi affiliations and geographical area of residence were recorded for demographic purposes. Participants were also invited to share recipes for cooking and eating Taewa if they wished. Recipes and suggestions for eating Taewa are being compiled and will be provided for public access through Tahuri Whenua's (National Māori Growers Collective) website. Table 4.1 summarises the manner in which the survey questions aligned to the survey goals.

Table 4.1 Alignment of Survey Questions to Survey Goals.

Survey Question	Range, commonly eaten, preferred Taewa varieties for eating	Preferred preparation, cooking and eating practices	Medicinal, healing, functional uses of Taewa	Sensory acceptability of Taewa	Cultural, historical or emotional value	Accessibility / availability of Taewa	Preferences of cooked and cooled Taewa products
Q1. Source of Taewa eaten						✓	
Q2. Grown Taewa?						✓	
Q3. NZ region eaten Taewa grown						✓	
Q4. Factors affecting Taewa consumption	✓		✓	✓	✓	✓	
Q5. Practices regarding cooked Taewa		✓					✓
Q6. Non-nutritional uses of Taewa			✓				
Q7. Taewa varieties eaten & preferred	✓					✓	
Q8. Preferred variety grown in residential region						✓	
Q9. Reasons for preferred variety			✓	✓	✓	✓	✓
Q10. Taewa eaten with or without skin		✓		✓			✓
Q11. Preferred preparation method		✓					✓
Q12. Preferred cooking method		✓		✓			✓
Q13. Preferred accompaniments to Taewa		✓		✓			✓
Q14. Preferred serving / eating temperature		✓		✓			✓
Q15. Preferred variety for cold salad & why		✓		✓			✓
Q16-19. Participant demographics (age, gender, ethnicity, iwi affiliations)	✓	✓	✓	✓	✓	✓	✓
Q20. NZ region of residence						✓	

4.3.1.3. Taewa variety names and descriptions

Including coloured photographs of all known Taewa cultivars in the survey would have considerably increased the number of pages in the survey, making it more cumbersome and time consuming to complete. This may have impacted on the number of participants who would have completed the survey. For this reason, inclusion of a table that listed a description of common tuber skin and flesh characteristics of Taewa varieties was deemed a better option in assisting participants to identify varieties. Participants were asked to identify each Taewa variety they had eaten by ticking beside the names in a list of varieties provided (Table 4.2) and/or describe them by selecting from the appropriate flesh and skin combinations provided (Table 4.3).

Table 4.2 Taewa Varietal Names Provided to Participants in the Survey Questionnaire.

Potato Variety Name Selections
Huakaroro / Karoro / "White Māori"
Karuparera / Kanohi Parera
Karupoti
Kohatuwhero / Red Rock
Kowiniwini / Kaupari
Māori Chief / Rangatira
Moemoe / Muimui / Nga Toko
Nga Oti Oti / Nga Outi Outi
Ngaupere
Paraketia / Parareka
Pawhero / Black Kidney / Old Red
Peruperu (Not purple skin & flesh)
Pink Fir
Poiwa
Raupi
Rokeroke / Whanako
Te Māori
Tūtaekuri / Urenika / Keretewha / Rongo Blue / Tuarua Waikato / Poko Hinau / Peruperu (purple skin & flesh)
Uwhi / Uwhiwhero
Waiporoporo
Wakaora / Whakaora / Ngauteuteu / Matariki
Whanako
Whataroa
Other (To be named by participant)

If participants did not know the varietal name, they were asked to select one flesh and one skin description that best described the Taewa they had eaten. A range of common Taewa tuber flesh and skin characteristics that were provided to assist in the identification of the Taewa eaten when the varietal name was not known is presented in Table 4.3.

Table 4.3 Taewa Tuber Descriptions Provided to Participants in the Survey Questionnaire.

Potato Flesh Description Selections	Potato Skin Description Selections
Purple	Purple
Creamy-yellow	Purple with cream/white around eyes
Creamy-yellow with purple, red or pink flecks	Pink/Red
White	Pink/Orange
White with purple centre	Creamy-yellow
White with purple, red or pink flecks	Mottled creamy-yellow and pink/red
Unknown	Mottled creamy-yellow and purple
	Unknown

4.4. Results

4.4.1. Survey Participant Demographics and Associations with Taewa

A total of 209 participants either returned a completed an online survey (181) or returned a posted questionnaire (28). All participants were adults aged 18 years or older, had previously eaten Taewa in New Zealand, and were familiar with how Taewa had been cooked. 67% of the participants were female, 33% were male. 58% of the participants stated they were of NZ Māori descent, 4% did not specify any ethnicity and 38% identified they were of non-Māori descent. Those of non-Māori descent were of European (NZ and non-NZ European); Australian; Cook Island; Indian; North American; Chinese; Papua New Guinean and Samoan ethnicity.

Most participants (192/209: 91.9%) resided in regions of the North Island of New Zealand at the time of the survey (Northland, 12; Auckland, 25; Waikato, 12; Bay of Plenty, 13; East Coast, 1; Hawkes Bay, 13; Central Plateau, 1; Taranaki, 6; Wanganui / Manawatu, 88; Wairarapa, 4; and Wellington, 15). However, 7 participants (3.3%) were residing in the South Island of New Zealand (Marlborough, West Coast and Canterbury 1 each respectively; Otago, 4); 2 (1.0%) were residing in Australia (although their Taewa experiences related to when they were residing in New Zealand); and 8 (3.8%) did not specify which region of New Zealand they were residing in.

All 209 participants confirmed they had previously eaten Taewa and indicated that they either selected at least one region the Taewa had been grown (195/207: 94.2% participants) or did not know where the Taewa they had eaten had been grown (14/207: 6.8% participants). 131 of the 209 participants were able to identify at least one name of a Taewa variety they had eaten (62.7%); 113 of the 209 participants gave some description of at least one variety they had eaten (54.1%) and only 8 of the 209 participants did not specify a name or description of a variety they had eaten (3.8%).

4.4.2. Nutritional Aspects Relating to Taewa Consumption

4.4.2.1. Range and Type of Taewa Varieties Eaten

Absolute identification of the varietal types posed some difficulty for the survey respondents, as varieties may be known by different names depending on the tribe or geographical region of the identifier.

For example, the dark purple fleshed, dark purple skinned Taewa variety may be known by any of the following names *Tūtaekuri, Urenika, Keretewha, Rongo Blue, Tuarua Waikato, Poko Hinau* or *Peruperu*.

In addition, the same name may be used to identify two or more different varieties. For example, Northern Māori may use *Peruperu* as a general name for all Māori potato varieties, while others may use *Peruperu* to describe the dark purple fleshed, dark purple skinned variety, or may associate *Peruperu* with a tuber that is creamy-white fleshed and has a predominantly yellow skin with irregular purple markings.

The method of preparation of the tubers prior to consumption also contributed to some identification issues. For example some participants were unable to identify the tuber's skin colour and characteristics because it had been removed prior to consumption.

4.4.2.1.a. Number of Different Taewa Varieties Eaten Per Participant

A breakdown of the number of Taewa variety types eaten per person by the 201 participants who specified a name or description of a variety they had eaten is given in Table 4.4. Based on these results, the majority of respondents (74.6%) ate between one to three Taewa variety types. It is of interest to find what these varieties were, since if they are common to a high percentage of the survey population, they may also be common to the general New Zealand population of Taewa eaters.

Table 4.4 Number of Taewa Varieties Identified as Eaten By Each Participant.
N = 201 (Participants who specified a Taewa variety by name or description)

Number of Variety Types Eaten by a Participant	Number of Participants (% of total)
1	61 (30%)
2	54 (27%)
3	35 (17%)
4	20 (10%)
5	16 (8%)
6-8	11 (5%)
11-13	4 (2%)

4.4.2.1.b. Range of Taewa Varieties Eaten

Twenty three Taewa varieties were identified by name by at least one of the 127 respondents who specified they had eaten at least one variety. These included all of the varieties listed in Table 4.2, except for the Whanako variety, which no one identified. In addition to these twenty two identified varieties, another two unlisted varieties (Wherowhero and Poko Hinau), were named as having been eaten.

Wherowhero is a variety which has creamy-yellow flesh and a pink/red skin, whereas Poko Hinau is likely to be another varietal name for the Tūtaekuri type variety because it was described as having purple skin and flesh, similar to that of the Tūtaekuri type variety. Taewa varieties with descriptions matching "creamy-yellow flesh with a pink/red skin" were also identified. Table 4.5 shows the frequency with which Taewa varieties were identified by name.

Table 4.5 Frequency With Which Taewa Varieties Were Able to be Identified by Name.

N = 127 (Respondents who were able to identify an eaten Taewa variety by name)

Potato Varieties and their Common Varietal Names	**Times Selected**
Tūtaekuri / Urenika / Keretewha / Rongo Blue / Tuarua Waikato / Poko Hinau / Peruperu (purple skin & flesh)	103
Peruperu (Not purple skin & flesh)	46
Moemoe / Muimui / Nga Toko	41
Huakaroro / Karoro / "White Māori"	32
Pawhero / Black Kidney / Old Red	21
Karuparera / Kanohi Parera	17
Māori Chief / Rangatira	16
Kowiniwini / Kaupari	15
Waiporoporo	13
Te Māori	11
Kohatuwhero / Red Rock	6
Wakaora / Whakaora / Ngauteuteu / Matariki	6
Pink Fir	5
Raupi	5
Karupoti	4
Paraketia / Parareka	4
Whataroa	3
Poiwa	2
Uwhi / Uwhiwhero	2
Wherowhero	2
Nga Oti Oti / Nga Outi Outi	1
Ngaupere	1
Rokeroke	1

Note: x…./ x…. = varietal names for the same Taewa cultivar

A number of Taewa varieties have similar tuber colourations, or are known by more than one varietal name. This poses difficulty in trying to determine which Taewa variety is being identified when a name or other tuber characteristics such as cooked texture or keeping quality is not known. To address this problem, when a variety description instead of a name was given or where there are multiple varietal names for the same cultivar type, one common "variety type" name was used. The "variety type" will also include the Taewa varieties that have similar tuber colourations to the descriptions given (see Table 4.6).

Table 4.6 Taewa Variety Types and Associated Cultivars.

Taewa Variety Type Name	Varieties Included
Huakaroro type	Huakaroro / Karoro / "White Māori" Matariki Ngauteuteu Wakaora / Whakaora
Karuparera type	Kanohi Parera / Karuparera Kaupari / Kowiniwini
Kohatuwhero type	Kohatuwhero / Red Rock Wherowhero
Moemoe type	Moemoe / Muimui / Nga Toko Ngaupere Paraketia / Parareka Poiwa Rokeroke / Whanako Whataroa
Nga Oti Oti type	Māori Chief / Rangatira Nga Oti Oti / Nga Outi Outi
Pawhero type	Black Kidney / Old Red / Pawhero Te Māori Waiporoporo
Tūtaekuri type	Keretewha / Peruperu (purple skin and flesh) / Poko Hinau / Rongo Blue / Tūtaekuri / Tuarua Waikato / Urenika
Uwhiwhero type	Pink Fir Uwhiwhero

Key: Names separated by / relate to varietal names of the same cultivar; Cultivars of a different variety are listed on a different line

Taewa tuber descriptions selected by the 113 respondents that had eaten at least one Taewa variety are shown in Table 4.7. Next to these descriptions are the Taewa cultivar types which they most likely relate to according to Dr Nick Roskruge, an Agricultural Scientist from Massey University, (Palmerston North, New Zealand) who is an expert on Taewa characteristics.

Table 4.7 **Frequency With Which Taewa Varieties Were Able to be Identified Using Tuber Descriptions.**

N = 113 (Respondents who were able to identify an eaten Taewa variety by description)

Potato Flesh Characteristics	Potato Skin Characteristics	Selected	Likely Variety(s)
Creamy-yellow	creamy-yellow	19	Huakaroro type
Creamy-yellow	mottled creamy-yellow and pink/red	3	Moemoe type
Creamy-yellow	mottled creamy-yellow and purple	5	Raupi or Moemoe type
Creamy-yellow	pink/orange	5	Uwhiwhero type
Creamy-yellow	pink/red	9	Kohatuwhero type
Creamy-yellow	purple	19	Pawhero type
Creamy-yellow	unknown	4	Unknown 1
Creamy-yellow / white	purple with white around the eyes	15	Karuparera type
Creamy-yellow with coloured flecks	creamy-yellow	2	Huakaroro type
Creamy-yellow with coloured flecks	mottled creamy-yellow and purple	3	Raupi or Moemoe type
Creamy-yellow with coloured flecks	pink/orange	1	Nga Oti Oti type
Creamy-yellow with coloured flecks	pink/red	3	Moemoe type
Creamy-yellow with coloured flecks	purple	11	Pawhero type
Creamy-yellow with coloured flecks	unknown	5	Moemoe type
White	mottled creamy-yellow and pink/red	1	Moemoe type
White	mottled creamy-yellow and purple	1	Raupi or Moemoe type
White	purple	7	Pawhero type
White	unknown	1	Unknown 1
White with purple centre	purple	13	Karupoti
White with coloured flecks	mottled creamy-yellow and purple	1	Raupi or Moemoe type
White with coloured flecks	pink/orange	1	Nga Oti Oti type
White with coloured flecks	purple	2	Pawhero type
White with coloured flecks	unknown	3	Unknown 2
Purple	purple (36) or unknown (5)	41	Tūtaekuri type
Purple	creamy-yellow	2	Huakaroro type
Purple	mottled creamy-yellow and pink/red	2	Moemoe type
Purple	mottled creamy-yellow and purple	1	Moemoe type
Purple	purple with white around the eyes	2	Karuparera type
Unknown	pink/orange	1	Uwhiwhero type
Unknown	pink/red	3	Kohatuwhero type
Unknown	purple	5	Unknown 3

Key: Coloured flecks =red, pink or purple colourations within the tuber flesh.

Thirty one combinations of Taewa tuber flesh and tuber skin descriptions were identified by at least one of the 113 respondents who specified at least one variety they had eaten. Three tuber descriptions were unable to be related to any variety with certainty, due to an unknown tuber flesh or skin description. These were labelled as Unknown 1 (white or creamy-yellow flesh with unknown skin colour); Unknown 2 (coloured flecks within predominantly white flesh and unknown skin colour); and Unknown 3 (unknown flesh colour with purple skin). All tuber descriptions given, including the "unknown" variety types, were likely to relate to one of the twenty three Taewa varieties specified by name rather than being a new or unspecified Taewa cultivar.

4.4.2.2. *Commonly Eaten Taewa Varieties*

4.4.2.2.a. Identified By Name

103 of the 127 respondents (81.1%) that were able to identify a Taewa variety by name, indicated that they had eaten a "Tūtaekuri type" variety (includes any of the Taewa varieties known as Tūtaekuri, Urenika, Keretewha, Rongo Blue, Tuarua Waikato, Poko Hinau or Peruperu, which have the purple skin and dark purple flesh characteristics in common).

Other varieties commonly identified included Moemoe / Muimui /Nga Toko (41/127: 32.3% of respondents); Huakaroro / Karoro /"White Māori" (32/127: 25.2% of respondents); Pawhero / Black Kidney / Old Red (21/127: 16.5% of respondents); Karuparera / Kanohi Parera (17/127: 13.4% of respondents); Māori Chief / Rangatira (16/127: 12.6% of respondents) and Kowiniwini / Kaupari (15/127: 11.8% of respondents).

The "Peruperu (not purple skin and flesh)" variety was also commonly identified as having been eaten (46/127: 36.2% of respondents). Since the varietal name "Peruperu (not purple skin and flesh)" could include a number of different Taewa varieties, it is not possible to quantify numbers with any degree of certainty without an accompanying tuber description.

Three Taewa varieties (Poiwa; Uwhi / Uwhiwhero and Wherowhero) were identified by name only twice and three (Nga Oti Oti / Nga Outi Outi; Ngaupere and Rokeroke) were identified by name only once by the 127 respondents.

4.4.2.2.b. Identified By Description

The most commonly identified description (41/113: 36.3% of participants), related to a variety that had purple flesh and either purple skin or an unknown skin colour (see Table 4.7). This description most likely relates to a Tūtaekuri type variety as it is the only Taewa variety that has dark-purple flesh throughout the majority of the tuber. Other commonly identified descriptions related to a variety that was purple-skinned with creamy-yellow flesh (19/113: 16.8% of participants); a variety that was creamy-yellow skinned with creamy-yellow flesh (19/113: 16.8% of participants); or a variety that was white or creamy-yellow fleshed with or without coloured flecks with mottled creamy-yellow and pink, red or purple skins (17/113: 15.0% of participants). These tuber descriptions most likely relate to Pawhero type varieties; Huakaroro type varieties and Moemoe type (or Raupi) varieties respectively.

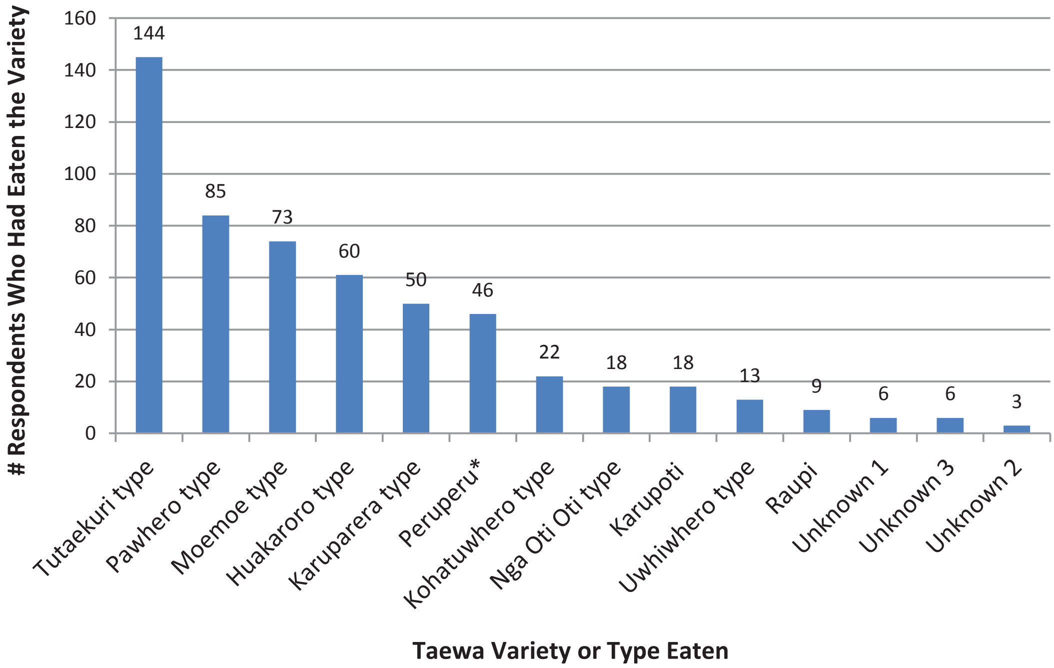
Descriptions most likely relating to Karuparera type varieties (creamy-yellow/white flesh / purple skin but white around the potato eyes; 15/113: 13.3% of participants) and the Karupoti variety (white flesh with a purple centre / purple skin; 13/113: 11.5% of participants) were also commonly identified. Descriptions relating to Uwhiwhero type varieties (creamy-yellow flesh and pink/orange skin; 5/113: 4.4% of participants) Nga Oti Oti type varieties (creamy-yellow or white flesh with coloured flecks and pink/orange skin; 2/113: 1.8% of participants) and were less commonly identified.

4.4.2.2.c. Most Commonly Eaten Taewa Varieties

By combining the sum of Taewa variety types that were identified by name or description from the results of the 201 respondents, an assumption of the most commonly eaten Taewa variety types can be made (see Figure 4.1). Photos of the five most commonly identified varieties are shown in Figure 4.2.

Figure 4.1 Combined results of Taewa varieties identified by name and/or description.

N = 533 (the total number of identifications of Taewa varieties by the 201 respondents that specified an eaten Taewa variety by name and/or description)

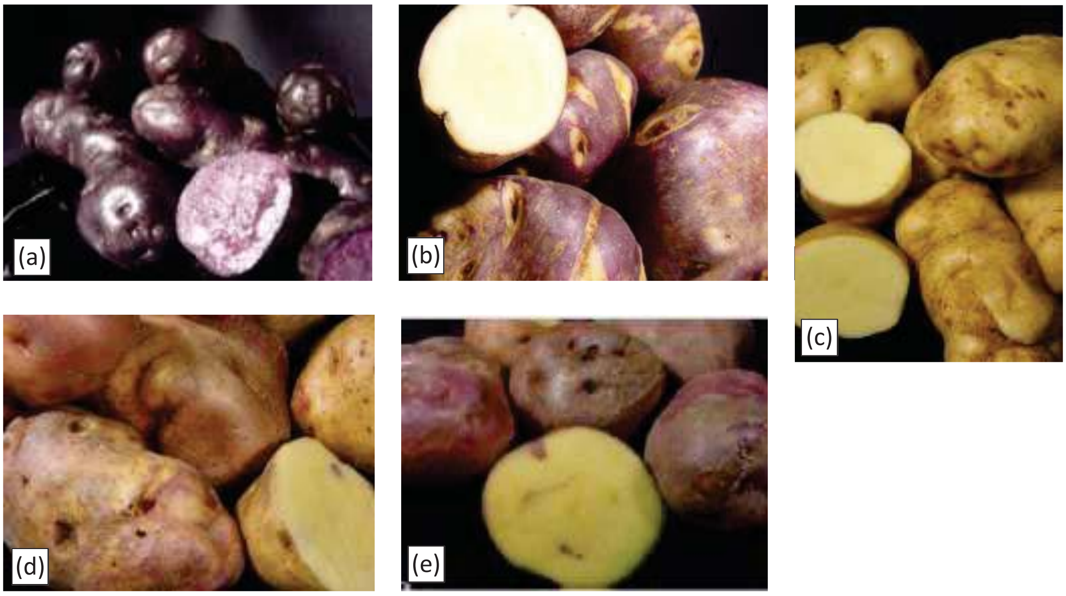


Key: Peruperu* = Could relate to a number of Taewa varieties but does not have purple skin and flesh. Unknown 1 = Variety(s) with creamy-yellow or white flesh with unknown skin colour; Unknown 2 = variety(s) with unknown flesh colour and purple skin; Unknown 3 = variety(s) with red, pink or purple coloured flecks in predominantly white flesh and unknown skin colour.

Thus, the Taewa varieties likely to be more commonly eaten include the Tūtaekuri type (144/201: 71.6% of respondents); Pawhero type (85/201: 42.3% of respondents); Moemoe type (73/201: 36.3% of respondents); Huakaroro type (60/201: 29.9% of respondents); Karuparera type (50/201: 24.9% of respondents) and Peruperu (46/201: 22.9% of respondents) varieties. Less commonly eaten Taewa varieties are likely to include Kohatuwhero type (22/201: 10.9% of respondents), Nga Oti Oti type & Karupoti (18/201: 9.0% of respondents each), Uwhiwhero type (13/201: 6.5% of respondents) and Raupi (9/201: 4.5% of 201 respondents).

Figure 4.2 Tuber Characteristics of Commonly Eaten Taewa.

(a) Tūtaekuri type; (b) Karuparera type (includes Karuparera / Kanohi Parera; Kowiniwini / Kaupari varieties); (c) Huakaroro type (includes Huakaroro / Karoro / "White Māori"; Wakaora / Whakaora / Ngauteuteu / Matariki varieties); (d) Moemoe type (includes Moemoe / Muimui / Nga Toko; Ngaupere; Paraketia / Parareka; Poiwa; Rokeroke / Whanako; Whataroa varieties); and (e) Pawhero type (includes Pawhero / Black Kidney / Old Red; Te Māori; Waiporoporo varieties).



Photos by Dr Nick Roskruge; Agricultural Scientist, Massey University, Palmerston North, NZ

It is of interest in identifying the possible reasons that contribute to why certain Taewa varieties were more commonly eaten than others. For example, perhaps commonly eaten varieties are more accessible across New Zealand because they are grow in more NZ regions, or a higher proportion of people eat them in several regions, or they are a preferred variety for eating.

4.4.2.3. *Taewa Cooking and Eating Preferences*

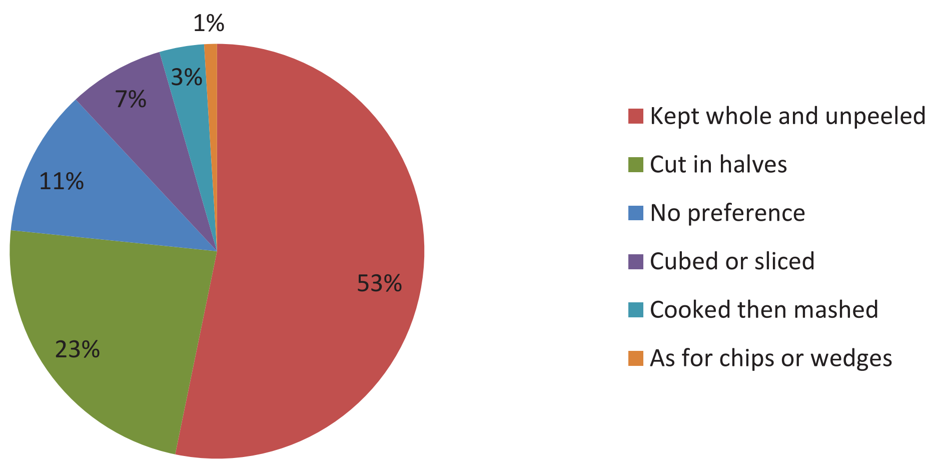
Discovering why certain Taewa varieties are preferred, or how current Taewa eaters eat Taewa, could give valuable insights into the most appropriate Taewa variety(s) to use in future Taewa products.

4.4.2.3.a. *Preferred Taewa Preparation and Cooking Practices*

Information from the group discussions suggested that a common method for cooking Taewa was to boil the Taewa whole (with the skin on) in a separate pot to any other potatoes or vegetables (see Section 3.4.1.3.). Thus survey participants were asked to identify from a list of options including those mentioned by the group participants, their most preferred method for preparing, and cooking their favourite Taewa variety. There were clear preferences demonstrated by the 201 survey respondents with regards to preparation and cooking method of Taewa (see Figures 4.3 and 4.4).

Figure 4.3 Preferred Method for Preparation of Taewa for Cooking.

N = 201 (Includes respondents who selected at least one of the preparation method options)

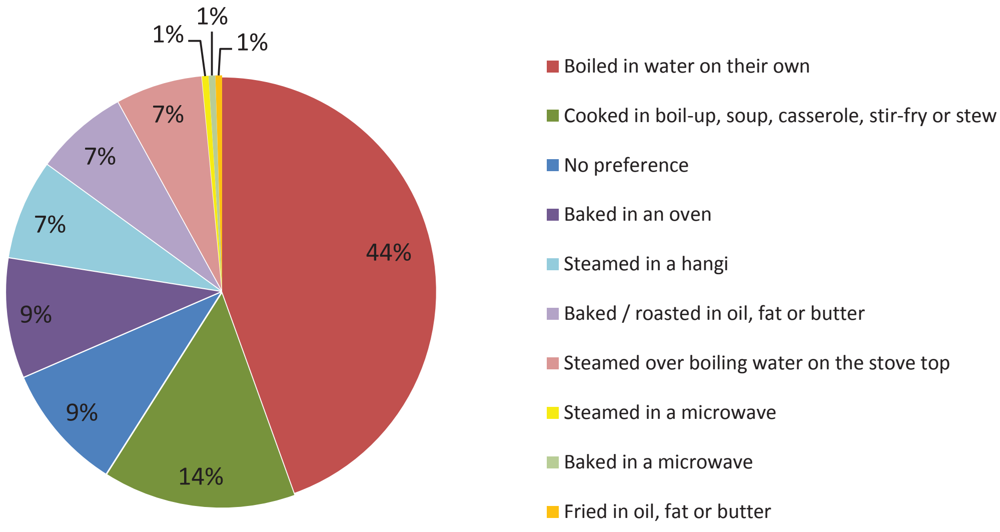


% of participants who selected the listed preparation method option

The most preferred preparation methods (Figure 4.3) were to cook the Taewa whole, unpeeled (107/201: 53.2% of respondents); or to slice in half before cooking (46/201: 22.9% of respondents). The most preferred cooking methods (see Figure 4.4.) were to boil the Taewa on their own (89/201: 44.3% of respondents) or to cook them in a boil-up, stew or casserole type method (29/201: 14.4% of respondents).

Figure 4.4 **Preferred Methods for Cooking Taewa.**

N = 201 (Includes respondents who selected at least one of the cooking method options)



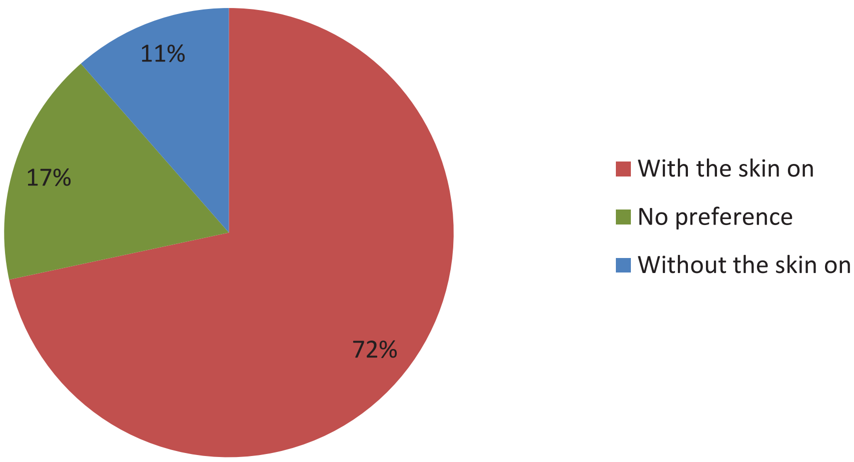
% of participants who selected the listed cooking method option

4.4.2.3.b. Preferences for Eating Taewa

Due to clear eating preferences by group participants when eating Taewa (Section 3.4.1.4.), survey participants were asked to identify whether they preferred to eat their Taewa with the skin on or off; and whether they preferred to eat cooked Taewa hot, warm or cold.

Figure 4.5 **Preferences for Eating Taewa with the Skin on or Removed.**

N = 201 (Includes respondents who selected at least one of the eating options)

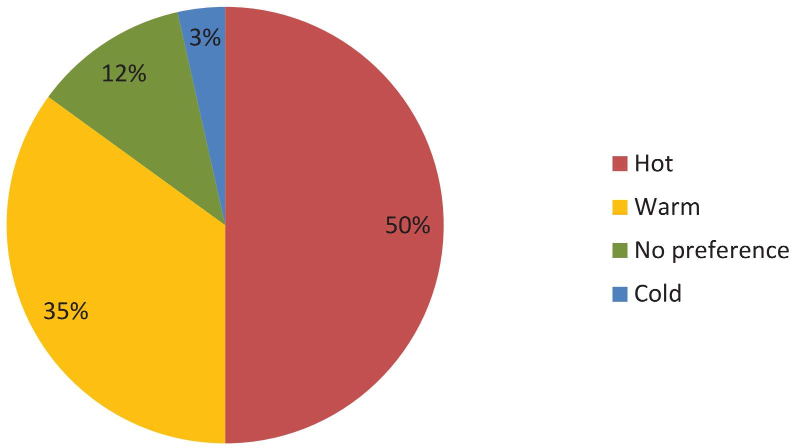


% of participants who selected the listed eating preference option

Similarly to the group discussion participants, the majority of the survey respondents (144/201: 71.6%) preferred to eat Taewa with the skin on, rather than with the skin removed (23/201: 11.4%); and 34 out of 201 respondents (16.9%) had no preference either way (Figure 4.5). 170 out of 200 survey respondents preferred to eat their cooked Taewa either hot (50%) or warm (35%) with only 30 out of 200 survey respondents (15%) preferring to eat their Taewa cold after cooking (Figure 4.6). Thus results from the survey of 200+ Taewa eaters suggest Taewa are likely to be preferentially eaten warmed and with the skin left on.

Figure 4.6 Preferences for Eating Taewa at Different Temperatures.

N = 200 (Includes respondents who selected at least one of the eating temperature options)



% of participants who selected the listed eating preference option

Participants were then asked to choose from a list of options (including those mentioned by the group participants), the meal accompaniments or condiments that they would prefer to use when eating Taewa. Participants were able to choose as many accompaniment options as desired or describe what they used if it wasn't listed, by including it under the "Other" category. The options provided by the survey and the number of respondents who chose the "Other" option, are shown in Table 4.8. The results were similar to the preferences mentioned during the Taewa group discussions (see Section 3.4.1.4.), the most preferred Taewa accompaniments selected by the survey participants included salt or salt-based seasonings (140/198: 70% of respondents); butter or margarine (113/198: 57% of respondents); and pepper (64/198: 32% of respondents). 39 of the 198 survey respondents (19.5%) preferred to eat the Taewa on their own, without any accompaniment.

Table 4.8 **Popularity of Different Taewa Meal Accompaniments.**

N = 198 (Respondents who chose at least one of the accompaniment options)

Taewa Accompaniment Options	Respondents Who Chose The Option #	%
Survey options provided		
Salt or other salt-based seasoning	140	70
Butter or margarine	113	57
Pepper	64	32
Nothing, I prefer to eat them on their own	39	20
Dried or fresh herbs (including garlic, mint)	35	18
Sour cream	28	14
Mayonnaise	18	9
Cheese	17	9
Cream	13	7
Chilli sauce	12	6
Tomato sauce / ketchup	8	4
"Other" options provided by 12 respondents		6
Olive oil	3	
Gravy	2	
Mustard based dressing	2	
Chutney	1	
French dressing	1	
Nicoise dressing	1	
Oyster sauce	1	
Salad greens	1	

Key: # = Number of participants who chose the option; % = Percentage of the 198 participants who chose the option

4.4.3. Non-Nutritional Applications for Taewa

It was also of interest to know if people were currently using, or had traditionally used or eaten Taewa for reasons other than primarily as a source of food. Survey participants were asked to select from a list of options, which practices they were aware of as having been used with Taewa.

The majority of participants (114/191: 59.7%) indicated that they knew of at least one of the practices listed in Table 4.9 below. The most commonly identified non-nutritional practice with regards to Taewa, included the use of special techniques with which to store Taewa (73/114: 64% of respondents). It was also of interest that a large proportion of respondents (70/114: 61.4%) believed in the potential health promoting effects of eating the purple fleshed-purple skinned Taewa variety.

Table 4.9 **Non-Nutritional Purposes For Using Taewa.**

N = 114 (Respondents who chose at least one of the uses of Taewa listed below)

Uses of Taewa	# Respondents
Storing potatoes in a particular way to prevent deterioration	73
Eating purple skin & flesh Taewa to promote health	70
Raw potato flesh on wounds or other ailments	31
Potato flesh or skin-medicinal or healing purposes	27
Eating cold, cooked Taewa to promote health	23
Using boiled potato water as a drink or tonic	19
Potato flesh or skin -health-promoting purposes	12
Using raw potato juice as a drink or tonic	12
Eating raw potato for medicinal/health-promoting purposes	11
Cooked potato flesh on wounds or other ailments	7
Potato flesh or skin used for ceremonial purposes	5
As a raising agent (such as in making bread)	4
As a wedding gift	1
To colour foods (bread)	1

Key: # = Number of participants who chose the option

Other more commonly selected practices indicated the use of *Rongoa* or other similar practices for treatment of skin ailments (31/114: 27.2%), or for medicinal or health promoting purposes (27/114: 23.7%). Parts of the tuber that were likely used included the tuber skin, flesh, juices and extracts – in either cooked or uncooked forms.

4.4.4. Factors Affecting Consumption of Taewa

The survey participants were asked a number of questions in order to verify the findings or suggestions from the group discussion and discover whether there may be any additional factors that might affect Taewa consumption.

4.4.4.1. General Factors Affecting Taewa Consumption

Survey participants were asked to rate on a 5 point scale (1 = not at all, 2 = little, 3 = moderately, 4 = strongly, 5 = very strongly), how strongly seven listed options might encourage or enable them to eat Māori potatoes more often. The seven options incorporated factors that were suggested by group participants as potentially affecting Taewa consumption. These factors included the impact of sensory qualities; availability / accessibility; loss of cultivation knowledge; economic viability; familiarity and potential health benefits. Table 4.10 shows how the seven survey options were aligned with these factors.

Table 4.10 Alignment of Survey Options with Factors Affecting Taewa Consumption.

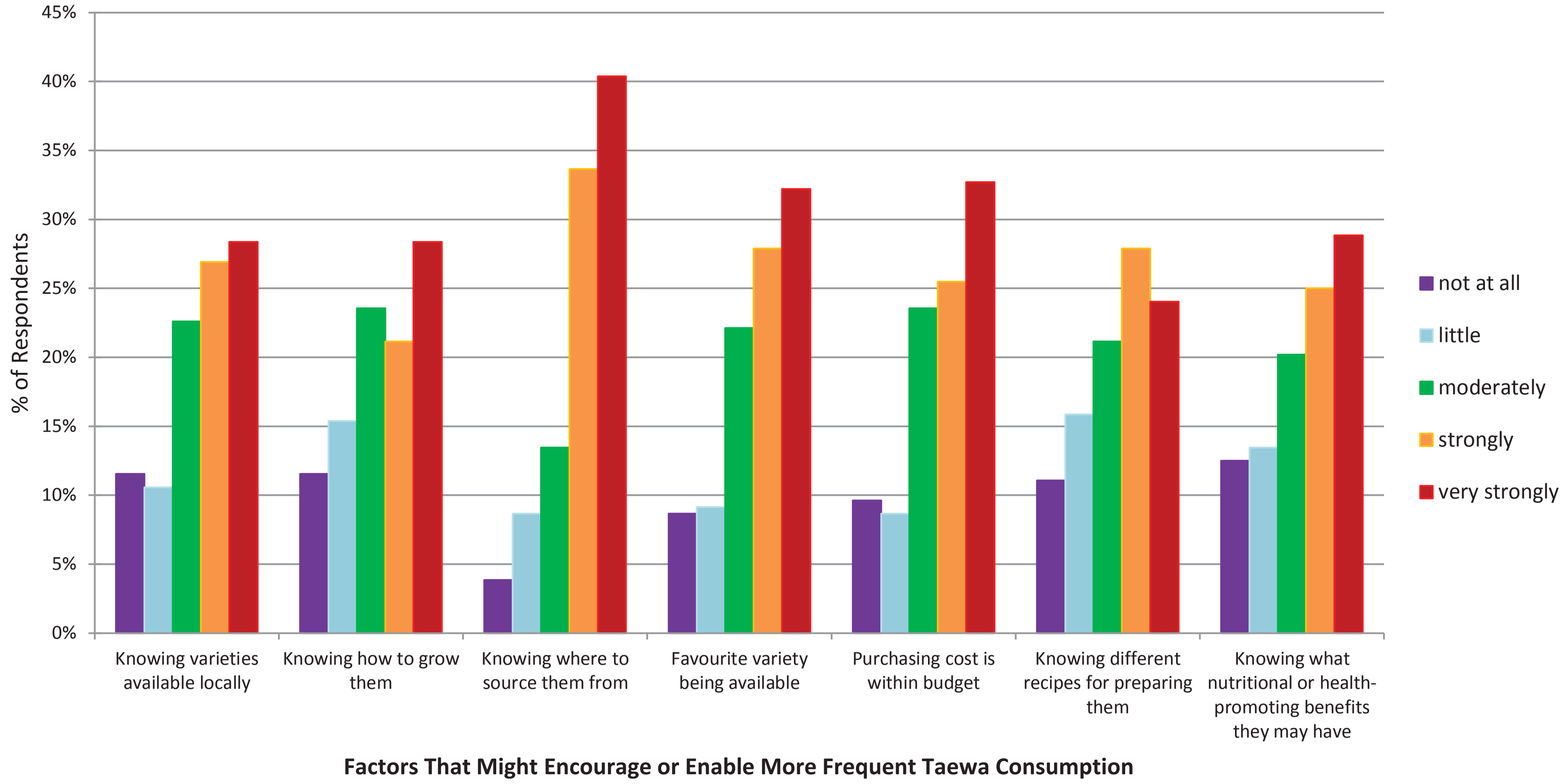
Survey Options	Sensory Qualities	Availability / Accessibility	Loss of Cultivation Knowledge	Impact of Economic Viability	Lack of Familiarity	Potential Health Benefits
Favourite variety being available	✓	✓				
Knowing where to source Taewa from		✓				
Knowing the varieties available locally		✓			✓	
Knowing how to grow them			✓		✓	
Purchasing cost is within budget				✓		
Knowing different recipes for preparing them	✓				✓	
Knowing nutritional or health-promoting benefits they have						✓

All except one of the 209 participants gave a rating for each of these options. Based on the results of the 208 respondents that gave a rating, the option that would most encourage or enable the participants to eat Taewa more often was knowing where to source the Taewa from. 154 of the 208 respondents (74%) rated “Knowing where to source them from” (i.e. an availability / accessibility factor), as a reason that would either very strongly (84/208: 40.4% of respondents) or strongly (70/208: 33.7% of respondents), encourage or enable them to eat Taewa more often.

Being able to eat their favourite variety of Taewa (sensory qualities, availability / accessibility factors) and the purchasing cost of the Taewa (impact of economic viability factor), were also rated as reasons that might affect the respondents’ Taewa consumption. The “Favourite variety being available” was rated either “strongly” or ”very strongly” by 125 of the respondents (60.1%) and “Purchasing cost is within budget” was rated “strongly” or ”very strongly” by 121 of the respondents (58.2%) (Figure 4.7).

Figure 4.7 **Factors That Might Encourage or Enable More Frequent Consumption of Taewa.**

N = 208 (Respondents that gave a rating for each of the factors listed). Each participant was asked to rate on a 5 point scale how strongly 7 factors might encourage or enable them to be able to eat Taewa more frequently. Factors incorporated included thosesuggested by group participants as potentially affecting Taewa consumption, and included the impact of sensory qualities; availability / accessibility; loss of cultivation knowledge; economic viability; familiarity and potential health benefits .



4.4.4.2. Sensory Qualities of Taewa

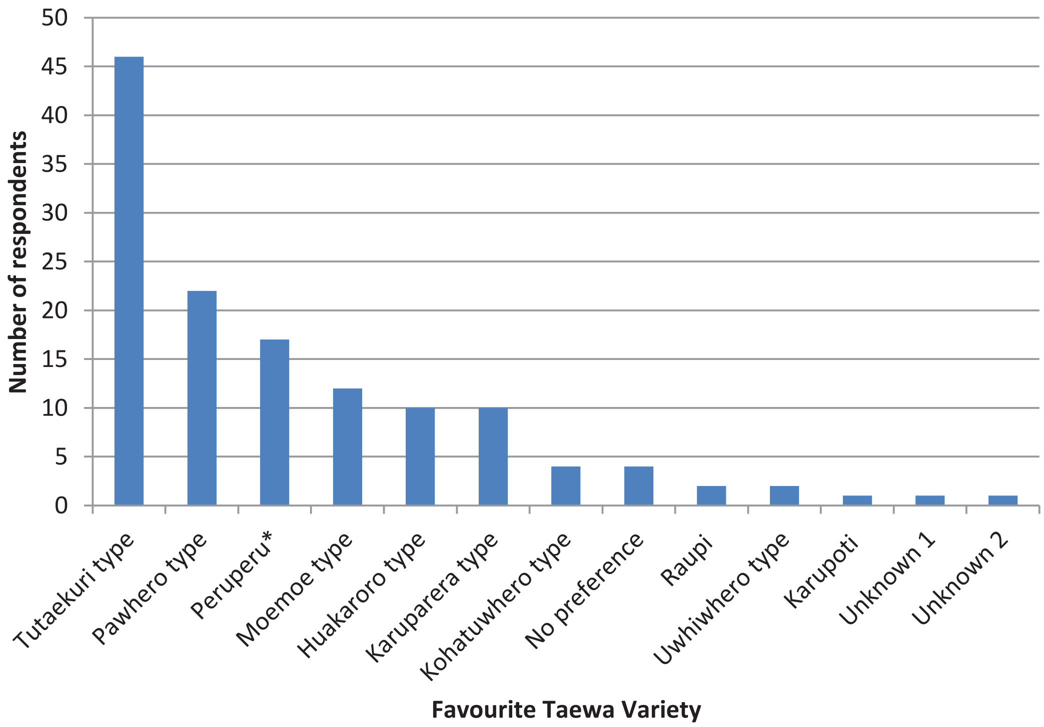
4.4.4.2.a. Preferred Taewa Eating Varieties

After identifying all the Taewa varieties they had eaten, the participants were asked to identify which was their most favourite variety for eating. 192 out of 209 participants (91.9%) provided either a name or description of their most preferred variety. However, 60 of the 192 respondents (31.3%) only identified or described one Taewa variety they had eaten and thus were excluded from the following analysis of Taewa preferences.

132 out of 209 participants (63.2%) identified or described more than one Taewa variety they had eaten, thus information from these 132 participants only were used to determine preferred eating varieties (see Figure 4.8). The Taewa varieties that were most often identified as being their favourite Taewa variety for eating included the Tūtaekuri type: (46/132: 34.8%); Pawhero type: (22/132: 16.7%); Peruperu (variable varieties): (17/132: 12.9%); Moemoe type: (12/132: 9.1%); Karuparera type and Huakaroro type varieties (both (10/132: 7.6% each).

Figure 4.8 Favourite Taewa Variety for Eating (Combined results of a Taewa variety identified by name or description.

N = 132 (Respondents who identified more than one eaten Taewa variety)



Key: Peruperu* = Could relate to a number of Taewa varieties but does not have purple skin and flesh.

4.4.4.2.b. Reasons for Eating Favourite Variety

In order to further explore factors that might impact Taewa consumption, survey participants were asked to select from a list of options which best explained why they preferred the favourite Taewa variety they had identified. This list incorporated factors previously suggested by group participants as affecting Taewa consumption (see Section 3.4.3) and fell into the following categories: sensory or nutritional qualities, familiarity, accessibility, performance qualities and emotional /spiritual values. The results of this exploration of factors affecting consumption of a favourite Taewa variety are shown in Table 4.11.

Table 4.11 Reasons Selected For Eating Favourite Taewa Varieties.

N = 132 (Respondents who named or described a favourite variety and had eaten two or more Taewa varieties. Reasons are grouped into factors previously suggested by group participants as affecting Taewa consumption)

Reason For Eating Favourite Variety	**# Respondents Who Chose The Reason**
Sensory or Nutritional Qualities	
I like the taste or flavour of this variety	92
I like the colour qualities of this variety	65
It tastes good COLD, the day after cooking it	56
It tastes good REHEATED, the day after cooking it	50
I like the nutritional benefits of this variety	22
Familiarity	
I have cooked it for myself or for my family	89
My parents or grandparents cooked it / I grew up with it	60
Accessibility	
I am able to easily access it	36
It is the only variety I have been able to access	27
Performance Qualities	
I like the size attributes of this variety	34
It performs best in the Māori potato dishes / recipes I like to eat	23
Emotional / Spiritual Value	
It holds personal significance to me	17
I have eaten it on a special occasion	14

Key: # = Number of participants who chose the option

Like the group discussion participants, sensory qualities (in particular taste and colour of the Taewa variety), seemed to be important reasons as to why the survey respondents preferred a certain variety. 92 of the 132 respondents (69.7%) selected “I like the taste or flavour of this variety”; 65 (49.2%) selected “I like the colour qualities of this variety”; 56 (42.4%) selected “It tastes good COLD, the day after cooking it” and 50 (37.9%) selected “It tastes good REHEATED, the day after cooking it”.

Familiarity with the Taewa variety also seemed to be an important reason as to why a Taewa variety was their favourite. 89 of the 132 respondents (67%) selected “I have cooked it for myself or for my family” and 60 (45%) selected “My parents or grandparents cooked it / I grew up with it”.

Although at least 13 of the 132 respondents (10%) selected all 13 of the reasons listed in the survey, less important reasons as to why a Taewa variety was preferred included those associated with emotional or spiritual value; nutritional value; performance qualities or accessibility to the favourite Taewa variety.

4.4.4.3. Availability and Accessibility of Taewa Varieties

Being able to obtain Taewa had been mentioned by group discussion participants as being a key barrier to being able to eat Taewa more often. Thus survey participants were asked a number of questions relating to the availability (quantity of Taewa available in any environment, at any given time); accessibility (extent to which Taewa can be obtained when needed), or economic viability of Taewa.

As shown in Section 4.4.4.1., knowing where to source Taewa from; being able to afford the purchasing cost; or being able to obtain their favourite Taewa variety appeared to be key factors in enabling the survey participants to be able to eat Taewa more often. Thus the data were analysed to discover which Taewa varieties are likely to be available based on the region within New Zealand that survey respondents said the Taewa they had eaten had been grown; and based on the location of a Taewa consumers’ residence.

The availability of a Taewa variety within a person’s geographical location is a major determinant of whether it is eaten or not. Thus it is of interest to see if certain Taewa varieties are grown in more New Zealand regions and / or eaten in more regions, as these factors might impact on the accessibility of the Taewa varieties.

Each survey participant was asked to select one of the twenty regions of New Zealand in which they resided, and if known, to select the New Zealand region(s) from which the Taewa they had eaten were grown (see Figure 4.9).

Figure 4.9 Regional Map of New Zealand.

Shadings in the figure below were used to enable the survey participant to more easily define which of the twenty New Zealand regions they were living in or the New Zealand regions in which the Taewa they had eaten were grown.

By combining the Taewa variety eaten with its growing region(s) or a respondents residential location, insight was gained into the proportion of residents within specific regions that ate each variety. In addition, information on the range of Taewa variety types and quantity of each Taewa variety type eaten, and therefore likely to be available, within each specific region would be gained. Assumptions on whether the Taewa eaten were sourced from areas outside of a respondents residential location could also be made.

It should be noted that data taken from the survey may not be representative of the entire New Zealand population of Taewa eaters; New Zealand regions in which Taewa grow; nor Taewa varieties eaten within New Zealand residential regions, but it provides an estimate of what may be likely to occur.

4.4.4.3.a. *Taewa Growing and Residential Regions*

Determining the regions the Taewa were grown in may identify regions which may have greater availability with regards to quantity as well the range of Taewa varieties. It is also of interest to see whether the Taewa that the respondents had eaten were actually grown in the regions in which the respondents lived. Table 4.12 shows all areas that Taewa were grown in (eighteen New Zealand regions) and each of the locations the respondents indicated they were residing (fifteen New Zealand regions). This table shows that some Taewa consumed by the respondents were grown in regions outside the respondent's residential region. This suggests that respondents either sourced Taewa from outside of their residential region, or were not living in their stated residential region when they ate the Taewa. It also shows that certain regions may be more likely than others to grow Taewa.

The majority of the Taewa were identified as being grown in the North Island of New Zealand and in regions from Wanganui / Manawatu northward. However, 5 respondents said the Taewa they had eaten were grown as far south as Otago or Southland. The Coromandel, Nelson and Southland regions were noted as growing Taewa, but none of the 209 participants in this study were residing in these locations. Respondents from ten out of the possible 20 residential regional groupings (including the respondents own region of residence, the Unspecified Residence and the Non-NZ residence group) indicated that the Taewa they had eaten were grown in the Northland, Hawkes Bay and Wanganui / Manawatu regions.

4.4.4.3.b. *Regional Distribution of Taewa Varieties by Growing Region*

Out of the total 209 survey participants, 8 (3.8%) had not selected any Taewa variety that they had eaten and an additional 14 (6.7%) did not know from which New Zealand regional area, the Taewa they had eaten had been grown in. Of the remaining 187 participants that specified at least one Taewa variety they had eaten and selected at least one area the Taewa had been grown in, 122 (65.2%) respondents knew at least one Taewa variety name and 103 (55.1%) respondents provided at least one Taewa description. The eighteen growing regions of the Taewa that were able to be identified by name or by description are presented in Tables 4.13 and Table 4.14 respectively. Based on the results from these 187 respondents, the Tūtaekuri type variety (purple skin and purple flesh) is likely to be the most widespread Taewa variety grown in New Zealand as it was indicated as having been grown in 17 of the 20 possible New Zealand regions as determined by the New Zealand map shown in Figure 4.9 (included all except the Fiordland, Southland or Stewart Island regions).

Other varieties likely to be widespread in New Zealand include Karuparera and Moemoe types (14 regions each); Huakaroro type (12 regions) and Pawhero type varieties (11 regions) (See Figure 4.2 for examples of tuber characteristics of commonly grown Taewa). The "Peruperu (not purple skin and flesh)" variety was indicated as having been grown in 15 New Zealand regions, but since this varietal name could include a number of different Taewa varieties, it is not possible to determine its correct growing regions with any degree of certainty without an accompanying tuber description from each respondent specifying this variety. The Karupoti variety was specified as having been grown in 14 New Zealand regions. However, one respondent specified nine regions it had grown in (including the Nelson, Canterbury, Otago and Southland regions which no other respondent specified Karupoti had grown in), and thus may be an inaccurate representation of the number of New Zealand regions it is grown.

Taewa varieties that are less likely to be wide-spread in New Zealand include the Uwhi / Uwhiwhero variety and the Nga Oti Oti / Nga Outi Outi variety which were specified as likely grown in a total of 4 and 2 regions respectively. Additionally, Nga Oti Oti / Nga Outi Outi were identified as grown only in the Waikato and Bay of Plenty regions and Taewa matching a "Nga Oti Oti type" description (includes the Nga Oti Oti / Nga Outi Outi but also Māori Chief / Rangatira variety) were also identified as grown in the Waikato and Bay of Plenty regions.

Wherowhero was a variety identified by name as grown in two regions (Hawkes Bay and Wanganui / Manawatu). However, Wherowhero may be present in other regions since varieties matching the Wherowhero's tuber descriptions are included within the "Kohatuwhero type", which were identified as additionally grown in Northland, Waikato, Bay of Plenty, East Coast and Wairarapa.By providing an opportunity to describe the Taewa eaten, additional Taewa varieties grown within a region (Karupoti, Tūtaekuri type, Kohatuwhero type, Raupi, Uwhiwhero type) along with new growing regions (West Coast and Southland) were able to be identified. New Taewa growing regions and Taewa variety types that were identified by description but not previously identified by name within a region are highlighted in blue in Table 4.14.

4.4.4.3.c. Regional Distribution of Taewa Varieties by Residential Region

Taewa are more likely to be eaten by residents within a particular region, if there are a good number of others within the same location who also eat them. Similarly, a Taewa variety is more likely to be commonly eaten if they are eaten in a greater number of regions.

Table 4.12 Location of Growing Regions of Taewa Eaten Based on Residential Location of Survey Respondents.

N = 201 (Includes those respondents who specified at least one eaten Taewa variety). This table lists each of the areas Taewa were grown (blue text), within each of the locations that respondents were residing (**green text**) at the time of the survey.

TAEWA GROWING REGIONS	# who said Taewa grown in area	RESIDENTIAL LOCATION OF RESPONDENTS																			
		Northland	Auckland	Coromandel	Waikato	Bay of Plenty	East Coast	Hawkes Bay	Central Plateau	Taranaki	Wanganui / Manawatu	Wairarapa	Wellington	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	Unspecified	Non NZ
Northland	39	12	11		2	2				1	6		1				1			1	2
Auckland	26	3	15		1						4									2	1
Coromandel	2		2																		
Waikato	21	1	1		8	4					5									1	1
Bay of Plenty	22	1	1		2	10					4		2							1	1
East Coast	16		3			1	1	2			6							1		2	
Hawkes Bay	34		1		2	1		11			11	1	2					2		2	1
Central Plateau	5							1			2	1									1
Taranaki	15				1	2			1	5	2		1							2	1
Wanganui / Manawatu	88	1	1			3		4			66	1	4			1				6	1
Wairarapa	7										3	3								1	
Wellington	12					1					2		9								
Nelson	2																	1			1
Marlborough	1												1								
West Coast	1														1						
Canterbury	5		1								1	1								1	1
Otago	4																	3			1
Southland	1																				1
Don't Know Region Grown	15		3								9		3								
Other Region	1	GB Is																			
# of 201 respondents residing in region		**14**	**24**	**0**	**12**	**13**	**1**	**13**	**1**	**6**	**85**	**4**	**15**	**0**	**1**	**1**	**1**	**4**	**0**	**4**	**2**

Key: x = Regions Taewa were grown that differed from a respondents residence; Unspecified = 4 respondents that gave no residence; Non NZ = 2 respondents living in Australia at the time the survey was completed. GB Is = Great Barrier Island;

Table 4.13 **Frequency of Taewa Variety Selection Within Each Taewa Growing Regions (Taewa Known by Name).**

N = 122 (Includes those respondents who knew the name of at least one Taewa variety and selected a NZ region it grew in)

TAEWA VARIETIES	Northland	Auckland	Coromandel	Waikato	Bay Of Plenty	East Coast	Hawkes Bay	Central Plateau	Taranaki	Wanganui / Manawatu	Wairarapa	Wellington	Nelson	Marlborough	Canterbury	Otago	# of Regions Variety Grown In
	TAEWA GROWING REGIONS																
Tūtaekuri	25	14	2	13	10	11	19	2	8	46	4	7	1	1	3	2	**16**
Peruperu *	21	6	2	9	5	8	8	1	2	19	1	4	1		2	1	**15**
Moemoe / Muimui / Nga Toko	8	7	2	7	6	6	9	1	5	24	1	6			1	1	**14**
Kowiniwini / Kaupari	8	4	2	5	3	4	5		2	5		1	1		1	1	**13**
Huakaroro / Karoro / "White Māori"	10	5	1	5	5	6	10	1	4	17		3			1		**12**
Karuparera / Kanohi Parera	5	2	1	5	4	4	3		3	11	1	1			1		**12**
Māori Chief / Rangatira	3			3	4	2	3	1	2	11	1	3		1	1		**12**
Pawhero / Black Kidney / Old Red	7	3		3	4	4	5	2	3	9		1				1	**11**
Te Māori	5	3	2	3	3	4	3		2	7		1			1		**11**
Waiporoporo	4	3	1	1	2	4	4		2	7		1				1	**11**
Paraketia / Parareka	2	1	1	1	1	1	1		1	3					1		**10**
Kohatuwhero / Red Rock	2	1		2	1	3	3		1	5							**8**
Whataroa	1	1	1	1	1	1				1		1					**8**
Karupoti	1			3	1	1	1		1	2							**7**
Raupi	1			1	1	1	1		2	5							**7**
Wakaora / Whakaora / Ngauteuteu / Matariki	2			1		1	2	1	1	6							**7**
Pink Fir	2			1		1	2		1	4							**6**
Nga Oti Oti / Nga Outi Outi				1	1												**2**
Uwhi / Uwhiwhero										1		1					**2**
Wherowhero							1			1							**2**
Ngaupere	1																**1**
Poiwa	2																**1**
Rokeroke	1																**1**
# of Taewa Varieties Grown in Region	**20**	**12**	**10**	**18**	**16**	**17**	**17**	**7**	**16**	**19**	**5**	**12**	**3**	**2**	**9**	**6**	
# of 122 Respondents Residing in Region**	**11**	**14**	**0**	**7**	**9**	**0**	**6**	**0**	**4**	**52**	**3**	**8**	**0**	**0**	**1**	**3**	

Key: Peruperu* = Could relate to a number of Taewa varieties but does not have purple skin and flesh. ** = The 122 respondents included 1 respondent residing in the West Coast and 3 respondents that did not provide a residence.

Table 4.14 **Frequency of Taewa Variety Selection Within Taewa Growing Regions (Taewa Identified by Description).**

N = 103 (Includes those respondents who described at least one Taewa variety and selected a NZ region it grew in)

TAEWA VARIETY "TYPES"	TAEWA GROWING REGIONS																
	Northland	Auckland	Waikato	Bay Of Plenty	East Coast	Hawkes Bay	Central Plateau	Taranaki	Wanganui / Manawatu	Wairarapa	Wellington	Nelson	West Coast	Canterbury	Otago	Southland	# of Regions Variety(s) Grew In
Karupoti*	5*	2*	2	1	2	4*	1	1*	4*		1	1*		1*	1*	1*	**14***
Tūtaekuri type	5	3	3	2	1	4	1	4	17	2	2		1				**12**
Pawhero type	6	5	3	4	1	8	2	3	18		3						**10**
Huakaroro type	2	4	4	2	2	4		1	10		2						**9**
Karuparera type	3	4	4	4	1				3	1	1						**8**
Moemoe type	2	6	2			4		1	10		1						**7**
Kohatuwhero type	5		4	5	1				2	1							**6**
Raupi		1	2	1					1		1						**5**
Unknown 1			1	2		1			1	1							**5**
Unknown 3	1		1	1					1	1							**5**
Uwhiwhero type	2	1							1								**3**
Nga Oti Oti type			1	1													**2**
Unknown 2		1							1								**2**
# of Taewa Variety "Types" Grown in Region	**9**	**9**	**11**	**10**	**6**	**6**	**3**	**5**	**12**	**5**	**7**	**1**	**1**	**1**	**1**	**1**	
# of 103 Respondents Residing in Region**	**9**	**12**	**8**	**9**	**1**	**6**	**1**	**2**	**40**	**1**	**9**	**0**	**1**	**0**	**0**	**0**	

Key : x = New Taewa growing region or Taewa variety(s) not previously identified by name within the region; * = One respondent selected only karupoti as variety eaten but many areas it grew in, thus the number of regions it grew in may be inaccurate. ** = The 103 respondents also included 2 respondents residing in Australia, 1 respondent residing in Marlborough and 1 respondent who did not provide a residence.

An assumption of the availability of Taewa variety types and numbers of Taewa eaters within each of the New Zealand regions respondents were located might be obtained by comparing the number of eaten Taewa variety types and the location of the 195 New Zealand respondents who identified a New Zealand residential region and an accurate name or description of a Taewa variety they had eaten.

The range and quantity of Taewa varieties eaten determined by where a respondent lived was slightly different to that obtained based on where a respondent stated the Taewa varieties were grown. It also assumes that the Taewa were actually eaten in the location in which the respondent was living at the time of the survey. Despite this uncertainty, it is likely that Taewa varieties that were eaten in more residential locations will be similar to those that were grown in more New Zealand regions.

Compared to the eighteen Taewa growing regions mentioned previously in 4.4.4.3.b., only fifteen of the possible twenty New Zealand residential regions are represented by locations in which survey respondents resided. The Coromandel, Nelson, Fiordland, Southland and Stewart Island regions did not contain any respondents and thus these regions were not able to be included. The frequency with which Taewa varieties were identified as having been eaten within the fifteen residential regions of the respondents are shown in Table 4.15 (by Taewa variety name); Table 4.16 (by Taewa tuber description) and Appendix 4.6 (combined summary of the data obtained from the 195 respondents).

As predicted (with the exception of Karupoti), the six Taewa variety types eaten by the greater percentage of the survey respondents (in descending order: Tūtaekuri type (144/201: 71.6%); Pawhero type (85/201: 42.3%); Moemoe type (73/201: 36.3%); Huakaroro type (60/201: 29.9%); Karuparera type (50/201: 24.9%) and Peruperu (46/201: 22.9%) and grown in a greater number of the 20 possible New Zealand regions (in descending order: Tūtaekuri type (17/20:); Peruperu (15/20); Karuparera type, Moemoe type and Karupoti (all 14/20); Huakaroro type (12/20); and Pawhero type (11/20) had also been eaten by respondents from a greater number of New Zealand residential regions. Of the fifteen New Zealand residential regions in which the 195 respondents resided, the Tūtaekuri type was eaten by respondents from 13 of the 15 residential regions; Pawhero type and Peruperu by respondents from 11 residential regions; and Moemoe, Huakaroro and Karuparera types were eaten by respondents from 9 residential regions. In addition, these six Taewa variety types were the only variety types that had been eaten by respondents residing in the South Island.

Table 4.15 Frequency of Variety Selection Within Respondent Residential Regions (Taewa Known by Name).

N = 123 (NZ-residing respondents who knew the name of at least one Taewa variety)

	RESIDENTIAL REGION OF RESPONDENTS															
TAEWA VARIETIES	**Northland**	**Auckland**	**Waikato**	**Bay Of Plenty**	**East Coast**	**Hawkes Bay**	**Central Plateau**	**Taranaki**	**Wanganui / Manawatu**	**Wairarapa**	**Wellington**	**Marlborough**	**West Coast**	**Canterbury**	**Otago**	**# Regions Variety Eaten In**
Peruperu *	8	6	5	1		2		1	15	2	3		1		1	**12**
Pawhero / Black Kidney / Old Red	1	3	2	3		1		1	7	1	1				1	**11**
Tūtaekuri	8	15	6	7		6		4	40	3	7				3	**11**
Moemoe / Muimui / Nga Toko	1	5	2	4		2		1	19		4				1	**10**
Kowiniwini / Kaupari	1	4	2	3					1		1			1	2	**9**
Waiporoporo	1	2	1	1		1			5		1				1	**9**
Huakaroro / Karoro / "White Māori"	1	6	2	4		3		1	13		1					**8**
Karuparera / Kanohi Parera		2	3	3					6	1	1					**6**
Māori Chief / Rangatira	1		1	4					6	2	2					**6**
Kohatuwhero / Red Rock			1	1		1			3							**4**
Paraketia / Parareka		1	1	1					1							**4**
Pink Fir	1			1		1			2							**4**
Te Māori	1	3		4					3							**4**
Karupoti			2	1					1							**3**
Whataroa		1		1							1					**3**
Raupi				2					3							**2**
Uwhi / Uwhiwhero									1		1					**2**
Wakaora / Whakaora / Ngauteuteu / Matariki				1					5							**2**
Nga Oti Oti / Nga Outi Outi			1													**1**
Ngaupere			1													**1**
Poiwa	2															**1**
Rokeroke		1														**1**
Wherowhero									2							**1**
# of Taewa Varieties Eaten In Region	**11**	**12**	**14**	**17**	**0**	**8**	**0**	**5**	**18**	**5**	**11**	**0**	**1**	**1**	**6**	
# of 123 Respondents Residing in Region	**11**	**15**	**7**	**9**	**0**	**6**	**0**	**4**	**54**	**3**	**8**	**0**	**1**	**1**	**4**	

Key: Peruperu* = Could relate to a number of Taewa varieties but does not have purple skin and flesh.

Table 4.16 **Frequency of Taewa Variety Selection Within Respondent Residential Region (Taewa Identified by Description).**

N = 110 (NZ-residing respondents that selected a Taewa description)

	RESIDENTIAL REGION OF RESPONDENTS															
TAEWA VARIEITIES	Northland	Auckland	Waikato	Bay Of Plenty	East Coast	Hawkes Bay	Central Plateau	Taranaki	Wanganui / Manawatu	Wairarapa	Wellington	Marlborough	West Coast	Canterbury	Otago	**# Regions Variety Eaten In**
Tūtaekuri type	3	3	4	2	1	4		1	18		3	1	1			**11**
Pawhero type	3	4	1	1		5	1	1	19		4					**9**
Huakaroro type	1	3	2	2	1	1			11		2					**8**
Karupoti		2	2	1		1		1	4		1					**7**
Kohatuwhero type	3	1	1	1					4	1	1					**7**
Moemoe type	2	4	3			1			10		2					**6**
Karuparera type	1	4	2	6					4							**5**
Unknown 3	1		1	1					1		1					**5**
Raupi		1	1	1							1					**4**
Unknown 1			1	1					1		2					**4**
Uwhiwhero type	2		1						3							**3**
Unknown 2		2							1							**2**
Nga Oti Oti type				1												**1**
# of Taewa Variety "Types" Eaten in Region	**8**	**9**	**11**	**10**	**2**	**5**	**1**	**3**	**11**	**1**	**9**	**1**	**1**	**0**	**0**	
# of 110 Respondents Residing in Region	**9**	**14**	**8**	**9**	**1**	**6**	**1**	**2**	**47**	**1**	**10**	**1**	**1**	**0**	**0**	

Key : x = New Taewa variety eating region or Taewa variety(s) not previously identified by name within the region; Unknown 1 = white or creamy-yellow flesh with unknown skin colour; Unknown 2 = coloured flecks within predominantly white flesh and unknown skin colour; and Unknown 3 = unknown flesh colour with purple skin.

4.4.4.3.d. Proportional Consumption of Commonly Eaten Taewa Varieties

The next stage of the analysis investigated whether the proportions of residents who had eaten the most commonly identified varieties (Tūtaekuri type; Pawhero type; Moemoe type; Huakaroro type; Karuparera type and Peruperu) changed between different New Zealand regions and whether there was a pattern of where certain varieties were eaten. A Taewa variety that is consistently eaten by a high proportion of residents, within more regions will likely be more accessible than those eaten by a low proportion of residents within fewer regions.

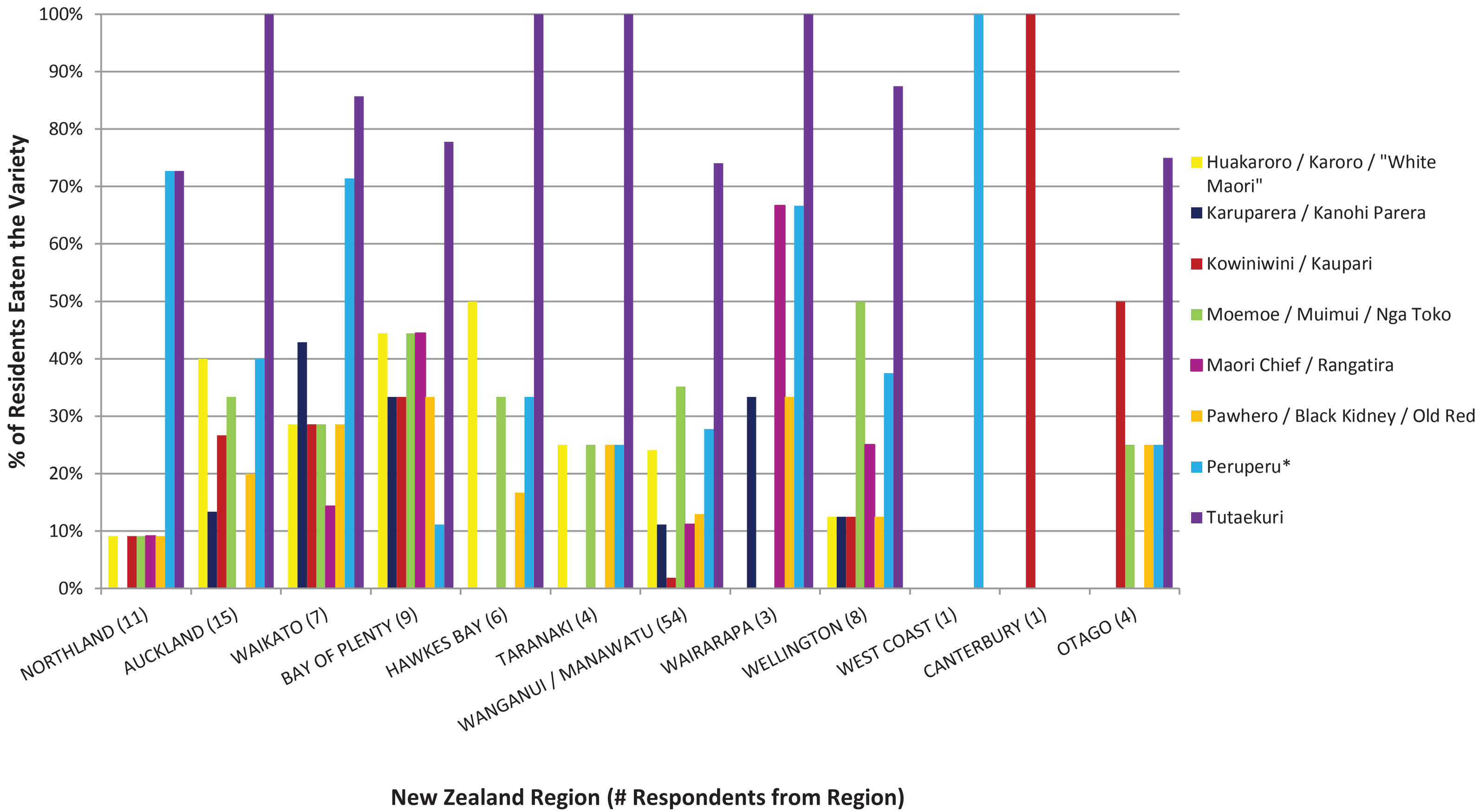
The percentages of the 127 respondents that had eaten any of the eight varieties most commonly identified by name (Tūtaekuri, Peruperu, Pawhero, Māori Chief, Moemoe, Kowiniwini, Karuparera and Huakaroro) are shown in Figure 4.10. These 127 respondents were able to identify eaten Taewa by their varietal name and were grouped into their residential location. Three of the 127 respondents (2.4%) did not specify a residential location and one respondent was residing in Australia at the time of the survey and so were not included in the graph.

Although Peruperu (light blue bar), had been eaten in 11 regions, only Northland (73%); Waikato (71%); Wairarapa (67%); and West Coast (100%) had a greater than 60% proportion of residents that had eaten Peruperu, whereas a consistently high proportion (73 - 100%) of the respondents within 10 regions had eaten Tūtaekuri. Māori Chief (magenta bar), in Wairarapa; and Kowiniwini (red bar), in Canterbury, were the only other varieties that were consumed by greater than 60% of the respondents within a region, however both of these regions only had three or less respondents. Therefore, this high proportional consumption is likely an artefact due to the low respondent numbers rather than being indicative of a high proportion of Māori Chief or Kowiniwini being eaten in Wairarapa or Canterbury respectively.

Moemoe (light green bar) and Pawhero (light orange bar) were eaten in 9 and 10 regional groupings respectively; however Moemoe was generally eaten by a greater proportion of residents than Pawhero. Residents from 8 regional groupings had eaten Huakaroro (yellow bar) and Kowiniwini (red bar), however, a greater proportion of respondents had eaten Huakaroro than Kowiniwini. Māori Chief (magenta bar) and Karuparera (dark blue bar) were eaten in only six regional groupings. Thus the proportional consumption of the eight most commonly eaten Taewa varieties showed a variable pattern of results, however Tūtaekuri was the most consistently consumed Taewa variety across the widest range of regions.

Figure 4.10 Consumption of the 8 Most Common Taewa Varieties Across New Zealand Residential Regions.

N = 123 (Respondents who knew the name of at least one Taewa variety and had indicated a NZ residential location)



Key: Peruperu* = Could relate to a number of Taewa varieties but does not have purple skin and flesh.

4.4.4.3.e. *Range of Taewa Variety Types Within a New Zealand Region*

The range of Taewa varieties available within a region of New Zealand may provide some insight as to whether certain varieties are more likely to be available in certain regions than others. However, it was discovered that the range of Taewa being eaten by respondents in this survey changed depending on how the number of varieties in each region, was determined. Differences in the range of Taewa varieties estimated based on Taewa growing regions or based on the respondent residential regions are discussed next.

Twenty three varieties of Taewa were identified by name by the survey respondents (Section 4.3.1.3). At least 21 of the 23 varieties were identified as having been grown in Northland (91.3%); 19 varieties in Wanganui / Manawatu (82.6%); 18 in Waikato (78.3%); 17 in the East Coast and Hawkes Bay (73.9% each); and at least 16 varieties in the Bay of Plenty and Taranaki regions (69.6% each). Canterbury had the greatest range of Taewa varieties being grown in a South Island region with at least 10 varieties identified as having been grown there (43.5%).

Thus by looking at the regions the Taewa varieties are grown in (Tables 4.13 and 4.14), it appears that the upper regions of the North Island (Northland, Waikato, Bay of Plenty, East Coast, Hawkes Bay, Taranaki) and the Wanganui / Manawatu regions of New Zealand have a greater range of Taewa varieties available because these locations were more likely to grow a wider range of Taewa than other regions in New Zealand, particularly those regions within the South Island.

However, if we look at the range of Taewa varieties eaten, based on the regions the survey respondents resided in (Tables 4.15 and 4.16), a different set of results are found.

The upper regions of the North Island (Northland, Auckland, Waikato, Bay of Plenty) and the Wanganui / Manawatu regions still consumed a greater range of Taewa varieties compared to other regions of New Zealand, however, a smaller range of varieties was found in all regions except for the Bay of Plenty and Auckland. For example, only 12 (52.2%), 9 (39.1%) and 2 (8.7%) of the possible 23 Taewa varieties had been eaten by respondents residing in the Northland, Hawkes Bay and East Coast regions respectively (compared to 23, 17 and 17 varieties identified as having been grown in these regions). In the South Island, Otago, rather than Canterbury residents ate the greatest range of Taewa varieties (6 varieties in Otago compared to 1 in Canterbury), despite a wider range of Taewa varieties grown in Canterbury versus Otago (10 versus 7 respectively).

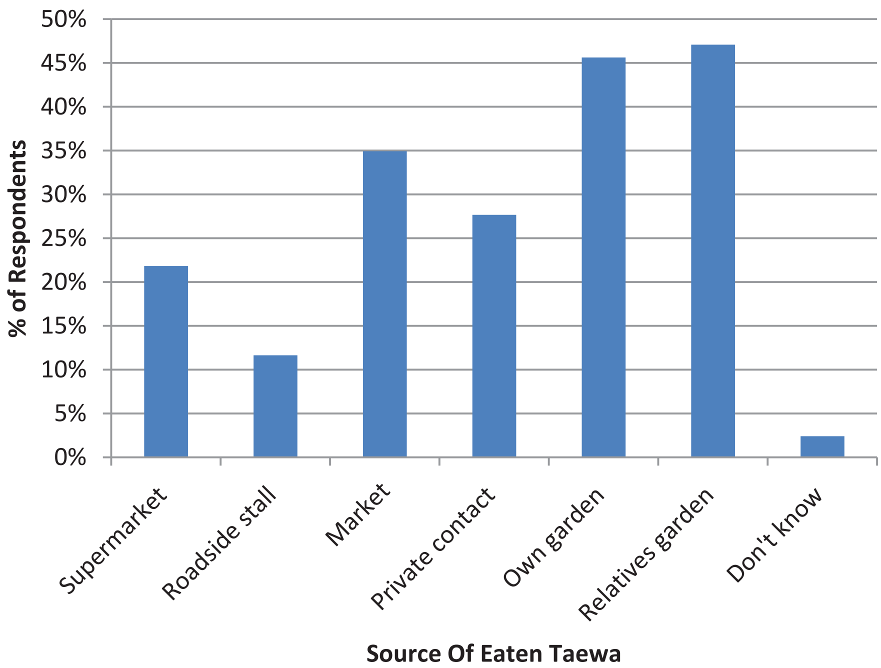
4.4.4.3.f. Potential Sources For Obtaining Taewa

Traditionally, Taewa were grown locally within a particular Māori tribal rohe (area) to feed the tribal members or to be used as an exchange for other provisions with other Māori iwi or settlers. In modern farming, other potato cultivars that boast a greater number of tubers per hectare, a thinner skin, shallower eyes or larger tuber size have mostly replaced the Taewa cultivars, so Taewa are not as commonly grown or found in local produce departments as they were during early European settlement in New Zealand (Harris and Niha, 1999).

It is therefore of interest to see where current day Taewa eaters are sourcing Taewa from, and whether there are differences in the types of Taewa suppliers in some New Zealand regions compared to others. Seven options ("Supermarket"; "Roadside stall"; "Market"; "Private contact"; "Own garden"; "Relatives' garden" or "Don't know") were provided for survey participants to select from as places from which they had sourced the Taewa they had eaten. The most frequently selected option included "Relatives' garden" (97/206: 47.1% of respondents) and a respondents' "own garden" (94/206: 45.6% of the respondents) (Figure 4.11).

Figure 4.11 Sources of Eaten Taewa

N = 206 (Respondents who selected at least one of the source options provided)

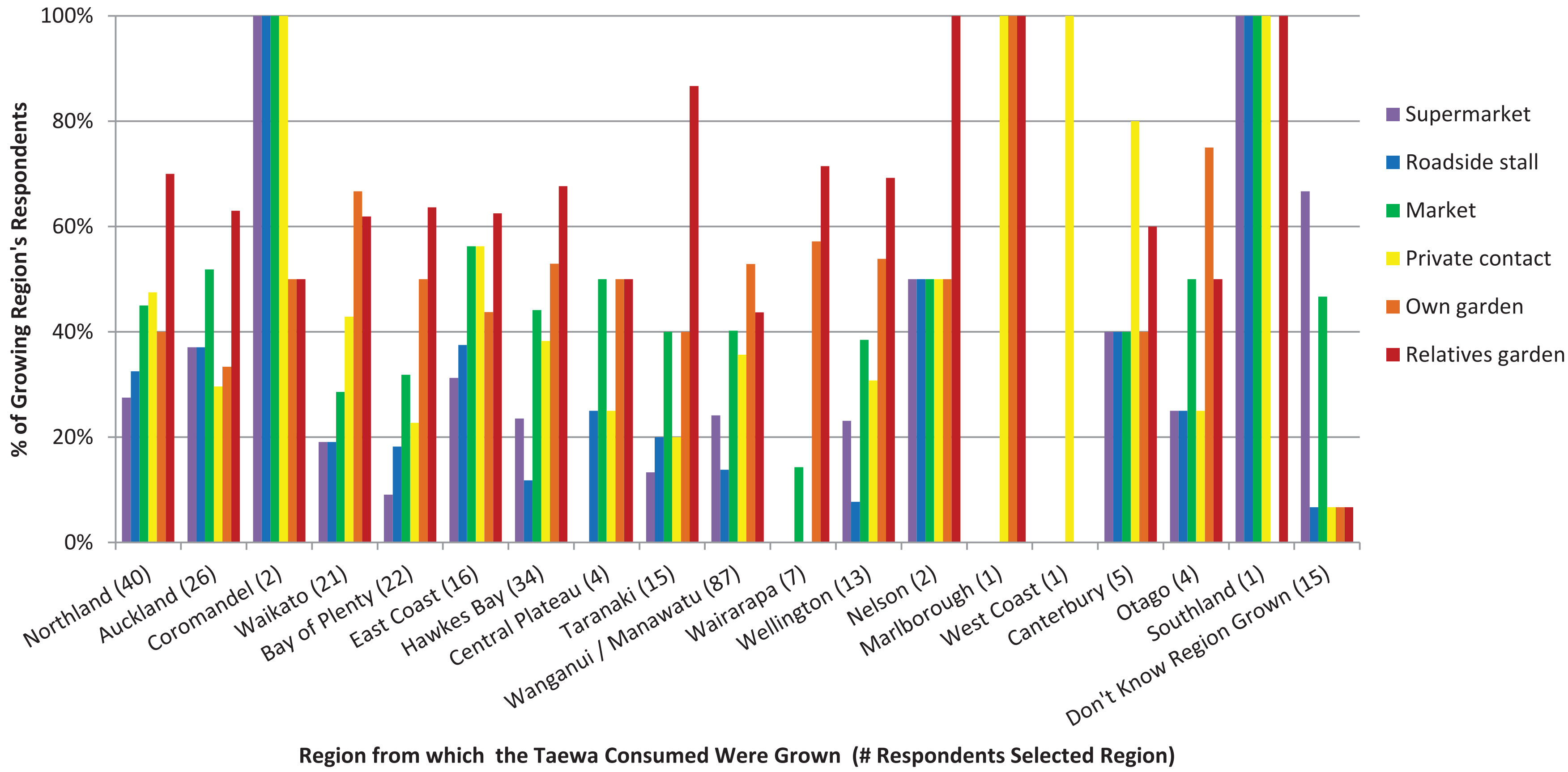


Despite being the most common places to purchase modern potatoes, “Roadside stalls” and the “Supermarket” were the places least likely selected for getting Taewa 24, (11.7%) and 45, (21.8%) of the 206 respondents respectively) in this survey. It is possible that some regions of New Zealand may have better relationships with local supermarkets or other markets (e.g. Fruit and Vegetable shops; Farmers Markets) than others, thus enabling better distribution and sales of Taewa. In addition, the regions previously highlighted as potentially good Taewa growing regions (see Section 4.4.4.3.b.) may also have a greater selection of Taewa suppliers. Thus it is of interest to see whether any patterns might emerge with regards to where Taewa were sourced within each of the 18 Taewa growing regions identified in Section 4.4.4.3.a.

For most growing regions, a relatives’ garden or the respondents own garden were the two most likely places Taewa had been sourced from (See Figure 4.12). However, respondents who indicated that the Taewa they had eaten were grown in the Waikato (21/206: 10.2%); Wanganui/Manawatu (87/206: 42.2%) and Otago regions (4/206: 1.9%), were more likely to have sourced the Taewa they had eaten from their own garden first; those respondents in the Canterbury region (5/206: 2.4%), were most likely to have sourced their Taewa from a private contact first, and those who didn’t know where the Taewa they had eaten were grown (15/206: 7.3%), were most likely to have sourced their Taewa from the Supermarket first.

Figure 4.12 Source of Taewa Consumed Within Each Growing Region.

N = 206 (Respondents who selected at least one of the source options provided)



4.4.5. Potential for Future Developments of Edible Taewa Products

Since a major aim of this PhD research is to provide data to help develop Taewa products offering additional nutritional and health benefits, questions surrounding participants' affinity to various practices with pre-cooked Taewa; or cooked and cooled Taewa products boasting additional resistant starch content were posed to survey participants.

4.4.5.1. Exploration of Pre-Cooked Taewa Preferences

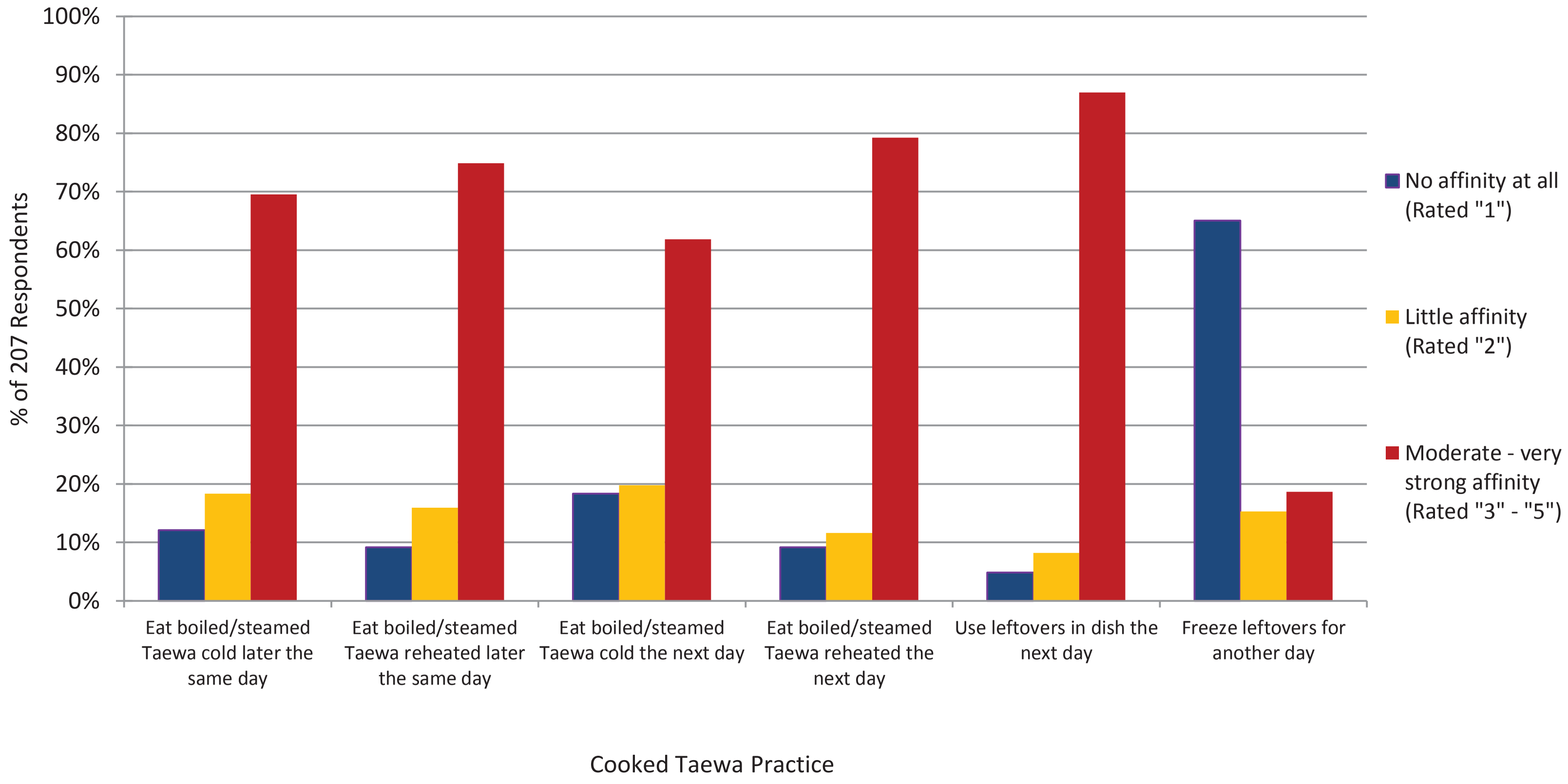
In order to gain some insight into current eating practices with regards to pre-cooked Taewa, survey participants were asked to rate on a 5 point scale, the likelihood of them carrying out each of the 6 listed practices with regards to cooked Taewa: (1 = not at all, 2 = a little, 3 = moderately, 4 = strong, 5 = very strong). The practices included:

- Eating boiled / steamed potatoes **cold** later the same day
- Eating boiled / steamed potatoes **reheated** later the same day
- Eating boiled / steamed potatoes **cold** the next day
- Eating boiled / steamed potatoes **reheated** the next day
- Using leftover potatoes for another dish the next day
- Freezing leftover potatoes to eat another day

Based on the results from the 207 survey respondents that rated each of the above practices relating to pre-cooked Taewa (Figure 4.13), the practice that had the most affinity (had a greater number of ratings between 3 and 5 and thus greater likelihood of being practiced) was "Using leftover potatoes for another dish the next day", whereas "Freezing leftover potatoes to eat another day" had the least affinity (had a greater number of ratings closer to 1 and thus least likelihood of being practiced).

Most survey respondents had a moderate to strong affinity towards "Eating boiled / steamed potatoes cold later the same day", (144/207: 69.6%); "Eating boiled / steamed potatoes reheated later the same day", (155/207: 74.9%); "Eating boiled / steamed potatoes cold the next day", (128/207: 61.8%); "Eating boiled / steamed potatoes reheated the next day", (164/207: 79.2%); and "Using leftover potatoes for another dish the next day", (180/207: 87%). Only 16 survey respondents (18.8%) had a moderate to strong affinity towards "Freezing leftovers for another day" - most (136 /207: 65.7%) stating to not do this practice at all.

Figure 4.13. Affinity with Practices Relating to The Use of Cooked Taewa.
N = 207 (Participants who gave an affinity rating for each of the practices relating to cooked Taewa).
“No affinity at all” includes participants who gave a rating of “1”; ”Little affinity” includes participants who gave a rating of “2”; “Moderate to strong affinity” includes participants who gave a rating of “3” (moderate) – “5” (very strong) to the listed practice.



4.4.5.2. *Exploration of Cooked and Cold Taewa Preferences*

Participants were asked to identify which of all the Taewa varieties they had eaten, was the one that they would most prefer to eat in a cold potato salad and why (see Table 4.17).

Table 4.17. Taewa Preference for Cold Potato Salad.

N = 147 (Respondents who provided a variety preference for cold Taewa).

Preferred Taewa Variety Reasons for preference	# Who Chose The Option	Typical Comments Related To Variety
Tūtaekuri	36	
Colour / Appearance	22	Colour difference; purple colour
Taste or Flavour	11	Creamy; nutty; delicate flavour
Appropriate Texture	11	Firm or waxy when cold
Other	6	Small ones better; better with skin off; health benefits.
Peruperu	25	
Colour / Appearance	10	Colour difference; purple colour
Taste or Flavour	8	Sweet; tasty
Appropriate Texture	10	Firm; denser; waxy; meatier; not so floury
Other	3	Has substance; easily cooked; compliments other veges
Pawhero Type	19	
Colour / Appearance	7	Purple skin
Taste or Flavour	7	Sweet
Appropriate Texture	8	Soft; firm
Other	1	Colour doesn't leach
Huakaroro type	14	
Colour / Appearance	1	Would look good with a purple skinned Taewa variety
Taste or Flavour	5	Buttery taste
Appropriate Texture	6	
Other	3	Bigger; readily available; goes with everything
Karuparera type	8	
Colour / Appearance	1	Would look good with a purple skinned Taewa variety
Taste or Flavour	2	Sweet
Appropriate Texture	5	Firm; holds together
Other	3	Quick cooking; good size for scraping; Mum used them
Moemoe type	8	
Colour / Appearance	2	Pinky flesh looks interesting
Taste or Flavour	2	Good flavour
Appropriate Texture	5	Softer; holds together well
Other	1	Good size for scraping / peeling

Of the 147 participants that responded to the question, the four most frequently preferred Taewa variety groups were a purple flesh, purple skinned variety (such as Tūtaekuri); Peruperu (variable varieties); a variety that had a white or creamy-yellow flesh and purple skin (such as Pawhero or Waiporoporo); or a variety that had creamy-yellow flesh and skin (such as Huakaroro). The most frequently selected reason for preferring a particular variety was due to an appropriate texture, for example a variety that was firm, waxy or would hold together when cold. Texture preference was followed by colour preference (in particular the purple colour difference of the purple fleshed and/or purple skinned varieties) and then taste preference (having a sweet, buttery, nutty, delicate, tasty, good taste).

4.4.6. Compilation of Taewa Recipes for Public Use

A number of suggestions, recipes and thoughts were contributed from the survey respondents and a good deal of interest was shown with regards to Taewa throughout the research discussed in Chapter 3 and 4 of this thesis. Once completed, a summary of the results obtained through contributions provided from group discussion and survey participants will be made available to the general public through the Tahuri Whenua website.

4.5. Discussion

4.5.1. Range of Commonly Eaten and Preferred Taewa Varieties

The exact number of Taewa cultivar lines available in New Zealand is uncertain due to the fact that absolute identification of a varietal type poses some difficulty. Taewa varieties may be known by different names depending on the tribe or geographical region of the identifier; or the same varietal name may be known by more than one cultivar. It should be noted that for the survey respondents, identification of a Taewa variety eaten using recall of tuber flesh and skin appearance characteristics may have introduced additional errors, as it relied on the correct recall of events that could have occurred decades previously and Taewa skin and flesh characteristics may vary from season to season due to growing conditions. For example, potato psyllid infection has been known to significantly alter the skin pigmentation of tubers thus making identification more difficult. However, at least 18 Taewa cultivars are being maintained within New Zealand institutional seed banks (Harris and Niha, 1999; Horticulture News, 2008) and there are indications from discussions with Māori as reported by Harris and Niha (1999) and FitzHerbert (2009) that there may be more Taewa cultivars (Harris and Niha, 1999; Savage *et al.,* 2000; Grower, 2001; FitzHerbert, 2009).

Twenty three Taewa varieties were identified by name in the survey and included all of the varieties listed in Table 4.2, except for the Whanako variety, which no respondent identified. In addition to these twenty two varieties, another two unlisted varieties (Wherowhero and Poko Hinau), were named as having been eaten. Wherowhero appears to be a separate variety to those listed in Table 4.2, however Poko Hinau may be another varietal name for Tūtaekuri based on the purple flesh, purple skin description given. Had Wherowhero been included, it may have been selected more often as a "Kohatuwhero type" variety (which included Kohatuwhero / Red Rock and Wherowhero varieties), as both have creamy-yellow flesh with a pink/red skin; a description which was selected by 9 respondents (see 4.7). Thus the survey data was able to identify an additional 8 Taewa varieties to those mentioned by the group discussion participants (see Section 4.4.2.1.b.).

To date, there appears to be limited information on which Taewa varieties are commonly eaten or preferred for eating. However, as Taewa are generally grown for the purpose of eating, it is likely that the currently existing Taewa varieties have survived (at least in part), due to their popular sensory characteristics.

In descending order of frequency, Taewa varieties commonly eaten by the survey respondents included Tūtaekuri, Pawhero, Moemoe, Huakaroro, Karuparera and Peruperu type varieties. These varieties were also prominent amongst those commonly eaten by the 25 group discussion participants. One reason why Tūtaekuri may have been identified as commonly eaten is because Tūtaekuri has a distinctive tuber colouring and it is the only Taewa variety that has a dark purple skin as well as deep purple flesh that usually extends throughout the entire tuber. Thus Tūtaekuri is easily recognisable, whereas the physical characteristics of other varieties may not be as memorable, thus making them less easily identifiable.

Five Taewa varieties were identified by name either only once (Nga Oti Oti / Nga Outi Outi; Ngaupere and Rokeroke) or twice (Poiwa; Uwhi / Uwhiwhero and Wherowhero). It is possible that these five varieties were not identified as frequently because they may be varietal names known only to certain Māori tribal regions, and so are names that are either less familiar or not used throughout New Zealand, or these may be varieties that are less widespread across New Zealand. By looking at where these varieties were grown, we were able to speculate whether they were specific to a region. Nga Oti Oti was identified by name as grown only in the Waikato and Bay of Plenty regions, and Taewa matching the Nga Oti Oti description were also identified in the Waikato and Bay of Plenty regions, which suggests that Nga Oti Oti may be a variety specific to the Waikato and Bay of Plenty regions.

Poiwa, Ngaupere and Rokeroke were identified by name, as grown only in Northland, hence these may be varietal names known primarily in the Northland region. However, since their tuber descriptions are similar to Moemoe, they may actually grow in an additional 6 regions, where Taewa fitting Moemoe tuber characteristics were described. Uwhi / Uwhiwhero and Wherowhero were only been identified by name twice, however tuber descriptions matching these two varieties were identified by 6 and 9 respondents respectively, who indicated they were grown in 4 and 8 New Zealand regions respectively. Thus Uwhi / Uwhiwhero and Wherowhero varieties may be more common than the initial numbers indicate.

Studies show that food preferences and reported frequencies of consumption of the same foods are significantly correlated with each other (Randall and Sanjur, 1981; Drewnowski and Hann, 1999). Data from survey respondents regarding their favourite Taewa variety also confirm the hypothesis that the most preferred Taewa varieties for eating were also among those most commonly eaten. In descending order of preference these were Tūtaekuri, Pawhero, Peruperu, Moemoe, Karuparera and Huakaroro type varieties.

Personal preference for a food's taste or flavour is a major contributing factor to food choice (Drewnoski, 1997; Dressler and Smith, 2013), as is a food's familiarity (Kratt *et al.,* 2000). The results from this survey also suggest that the reasons that Taewa varieties were selected as being preferred for eating were mostly due to their taste (not only because it tasted good in general, but also tasted good cold and reheated) and familiarity to the consumer (because it had been cooked by the respondent or by the respondents' parents or grandparents).

When survey respondents were asked what factors would enable them to eat Taewa more often, the "favourite variety being available" was rated strongly or very strongly, by 60.1% (125/208) of the respondents. However, when asked if their favourite variety was being grown in their regional location, 55.3% (110/199) of the survey respondents didn't know. Thus it was interesting that when asked why the respondent preferred to eat a variety, "being able to easily access their favourite Taewa variety" seemed to be of minor importance (only selected by 49/200: 24.5% of respondents), when it was expected that it would be of high importance. It does suggest however, that despite a favourite Taewa variety not being easily accessible, it may still be the preferred variety for eating and may be preferred over another Taewa variety that is more accessible.

4.5.2. *Preferred Preparation, Cooking and Eating Practices Associated with Taewa*

Traditional methods of cooking Taewa likely included roasting over embers, steaming in a hangi (earth oven) or boiling in a hot spring in flax (*phormium tenax*) baskets, as iron pots were not common in Māori villages until the 1830s (Thomson, 1859; Leach, 1981; Leach, 1984). Interestingly, cooking of indigenous potatoes by the indigenous Andean peoples was also traditionally done by simple boiling or steaming, however the skins were not usually eaten and chilli peppers were the usual condiment (Brush *et al.,* 1981). Again, similar to Māori, sod or fieldstone ovens for roasting potatoes at harvest time was a favourite variation in cooking potatoes by the indigenous Andean peoples (Brush *et al.,* 1981).

Following the introduction of metal pots after the 1830s, boiling potatoes (Taewa and modern varieties) in iron pots appears to have become a common method of cooking potatoes (Marshall, 1836). Between 1988 and 2003, "boil-ups" (traditionally include a combination of meat and bones (e.g. pork), greens such as puha (sow thistle), watercress or cabbage, and kūmara(Māori name for sweet potato) or potatoes, boiled together) were still being reported as being frequently eaten by Māori (Metcalf *et al.*, 1998; Ferguson, 2002; Metcalf *et al.,* 2008).

In 2006, across Māori participating in the Te Wai o Rona: Diabetes Prevention Strategy, "Boil-ups" were identified as being consumed at least annually by four out of five (80%) of the 2,669 self-identified Māori from the Waikato and Southern Lakes Districts of New Zealand (Rush *et al.,* 2010). Since potatoes (both modern and Taewa) are often incorporated into these "Boil-ups", it is likely that this remains one of the common methods of cooking Taewa to date. Thus it was of interest to discover to what extent, traditional, post-European contact or modern preparation practices are preferred for the consumption of Taewa.

It was of interest that although "Boil-ups" were consumed at least annually by 80% of the participants in the Rush *et al.,* 2010 study, "Boil-ups" were identified as being only the second most preferred method (29 of the 201 respondents: 14.4%) for cooking Taewa in this survey. The survey respondents preferred Taewa to be prepared for cooking by leaving them whole and unpeeled (107/201: 53.2%) and cooked by boiling in water on their own (89/201: 44.3%). A possible reason for this preference for cooking Taewa on their own is that perhaps the unique flavour of the Taewa is preferred to be savoured alone rather than lost through mixing with other flavours inherent in a "Boil-up".

The most common preferences for eating Taewa are likely to include eating Taewa with the skin on (144/201: 71.6% of respondents); eating them hot or warm (170/200: 85% of respondents); and with salt, butter and pepper (139/200: 69.5%; 113/200: 56.5%; and 64/200: 32% of respondents respectively). However, there was also a noted preference for eating Taewa without any accompaniment by 39 of 200 (19.5%) respondents, with this preference matching the sentiments expressed by some of the Taewa group discussion participants. Thus current preferences for cooking and eating Taewa appear to be a mixture of traditional and modern practices.

4.5.3. Medicinal, Healing, Functional Uses of Taewa

Indications from the survey are that there were, or are still, practices relating to non-nutritional usage of Taewa, thus giving support to those mentioned by the group discussion participants (see Section 3.4.2.). The most commonly identified non-nutritional practice with regards to Taewa, included the use of special techniques with which to store Taewa. This is not surprising, as a number of sources have recorded an observation of fern leaves from the *mamaku* (*Cyathea dealbata*) being used to cover stored seed Taewa (Harris and Niha, 1999).

The survey results indicate that respondents were aware of the potential health promoting effects of eating purple-skinned, purple-fleshed Taewa varieties as 70 out of 114 respondents, (61.4%), selected "consumption of potatoes with purple skin or flesh to promote health" as a practice they themselves, or others they knew of, as having practiced. Additionally, respondents mentioned "health benefits" as a reason for selecting Tūtaekuri as a preferred variety for a cold potato salad. Other commonly selected practices indicated the use of *Rongoa* or similar practices for treatment of skin ailments, or for medicinal or health promoting purposes.

It appears that other cultures have used potatoes in similar ways for healing or health promoting purposes, as raw potatoes have been used traditionally in Europe for treatment of gastrointestinal disorders, and topical potato preparations have been used as a hot pack for pain or for softening furuncles (Vlachojannis *et al.,* 2010) and boiled potato peels have been used as a dressing for burn wounds in India (Subrahmanyam, 1996). Based on the options selected by survey respondents, the parts of the tuber that were likely used for non-nutritional practices included the use of tuber skin, flesh, juices and extracts, in either cooked or uncooked forms.

These survey results also indicated the respondents knew a number of non-nutritional uses of Taewa using potato plant leaves; the tuber (flesh, skin, juices; cooked or uncooked) and extracted starch or pigments for a healing, medicinal or other functional purpose. Although beyond the scope of this present PhD research, the survey results show that there may be other potentially health-promoting components in Taewa that could be explored. Had there been an opportunity to question the survey participants further (as was possible in the group discussions), further information on the specific uses or purposes may have been discovered.

4.5.4. Sensory Acceptability of Taewa Varieties

Sensory attributes of a food are significant factors in determining food choice (Drewnowski, 1997; Clark, 1998; Glanz *et al.,* 1998; Dressler and Smith, 2013). As observed from the group discussion participants, sensory qualities (in particular taste and colour of the Taewa variety), seemed to be important reasons as to why the survey respondents preferred eating a certain Taewa variety (see Section 4.4.4.2.b.). The colour and taste attributes unique to Taewa varieties are traits that Taewa suppliers may be able to exploit through recipes or accompaniments that would highlight their variable colours and blend well or enhance their unique flavours in a way that a modern white fleshed, white-skinned potato is unable to do.

However, investigations into Taewa eating preferences with subjects unfamiliar with Taewa should also be carried out since those who have regularly eaten Taewa are likely to have built up habitual practices relating to cooking and eating Taewa and would be familiar with the physical and sensory characteristics associated with Taewa, whereas those unfamiliar with Taewa would not.

4.5.5. Cultural, Historical or Emotional Value Associated with Taewa

As well as becoming a staple item in the diet of Māori in the early 1800s, Taewa were an important trade commodity within Māori communities as well as for European colonists (Hargreaves, 1959; Harris and Niha, 1999, McAloon, 2002).

Taewa are considered a *taonga*:

> "...a treasured possession whose care and conservation is a matter of historical record and contemporary pride and interest for Māori" (Lambert, 2007);

> “...which have been passed down through generations, and facilitate an important link between the people and the land. Taewa strengthen a relationship with this most precious resource (the land), (are) founded in whakapapa and fostered through care and nurture” (McFarlane, 2007).

Taewa are considered to be:

> “...some of the most deeply treasured Māori foods available to us today” (Te Waka Kai Ora, 2010).

For Māori, Taewa crop production remains linked with several cultural, historical, spiritual and emotional aspects such as whakapapa (genealogy and creation); whanaungatanga (kinship, family relations); wairuatanga (spirituality); manaakitanga (hospitality, kindness); tikanga (customs and habits) as well as economic survival (Roskruge, 1999). Understandings from the group discussions also indicated that Taewa are associated with significant cultural, historical, spiritual or emotional value (Section 3.4.3.2).

Although not explored extensively in the survey, results obtained also indicate that an emotional or spiritual value was associated with the reasons for why a favourite variety was eaten. This association of cultural, historical, spiritual or emotional value is not surprising due to the 200+ years of association of Māori in cultivating, eating and supplying Taewa.

4.5.6. Accessibility and Availability of Taewa

Accessibility, availability, convenience and economic considerations also influence food choices (Glanz *et al*., 1998). Following the Māori Wars of the early 1860s, a loss of productive land, and the introduction of modern cultivars boasting greater yields, resulted in Taewa production being greatly reduced (Hargreaves, 1959; Grey, 1994; Roskruge 1999). A potato blight in 1905-1906 further crippled the production of Taewa (Harris and Tipene, 2006) and from that time until the early 1990s, Taewa production was relegated to a few marae gardens and backyard crops.

Graham Harris and Nick Roskruge have done much to restimulate interest in Taewa, both nationally and internationally (FitzHerbert, 2009). Harris and Niha spent three years gathering stories and collecting Taewa varieties, while piecing together the history of the introduction and exchanges of Taewa that occurred, recording information about Taewa varieties and investigating the extent to which Taewa are grown today (Harris and Niha, 1999).

Dr Roskruge worked with Māori growers to collect and maintain a seed bank of Taewa, the collective aim being to reinvigorate the growing of traditional Māori vegetables whilst prioritising *tikanga* and growing of vegetables to support marae and whanau, before considering the commercial opportunities (Lambert, 2007; McFarlane, 2007; FitzHerbert, 2009).

In 2004, a national collective of Māori vegetable growers (Tahuri Whenua Inc Soc.) was established and its numbers have continued to grow to include both Māori and non-Māori enthusiasts. The group has associations with agricultural, research, educational, marketing and community sectors both nationally and internationally (Grower, 2001; Roskruge, 2005; FitzHerbert, 2009). Thus it was of interest to investigate how availability or accessibility factors to Taewa might yet affect Taewa consumption in 2010 and 2011.

4.5.6.1. Suppliers of Taewa

As was found with the group discussion participants, being able to obtain the Taewa (whether through knowing where to source Taewa from; or being able to afford the purchasing cost; or being able to obtain their favourite Taewa variety) appeared to be a key factor in enabling the survey participants to be able to eat Taewa more often. Therefore, although the number of Taewa growers and suppliers may be increasing, based on the survey results, knowing where to source Taewa from, could yet be a major barrier to people being able to eat Taewa, since this appeared to be a more important factor than the purchasing cost, knowing how to grow it, or knowing a Taewa variety's nutritional value.

The majority of the survey respondents said the Taewa they had previously eaten were most often sourced from a relative's garden or their own garden. So while some people appear to have the knowledge of how to grow Taewa, or have, (or had) family contacts from whom to source Taewa from, their ability to grow Taewa or the family contacts from whom they sourced the Taewa, may no longer exist. Respondents who said the Taewa they had eaten were grown in the Waikato; Wanganui/Manawatu and Otago regions, were more likely to have sourced the Taewa they had eaten from their own garden, suggesting that perhaps these regions have (or had), a greater number of home or community Taewa growers. Very few survey respondents had bought their Taewa from the supermarket, which is where most consumers of modern potatoes would source their potatoes.

Thus, the availability of a regular, well-advertised supplier of Taewa could be an important step in enabling those who hadn't eaten Taewa before to be able to try them, and for those who had eaten them before, to be able to keep eating them if they weren't already growing Taewa themselves.

4.5.6.2. Commonly Grown Taewa

Observations during the acquisition of Taewa cultivars by Graham Harris and Poai Pakeha Niha from 1996 to 1999 indicated that in decreasing order, commonly grown Taewa varieties appeared to include Urenika (varietal name for Tūtaekuri), Moemoe, Huakaroro and Peruperu (Harris and Niha, 1999). Other Taewa that have been indicated as commonly grown include Karuparera, Pāwhero, Te Māori, Raupi and Kohatuwhero (McFarlane, 2007).

Survey results showed that the Tūtaekuri type variety (purple skin and purple flesh) is likely to be the most widespread Taewa variety grown in New Zealand; being grown in 17 of the 20 New Zealand regions as determined by the New Zealand map shown in Figure 4.9. Tūtaekuri was not indicated as having been grown in Fiordland, Southland or Stewart Island regions, but this may have been due to the fact that none of the 209 survey participants indicated that they resided in these regions.

Tūtaekuri type; Peruperu; Karuparera type; Moemoe type; Karupoti; Huakaroro type; and Pawhero type (includes Pāwhero, Waiporoporo and Te Māori varieties), were grown in a greater number of regions and eaten by respondents from a greater number of New Zealand residential regions than other varieties of Taewa. Thus apart from the Raupi and Kohatuwhero varieties mentioned by McFarlane, (2007), these survey results support what has previously been suggested as being commonly grown Taewa.

In addition, Tūtaekuri, Pāwhero type, Peruperu, Moemoe, Huakaroro and Karuparera were the only varietal types that had been eaten by respondents residing in the South Island, giving further support that these Taewa varieties are not only likely to be the most commonly grown, but are likely to be the most widespread throughout New Zealand. Pawhero was found in a greater number of New Zealand regions than Huakaroro, but a higher proportion of people in the region's growing Huakaroro had eaten it, suggesting perhaps that Huakaroro is the more preferred variety for eating. Looking at the survey results, it may appear that Karuparera is more likely to be eaten in the upper and lower regions of the North Island rather than in the central coastal regions of the North Island (Hawkes Bay and Taranaki). But again, this appearance of a pattern may be due to the small respondent numbers in these two locations.

Due to the low survey respondent numbers in some regions of New Zealand, extrapolating patterns in Taewa variety distribution in these areas cannot be done with any degree of certainty.

4.5.6.3. Regional Distribution of Taewa

Harris and Niha (1999), reported that Taewa were found on the East Coast (East Cape, Gisborne, Hawkes Bay); rural areas of the Waikato; the Bay of Plenty; and the West Coast from Taranaki to Wellington regions of the North Island. They also found that some were being grown as far south as the Chatham Islands located in the South Island of New Zealand (Harris and Niha, 1999).

A three year study mapping the travels of Taewa seed during 2008 – 2010 from the Manawatu region to other areas of New Zealand, found that Taewa had travelled as far north as Kaitaia and as far south as Invercargill (See Appendix 4.7). Tahuri Whenua Inc Soc includes a national collective of New Zealand Taewa growers from all over New Zealand. Thus it was of interest to see whether data from the survey respondents also indicated that access or availability to Taewa was as widespread throughout New Zealand as the distribution of Taewa seed or location of Taewa growers appears to be.

By looking at the regions survey respondents said the Taewa varieties they had eaten had grown in, it appears that the upper regions of the North Island (Northland, Waikato, Bay of Plenty, East Coast, Hawkes Bay, Taranaki) and the Wanganui / Manawatu regions of New Zealand have a greater range of Taewa available, because these locations were more likely to grow a wider range of Taewa varieties than other regions in New Zealand. This is likely due to the preferential climatic conditions for potato growing in these regions. However, it was also found that some regions associated with a greater range of Taewa varieties, had a higher than average range of Taewa varieties eaten per respondent. For example, only 13 respondents were residing in the Bay of Plenty, but 17 Taewa varieties were eaten between them and 8 of the 13 respondents (62%) had eaten between 3 – 13 Taewa varieties each.

Respondents from ten out of the possible 20 residential regional groupings indicated that the Taewa they had eaten were grown in the Northland, Hawkes Bay and Wanganui / Manawatu regions, thus implying that these three regions are likely to be good growing and supplying regions for Taewa (see results in Table 4.12).

Assuming that Northland, Hawkes Bay and the Manawatu / Wanganui regions are indeed major Taewa supply regions, Taewa may be travelling some distance from their growing regions to their final destination. For example, according to the results from the 201 respondents who specified at least one eaten Taewa variety, Taewa grown in Northland may have travelled to Auckland, Waikato, Bay of Plenty, Taranaki, Wanganui / Manawatu, Wellington and as far south as Canterbury.

Perhaps by being grown at a more central location in the North Island, Taewa grown in the Hawkes Bay were more likely to have travelled to nearby regions, but may have ended up as far north as Auckland and as far south as Otago. Taewa grown in the Wanganui / Manawatu region may have travelled as far north as Northland or Auckland and as far south as the West Coast.

Some Taewa variety names may be specific to, or are varieties that only grow in certain regions within New Zealand. This may be the case with the Nga Oti Oti / Nga Outi Outi variety which was only selected as being grown in the Waikato and Bay of Plenty regions. Other reasons that may explain why some varieties don’t appear to be grown as extensively as others, may be due to the fact that a respondent, 1) did not know that a potato they had eaten was a Māori potato and 2) did not know the Taewa varietal names associated with the varieties they had eaten.

Since about half (103) of the 201 survey respondents that specified a Taewa variety they had eaten, did this through identifying by a description rather than a name, it is likely that a lack of familiarity with Taewa varietal names is a key reason a variety type may not be identified as being grown within a particular region. In addition to this, 38 of the respondents who knew at least one name of a Taewa variety they had eaten, did not know the names of other varieties they had eaten and so also selected tuber characteristics as described in Table 4.3.

Differences in the range of Taewa varieties estimated to be eaten in a New Zealand location based on a) whether the Taewa was grown in the location or b) a respondent living in the located had eaten it, are likely due to the fact that survey participants were not asked to specify the growing region that related to each individual Taewa variety they had eaten. Thus multiple growing areas may have been allocated to the same variety. This could have been because they selected all the regions they knew the variety(s) they had eaten do grow in, or they may have eaten the variety multiple times and each time it may have been sourced from a different region.

In reality, a greater range of Taewa varieties consumed within a region may be due to a number of reasons, such as favourable growing conditions; greater numbers of Taewa eaters, growers and enthusiasts; or better access to Taewa varieties within those regions.

4.5.7. Future Edible Taewa Products

A Taewa variety that would be best suited for a potential food marketing product would be one that is already well-known; one that people commonly eat, and prefer to eat; and whose cultivation and consumption is widespread across New Zealand regions.

Results from the survey suggest that the Taewa varieties that best fit these criteria are likely to include Tūtaekuri; Peruperu; Moemoe; Karuparera or Kowiniwini; Huakaroro or a purple skinned, white-creamy fleshed, waxy variety such as Pawhero or Waiporoporo.

To some Taewa group discussion participants, a clear marketing potential of Taewa compared to modern potato varieties was the inherent, unique flavour of some of the Taewa varieties. It was felt that adding flavour or cooking the Taewa with other ingredients would spoil the unique flavour of the Taewa. Thus a potential Taewa product may only need to be flavoured with salt in order to be acceptable to the majority of consumers.

4.5.7.1. Preferences of Cooked and Cooled Taewa Products

Based on the results from the survey, the preferred Taewa varieties for eating cold such as in a cold potato salad included Tūtaekuri; Peruperu; Huakaroro:; and a purple-skinned, white-creamy fleshed “Pawhero type” variety (such as Pawhero, Waiporoporo or Te Māori). The reasons these varieties were chosen were due to an appropriate texture (firm, waxy); their colour attributes (purple or buttery-yellow) or taste (sweet, nutty, delicate, tasty).

An appropriate texture makes sense with regards to a preferred potato variety characteristic for a cold potato salad, since a variety that is floury, or mashes up easily during cooking does not look as visually appealing in a cold potato salad compared to one that has a firm, waxy texture. The colour attributes/characteristics distinctive in Taewa tubers compared to the usual white fleshed, white skinned modern varieties may also be of significant marketing potential, but would need to be tested with potato consumers unfamiliar with Taewa to gauge acceptance of the different characteristics of Taewa with a wider cross-section of potential consumers.

Survey results suggest there may be a potential for parboiled or pre-cooked Taewa products most likely made from Tūtaekuri, Huakaroro or a purple-skinned, white-creamy fleshed waxy Taewa variety that consumers might eat either cold (such as in a cold potato salad) or that the consumer can finish off cooking and serve hot at a later stage (such as parboiled whole or cut potatoes destined for later boiling, roasting, stewing or other cooking methods), in order to cater for serving temperature preferences, while still providing the potential for additional health benefits of an increased resistant starch content.

Testing preferences with consumers unfamiliar with Taewa would also be warranted to ensure greater market acceptability of a preferred cooking or eating practice. However, a Taewa product that is parboiled whole, with the skin on, then vacuum-packed so that cooking might be completed by the consumer just before consumption and then served hot might align with the preferences (eating Taewa with the skin on, eating them hot or warm, and with butter, salt and pepper) shown by these 200+ Taewa eaters.

4.5.8. Key summary of information gained from this survey

- Commonly eaten Taewa varieties appear to include Tūtaekuri type (varieties with purple skin and flesh); Pawhero type (varieties with purple skins; white or creamy flesh); Peruperu type (variable varieties); Moemoe type (varieties with mottled purple/pink/yellow skins; creamy-white flesh with coloured flecks); Karuparera type (varieties with purple skins, white around eyes; creamy-white flesh); and Huakaroro type (yellow skin and flesh) varieties.
- Commonly eaten Taewa varieties are more likely to be the most preferred varieties, those grown in a greater number of regions, and eaten by residents in a greater number of regions across New Zealand than others.
- Preferences with regards to preparing, cooking and eating Taewa appear to include boiling them whole, unpeeled and on their own; then eating them hot or warm, with the skin on and seasoned with butter, salt and pepper.
- If destined to be pre-cooked or served cold, Taewa varieties should be waxy; be purple or buttery-yellow, be an appropriate size for the intended dish and have a sweet, nutty, delicate taste.

Thus future research geared towards the development of Taewa products with potential health benefits should:

- be selected from among the most commonly eaten Taewa varieties
- include Taewa varieties that have a range of tuber cooking qualities; sensory attributes and potential health attributes (red to purple skinned, or purple fleshed)
- be cooked by boiling whole, with the skin on, in slightly salted water
- be tested for sensory acceptability at warm and cool serving temperatures by those whom are familiar as well as those who are unfamiliar with Taewa characteristics

Aside from providing new knowledge on the current availability, cooking and consumption practices of Taewa, the key findings from this survey feed into the decisions made on the choice of Taewa varieties, cooking methods used and potential trial participants for the two studies described in the following chapters.

CHAPTER 5

Investigation of Resistant Starch Manipulations and Antioxidant Activity of Raw, Cooked and Reheated Taewa

5.1. Introduction

5.1.1. Manipulation of Resistant Starch in Cooked Potatoes

When cooked potatoes are subjected to a period of cooling after cooking, the *in vitro* digestibility of the starch contained within them decreases (Mishra *et al.,* 2008), and the glycaemic effect of the cooked and cooled potatoes is reduced (Pi-Sunyer, 2002; Fernandes *et al.,* 2005; Leeman *et al.,* 2005; Tahvonen *et al.,* 2006).

It has been proposed that the reduction in carbohydrate digestibility of potatoes during cool storage after cooking is due to processes such as partial starch retrogradation (Karlsson and Eliasson, 2003). Starch retrogradation causes an aggregation or annealing of amylose molecules which restricts the access of digestive enzymes to the starch molecule, thus limiting or slowing its digestion and increasing both the slowly digestible starch (SDS) as well as the RS content (Sajilata *et al.,* 2006, Fuentes-Zaragoza *et al.,* 2010).

For humans, RS has been defined as starch and starch degradation products that resist digestion in the small intestine (Asp *et al.,* 1996). RS, like dietary fibre (DF), does not contribute to the postprandial rise in blood glucose, as it bypasses duodenal digestion and instead enters the human large bowel where it is fermented by resident bacterial flora (Annison & Topping, 1994; Asp *et al.,* 1996). RS also has other health benefits, such as stimulating increased digestive tract activity and providing metabolites such as short-chain fatty acids (SCFA) formed during RS fermentation in the colon that are able to be utilised by beneficial bacteria (Cummings, *et al.,* 1996; Topping & Clifton, 2001). Thus eating cooked potatoes that have been through cooling treatments to maximise potential SDS and RS is of particular benefit to persons needing to manage their blood glucose levels, and could provide additional benefits through the functional role of RS as a prebiotic substrate.

A trend towards consumption of chilled or refrigerated convenience foods such as refrigerated mashed potato and potato salads has increased in the last decade (AHDB, 2012; USPB, 2011). However, a survey of *Taewa* consumer cooking and consumption practices in Chapter 4 of this thesis found that of 200 respondents, 170 / 200, (85%) preferred to eat their Taewa warmed or hot and only 7 / 200, (3.5%) respondents indicated that they preferred to eat Taewa cold (Section 4.4.2.3.b.). As a result of these survey findings, an investigation into the impact of reheating 24 h-cooled potatoes on RS content was included as part of this study.

Thus, in order to ascertain the changes in the percentage resistant starch content (RSC) of cooked potatoes occurring due to retrogradation of starch during cooling, starch digests of boiled potato were measured in 4 Taewa cultivars (Huakaroro, Karuparera, Moemoe and Tūtaekuri), and one modern potato cultivar (Nadine) following different cooling periods. Concurrently, the effect on RSC due to reheating the cooled samples was also measured.

It was hypothesised that cooked and 24 h-cooled potatoes would have a greater RS content than either just cooked potatoes, or potatoes that have been cooked, cooled and then reheated.

5.1.2. Antioxidant Potential of Potatoes

Potatoes have recently gained recognition for their content of a diverse range of flavanols, anthocyanins and carotenoid compounds (Al-Saikhan *et al.,* 1995; Brown, 2008). Diets rich in antioxidant flavonoids and carotenoids have been associated with a lower incidence of atherosclerotic heart disease, (Hertog *et al.,* 1993; Wang *et al.,* 1999); certain cancers, (Knekt *et al.,* 1997; Van Duyn and Pivonka, 2000); macular degeneration and severity of cataracts (Brown *et al.,* 1999).

In addition to the phenolic compounds present in brown-skinned, white-yellow fleshed potatoes, potato tubers with red, blue and purple colour variations in the skin or flesh also have anthocyanin compounds which are responsible for producing their vivid colour pigmentations. Potato tubers with coloured flesh and or skins are likely to have a much greater potential total antioxidant activity than their white or yellow fleshed, brown-skinned counterparts, due to their greater overall phenolic concentration (Evers and Deuber, 2012). Thus, it is not surprising that considerable investigation of phenolic content of a range of potato cultivars has occurred in recent years by researchers around the world (Reyes, *et al.,* 2005; Hamouz *et al.,* 2007; Lachman *et al.,* 2008; Šulc *et al.,* 2008; André *et al.,* 2009; Mader *et al.,* 2009; Rumbaoa *et.al.,* 2009; Xu *et al.,* 2009; Blessington *et al.,* 2010; Natella *et al.,* 2010; Stushnoff *et al.,* 2010; Kaspar *et al.,* 2011; Madiwale *et al.,* 2011; Navarre *et al.,* 2011).

An increasing number of potato varieties with red or dark blue/purple coloured skins and/or purple flesh are being assessed for their suitability to be grown commercially around the world (Voss *et al.,* 1999; Stelljes, 2001; Reddivari, 2007; Rodriguez-Saona *et al.,* 2008). Purple Heart (purple skin; purple and white flesh) and Purple Passion (purple skin, yellow flesh) are examples of new potato cultivars that have appeared in the New Zealand supermarkets in 2009 and 2010 respectively (Crop and Food Research, 2007; Plant and Food Research, 2013).

Varieties of traditional *Taewa* tubers in New Zealand exhibit variable skin and flesh colourings, some of which have been found to provide significant antioxidant activity (Lewis *et al.,* 1998; Lister, 2001). Thus 3 Taewa tubers of varying tuber skin and flesh colours: Tūtaekuri (dark purple skin and flesh); Huakaroro (yellow skin and flesh) and Moemoe (dark purple skin, creamy flesh dotted with occasional red or purple flecks), and a modern variety: Nadine (brown skin, white flesh), will be analysed for antioxidant potential. It is hypothesised that due to the greater skin and flesh pigmentation of Tūtaekuri and Moemoe, that these two Taewa varieties will have greater antioxidant activity than either Huakaroro or Nadine.

5.2. Experiment One:

Investigation of the Resistant Starch Content (RSC) of Cooked, Cooled then Reheated Boiled Potatoes

5.2.1. Aim

The aims of this trial was to investigate; a) to what extent the percentage resistant starch content (RSC) of four common varieties of Taewa and a modern potato variety changes over a 48 h period following cooking and b) what the effects of reheating the pre-cooked, cooled potatoes had on the RSC.

5.2.2. Materials and Methods

5.2.2.1. Chemicals and Standards

The Total Starch and RS kits (pancreatic alpha-amylase (3,000 U/mL); amyloglucosidase (3300 U/mL); GOPOD reagent buffer; GOPOD reagent enzymes; D-Glucose (1 mg/mL) standard solution)) were obtained from Megazyme International Ltd., Bray, Co. Wicklow, Ireland. All other reagents and chemicals used were of analytical grade and procured from local New Zealand suppliers such as Biolab Scientific Ltd, and Global, Pure Science Ltd.

5.2.2.2. Potato tuber samples (Changes in RS in Cooked Potato Following Progressive Cooling Periods)

The tubers of four traditional New Zealand Taewa cultivars (*Solanum tuberosum* L. cv. Huakaroro, Karuparera, Moemoe, Tūtaekuri) used in this trial were sourced from a virus free programme through Tahuri Whenua (National Maori Vegetable Growers Collective), and grown at the Massey University site (40°22’40”S; 175°36’27”E) in Manawatu Silt Loam soil.

Planting of the Taewa used for the Sample 1, 2 and 3 RS analysis was carried out in October 2008 and tubers were harvested in June-July 2009. Planting of the Taewa used for Sample 4 and 5 RS analysis was carried out in October 2009 and tubers were harvested in June 2010.

Whole tubers (each 60-80 g in weight, total weight of 1-2 kg) of the modern potato cultivar (Nadine) were purchased prewashed, from Foodstuffs (NZ) Ltd, (New World supermarket, Palmerston North, NZ). Nadine was used as the modern variety for comparison as it has been used as the comparative modern variety throughout this research and it is a variety commonly available and purchased from local supermarkets.

Nadine tubers used for Sample 1, 2 and 3 RS analysis were purchased in November 2009 and stored whole in a chiller with the 2009 harvest of the four varieties of Taewa tubers just prior to analysis in November 2009. Nadine tubers used for Sample 4 and 5 RS analysis were purchased in July 2010 and stored in a chiller with the four varieties of Taewa tubers just prior to analysis in July-August 2010.

Uniformly sized tubers were selected from each cultivar. All tubers were washed to remove dirt and then patted dry prior to analysis.

RS analysis was carried out on five separate sets of potato samples (sample trials 1-5), and measured at different time points over a 0-48 h cooling period. However, data from sample trial 2 representing the 0-6 h, 24 h and 48 h portions and sample trial 3 representing the 6-12 h portions were combined in order to track changes in RS over a 48 h period.

5.2.2.2.a. Sample trial 1 RS Analysis

Unpeeled tubers (n = 3-4; total preboiled weight of 240 -270 g) were cooked by immersing them whole, into a boiling water. The potatoes were kept simmering for 30 min, drained, covered in cold water and then drained again. The tubers were then cooled at room temperature for 45 min and patted dry.

The cooked potatoes were cut into 1 cm cubes, mixed carefully in a bowl so as to keep the skin intact on the cubes and divided into 7 equal portions. One portion was used for the determination of the dry matter content (AOAC methods 930.15 and 925.10; Section 2.2.3.1). A second portion was kept aside to represent the “0 h-cooled” portion. This “0 h-cooled” portion was incubated for *in vitro* RS digestion analysis (Section 5.2.2.3.) within 2 h of cooking. The remaining five portions were stored at 4^{o}C in plastic, airtight containers labelled “2.5 h-cooled”; “5 h-cooled”; “24 h-cooled” and “48 h-cooled”.

Approximately 30 min prior to the required *in vitro* starch digestion analysis time-point, the relevant time-cooled portion was pushed through a 1.5mm metal sieve to uniformly mix the skin and flesh portions of the potato. Where necessary, skin segments were reduced to a 1.5-2 mm size with a kitchen vegetable knife and then mixed in with the potato flesh.

Once samples for the 24 h-cooled portion had been taken out for the *in vitro* starch analysis, the remainder of the potato portion was reheated by microwaving on medium power level for 1 minute in a National Genius NE-7090 (65-650wattage) oven. The portions were mixed thoroughly, 0.5 g samples were removed and analysis of the reheated time-cooled portion was commenced within 10 min of reheating. *In vitro* starch digests of reheated and non-reheated samples from the same time-cooled portion were carried out simultaneously.

5.2.2.2.b. Sample trial 2 and 3 RS Analysis

Potato preparation and cooking were as previously described for the Sample trial 1 RS analysis except that two groups of potatoes (sample trial 2 vs sample trial 3) were cooked 17 h apart for logistical purposes in order to prepare samples for starch digestions that would represent progressive two hour cooling periods between "0 h" and "12 h". Starch digestions were also carried out at "24 h" and "48 h" after cooking.

Once cooked and cubed, the first group of potatoes (Sample trial 2) were divided into six equal portions. One portion was kept aside and dry matter content determined as described previously in Chapter 2 (Section 2.2.3.1.). A second portion representing the "0 h-cooled" portion was incubated for *in vitro* starch digestion analysis within 2 h of cooking. The remaining five portions were stored at 4^{o}C in plastic, airtight containers labelled "2 h cooled"; "4 h-cooled"; "6 h-cooled"; "24 h-cooled" and "48 h-cooled" and were prepared and analysed for RS in the same manner as Sample trial 1, after the appropriate time of cooling had been achieved.

The second group of potatoes (Sample trial 3) were prepared in the same manner as for Sample trial 2. However the second group was split into five equal portions and after the portion for the determination of dry matter content was set aside, the remaining four portions were stored at 4^{o}C in plastic, airtight containers labelled "6 h-cooled", "8 h-cooled", "10 h-cooled", and "12 h-cooled" and were prepared and analysed for RS in the same manner as Sample trial 1, after the appropriate time of cooling had been achieved..

Reheated samples of 0, 2, 4, 6, 8, 10, 12, 24 and 48 h-cooled portions were reheated in the same manner as Sample trial 1 and analysed for RS at the same time as their respective cooled counterpart.

5.2.2.2.c. Sample trial 4 & 5 RS Analysis

Potato preparation and cooking of sample trials 4 and 5 were as previously described for Sample trials 2 and 3 except that the Taewa potatoes used had been harvested within two months of analysis (*cf* >6months post-harvest of Sample trials 2 and 3). Additionally, in an effort to minimise tuber variation between the two groups of cooked samples representing the "0-6 h, 24 h and 48 h-cooled" grouping and "6 – 12 h-cooled" grouping, each potato was cut in half from the bud to stolon end before cooking. Half of each potato was used for the "0 - 6 h, 24 h and 48 h-cooled" grouping (group 1) and the other half of each potato used for the "6 – 12 h-cooled" grouping (group 2). Potato samples were wrapped in foil and refrigerated at $4^{o}C$ until the time to reheat them had been reached.

5.2.2.3. RS Determination

The method used to determine the RS in cooked potato samples is described in the AOAC method 2002.02. RS was expressed as the percentage of resistant starch (anhydro-glucose) per 100 grams of fresh weight potato sample.

5.2.2.4. Statistical Analysis of Predicted RS Data

Data were analysed using the ANOVA model with Fixed Effects, Temperature (Cooled vs Cooled and Reheated); Potato Variety (Huakaroro, Karuparera, Moemoe, Tūtaekuri, Nadine); Storage (>6 months vs 2 months) and Sample (5 samples used to measure overall changes in RS due to cooling).

The factors and interactions which were proved to be significant from the ANOVA model were fitted into a linear mixed effects model and run on an R statistical program where the random effects are the potato id, and it was only fitted for the purpose of prediction estimation. The code used to predict the estimates for the prediction data was an R program (R statistical program developed by the R Core Team (2013). *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria).

The R program fits a model to the RS data by investigating which factors (the potato sample, variety of potato, the age of the potato, the temperature and the timing) were significant in having an effect on the RS content in the potato.

The model was then used to make predictions of the RS content for each contrast; storage (>6months vs <2months post-harvest); temperature (cooled vs cooled, then reheated); treatment (Samples 1-5) and variety (Huakaroro, Karuparera, Moemoe, Tūtaekuri, Nadine) combinations from time 1-51 h. Including the term "poly" allowed time to be fitted as a polynomial (e.g. time + time^2), which allowed for time to be analysed as a quadratic rather than in a linear manner. The purpose of using an R program such as this was to enable predictions to be made with regards to the change in RS of the five potato cultivars should the experiment be carried out again under similar conditions.

The R program used to predict the RS data was created on 10/01/2014, by Alison Sefton, Palmerston North, New Zealand.

The ANOVA model used was:

```
potato8.aov<-aov(rs~contrast+temp+treatmentv+varietyv+poly(time,2)+
treatmentv*varietyv+treatmentv*poly(time,2)+ varietyv*poly(time,2)+temp:poly(time,2)
+Error(id), data=potato2)
```

5.2.3. Experiment One: Results

Results of the analysis of percentage RS in cooled or cooled, then reheated potato samples from 5 potato cultivars are shown in Table 5.1 (Percentage of RS in cooled potato) and Table 5.2 (Percentage of RS in cooled, then reheated potato).

5.2.3.1. Resistant Starch Content of Cooled Potato Samples

In all cultivars, the percentage resistant starch content (RSC) increased 2-3 fold during cooling at 4^{o}C from the initial RSC in the cultivar (measured within 2-3 h of cooking) to the time point at which the maximum RSC was attained. However, the initial RSC of the sample and the extent to which the maximum percentage of RSC increased varied depending on the cultivar. The rate of the increase in RSC did not appear to follow a linear or curvilinear progression but rather suggested that RSC may rapidly increase between 0 and 6-7 h of cooling, then either continue to increase more slowly thereafter, or decrease considerably (Nb. in some cases the RSC fell very close to, or below the initial RSC levels measured between 6 and 12 h of cooling). Between 12 and 48 h of cooling the RSC of most samples reached maximal levels (Table 5.1). In addition, all Taewa varieties generally had a higher and faster rate of increase in RSC whereas Nadine had a much lower, and slower rate of increase in RSC and occasionally showed a decrease in RSC from the initial analysis taken after boiling.

Table 5.1 Percentage Resistant Starch Content (RSC) of 5 Cooked Potato Cultivars During Cooling.

Except where indicated, values shown are means of duplicate assays in 5 samples of fresh weight cooked potato for each of the five cultivars.

Sample	Hours cooled	Huakaroro	Karuparera	Moemoe	Tūtaekuri	Nadine
		Mean RSC in fresh weight potato samples				
Sample 1, >6months storage	**0**	0.54 ±0.00	0.55 ±0.01	0.34 ±0.00	0.96 ±0.01	0.36 ±0.02
	2.5	0.75 ±0.01	0.80*	0.94 ±0.02	1.45 ±0.03	0.48*
	5	0.91 ±0.00	0.96 ±0.00	0.96 ±0.00	1.53 ±0.00	0.53 ±0.00
	24	1.32 ±0.00	1.59*	1.44 ±0.06	1.96 ±0.04	0.61*
	48	1.31 ±0.01	1.34 ±0.07	1.45 ±0.06	2.06 ±0.00	0.76 ±0.01
Sample 2, >6months storage	**0 #**	0.78 ±0.02	0.75 ±0.03	0.74 ±0.03	0.84 ±0.09	0.86 ±0.12
	2	0.89 ±0.06	0.86 ±0.00	0.86 ±0.01	0.96 ±0.02	1.39*
	4	1.54 ±0.01	1.12 ±0.00	1.57 ±0.01	1.72 ±0.04	1.18 ±0.01
	6	1.12 ±0.02	0.98 ±0.06	1.09 ±0.00	1.09 ±0.04	0.79 ±0.05
	24	1.30 ±0.03	1.01 ±0.00	1.26 ±0.01	1.16 ±0.05	0.68 ±0.01
	48	1.28 ±0.02	1.09 ±0.02	1.30 ±0.02	1.23 +0.01	0.73 ±0.00
Sample 3, >6months storage	**6**	0.75 ±0.00	0.89 ±0.01	0.93 ±0.01	0.95 ±0.01	0.51 ±0.01
	8	0.91 ±0.01	1.12 ±0.01	1.10 ±0.03	1.03 ±0.05	0.55 ±0.00
	10	0.85 +0.01	0.99 ±0.01	0.87 ±0.00	0.63 ±0.04	0.44 ±0.01
	12	0.78 ±0.00	1.18 ±0.05	1.09 ±0.00	0.96 ±0.00	0.46 ±0.01
Sample 4, <2months storage	**0 #**	0.31 ±0.01	0.38 ±0.03	0.39 ±0.01	0.64 ±0.07	0.09 ±0.01
	2	0.42 ±0.01	0.33 ±0.01	0.35 ±0.01	0.27 ±0.01	0.05 +0.01
	4	0.56 ±0.05	0.66 ±0.00	0.42 ±0.03	0.64 ±0.00	0.11 ±0.01
	6 #	0.84 ±0.14	0.90 ±0.11	0.77 ±0.06	1.14 ±0.10	0.07 ±0.03
	8	0.73 ±0.03		0.65 ±0.01	0.93 ±0.04	0.15 ±0.01
	10	0.94 ±0.01	0.81 ±0.09	0.32 ±0.01	0.92 ±0.07	0.09 ±0.01
	12	0.40 ± 0.01	0.99 ±0.10	0.26 ±0.00	0.20 ±0.01	0.09 ±0.00
	24	1.08 ±0.07	0.47 ±0.00	1.17 ±0.08	1.27 ±0.06	0.25 ±0.01
	48	1.34 ±0.13	1.23 ±0.00	1.07 ±0.04	1.53 ±0.05	0.15 ±0.01
Sample 5, <2months storage	**0 #**	0.4 ±0.070	0.49 ±0.02	0.52 ±0.03	0.70 ±0.01	0.29 ±0.03
	2	0.37 ±0.03	0.57 ±0.05	0.37 ±0.04	0.77 ±0.05	0.25 ±0.01
	4	0.57 ±0.03	0.49 ±0.04	0.58 ±0.05	0.90 ±0.06	0.29 ±0.03
	6 #	0.93 ±0.06	0.70 ±0.09	0.83 ±0.01	1.11 ±0.02	0.35 ±0.01
	8	1.00 ±0.04	0.82 ±0.01	1.05 ±0.03	1.15 ±0.01	0.30 ±0.02
	10	0.43 ±0.04	0.76 ±0.00	0.90 ±0.02	1.26 ±0.00	0.40 ±0.01
	12	1.00 ±0.02	1.02 ±0.03	0.71 ±0.01	1.59 ±0.16	0.29 ±0.02
	24	0.7 ±0.02	0.80 ±0.02	0.95 +0.06	1.36 ±0.04	0.55 ±0.10
	48	1.41 ±0.07	1.54 ±0.11	1.50 ±0.06	1.58 ±0.07	0.50 ±0.00

Key: * = represents one observation only due to one duplicate being lost; # = mean of four observations; blank = both duplicates lost

All Taewa, (except Karuparera in Sample trial 2) had a greater maximum RSC than Nadine in all five of the sample trials tested after the same period of cooling. Of all five cultivars, Tūtaekuri generally had the greatest initial RSC measurement (except in Sample trial 2); attained the greatest maximum RSC in all five sample trials undertaken (except in Sample trial 3) and also achieved the greatest maximum RSC range (1.53 ±0.05 - 2.06 ±0.00 g/100 g FW whole tuber samples). Huakaroro attained a maximum RSC range of 1.32 ±0.00 – 1.54 ±0.01 g/100 g FW whole tuber samples, Moemoe 1.17 ±0.08 – 1.57 ±0.01 g/100 g FW whole tuber samples and Karuparera 1.12 ±0.00 – 1.59 ±0.00 g/100 g FW whole tuber samples. Nadine had the lowest maximum RSC range of all five cultivars at 0.25 ±0.00 – 1.39 g/100 g FW whole tuber samples.

5.2.3.2. Resistant Starch Content of Cooled, then Reheated Potato Samples

In general, reheating cooled samples for a minute in a microwave at medium power appeared to slightly decrease the RSC content compared to the cooled equivalent sample that had been measured after a similar period of cooling. The cooled then reheated samples also appeared to follow a non-linear, non-curvilinear rate in RSC increase as cooling time progressed with a similar pattern in rapid increase between 0 and 6-7 h of cooling, but then a fall between 8 – 12 h followed by a second increase occurred thereafter at some point between 12, 24 or 48 h cooling.

Again, despite being reheated, Tūtaekuri achieved the greatest maximum RSC range of all five cultivars (1.10 ±0.01 – 1.77 ±0.05 g/100 g FW whole tuber samples) and for all sample trial portions measured (except Sample trial 5, after 8 h cooling where Moemoe achieved the greatest maximum RSC of 1.38 ±0.08 g/100 g FW whole tuber samples). Again, all Taewa (except Karuparera, Sample trial 2 after 2 h of cooling) had a greater maximum RSC than Nadine for all sample portions measured after a similar period of cooling. Huakaroro achieved a maximum RSC range of 0.76 ±0.00 – 1.48 ±0.01 g/100 g FW whole tuber samples; Moemoe 1.03 ±0.02 – 1.57 ±0.01 g/100 g FW and Karuparera 0.96 ±0.05 – 1.37 ±0.09 g/100 g FW. Nadine again attained the lowest maximum RSC range of all five cultivars at 0.31 ±0.01 – 1.20 ±0.02 g/100 g FW whole tuber samples (Table 5.2).

Table 5.2 **Percentage of Resistant Starch Content (RSC) of 5 Cooked Potato Cultivars which were Cooled and Reheated.**

Except where indicated, values shown are means of duplicate assays in 5 samples of fresh weight cooked potato for each of the five cultivars.

Sample	Hours Cooled	Huakaroro	Karuparera	Moemoe	Tūtaekuri	Nadine
		Mean RSC in fresh weight potato samples ± standard error				
Sample 1, >6months storage	**24**	O.84 ±0.03	1.02*	1.14 ±0.01	1.57 ±0.02	0.51*
Sample 2, >6months storage	**2**	0.84 ±0.02	0.56 ±0.01		0.95 ±0.02	0.82 ±0.16
	4	1.48 ±0.01	1.18 ±0.00	1.57 ±0.01	1.77 ±0.05	1.20 ±0.02
	6	1.02 ±0.00	0.85 ±0.01		0.87 ±0.01	0.82 ±0.02
	24	0.92 ±0.01	0.89 ±0.02	0.99 ±0.02	1.01 ±0.02	0.67 ±0.01
	48	0.91 ±0.01	1.08 ±0.02	0.90 ±0.01	1.10 ±0.01	0.71 ±0.00
Sample 3, >6months storage	**6**	0.67 ±0.02	0.78 ±0.07	1.00 ±0.02	1.10 ±0.01	0.57 ±0.04
	8	0.76 ±0.00	1.02 ±0.01	0.88 ±0.00	0.75 ±0.01	0.31 ±0.00
	10	0.75 ±0.02	0.63 ±0.01	0.71 ±0.02	0.67 ±0.01	0.48 ±0.00
	12	0.73 ±0.01	0.72 ±0.00	1.03 ±0.02	0.86 ±0.01	0.41 ±0.01
Sample 4, <2months storage	**2**	0.36 ±0.02	0.38 ±0.03	0.27 ±0.02	0.29 ±0.01	0.14 ±0.00
	4	0.68*	0.69 ±0.02	0.43 ±0.02	0.65 ±0.08	0.15 ±0.00
	6 #	0.92 ±0.12	0.91 ±0.06	0.59 ±0.22	1.02 ±0.04	0.18 ±0.01
	8	0.50 ±0.02	0.52 ±0.01		0.66 ±0.04	0.22 ±0.00
	10	0.19 ±0.01	0.22 ±0.02	0.41 ±0.02	0.58 ±0.04	0.17 ±0.01
	12	0.08 +0.00	0.59 ±0.01	0.41 ±0.04	0.67 ±0.04	0.11 ±0.00
	24	1.15 ±0.07	0.96 ±0.05	1.37 ±0.02	1.55 ±0.16	0.31 ±0.01
	48	1.09 ±0.07	0.45 ±0.02	1.04 ±0.02	1.68 ±0.17	0.21 ±0.00
Sample 5, <2months storage	**2**	0.30 ±0.05	0.62 ±0.03	0.28 ±0.04	0.38 ±0.03	0.20 ±0.02
	4	0.49 ±0.02	0.33 ±0.03	0.67 ±0.14	0.49 ±0.05	0.17 ±0.04
	6 #	0.92 ±0.13	0.41 ±0.11	0.68 ±0.04	1.06 ±0.03	0.32 ±0.01
	8	0.75 ±0.02	0.24 ±0.04	1.38 ±0.08	0.99 ±0.07	0.32 ±0.01
	10	0.30 ±0.05	0.65 ±0.01	0.74 ±0.00	0.93 ±0.02	0.33 ±0.00
	12	0.66 ±0.02	0.79 ±0.01	0.43 ±0.05	0.72 ±0.02	0.31 ±0.04
	24	0.87 ±0.06	0.42 ±0.06	0.55 ±0.05	1.00 ±0.03	0.34 ±0.03
	48	0.74 ±0.02	1.37 ±0.09	0.57 ±0.02	1.21 ±0.08	0.25 ±0.00

Key: * = represents one observation only due to one duplicate being lost; # = mean of four observations; blank = both duplicates lost

5.2.3.3. Prediction of Change in Percentage Resistant Starch Content (RSC)

Due to the logistical limitations in being able to prepare assays at evenly-spaced 2 h periods over the 48 h-cooling period and the variation this introduced into the data, prediction models were used to estimate the increase in RS that would be expected to occur by combining all the values for each respective "sample trial" (included all duplicates, and at all time periods measured within each cultivar).

This was done using the R statistical program for both the cooled, and cooled then reheated data. Results of the statistical analysis are summarised in Table 5.3 while a summary of the predicted RSC of each cultivar between 1-50 h of cooling are summarised in Table 5.4 (cooled samples) and Table 5.5 (cooled then re-heated samples).

ANOVA statistical analysis showed that temperature (cooled vs cooled and reheated); potato variety (Huakaroro, Karuparera, Moemoe, Tūtaekuri and Nadine); post-harvest storage time (>6 months vs 2 months); as well as each potato sample trial set had a significant effect (P <0.001) on RSC (Table 5.3).

Table 5.3 **ANOVA Statistical Analysis of Changes in Potato Resistant Starch Content Due To Cooling and Reheating Treatments**.

(Fixed Effects: Temperature (Cooled vs Cooled and Reheated); Potato Variety (Huakaroro, Karuparera, Moemoe, Tūtaekuri, Nadine); Storage (>6 months vs 2 months); Sample (5 samples used to measure overall changes in RS due to cooling).

Effects	**df**	**Sum Sq**	**Mean Sq**	**F value**	**Pr (> F)**
Error: ID					
contrast	1	0.037	0.037		
Error: Within					
Contrast	1	0.037	0.037		
Temperature (temp)	1	0.899	0.899	17.687	<0.001
Potato Variety (var)	3	26.263	8.754	172.301	<0.001
Storage (sto)	1	14.526	14.526	285.900	<0.001
Sample (sample)	3	3.348	1.116	21.967	<0.001
Poly (time, 2)	2	12.985	6.492	5,163	<0.001
sample x var	16	4.197	0.262	5.163	<0.001
sample x poly(time, 2)	8	3.330	0.416	8.193	<0.001
var x poly(time, 2)	8	2.587	0.323	6.364	<0.001
temp x poly(time, 2)	2	1.063	0.532	10.464	<0.001
Residuals	591	30.028	0.051		

Key: df = degrees of freedom; P value <0.001 equates to > 99.99% confidence in significant difference; The response variable is “rs” which is the resistant starch.

5.2.3.4. *Prediction of Changes in Percentage Resistant Starch Content (RSC) of Boiled Potato due to Cooling; Cooling then Reheating*

5.2.3.4.a. Effect of Cooling Cooked Potato for 1-51 h Periods on RSC

The prediction data showed that in all five cultivars, RSC is likely to increase in a curvilinear type fashion in boiled and 4^{o}C cooled potato samples, up to the time the maximum RSC is achieved. In the Taewa cultivars, and sample trials 1, 4 and 5, RSC had increased by 43-79% after 24 h of cooling, and then by an additional 14-30% thereafter. In sample trial 2 across all cultivars, the RSC at 1 h was much higher than in other sample trials although the maximum RSC reached was generally comparable to sample trials 1, 4 and 5. In Nadine across all sample trials, the rate of increase in RSC was both slower and to a lesser extent (See Table 5.4, and Figures 5.1a, c, e, g and i for the effect of cooling on RSC).

Between 24 and 48 h of cooling or soon after, RSC appeared to plateau and reach the maximum RSC. After the maximum RSC is achieved, RSC appears to slightly decrease as cooling time progresses. The rate and extent of the RSC increase varied depending on the potato cultivar. Of all five potato cultivars, Moemoe and Nadine generally reached their maximum RSC earlier and Karuparera last.

Tūtaekuri is likely to achieve the greatest RSC in whole, boiled, cooled potato (1.45-2.09% /100 g FW), followed by Moemoe (1.19-1.50% /100 g FW), Karuparera (1.15-1.46% /100 g FW), Huakaroro (1.24-1.38% /100 g FW), with the least RSC in Nadine (0.44-0.98% /100 g FW).

The rate and extent of the RSC increase also varied depending on the length of time the potatoes had been stored postharvest prior to cooking. Sample trials 1, 2 and 3 were from potatoes that had been stored for over 6months, whereas sample trials 4 and 5 were from potatoes that had been stored for less than 2 months. The maximum RSC appeared to be reached earlier in whole, boiled, cooled potato samples that had been stored for over 6 months prior to cooking (32-50 h) compared to those that had been stored for less than 2 months (42-51 h). Additionally, greater maximum RSC was generally seen across all five cultivars in whole, boiled, cooled potato samples that had been stored for over 6 months prior to cooking (0.78-2.09% /100 g FW) compared to those that had been stored for less than 2 months (0.44-1.62% /100 g FW).

Table 5.4 **Predicted Change in Percentage Resistant Starch Content of Cooked Potato Samples over 51 h Due to Cooling at 4^{o}C.**

Results shown are the predicted change in % Resistant Starch Content in 5 separate sample trials for 5 potato cultivars.

Sample	Cooling Period (hour)	Huakaroro	Karuparera	Moemoe	Tūtaekuri	Nadine
		Predicted % RSC after selected hours of cooling at 4^{o}C				
Sample 1, >6months storage	**1**	0.55	0.69	0.63	1.13	0.41
	6	0.75	0.85	0.86	1.35	0.51
	12	0.95	1.02	1.08	1.58	0.61
	24	1.24	1.27	1.39	1.92	0.74
	48	1.35	1.46	1.43	2.06	0.72
Time (hour) and max % RS attained		*(40) 1.38*	*(47) 1.46*	*(37) 1.50*	*(41) 2.09*	*(35) 0.78*
Sample 2, >6months storage	**1**	0.99	0.89	0.99	0.99	0.98
	6	1.08	0.94	1.11	1.11	0.97
	12	1.16	0.99	1.22	1.22	0.96
	24	1.28	1.08	1.35	1.38	0.92
	48	1.27	1.15	1.28	1.41	0.78
Time (hour) and max % RS attained		*(35) 1.32*	*(50) 1.15*	*(32) 1.38*	*(38) 1.45*	*(1) 0.98*
Sample 3, >6months storage	**6**	0.83	1.00	0.99	0.94	0.60
	12	0.84	0.98	1.02	0.98	0.51
Sample 4, <2months storage	**1**	0.41	0.45	0.32	0.56	0.07
	6	0.59	0.59	0.52	0.76	0.14
	12	0.77	0.74	0.73	0.98	0.23
	24	1.06	0.99	1.03	1.30	0.35
	48	1.27	1.28	1.17	1.55	0.44
Time (hour) and max % RS attained		*(47) 1.27*	*(51) 1.30*	*(42) 1.19*	*(47) 1.55*	*(45) 0.44*
Sample 5, <2months storage	**1**	0.49	0.51	0.49	0.73	0.29
	6	0.64	0.62	0.66	0.90	0.34
	12	0.79	0.74	0.84	1.09	0.39
	24	1.03	0.94	1.10	1.37	0.47
	48	1.24	1.24	1.24	1.62	0.56
Time (hour) and max % RS attained		*(50) 1.24*	*(51) 1.26*	*(43) 1.25*	*(50) 1.62*	*(51) 0.56*

5.2.3.4.b. Effect of Reheating Cooked and Cooled Potatoes on RSC

The prediction data shows that in all five cultivars, RSC of reheated cooked and cooled potato generally follows a similar pattern in rate and extent of increase of RSC compared to a non-reheated cooled sample. However, reheated samples were both slower in rate of increase and lower in regards to the extent of RSC attained (Table 5.5, Figures 5.1b, d, f, h, j).

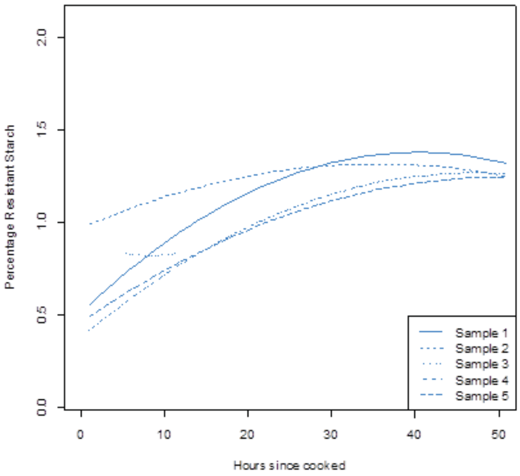
Table 5.5 Predicted Change in Percentage Resistant Starch Content of Cooked Potatoes Due to Cooling Periods of 1-51 h at 4°C, followed by Reheating.

Sample	Cooling Period (hour)	Huakaroro	Karuparera	Moemoe	Tūtaekuri	Nadine
		Predicted % RSC after selected hours of cooling at 4°C, then reheating				
Sample 1, >6months storage	1	0.59	0.73	0.67	1.16	0.44
	6	0.71	0.81	0.82	1.31	0.47
	12	0.84	0.90	0.96	1.47	0.50
	24	1.01	1.05	1.16	1.69	0.52
	48	1.08	1.19	1.16	1.79	0.45
Time (hour) and max % RS attained		*(40) 1.10*	*(51) 1.20*	*(36) 1.23*	*(41) 1.81*	*(25) 0.52*
Sample 2, >6months storage	1	1.02	0.92	1.03	1.02	1.01
	6	1.04	0.90	1.07	1.06	0.93
	12	1.05	0.88	1.10	1.11	0.84
	24	1.06	0.85	1.13	1.16	0.69
	48	1.00	0.88	1.01	1.14	0.51
Time (hour) and max % RS attained		*(22) 1.06*	*(1) 0.92*	*(24) 1.13*	*(33) 1.17*	*(1) 1.01*
Sample 3, >6months storage	6	0.79	0.96	0.95	0.90	0.56
	12	0.73	0.86	0.91	0.87	0.40
Sample 4, <2months storage	1	0.45	0.48	0.35	0.59	0.10
	6	0.55	0.54	0.48	0.72	0.10
	12	0.66	0.62	0.61	0.86	0.11
	24	0.83	0.76	0.81	1.08	0.13
	48	1.00	1.01	0.90	1.28	0.17
Time (hour) and max % RS attained		*(51) 1.00*	*(51) 1.04*	*(42) 0.92*	*(51) 1.28*	*(51) 0.17*
Sample 5, <2months storage	1	0.52	0.54	0.52	0.76	0.32
	6	0.60	0.58	0.62	0.86	0.30
	12	0.67	0.62	0.72	0.97	0.27
	24	0.81	0.72	0.87	1.15	0.25
	48	0.97	0.97	0.97	1.35	0.29
Time (hour) and max % RS attained		*(51) 0.99*	*(51) 1.00*	*(45) 0.98*	*(51) 1.36*	*(1) 0.32*

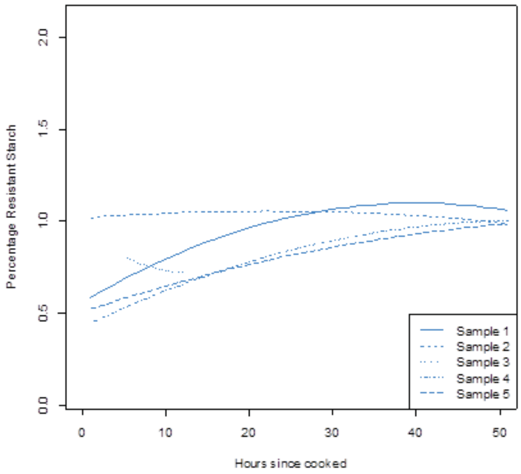
Figure 5.1 **Change in Resistant Starch Content in Boiled Potatoes Due to Cooling and Reheating.**

Graphs were generated from the means of 2-4 replicate analysis of five separate sample trials and expressed as g RS/100 g of boiled potato (FW basis).

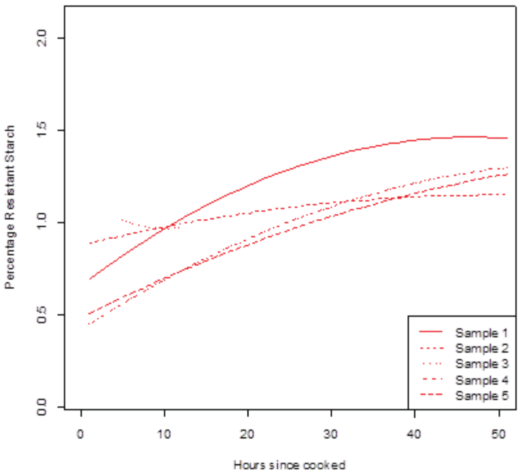
a) Cooled Huakaroro



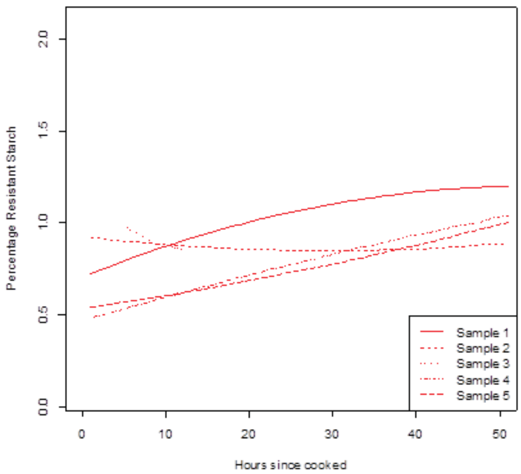
b) Cooled then Reheated Huakaroro



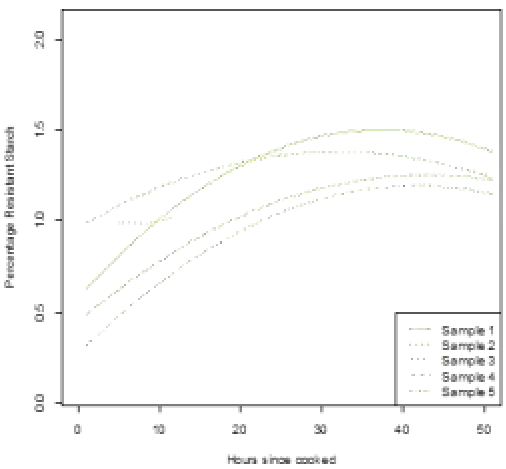
c) Cooled Karuparera



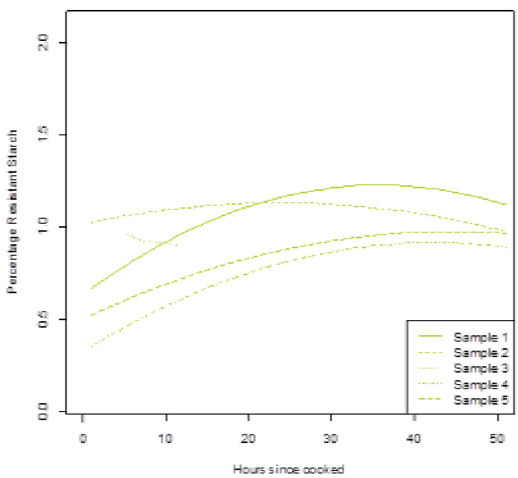
d) Cooled then Reheated Karuparera



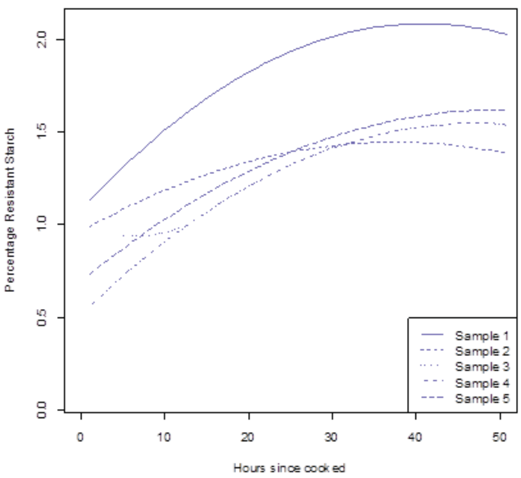
e) Cooled Moemoe



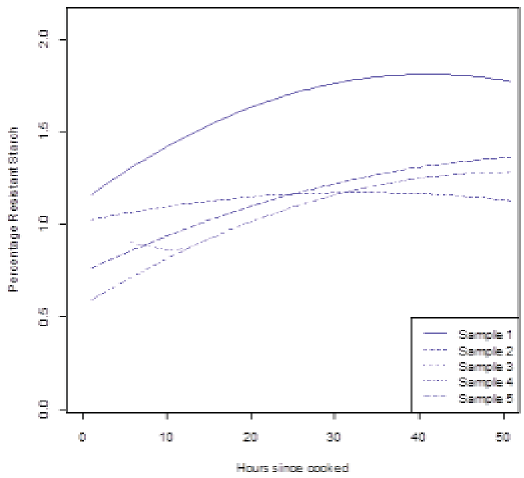
f) Cooled then Reheated Moemoe



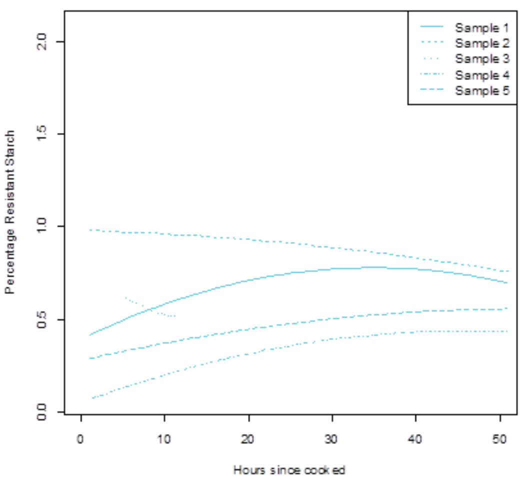
g) Cooled Tūtaekuri



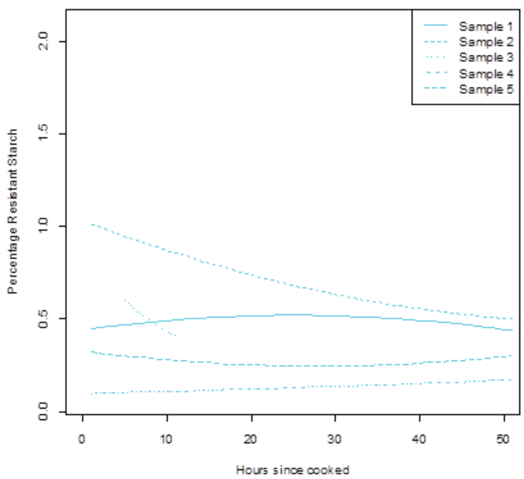
h) Cooled then Reheated Tūtaekuri



i) Cooled Nadine



j) Cooled then Reheated Nadine



In Taewa cultivars for potato sample trials 1, 4 and 5; RSC had increased 18-53% after 24 h of cooling, however in Nadine and in sample trial 2 of all cultivars minimal increases or even losses in RSC occurred by 24 h of cooling. As the reheated samples generally followed a similar pattern to non-reheated samples with regards to accruing RSC, Moemoe and Nadine again reached their maximum RSC before 45 h while Karuparera, Huakaroro and Tūtaekuri generally reached their maximum RSC later, or may not have even reached their maximum RSC by 51 h.

Tūtaekuri achieved the greatest RSC in whole, boiled, cooled then reheated potato (1.17-1.81% /100 g FW), followed by Moemoe (0.92-1.23% /100 g FW), Karuparera (0.92-1.20% /100 g FW), Huakaroro (0.99-1.10% /100 g FW), with the least RSC in Nadine (0.17-1.01% /100 g FW).

As for the non-reheated samples, the maximum RSC was generally reached earlier than in the reheated samples when the potatoes were stored for over 6 months prior to cooking compared to those that had been stored for less than 2 months. Greater maximum RSC was generally seen across all five cultivars in whole, boiled, cooled then reheated potato samples that had been stored for over 6 months prior to cooking (0.52-1.81% /100 g FW) compared to those that had been stored for less than 2 months (0.17-1.36% /100 g FW).

5.2.4. Experiment One: Discussion

In the raw potato tuber, starch may contribute from 8 – 29% of the tuber's fresh weight and thus is the major contributor to the total tuber carbohydrate content (Table 1.3). Raw potato starch cannot be digested by humans, so potatoes are generally prepared for consumption by a number of cooking methods such as boiling (with or without the skin), baking, steaming, microwaving or frying. Following cooking, potato starch becomes highly digestible, but upon cooling, a percentage of the potato starch will retrograde and form slowly digestible starch (SDS) or retrograded resistant starch (RS_3 starch) (Englyst *et al.,* 1992; Brown *et al.,* 1995).

These changes in starch due to heating and cooling have a profound influence on the functional properties of foods (such as potatoes) but are also of significant nutritional importance because they influence the relative digestibility of starch in the gastrointestinal tract and thus will effect blood glucose levels and the contribution of substrates available for beneficial colonic bacteria (as discussed in Section 1.3.1.2). Hence the purpose of this experiment was to follow the change in the percentage of resistant starch content (RSC) in four or five potato cultivars that had been boiled over 48 h of cooling at 4^{o}C so as to determine a) the extent of RSC accrued by 24 and 48 h of cooling b) to what extent RSC might be accrued in 3-4 cultivars of Taewa compared to Nadine in order to collect information for the development of future Taewa products that would be able to be marketed as having improved health benefits.

5.2.4.1. Change in Percentage of Resistant Starch Content of Cooked Potatoes during Cooling

Tracking the change in percentage resistant starch content (RSC) over 48+ h of cooling from time of cooking showed that when compared to the initial RSC of the five potato cultivars analysed (Huakaroro, Karuparera, Moemoe, Tūtaekuri, Nadine), the RSC increased 1.5 to approximately 2-fold during the first 24 h period of cooling. Further increases in RSC between 24 and 48 h occur, however by 50 h of cooling, the RSC plateaued or had begun to decrease.

These results are similar to those found by other researchers. García-Alonso and Goni (2000) found that RSC increased from 0.22% to 0.95% FW in boiled potatoes (cultivar not specified) which were then cooled in a refrigerator ($4^{o}C$) for 24 h. Monro *et al.,* (2009) examined the effects of relative starch digestibility in nine modern NZ potato cultivars following cooking and then cooling. After cooling of boiled potatoes for 44 h at $4^{o}C$, RSC almost doubled within each cultivar with a range in RSC of 0.58-1.05 g/100 g FW in whole, just boiled potato which increased to 0.76-1.96 g/100 g FW in whole, boiled then 44 h-cooled potato (Monro *et al.,* 2009).

Thus, although cooling cooked potato for up to 48 h may enable a greater RSC to be accrued compared to that at 24 h cooling, the increases in RSC over the additional 24 h is likely to be minimal, but the extended cold storage may have an effect on consumer sensory acceptability due to the development of undesirable changes in flavour, texture or appearance.

A rapid increase or sharp peak in RSC may also occur sometime between 5 – 12 h of cooling (Section 5.2.3.1, Table 5.1). Should this peak occur, consumers may be able to maximise RSC while minimising the affect that cold storage may have on sensory acceptability. However multiple assays of the same potato cultivar at multiple time-points between 5 and 12 h of cooling is recommended to fully characterise the rapid increases and/or peaks shown in the analyses. The results obtained may have been subject to experimental error and generally relate to duplicate observations only at each time point for each cultivar.

Mishra *et al.,* (2008) found that cooling boiled potato for 44 h at $4^{o}C$ caused a 2 – 9 fold increase in the SDS component of the total starch content compared to the un-cooled samples in nine modern, New Zealand potato cultivars. However, the extent of the SDS increase depended on the cultivar. Of interest was the fact that Nadine accrued the least SDS of the nine cultivars studied, while Frisia, another “waxy” type variety accrued the greatest SDS content (Mishra *et al.,* 2008). Thus it appears that the cooked textural characteristics of a tuber (waxy vs floury), may not necessarily predict the extent of starch retrogradation of a tuber during cooling. Retrogradation measured at 2, 6 and 24 h of cooling at $6^{o}C$ following blanching was also shown to increase as the cooling period increased in two modern cultivars, but the extent of retrogradation differed between the cultivars (Karlsson and Eliasson, 2003). Monro *et al.,* (2009) also found vast differences in starch digestibility components between nine modern New Zealand potato cultivars (Draga, Nadine and Frisia (waxy); Desiree, Karaka and Moonlight (general purpose); and Agria, Fronkia, White Delight (floury)) as well as between 37 other potato lines (unable to be named due to commercial sensitivity).

These studies suggest that there are likely to be inherent cultivar differences that will also impact on the relative starch digestibility components. Of the five cultivars studied in this research, Tūtaekuri is likely to have the greatest and Nadine the least initial RSC immediately following boiling as well as the greatest and least RSC respectively, after 24 h and 48 h cooling. Nadine was one of the nine cultivars measured by Monro *et al.,* (2009) and in their study the RSC in Nadine increased after boiling from 0.93 g to 1.57 g/100 g FW following 44 h cooling at 4°C whereas in the current study I found that Nadine generally accrued a lower maximum RSC (0.25 ±0.00 – 1.39 g/100 g FW whole tuber samples (Table 5.1).

The difference in RSC present in the Taewa (particularly Tūtaekuri) compared to Nadine are likely due to inherent cultivar differences and their respective dry matter and total starch content (Table 5.6). However, Tūtaekuri also appears to accumulate RSC at a much greater rate than Nadine over a 24 h period of cooling as shown by the fact that Tūtaekuri had accrued 2-3 times more RSC as Nadine by 24 h. Huakaroro, Karuparera and Moemoe are each likely to have a slightly different rate and extent of increase in RSC over 24 or 48 h of cooling but all are likely to accumulate a greater RSC than Nadine. Thus these four Taewa (in particular Tūtaekuri), are likely to have greater benefits with regards to potential RSC than Nadine and comparable RSC compared to other modern New Zealand cultivars.

5.2.4.2. Change in Percentage of Resistant Starch Content due to Reheating Cooled Potato

In general, reheating cooled samples for 1 min in a microwave at medium power appeared to slightly decrease the RSC content (Section 5.2.3.2.; Figures 5.1b, d, f, h, j), compared to the cooled, un-reheated equivalent (Figures 5.1a, c, e, g, i). However, this decrease in RSC due to reheating did not always occur. Sample trial 4, of the original (unpredicted) data showed that after 24 h cooling, the reheated samples for all cultivars achieved a greater RSC than their 24 h-cooled, un-reheated equivalent (Section 5.2.3.2).

It is possible that the reheated samples had cooled again prior to RSC analysis taking place, and thus further digestible starch had retrograded, adding to that starch that had already retrograded prior to cooling, however all sets samples were analysed similarly, so this could be a batch effect.

5.3. Experiment Two:

Total Starch Content and Resistant Starch Content and Antioxidant Activity of Raw, Freshly Boiled, 24 h-Cooled, and 24 h-Cooled and Reheated Potato Tuber Samples

5.3.1. Aim

The aims of this trial was to investigate; (a) to what extent the dry matter (b) percentage total starch content (c) resistant starch content (RSC) and (d) antioxidant activity of three common varieties of Taewa and a modern potato variety changes during a series of common household processing techniques. The sequence of processing techniques to be measured included: a) cooking by boiling in hot water; b) cooling at 4^{o}C for 24 h following cooking and then reheating to 18^{o}C; and c) cooling at 4^{o}C for 24 h following cooking and then reheating to 55^{o}C.

5.3.2. Materials and Methods

5.3.2.1. Chemicals and Standards

The Total Starch and RS kits (pancreatic alpha-amylase (3,000 U/mL); amyloglucosidase (3300 u/mL); GOPOD reagent buffer; GOPOD reagent enzymes; D-Glucose (1 mg/mL) standard solution)) were obtained from Megazyme International Ltd., Bray, Co. Wicklow, Ireland. 2,4,6-tripyridyl-s-triazine (TPTZ); sodium acetate; ferric chloride; gallic acid; Folin-Ciocalteu's phenol reagent; ferrous sulphate; 2, 2-diphenyl-1-picrylhydrazyl (DPPH); ascorbic acid; and 6-hydroxy-2,5,7,8-tetramethyl-chroman-2-carboxylic acid (Trolox) were obtained from Sigma Chemical Inc., Australia. All other reagents and chemicals used were of analytical grade and procured from New Zealand chemical suppliers such as Biolab Scientific Ltd, Global, Pure Science Ltd.

5.3.2.2. Changes in Total and Resistant Starch Content and Antioxidant Activity in Potato tuber samples due to Boiling, 24 h Cooling and Reheating

Tubers of three traditional New Zealand Taewa cultivars (*Solanum tuberosum* L. cv. Huakaroro, Moemoe, Tūtaekuri) were sourced from a virus free programme through Tahuri Whenua (National Maori Vegetable Growers Collective), and sown on September 15th 2011 and grown in buckets of potting mix soil. Harvesting was carried out in late March 2012 and analytical work was carried out from May to July 2012.

Tubers from the modern potato cultivar (Nadine) were purchased prewashed, from Foodstuffs (NZ) Ltd, New World supermarket in Palmerston North in May, 2012. Raw, uniformly sized tubers (2 kg) were selected from each cultivar. All tubers were washed to remove dirt and then patted dry. In order to minimise variation while the potato samples went through the various analyses, dry matter content; starch determinations (RS and total starch) and antioxidant activity were carried out concurrently.

5.3.2.2.a. Raw Potato

Whole, unpeeled potatoes (approximately 700 g; 6-8 tubers) were cut into wedges, then homogenised in a kitchen processor to ensure even mixing of the skin and flesh. Once mixed, samples were partitioned out for antioxidant (Ferric Reducing Antioxidant Power (FRAP), Total Phenolic Content (TPC), and diphenyl-picrylhydrazyl (DPPH) assays); RS / total starch; and dry matter /moisture analysis on fresh raw homogenised sub-samples and for antioxidant (FRAP, TPC and DPPH assays), analysis on ethanol extracted raw, freeze-dried sub- samples.

5.3.2.2.b. Preparation and Treatment of Boiled Potato

Unpeeled, whole potato (approximately 1.3 kg) were cooked by immersing the potatoes into a boiling 1.5 L 1% NaCl solution. The potatoes were brought to the boil, simmered for 30 min, drained, covered in cold water and then drained again. They were then cooled at room temperature for 45 min and patted dry. A representative boiled sample (320 – 350 g) was set aside for the analysis of "Just boiled" potato samples. The remaining boiled potato sample (~960 - 1030 g) was put into a fridge at 4^{o}C and cooled for 24 h to be used for future analysis of boiled, 24 h-cooled and warmed to 18^{o}C samples or boiled, 24 h-cooled and warmed to 55^{o}C samples.

5.3.2.2.c. "Just Boiled" Potato Samples

Once cooled to room temperature (18^{o}C), the whole, unpeeled cooked potato sample (320-350 g) was cut into 1cm cubes, pushed through a 1.5mm metal sieve and carefully mixed. The sample was then partitioned out for antioxidant (FRAP, TPC and DPPH assays), RS / total starch and dry matter / moisture analysis on the freshly boiled sub-sample, and for antioxidant (FRAP, TPC and DPPH assays), analysis on ethanol extracted freeze-dried sub-sample.

5.3.2.2.d. Boiled, 24 h-cooled , Warmed to 18^{o}C or 55^{o}C Potato Samples

Boiled, 24 h-cooled whole, unpeeled potato samples (550-600 g) were taken out of the fridge and cut into 1cm cubes with care to keep the skin segments attached.

A representative portion (approximately 300 g each) of cubed potato was warmed in enclosed metal bain-marie trays sitting in water baths set at either 18^{o}C or 55^{o}C for 30 min. The 18^{o}C or 55^{o}C warmed cubes were then pushed through a 1.5mm metal sieve and mixed and partitioned out for antioxidant, RS / total starch and dry matter / moisture analysis for fresh analysis as previously described for the "Just Boiled" samples. The remaining boiled, 24 h-cooled whole potatoes (approximately 400 g) were sliced to <1cm thickness, placed in a single layer in zip-lock plastic bags and frozen at -20^{o}C, then freeze-dried to be used for future antioxidant analysis.

5.3.2.3. Dry Matter

Dry matter content of the samples was determined using the AOAC methods 930.15 and 925.10.

5.3.2.4. In Vitro Starch Digestion

The method used to determine the RS and non-resistant (solubilised) starch concentration in cooked potato samples is described in the AOAC method 2002.02.

5.3.2.5. Antioxidant Analysis

Sourcing and preparation of potato samples was as described in Section 5.3.2.2. All samples destined for antioxidant analysis were washed, cleaned, weighed and prepared for cooking or reheating in a manner analogous to those that might be used in any household kitchen. However, once the samples were ready for phenolic extraction, every effort was made to minimise as little interference due to light degradation as possible. This included weighing out samples in a darkened room; keeping samples in metal pots with lids on during cooling; storing samples in foil-covered bags or containers; and phenolic analyses being carried out in a darkened room.

5.3.2.5.a. "Fresh", Water-Extracted Potato Tuber Samples (Used for FRAP, TPC and DPPH analysis)

Representative samples of raw; just boiled; 24 h-cooled and warmed to 18^{o}C; and 24 h-cooled and warmed to 55^{o}C potatoes were prepared as described in Section 5.3.2.2. In a darkened room, an Ultraturrex LabServ Homogeniser (D500 Series, BioLab Ltd, Auckland, NZ); was used to blend 1 part potato sample with 1 part milliQ water at 10,000rpm (~ 14500 x *g*) for 10 min.

The sample was centrifuged in a Sorvall Evolution RC centrifuge (Kendro Laboratory Products, Newton, Connecticut, USA) at 10,000 rpm (~14500 x *g*) for 5 min to remove plant debris before the supernatant was removed into aluminium foil-covered 25 mL plastic tubes. The tubes were stored at -20^{o}C until ready for Ferric Reducing Antioxidant Power (FRAP), Total Phenolic Content (TPC), and diphenyl-picrylhydrazyl (DPPH) antioxidant analysis.

5.3.2.5.b. Freeze-dried, Ethanol-Extracted Potato Tuber Samples (Only used for FRAP analysis)

Representative samples of raw; just boiled; 24 h-cooled and warmed to 18^{o}C; and 24 h-cooled and warmed to 55^{o}C potatoes were prepared as described in Section 5.3.2.2. Freeze-dried samples were ground using a low-speed / low-heat coffee and spice grinder (Model: CG2B, Breville Ltd., China) in a darkened room. Ground samples were kept in zip-locked plastic bags and then stored together in foil bags until analysis.

Ground freeze-dried potato samples (1 g) were accurately weighed into 50 mL, aluminium foil-covered falcon tubes in a dark room. Polyphenols within the potato sample were then extracted in 10 – 25 mL of solvent mixture which was comprised of an 80 : 20 : 5 ratio of absolute ethanol; MilliQ water and 99% formic acid. The potato and solvent were mixed using an Ultraturrex LabServ Homogeniser (D500 Series, BioLab Ltd, Auckland, NZ) at a speed of 10,000 rpm (~ 14500 x *g*) for ~1 min. These were allowed to stand for 30 min before being centrifuged in a Sorvall Evolution RC centrifuge (Kendro Laboratory Products, Newton, Connecticut, USA) at 3000 rpm (~ 1942 x *g*) for 10 min. The supernatant was removed into aluminium foil-covered 25 mL plastic tubes and stored at -20^{o}C until ready for FRAP analysis.

5.3.2.6. Total Phenolic Content Analysis

The amount of total phenolic content (TPC) in potato tuber extracts was determined according to the Folin-Ciocalteu procedure as described by Molan *et al.,* (2008b) with some modifications (Molan *et al.,* 2009). The TPC of the extract was expressed as mg gallic acid equivalent (GAE) per gram of potato tuber on a fresh weight basis.

5.3.2.7. Ferric Reducing Antioxidant Power (FRAP) Analysis

The method used to determine FRAP in extracted potato tuber samples is based on the protocol described by Benzie and Strain (1996), with minor modifications. Briefly, an aliquot (8.5 µL) of extracted potato tuber was added to 275 µL of diluted FRAP reagent on a microplate which was incubated at 37^{o}C for 30 min.

Absorbance was then measured at 595 nm using a Wallac 1420 Multilabel Counter plate reader (Victor3, Perkin Elmer Life and Analytical Sciences, Turku, Finland). The working FRAP reagent was prepared by mixing 10 volumes of 300 mmol/L acetate buffer, pH 3.6, with 1 volume of 10 mmol/L TPTZ (2,4,6-tripyridyl-s-triazine) in 40 mmol/L hydrochloric acid and with 1 volume of 20 mmol/L ferric chloride. A standard curve was prepared using different concentrations (0 – 1.5 mg/mL) of ferrous sulphate heptahydrate and (0 – 1.0 mg/mL) 6-hydroxy-2,5,7,8-tetramethyl-chroman-2-carboxylic acid (Trolox) which were freshly prepared at room temperature.

The antioxidant capacity was expressed as mg $FeSO_4$ equivalents per gram of potato sample on a fresh weight basis. All solutions were used on the day of preparation and all determinations were performed in triplicate.

5.3.2.8. Scavenging of diphenyl-picrylhydrazyl (DPPH) radicals

The scavenging activity of the stable 2, 2-diphenyl-1-picrylhydrazyl (DPPH) free radical is used to detect scavenging of free radicals by the tested compound. This assay was performed using a previously described method (van Amsterdam *et al.,* 1992) with some minor modifications. Briefly, 25 µL of potato tuber extract was allowed to react with 250 µL of 0.2 mM DPPH in 95% ethanol in a 96-well microplate. The plate was then incubated at 37^{o}C for 30 min after which the absorbance was measured at 550 nm using a Wallac 1420 Multilabel Counter microplate reader (Victor3, Perkin Elmer Life and Analytical Sciences, Turku, Finland). The scavenging capacity of the sample was compared to that of ascorbic acid (0.1– 1.0 mM ascorbic acid), which was used as a positive control. The antiradical activity was calculated as a percentage of DPPH decolouration relative to a negative control using the following equation:

$$= \frac{\text{(absorbance of control incubation - absorbance of the potato tuber extract)}}{\text{absorbance of control incubation}} \times 100$$

5.3.3. Statistical Analysis

Differences in dry matter, resistant and total starch content and three measures of antioxidant potential (FRAP, TPC and DPPH analysis) were tested using the maximum likelihood technique (REML). The data was shown to be normally distributed prior to REML analysis. All statistical tests were performed using SAS V9 (SAS, 2007).

5.3.4. Experiment Two: Results

5.3.4.1. Effect of Cultivar and Processing Treatment on Dry Matter, Total Starch and Resistant Starch Content

In order to determine the potential health benefits of potato samples destined for Sensory Evaluation (Chapter 6), percentage dry matter, percentage total starch and percentage resistant starch content (RSC) was measured in 3 Taewa cultivars (Huakaroro, Moemoe and Tūtaekuri) and 1 modern cultivar (Nadine) that had been harvested in 2012. Three stages of treatment that represented just boiled potatoes (BOIL); boiled, 24 h-cooled, warmed to 18^{o}C (RH18; representing potatoes used in a cold potato salad for instance); and boiled, 24 h-cooled, warmed to 55^{o}C (RH55; representing pre-cooked potatoes warmed before eating) were analysed in order to compare the possible effect of 24 h cooling and then reheating on the RSC. Results are shown in Table 5.6.

Significant differences ($p < 0.05$) in dry matter content (DM) occurred between cultivars at each treatment stage and significant effects ($p < 0.05$) in DM due to treatments (BOIL, RH18, and RH55) occurred within a cultivar (Table 5.6). With regards to the DM content of each cultivar, the order of greatest DM content to least DM content remained the same across treatments. Tūtaekuri had the greatest DM content (27.8 – 30.1%), followed by Huakaroro (23.9 – 25.7%), Moemoe (23.3 – 24.1%), and Nadine consistently had the least (14.9 – 15.1%) percentage DM. No effect of treatment ($p > 0.05$) was seen in Nadine, however in Huakaroro and Moemoe, RH18 and RH55 caused DM to decrease compared to the BOIL treatment, ($p < 0.05$), however in Tūtaekuri, DM increased following RH18 and RH55 treatment ($p < 0.05$) (Table 5.6).

In general, total starch content (TS) was significantly different ($p < 0.05$) between each of the four cultivars across each treatment. The order of cultivar from greatest TS content to least TS content was similar regardless of treatment.

Tūtaekuri had the greatest TS, followed by Huakaroro and Moemoe, and Nadine consistently had the least TS (16.1 – 17.3%, 11.8 – 15.7%, 10.5 – 15.2% and 8.0 – 8.3% respectively). The only exception to this pattern occurred in the BOIL treatment, where Moemoe had the 2nd highest TS content and Huakaroro the 3rd highest TS content. Again, no effect of treatment ($p < 0.05$) was seen in Nadine, but cooling and reheating caused a significant decrease in TS ($p < 0.05$) in the three Taewa.

In general, the percentage resistant starch content (RSC) was significantly different ($p < 0.05$) between each of the four cultivars for each treatment and followed a similar order of greatest to least RSC (Tūtaekuri > Moemoe > Huakaroro >Nadine) as shown by the cultivars for TS. Cooling and reheating the boiled potato caused RSC to increase in each of the cultivars and was significantly different ($p < 0.05$) between each BOIL, RH18 and RH55 treatment for all cultivars (except in Nadine where the RSC of the RH18 and RH55 samples were the same). In general, cooling for 24 h, then reheating to 55°C accrued the greatest RSC (Table 5.6).

Table 5.6 Dry Matter, Total Starch and Resistant Starch Content of Boiled, 24 h-Cooled then Reheated Potato Samples.

Results of dry matter, total starch and resistant starch content in 3 Taewa cultivars (Huakaroro, Moemoe and Tūtaekuri) and 1 modern cultivar (Nadine).

	Huakaroro g/100 g FW	Moemoe g/100 g FW	Tūtaekuri g/100 g FW	Nadine g/100 g FW
Dry Matter Content	*Mean of duplicate assays*			
BOIL	25.68^{bx}	24.09^{cx}	27.84^{az}	14.99^{d}
RH18	23.90^{bz}	23.39^{cy}	29.55^{ay}	14.88^{d}
RH55	24.20^{by}	23.51^{cy}	30.11^{ax}	15.09^{d}
Total Starch	*Mean of duplicate assays*			
BOIL	15.67^{bx}	15.17^{bx}	17.30^{ax}	8.33^{c}
RH18	11.37^{cy}	12.83^{by}	16.12^{ay}	8.19^{d}
RH55	11.83^{cy}	10.51^{bz}	17.16^{ax}	8.02^{d}
Resistant Starch	*Mean of duplicate assays*			
BOIL	1.26^{bz}	1.41^{bz}	1.70^{az}	0.63^{cy}
RH18	1.78^{cy}	1.93^{by}	3.21^{ay}	0.88^{dx}
RH55	2.33^{cx}	2.57^{bx}	3.41^{ax}	0.95^{dx}

Key: BOIL = just boiled potatoes; RH18 =boiled, 24 h-cooled, warmed to 18°C; RH55 = boiled, 24 h-cooled, warmed to 55°C.

Pair-wise differences: For each analysis, values within the same treatment (across a row) that share the same superscript letter (a,b,c,d) are not significantly different ($p < 0.05$) between cultivars. Values within the same cultivar that share the same superscript letter (x, y, z,), are not significantly different ($p < 0.05$) between treatments.

5.3.4.2. *Regression Analysis of the Effect Of Processing Method and Cultivar on the Total Phenolic Content (TPC), diphenyl-picrylhydrazyl (DPPH) radicals and Ferric Reducing Antioxidant Power (FRAP)*

Analysis showed that effect of processing treatment (RAW; BOIL; RH18; or RH55), and potato variety (Huakaroro, Moemoe, Tūtaekuri, Nadine) were each highly significant with regards to the three measures of antioxidant potential and as expected, the extraction method used for the FRAP analysis (water vs ethanol extraction) also has a significant effect on the subsequent analysis. The effect of processing treatment, potato variety and extraction method on TPC, DPPH-scavenging activity and FRAP values of aqueous extracts from tubers of 3 Taewa varieties (Huakaroro, Moemoe and Tūtaekuri) and 1 modern potato variety (Nadine) are shown in Table 5.7. Results of the analysis of TPC, DPPH and FRAP in RAW, BOIL, RH18 and RH55 potato samples from four cultivars are shown in Table 5.8.

Table 5.7 Effect of Processing Treatment, Potato Variety and Extraction Method on Measures of Antioxidant Potential.

Effects	**df**	**TPC** *P value*	**DPPH** *P value*	**FRAP** *P value*
Processing Treatment (tmt)	3	<0.001	<0.001	<0.001
Potato Variety (var)	3	<0.001	<0.001	<0.001
Extraction method (ext)	1	NA	NA	<0.001
tmt x var	9	<0.001	<0.001	<0.001

Key: df = degrees of freedom; TPC = total phenolic content (mg gallic acid equivalent/g fresh weight tuber); DPPH = 2, 2-diphenyl-1-picrylhydrazyl (% radical-scavenging activity); FRAP = Ferric reducing antioxidant power (mg Fe2+/g fresh weight tuber); NA = not applicable.

5.3.4.3. *Effect of Cultivar and Processing Treatment on Total Phenolic Content (TPC)*

Significant differences in TPC content ($p < 0.05$) occurred between varieties in all treatments. Tūtaekuri had the greatest TPC (0.52 - 0.62 mg GAE/g potato FW), while Nadine had the least TPC (0.21 – 0.24 mg GAE/g potato FW) regardless of treatments. In addition, the TPC of Nadine was significantly lower than all of the Taewa ($p < 0.05$) and the TPC in Tūtaekuri was significantly higher to the other two Taewa varieties ($p < 0.05$), while the TPC were generally similar between Huakaroro and Moemoe.

Overall, neither BOIL, RH18 or RH55 treatments caused a significant decrease in total phenolic content relative to RAW samples ($p < 0.05$), however significant increases in TPC ($p < 0.05$), did occur in Moemoe after boiling and in Tūtaekuri after cooling and reheating. (Table 5.8, Figure 5.2).

Table 5.8 Total Polyphenol Content (TPC) and Antioxidant Activities of Potato Samples.

All analyses involved a 1:1 water extraction of potato samples from 3 Taewa cultivars (Huakaroro, Moemoe and Tūtaekuri) and 1 modern cultivar (Nadine) that were analysed at 4 stages of a treatment that represented raw potatoes; boiled potatoes; potatoes used in a cold potato salad (boiled, 24 h-cooled and warmed to 18°C); and pre-cooked potatoes that are warmed before eating (boiled, 24 h-cooled and warmed to 55°C).

	Huakaroro	Moemoe	Tūtaekuri	Nadine
TPC (mg GAE/g potato FW)	*Mean of 4 incubations (± SE)*			
RAW	0.36 ± 0.01^{b}	0.28 ± 0.01^{by}	0.53 ± 0.01^{ay}	0.24 ± 0.00^{c}
BOIL	0.33 ± 0.01^{c}	0.36 ± 0.01^{bx}	0.52 ± 0.01^{ay}	0.21 ± 0.00^{d}
RH18	0.33 ± 0.00^{b}	0.36 ± 0.01^{bx}	0.57 ± 0.03^{ax}	0.21 ± 0.00^{c}
RH55	0.36 ± 0.01^{b}	0.37 ± 0.01^{bx}	0.62 ± 0.01^{ax}	0.22 ± 0.00^{c}
DPPH (% Antiradical activity)	*Mean of 3 incubations (± SE)*			
RAW	58.6 ± 1.00^{bz}	47.5 ± 0.75^{by}	64.8 ± 0.35^{ay}	48.0 ± 0.62^{cz}
BOIL	76.2 ± 0.29^{bx}	74.7 ± 0.26^{cx}	79.8 ± 0.24^{ax}	56.8 ± 0.72^{dy}
RH18	69.2 ± 0.44^{cy}	73.7 ± 0.27^{bx}	80.2 ± 0.26^{ax}	65.7 ± 0.46^{dx}
RH55	75.7 ± 0.35^{cx}	74.0 ± 0.48^{bx}	80.1 ± 0.18^{ax}	58.0 ± 0.64^{dy}
FRAP water extraction (mg Fe^{2+} /g potato FW)	*Mean of 4 incubations (± SE)*			
RAW	0.78 ± 0.07^{bz}	0.77 ± 0.02^{by}	0.92 ± 1.00^{aby}	0.93 ± 0.02^{ax}
BOIL	0.95 ± 0.04^{cx}	1.09 ± 0.01^{bx}	1.40 ± 0.04^{ax}	0.62 ± 0.01^{dy}
RH18	0.85 ± 0.03^{cy}	1.02 ± 0.01^{bx}	1.48 ± 0.01^{ax}	0.68 ± 0.02^{dy}
RH55	0.85 ± 0.02^{cy}	1.05 ± 0.02^{bx}	1.42 ± 0.02^{ax}	0.66 ± 0.05^{dy}
FRAP ethanol extraction (mg Fe^{2+} /g potato FW)	*Mean of 2 or 3 incubations (± SE)*			
RAW *	1.97 ± 0.10^{bx}	2.15 ± 0.04^{bx}	3.64 ± 0.01^{ax}	1.20 ± 0.03^{cx}
BOIL	1.05 ± 0.22^{cy}	1.24 ± 0.08^{by}	2.38 ± 0.02^{az}	0.81 ± 0.04^{dy}
RH18	1.02 ± 0.01^{cy}	1.23 ± 0.01^{by}	2.71 ± 0.04^{ay}	0.72 ± 0.01^{dy}
RH55	1.15 ± 0.01^{cy}	1.36 ± 0.00^{by}	2.24 ± 0.01^{az}	0.64 ± 0.00^{dy}

Key: RAW = raw potatoes; BOIL = just boiled potatoes; RH18 =boiled, 24 h-cooled, warmed to 18°C; RH55 = boiled, 24 h-cooled, warmed to 55°C; RAW* = mean of 3 incubations; TPC = total phenolic content (mg gallic acid equivalent/g fresh weight tuber); DPPH = 2, 2-diphenyl-1-picrylhydrazyl (% radical-scavenging activity); FRAP = Ferric reducing antioxidant power (mg Fe^{2+}/g fresh weight tuber).

Pair-wise differences: For each analysis, values within the same treatment (across a row) that share the same superscript letter (a,b,c,d) are not significantly different ($p < 0.05$) between cultivars. Values within the same cultivar that share the same superscript letter (x, y, z,), are not significantly different ($p < 0.05$) between treatments.

5.3.4.4. *Effect of Cultivar and Processing Treatment on Antioxidant Capacity (DPPH and FRAP)*

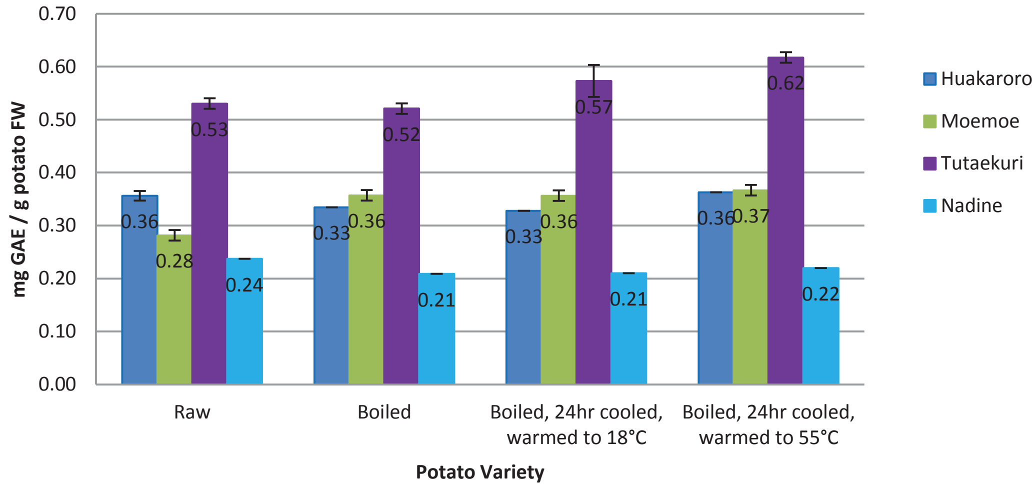
Significant differences ($p < 0.05$) were observed between each of the cultivars with regards to their relative antiradical activity (as measured by the potato's DPPH scavenging ability) as well as their ferric reducing ability (as measured by the Ferric Reducing Antioxidant Power (FRAP) assay). In general, Tūtaekuri showed the greatest antioxidant capacity and Nadine the least regardless of the antioxidant assay or extraction method used. In all cases, except the RAW, FRAP water extraction, Nadine had the least antioxidant capacity which was significantly lower than all three Taewa ($p < 0.05$) and Tūtaekuri had the greatest antioxidant activity and was significantly higher than the other two Taewa cultivars ($p < 0.05$) (Table 5.8, Figures 5.3-5.6).

The percentage DPPH radical scavenging activity significantly increased ($p < 0.05$) after boiling and remained significantly greater ($p < 0.05$) after cooling and reheating compared to the RAW samples in all cultivars. This increase was particularly marked in Moemoe which increased by 47.5 to 74.7% in BOIL compared to RAW ($P < 0.05$).

Significant differences ($P < 0.05$) in FRAP values occurred between treatments depending on the extraction method used. Ethanol-extracted FRAP values were generally higher than water-extracted FRAP values, but also boiling had a significant effect ($p < 0.05$) depending on whether the sample had been water or ethanol extracted (Table 5.8, Figures 5.4 and 5.5). The water-extracted FRAP values increased significantly after boiling ($p < 0.05$) in all three Taewa varieties, and either remained the same after cooling and reheating (Moemoe, Tūtaekuri) or decreased ($P < 0.05$)(Huakaroro). In contrast, water-extracted FRAP values were significantly lower after boiling ($p < 0.05$) in Nadine and remained lower after cooling and reheating. However, in ethanol extracted samples, FRAP values decreased significantly after boiling in each of the cultivars ($p < 0.05$) and generally remained unchanged after cooling and reheating (Table 5.8, Figures 5.4 and 5.5).

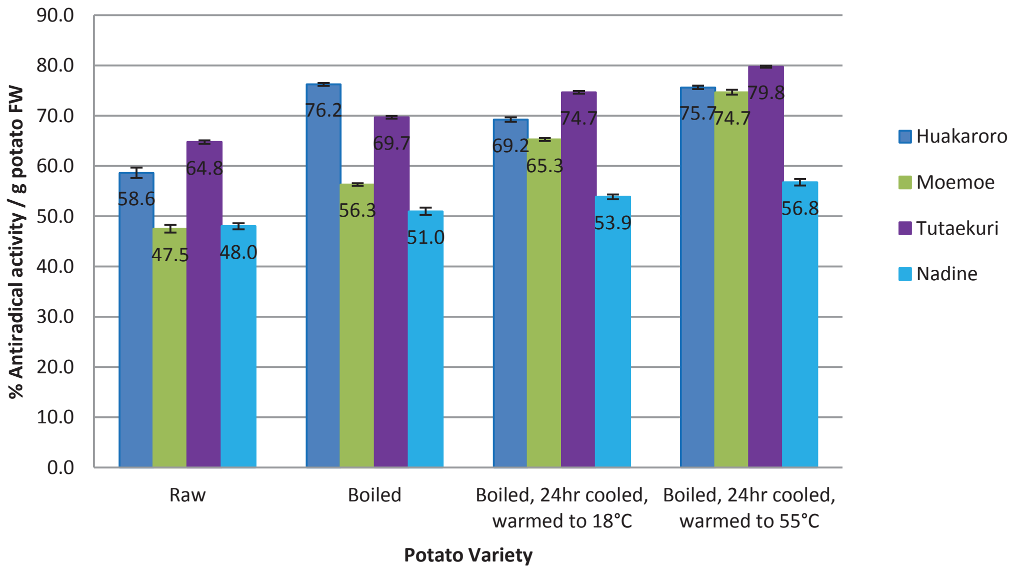
As expected, the Trolox Equivalent (TE) FRAP pattern achieved by the ethanol extraction of cultivars at all treatments was similar to the ethanol extracted Fe^{2+} FRAP pattern. In all treatments, Tūtaekuri again had the greatest TE antioxidant potential, followed by Moemoe and Huakaroro, and Nadine had the least TE antioxidant potential (Figure 5.7).

Figure 5.2 **Total Polyphenolic Content of Processed Potato Samples (Water Extraction).** Data is expressed as mg gallic acid equivalent (GAE) per gram of potato tuber on a fresh weight (FW) basis**.** Analysis involved a 1:1 water extraction of raw potato samples from 3 Taewa cultivars (Huakaroro, Moemoe and Tūtaekuri) and 1 modern cultivar (Nadine).



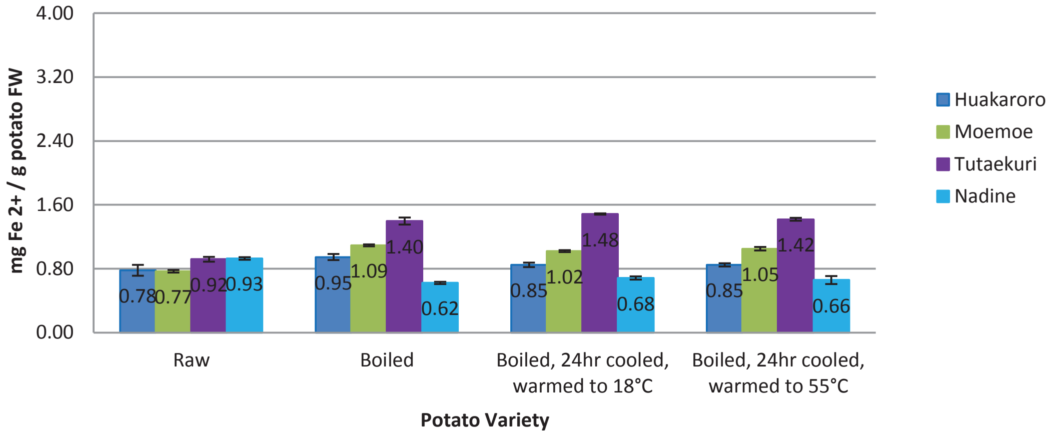
Key: Values represent the mean of four observations. Bars indicate standard errors. Samples were analysed at 4 stages of preparation representative of raw potatoes; boiled potatoes; potatoes used in a cold potato salad (boiled, 24 h-cooled and warmed to 18^{o}C); and pre-cooked potatoes that are warmed before eating (boiled, 24 h-cooled and warmed to 55^{o}C). The assay for each sample was carried out in quadruplicate for a single extraction.

Figure 5.3 **DPPH Scavenging Activity of Processed Potato Samples (Water Extraction).** Data is expressed as % antiradical activity per gram of potato sample on a fresh weight (FW) basis Analysis involved a 1:1 water extraction of raw potato samples from 3 Taewa cultivars (Huakaroro, Moemoe and Tūtaekuri) and 1 modern cultivar (Nadine).



Key: Values represent the mean of three observations. Bars indicate standard errors.
Samples were analysed at 4 stages of preparation representative of raw potatoes; boiled potatoes; potatoes used in a cold potato salad (boiled, 24 h-cooled and warmed to 18^{o}C); and pre-cooked potatoes that are warmed before eating (boiled, 24 h-cooled and warmed to 55^{o}C). The assay for each sample was carried out in triplicate for a single extraction.

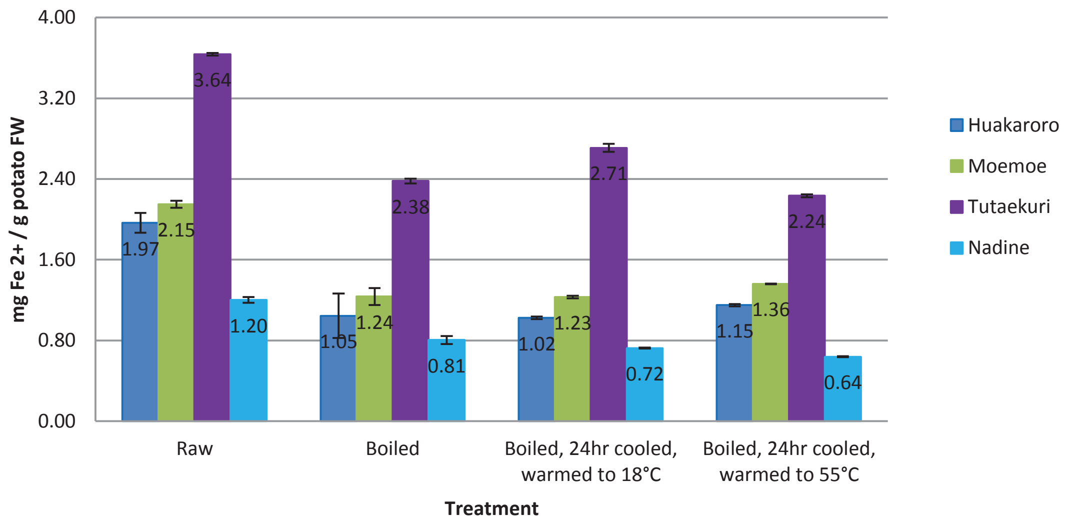
Figure 5.4 **Ferric Reducing Antioxidant Power of Processed Potato (Water Extraction).**
Data is expressed as mg Fe^{2+} equivalents per gram of potato sample on a fresh weight (FW) basis. Analysis involved a 1:1 water extraction of potato samples from 3 Taewa cultivars (Huakaroro, Moemoe and Tūtaekuri) and 1 modern cultivar (Nadine



Samples were analysed at 4 stages of a treatment that might represent raw potatoes; boiled potatoes; potatoes used in a cold potato salad (boiled, 24 h-cooled and warmed to 18°C); and pre-cooked potatoes that are warmed before eating (boiled, 24 h-cooled and warmed to 55°C).

Figure 5.5 **Ferric Reducing Antioxidant Power of Processed Potato (Ethanol Extraction) (expressed as mg Fe^{2+} equivalents).**

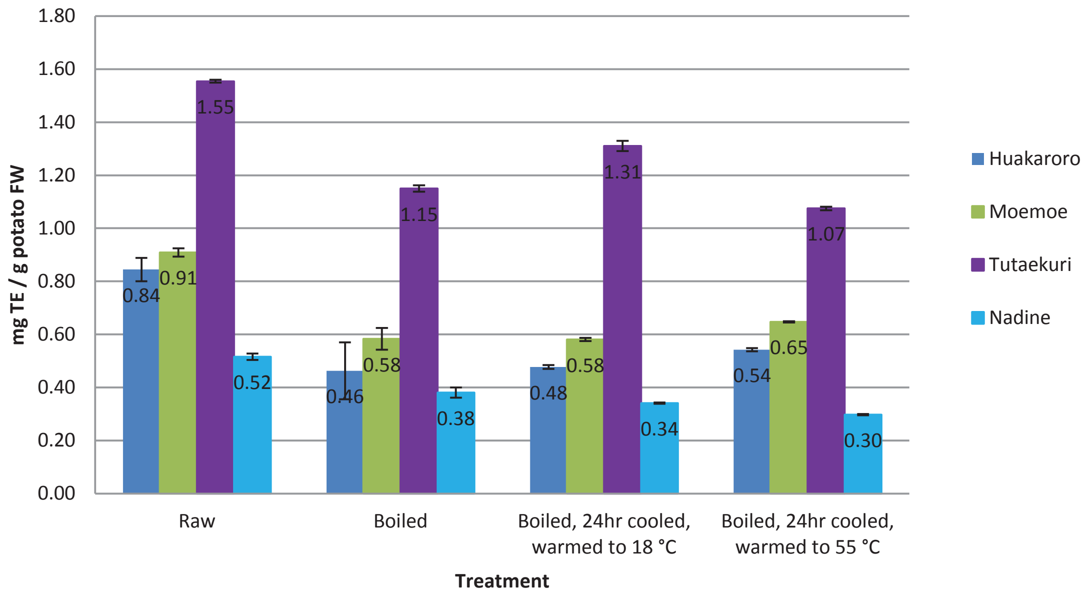
Data is expressed as mg Fe^{2+} equivalents per gram of potato sample on a fresh weight (FW) basis. Analysis involved an ethanol extraction (80:20:5 ratio of absolute ethanol; MilliQ water and 99% formic acid) of potato samples from 3 Taewa cultivars (Huakaroro, Moemoe and Tūtaekuri) and 1 modern cultivar (Nadine).



Each cultivar was analysed at 4 stages of a treatment that might represent raw potatoes; boiled potatoes; potatoes used in a cold potato salad (boiled, 24 h-cooled and warmed to 18°C); and pre-cooked potatoes that are warmed before eating (boiled, 24 h-cooled and warmed to 55°C). The assay for raw samples was carried out in quadruplicate for triplicate extractions. Values given for each sample are means of 12 observations. The assay for cooked samples was carried out in triplicate for duplicate extractions. Values given are means of 6 observations.

Figure 5.6 Ferric Reducing Antioxidant Power of Processed Potato (Ethanol Extraction) (expressed as mg Trolox equivalents (TE).

Data is expressed as mg TE equivalents per gram of potato sample on a fresh weight (FW) basis. Analysis involved an ethanol extraction (80:20:5 ratio of absolute ethanol; MilliQ water and 99% formic acid) of potato samples from 3 Taewa cultivars (Huakaroro, Moemoe and Tūtaekuri) and 1 modern cultivar (Nadine).



Each cultivar was analysed at 4 stages of a treatment that might represent raw potatoes; boiled potatoes; potatoes used in a cold potato salad (boiled, 24 h-cooled and warmed to 18^{o}C); and pre-cooked potatoes that are warmed before eating (boiled, 24 h-cooled and warmed to 55^{o}C).

5.3.5. *Experiment Two: Discussion*

As previously discussed in Section 5.2.4., raw potato starch becomes highly digestible following cooking, but upon cooling, a percentage of the potato starch will retrograde and form slowly digestible starch (SDS) or retrograded RS (Englyst *et al.,* 1992; Brown *et al.,* 1995).

All potatoes have varying levels of bioactive phytochemicals (discussed in Section 1.3.2.). These include compounds such as phenolic acids and flavonoids (Lewis *et al.,* 1998; Shakya and Navarre, 2006; Andre *et al.,* 2007; Friedman, 2007; Albishi *et al.,* 2013); carotenoids, particularly in orange-yellow fleshed varieties (Brown, 2005; Burgos *et al.,* 2009) and anthocyanins, particularly in potatoes with pink, red, blue or purple coloured skins and flesh (Lewis *et al.,* 1998; Brown, 2005; Andre *et al.,* 2007; Navarre *et al.,* 2011). Some of these phytochemicals appear to contribute to improved health and the reduction of the development of diseases through their antimutagenic, anticarcinogenic, antioxidant, antibacterial and immunity boosting functions (Liu, 2003; Liu, 2004; Rahal *et al.,* 2014).

Potatoes with coloured skin and flesh (particularly red-fleshed and dark purple-fleshed varieties), are more likely to contain greater amounts of antioxidative phytochemicals (and thus have greater overall potential antioxidant activity and greater potential health benefits), than white-fleshed, white-skinned varieties (Lewis *et al.,* 1998; Hamouz *et al.,* 2011; Navarre *et al.,* 2011; Lachman *et al.,* 2012; Hu *et al.,* 2012; Albishi *et al.,* 2013; Kulen, 2013).

Extractions from raw Taewa skin and flesh (in particular the purple-skinned, purple-fleshed variety Tūtaekuri / Urenika) have been shown to exhibit variable degrees of phenolic, flavonoid and anthocyanin content and *in vitro* antioxidant activity (Lewis *et al.,* 1998; Gould *et al.,* 2006; Philpott *et al.,* 2009; Chong *et al.,* 2013).

However, it was important to determine the effect of cooking treatments on phenolic content as potatoes are not eaten in their raw state. Thus the purpose of this experiment was to determine through, using three measures of antioxidant potential, whether boiling, cooling for 24 h, and then warming to 18^{o}C or 55^{o}C might affect antioxidant potential of potato samples. It was also of interest to see how three popular Taewa varieties Tūtaekuri, Huakaroro and Moemoe compare with Nadine regards to antioxidant potential during this cooking and reheating process.

The purpose of measuring total starch and RS while concurrently measuring antioxidant activity of potato samples that had just been boiled, cooled for 24 h and then later reheated to 18^{o}C or 55^{o}C was in order to estimate and gauge the effect the various treatments might have (and thus potential health benefit in terms of increased RS as well as antioxidant potential) on similarly prepared samples destined for future sensory analysis of 24 h-cooled and reheated samples (Chapter 6).

5.3.5.1. Effect of Cultivar and Processing Treatment on Dry Matter, Total Starch and RS

Dry matter and starch content is known to vary significantly between cultivars (Lisinska and Leszcynski, 1989; Burlingame *et al.,* 2009). The current research has previously shown (Section 2.2.4.2. and Section 5.3.4.1.), that the dry matter content of the Taewa varieties are all significantly greater ($p < 0.05$) than Nadine, but research in this chapter shows that in addition, DM is also likely to be significantly different ($p < 0.05$) between the Taewa cultivars. A similar phenomenon occurred between the cultivars with regards to TS and RS. These differences suggest inherent cultivar differences with regards to nutrient content and therefore present an opportunity to select Taewa cultivars with a greater content of a desired nutrient.

Processing treatments affected the DM, TS and RS in different ways in each of the four cultivars. For example, RH55 treatments affected TS in a different way for each of the Taewa. While DM and TS were unaffected by boiling or cooling and reheating in Nadine, significant increases in RS ($p < 0.05$) occurred in both RH18 and RH55. In Tūtaekuri, significant increases in DM ($p < 0.05$) occurred after both RH18 and RH55, but DM was decreased ($p < 0.05$) in Huakaroro and Moemoe following cooling and reheating.

Results previously discussed in Section 5.2.4 showed that the percentage of resistant starch content (RSC) is likely to increase by 1.5 to 2 fold over a 24 h period of cooling at 4^{o}C. The current results support this, with samples that were reheated to 18^{o}C (RH18) showing a RSC increase from 37% - 89%, and samples reheated to 55^{o}C (RH55) showing a RSC increase from 51% - 100%.

As discussed in Section 2.5.5., RS (and dietary fibre) are nutrients likely to be of consequence in potatoes. Par-boiling did not appear to have any major effect on nutrient content (apart from 45-54% losses in vitamin C), and resulted in slightly increased fibre content. Thus the RH18 and RH55 samples are likely to have superior nutritional value to the BOIL samples. With regards to cultivars, Taewa samples (particularly Tūtaekuri) are likely to have 2-3 times as much RSC compared to Nadine and thus these results suggest that Taewa should replace Nadine as the preferred potato cultivars for the development of 24 h-cooled potato products due to their greater health potential.

5.3.5.2. Effect of Cultivar and Processing Treatment on Antioxidant Capacity

As expected, due to the colour differences between the Taewa and modern potato varieties, differences between cultivars ($p < 0.05$) with regards to the antioxidant capacity (as shown by the greater total phenolic content (TPC), percentage DPPH radical scavenging activity and ferric reducing antioxidant power) were observed. In each of the measures of antioxidant capacity (TPC, DPPH and FRAP following either water or ethanol extraction), Tūtaekuri had the greatest capacity, Nadine had the least capacity and Huakaroro and Moemoe were intermediate between the two (although Moemoe was more often second in capacity to Tūtaekuri than Huakaroro).

This greater antioxidant potential of Tūtaekuri is likely due to the greater TPC and anthocyanin content (Sections 2.4.4.1 and 5.3.4.3) compared to the other varieties. Apart from FRAP ethanol extractions, the BOIL, and either RH18 or RH55 treatments caused significant increases in antioxidant capacity ($p < 0.05$) compared to the RAW sample for each of the varieties.

Differences in the impact of cooking treatments on phenolics (and hence antioxidant potential) have been found in recent studies. Gould *et al.,* (2006) used extracts from fresh homogenised samples in a 70:23:7 ratio of methanol, water and acetic acid. Antioxidant activities (IC_{50} values) were estimated as volumes of the extracts required to scavenge 50% of the free radicals in a 200 µl aliquot of 100 µM 1,1-diphenyl-picrylhydrazyl (DPPH) in methanol. The study found that a 10% extract of boiled Tūtaekuri skin and flesh had the same scavenging activity as raw Tūtaekuri skin and flesh (raw and boiled Tūtaekuri skin = mean IC_{50} of 0.10 ±0.01mM ascorbic acid equivalents; raw and boiled Tūtaekuri flesh = mean IC_{50} of 0.03 ±0.00mM Ascorbic acid equivalents) (Gould *et al.,* 2006).

In the current research, DPPH scavenging activity of boiled whole tuber samples also increased in comparison to raw samples for each cultivar. In raw Tūtaekuri samples, the percentage DPPH scavenging activity was 64.8 ±0.35 mM ascorbic acid equivalents, whereas in the boiled Tūtaekuri samples the percentage DPPH scavenging activity was 79.8 ±0.24 mM ascorbic acid equivalents. Differences in agronomical conditions may explain the different results found between this research and that of Gould *et al.,* (2006), however different solvent extraction methods (water extraction used in the current research vs 70:23:7 ratio of methanol, water and acetic acid solvent extraction used in Gould *et al.,* (2006)) may also explain the differences in results. Like Gould *et al.,* (2006), Blessington *et al.,* (2010) found no difference in total phenolic content (TPC) and antioxidant capacity between raw and 25 min boiled potatoes from eight genotypes, but TPC and antioxidant capacity were higher in baked, fried and microwaved samples.

In a study of 4 coloured potato cultivars by Burmeister *et al.,* (2011), the total pigment content (anthocyanin plus carotenoid content) in whole potatoes decreased following 25 min of boiling. Another study of different cooking methods on 3 coloured potato cultivars also found that antioxidant activity and phenol content decreased in all cultivars following boiling, steaming, microwaving and frying, compared to uncooked treatments. However the retention of antioxidant activity and phenol contents was greatest in the purple skinned, purple-fleshed cultivar (Li *et al.,* 2012). Conversely, Lachman *et al.,* (2012) found that boiling five coloured whole potato cultivars in a pressure cooker for 15 min increased anthocyanin content by a factor of 4.22 compared to raw uncooked samples. In addition, there was a high correlation between greater antioxidant activity and higher anthocyanin content, suggesting that antioxidant activity would also have been higher in the boiled samples although it was not measured in the study (Lachman *et al.,* 2012).

Burgos *et al.,* (2013) examined the effect of boiling on total phenolic content, (TPC), total anthocyanin content (TAC), phenolic acids (PA) and antioxidant activity (AO: using DPPH and 2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid (ABTS) assays) on 4 native Andean accessions with differing degrees of purple pigmentation. They found that boiling increased TPC and AO in all accessions whereas no significant difference was found between TA in all but 1 accession (Burgos *et al.,* 2013).

Reasons for the differences in the effects of cooking may be varied, but may include differences in analytical techniques and thus the forms of compounds that are being extracted and detected, and inherent cultivar differences and their response to the cooking treatments.

5.3.5.3. Differences in Extraction Method

Differences in FRAP determinations between treatments ($P < 0.001$) occurred depending on the extraction method. Firstly, greater FRAP was observed in all cultivars and in all treatments (BOIL, RH18 and RH55) when the samples were extracted using ethanol, compared to when extracted by water (apart from Nadine RH55 water-extracted samples). Secondly, compared to the raw samples, FRAP was increased ($p < 0.05$) following boiling if extracted by water but decreased ($p < 0.05$) following boiling if extracted by ethanol. Thirdly the FRAP of the raw, ethanol extracted samples was the greatest of all ethanol extracted treatments, whereas the FRAP achieved by the raw, water extracted samples was generally the lowest of all the water extracted treatments (see Table 5.6 and Figures 5.6 and 5.7).

Differences due to extraction method are not unexpected as the extraction solvent composition, and the extraction time have been found to have a great impact on the final determined amount of antioxidant activity (Michiels *et al.,* 2012). Burgos *et al.,* (2013) found that total phenolic content (TPC) was optimised in raw samples when extracted with 80 or 90% methanol ($p < 0.001$), whereas the TPC concentrations determined in cooked samples were higher when the samples were extracted with 60% methanol ($p < 0.001$). Sonication times ranging from 5 to 30 min were tested using 80% and 60% methanol for extracting the TPC from raw and cooked samples, respectively. It was found that 5 min was sufficient to extract TPC efficiently from both raw and cooked potato samples. For practical purposes 10 min sonication for each extraction was considered the optimal method (Burgos *et al.,* 2013).

Water extraction was used due to existing capability in antioxidant potential at Massey University (Molan *et al.,* 2008a, 2008b and 2009). However this method may be more suited to tea-leaf extracts rather than potato tuber extracts.

Thus in future, determining the optimum extraction solvent composition and extraction time would help standardise or optimise the method for determining antioxidant potential in raw, cooked, or reheated potato.

5.4. Summary of Chapter 5

One of the goals of this PhD research was to incorporate characteristics of nutritional or health value found in the Taewa with familiar and popular Taewa cooking practices so as to develop a Taewa product with improved health benefits.

As discussed in Section 1.3.1.2, cooked, then cooled potatoes may have improved health benefits due to the increased ratio of indigestible RS and slowly digestible starch relative to the easily digestible starch. Decreasing the digestibility of high carbohydrate foods is of great benefit to those who may need to monitor blood glucose levels. Additionally, like fibre, RS can contribute to bowel health by acting as a metabolic substrate for beneficial colonic bacteria.

Boiled Tūtaekuri, Huakaroro, Karuparera and Moemoe are each likely to have a slightly different rate of increase and ultimate RSC over 24 or 48 h of cooling, but all accumulate a greater RSC than Nadine at each time point. Thus these four Taewa (in particular Tūtaekuri), appear to have a greater benefit with regards to potential RSC than Nadine in addition to their greater total dietary fibre content (Section 2.5.4.3.). These Taewa are also comparable in RSC and total dietary fibre content compared to other modern New Zealand cultivars.

In experiment 1, reheating pre-boiled, cooled potato samples appeared to slightly reduce RSC in comparison to their non-reheated counterparts; however the decrease was relatively small. However, in experiment 2, the RSC in RH18 and RH55 samples was 1.5 – 2 times greater than the RSC in the BOIL (recently boiled) samples. Thus 24 h-cooled potatoes (which have the health benefits associated with additional RSC) that can be heated to 18^{o}C and 55^{o}C could translate into precooked commercial products used in a potato salad or warmed in the microwave prior to consumption (such as pre-cooked, refrigerated potato cubes designed to be reheated at home in the microwave).

Potatoes with highly coloured tuber skin or flesh are likely to have greater phenolic content and thus have greater potential antioxidant content that may contribute to improved health benefits such as anti-inflammatory, antibacterial, antimutagenic and especially antioxidant functions (Rahal *et al.,* 2014).

This research found that in water extracted potato samples, neither boiling (BOIL), nor boiling followed by 24 h cooling and reheating to 18°C (RH18) or 55°C (RH55) negatively affected antioxidant potential, instead the antioxidant capacity significantly increased ($p < 0.05$) in all cultivars, especially the Taewa. These results are promising in regards to the additional health value of 24 h-cooled Taewa products. An initial hypothesis at the start of this work suggested that as Taewa exhibit highly variable tuber flesh and skin colourations they will have a greater total phenolic content (and thus antioxidant potential) than white skinned, white fleshed modern varieties such as Nadine. Results of this study support this hypothesis since antioxidant potential was generally highest in Tūtaekuri, followed by Moemoe or Huakaroro, and lowest in Nadine which correlated to their relative total phenolic content (Sections 2.4.4.1, 5.3.4.3 and Table 5.8) and tuber colourations.

As with other research discussed previously (Michiels *et al.,* 2012; Burgos *et al.,* 2013), this research found that the solvent used for phenolic extraction appears to have significant influence on the phenolic compounds or antioxidant capacity that is measured, or detected as ethanol extracted potato samples generally showed significantly greater FRAP values ($p < 0.001$) compared to water-extracted FRAP values and thus had an impact on the estimation of RAW FRAP values in particular and the potential effect of boiling. Further experimentation to determine the optimal phenolic extraction procedure for potato is thus recommended.

Although Tūtaekuri is likely to have the greater potential health benefits with regards to greater RS content as well as potential antioxidant value, its uncommon appearance (dark purple skin and flesh) may have an impact on consumer acceptance as varieties with white or red skins and white or yellow-fleshed tubers are more common in New Zealand. Investigations of consumer acceptance of purple-skinned varieties currently available in New Zealand (such as purple passion and purple heart) would be helpful with respect to gauging acceptance of Tūtaekuri.

Taewa are not varieties commonly eaten by the general New Zealand population, thus the potential consumer acceptance of 24 h-cooled Taewa products should be measured by sensory evaluation with subjects both familiar and unfamiliar to Taewa. However, due to the variability in flesh and skin colours of Huakaroro (yellow skin, yellow flesh), Karuparera (dark purple skin with white around the eyes, creamy-white flesh) and Moemoe (mottled pink-purple skin, creamy-yellow flesh), these three Taewa could provide alternative Taewa varieties for 24 h-cooled Taewa products as they contain greater RSC and antioxidant potential compared to Nadine should Tūtaekuri be less preferred in terms of sensory acceptability.

CHAPTER 6

Evaluation of Sensory Parameters of Four Pre-boiled, 24 hour Cooled Potato Varieties Served at Two Temperatures

6.1. Introduction

Taewa tubers have been found to have excellent potential nutritional value and coloured Taewa tubers have potential antioxidant value (Chapter 2). In addition, pre-boiled, 24 h-cooled Taewa have potential health or nutritional benefits with respect to greater potential antioxidant activity and/or greater resistant starch (Chapter 5). These factors indicate potential for the development of a healthy Taewa product. However as discussed in Section 1.6., what we choose to eat is not solely determined by nutritional needs and benefits, but can be influenced by a large range of factors such as sensory appeal, culture, familiarity, cost, and social influences (Drewnowski, 1997; Glanz *et al.,* 1998; Kratt *et al.,* 2000; Connors *et al.,* 2001; Wardle *et al.,* 2005).

With regards to the most popular Taewa varieties, Taewa cooking methods and factors influencing Taewa consumption, research findings (Chapters 3 and 4) suggest that the most preferred way of eating Taewa is boiled and served hot, and sensory attributes ("taste" and flavour, appearance, texture, bitterness, temperature), and familiarity are among the factors that might affect consumer acceptability (Chapters 3 and 4). However, the research described in Chapters 3 and 4 of this thesis recruited participants that had "*previously eaten Taewa and had cooked or seen Taewa being cooked*", and little is known about the appeal of Taewa to the proportion of the population who are not familiar with the culinary and sensory attributes of Taewa. Thus, in order to assess potential consumer acceptability of new Taewa products, acceptability of key sensory characteristics such as flavour, texture, appearance, aroma, serving temperature or other food characteristics appropriate to the product should be measured in those who have not eaten Taewa before as well as those who have. Due to the apparent preference for hot, cooked Taewa, it is also of interest to see whether sensory ratings for pre-boiled, 24 h-cooled potato samples are higher when served at 55°C compared to those served at room temperature, 18°C.

Consumer choice and acceptability has been shown to be affected when product information about potential health benefits of ingredients contained within a product are provided (Pelchat and Pliner, 1995; Kozup *et al*., 2003; Luckow *et al*., 2006; Baixauli *et al.*, 2008). Thus it is of interest to see whether providing information regarding potential health or nutritional benefits of pre-boiled and 24 h-cooled potato products (greater resistant starch content) or potatoes with high anthocyanin content (greater potential antioxidant activity) might influence sensory acceptability scores.

6.2. Aim

The aims of this research were to evaluate; a) whether serving temperature (18°C or 55°C) had an influence on scores for key sensory attributes (appearance, taste, texture, aftertaste) of potato samples which had been previously boiled and cooled for 24 h ; b) which of the four potato varieties (Taewa varieties: Huakaroro, Moemoe, Tūtaekuri; modern variety: Nadine) were preferred for consumption at the two serving temperatures; c) whether receiving information regarding potential nutritional or health benefits of Taewa influenced the likelihood of future Taewa purchasings and d) whether previous exposure to Taewa influenced the scores assigned during sensory testing or influenced the likelihood of consuming potato products with potential health benefits in the future.

6.3. Materials and Methods

6.3.1. Potato tuber samples

The Taewa varieties used in this trial; Huakaroro, Moemoe and Tūtaekuri (*Solanum tuberosum* L. cv. Huakaroro, Moemoe, Tūtaekuri) were selected as a previous consumer survey among 209 Taewa eaters in New Zealand found these varieties to be among the most preferred for consumption (Section 4.4.4.2.a.), most commonly eaten (Section 4.4.2.2.c.) and most available throughout New Zealand regions (Section 4.4.4.3.e.). These three Taewa varieties also had varying levels of glycoalkaloid content and antioxidant potential (Section 2.4). The Taewa cultivars were sourced from a virus free programme through Tahuri Whenua (National Māori Vegetable Growers Collective), where the initial seed tubers are grown in South Canterbury, but the crop is then grown elsewhere. All the Taewa used in this study were grown at the Massey University Crop Unit (40°22’40”S; 175°36’27”E) in Manawatu Silt Loam soil and harvested in mid June 2011.

Sixty to eighty gram whole tubers of the modern potato cultivar (Nadine) were purchased prewashed, from Foodstuffs (NZ) Ltd, (New World supermarket, Palmerston North, NZ). Although one of the objectives of this chapter was to ascertain the sensory acceptability of Taewa in subjects who were either familiar with, or not familiar with the culinary and sensory attributes of Taewa, it was felt that Nadine should also be included as Nadine had been used as the comparative modern variety throughout the thesis and could act as a “control” due to the fact that it is a white skinned, white-fleshed variety, commonly eaten in New Zealand.

Uniformly-sized tubers were selected from each cultivar. All tubers were washed to remove dirt and then patted dry. Unpeeled tubers (1 kg) of each cultivar were cooked by immersing the potatoes whole, into a boiling 1.0% salt solution (iodised table salt).

The potatoes were kept simmering until a kitchen fork could easily penetrate them, at which point the potatoes were drained, cooled to room temperature, and then covered and kept at 4°C for 24 h. Cooking times varied for the different varieties based on tuber size; with Nadine and Moemoe cooked for 30 min and Huakaroro and Tūtaekuri for 20 min (each timed from start of re-boil after addition of potatoes).

Two hours prior to the start of the sensory trial, potatoes were brought out of cool storage and cut into 1.5 cm cubes ensuring one side of the cube had the skin still attached. Cubes were placed into two separate, covered, metal bain-marie containers, which were immersed in waterbaths set at either 18°C (room temperature) or 55°C (warmed temperature) so the samples had reached the appropriate temperature prior to the sensory trial beginning. Participants were served a pottle containing 1 cube for each potato type at each temperature and were asked to eat the entire piece when evaluating each sample.

6.3.2. Participants

Discussions with the Chairman of the Human Ethics Committee deemed this study to be of low risk and thus notification of the details for the intended study was lodged with the Massey University Human Ethics Committee in June 2011 (see Appendices 6.1-6.3 for copies of the participant consent form, information sheet and trial advertisement).

Fifty six volunteer participants were recruited among students and staff of Massey University, Palmerston North, New Zealand on the basis of their interest, availability, and willingness to eat cooked potato products.

6.3.3. Sensory evaluation protocol

Interested participants were invited to attend a sensory evaluation session at the Massey University Sensory Evaluation Laboratory (Institute of Food, Nutrition and Human Health, Turitea Campus, Palmerston North, NZ). Each participant tasted a total of 8 samples (four varieties of potato offered at the two different serving temperatures; 18°C, or warmed to 55°C) prior to the tasting. The order in which samples from the four potato varieties were offered to each participant were rotated both within and between temperature groups (18°C or 55°C) to minimise any “learned” or order of presentation effect.

Consumers were asked to eat the entire sample provided, and rate the "appearance", "flavour", "texture", "aftertaste" and "overall acceptance" of each sample on a nine-point category scale with the ends anchored at "dislike extremely" through to "like extremely" and a neutral central point: "neither like nor dislike".

All of the responses for "appearance", "flavour", "texture", "aftertaste" and "overall acceptance" were converted to numerical scores to facilitate statistical analysis. For example "dislike extremely" was assigned a numerical score of "1"; "neither like nor dislike" a score of "5"; and "like extremely" was assigned a score of "9" (see Appendix 6.4 for evaluation form).

The experiment included a variation in the evaluation form where half of the trial participants (28 of 56) were given additional information regarding the potential health and nutritional benefits of consuming potato with greater resistant starch content and potato cultivars with greater anthocyanin content. This health and nutritional information was included following the sensory assessment section as the goal was not to influence the ratings of the sensory scores but to see whether it might impact on the likelihood of purchasing Taewa in the future.

It was explained that consuming pre-cooked and 24 h-cooled potato would provide greater resistant starch content than just cooked, or warmed, cooked potato. It was also explained that consuming potato cultivars with purple flesh or red, blue, pink or purple-skinned coloured tuber pigmentations would provide greater antioxidant activity than a white-fleshed, brown-skinned variety. Participants were also informed that certain Māori potatoes had significantly more resistant starch and anthocyanin content than the Nadine variety (see Appendix 6.5 for nutritional information sheet given).

In the final section of the sensory questionnaire, all 56 study participants were asked to indicate their age group, gender and whether they had eaten Māori potatoes previously. All participants were also asked to rate their likelihood of purchasing Māori potatoes in the future on a nine-point category scale anchored with "extremely unlikely" through to "extremely likely" and a central neutral point of "neither likely or unlikely".

6.3.4. Statistical Analysis

This experiment involved data that included fixed, random and covariate effects, so the residual maximum likelihood technique (REML) was used for analysis. The data was shown to be normally distributed prior to REML analysis.

The fixed effects were potato variety (Huakaroro, Moemoe, Tūtaekuri, Nadine); serving temperature (room temperature; 18^{o}C or warmed; 55^{o}C); nutritional information (with and without) and whether participants had eaten Taewa before (not sure, yes, no).

The random effects were the participant and sample presentation order, however the sample presentation order within each temperature group was randomised in order to minimise presentation effects. All analysis was performed using SAS V9 (SAS, 2007).

Model 1
Response = temp + var + info and interactions + U (info).

Model 2
Response = info + var + temp and interactions + U (info*ebef).

Where:

info = whether nutritional information was provided (yes or no)

var = potato variety (Huakaroro, Moemoe, Tūtaekuri, Nadine)

temp = serving temperature (room temperature, 18^{o}C or warmed, 55^{o}C)

ebef = whether participants had eaten Taewa before (not sure, yes, no)

U = random effects (subject)

6.4. Results

The 56 participants that took part in the sensory trial were between 18 and 69 years of age, 34 (61%) were female, 22 (39%) were male and 32 (57%) definitively stated that they had previously eaten Taewa before participating in the sensory trial, 12 (21%) were unsure if they had previously eaten Taewa before and 12 (21%) had never eaten Taewa before.

Serving temperature; having nutritional information regarding the benefits of cooked then cooled potato, or potato with greater anthocyanin content; having previously eaten Taewa; participant age or gender all had no effect on the liking scores. Only potato variety had a significant effect on the liking ratings ($p < 0.001$), as shown in both Table 6.1 (Model 1) and Table 6.2 (Model 2).

The interaction between the fixed effects of a) having nutritional information or not, and b) having eaten Taewa before or not, showed a trend on liking scores of flavour ($p = 0.0935$) and overall acceptance ($p = 0.0973$) (see Table 6.2).

Table 6.1 **REML results of Sensory Attribute Ratings versus Fixed Effects (Model 1).**

(Sensory attributes: Appearance; Texture; Flavour; Aftertaste; Overall Acceptance; Fixed Effects: Nutritional Information; Potato Variety; Serving Temperature)

Effects	**df**	**Appearance**	**Texture**	**Flavour**	**Aftertaste**	**Overall Acceptance**
		P value	*P value*	*P value*	*P value*	*P value*
Serving Temperature (temp)	1	0.3119	0.6106	0.6268	0.2387	0.7379
Potato Variety (var)	3	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Nutritional Information (info)	1	0.1376	0.6906	0.6126	0.4585	0.4034
temp x var	3	0.4212	0.4268	0.8486	0.1533	0.6510
temp x info	1	0.1083	0.9492	0.7099	0.7551	0.7379
var x info	3	0.9410	0.4899	0.3539	0.2793	0.5956
temp x var x info	3	0.6510	0.4635	0.7484	0.6941	0.9979

Key: df = degrees of freedom; P<0.1 equates to a 90% confidence in significant difference; P<0.0001 equates to > 99.9% confidence in significant difference.

Table 6.2 **REML results of Sensory Attribute Ratings versus Fixed Effects (Model 2).**

(Sensory attributes: Appearance; Texture; Flavour; Aftertaste; Overall Acceptance; Fixed Effects: Nutritional Information; Eaten Taewa Before; Potato Variety; Serving Temperature)

Effects	**df**	**Appearance**	**Texture**	**Flavour**	**Aftertaste**	**Overall Acceptance**
		P value	*P value*	*P value*	*P value*	*P value*
Serving Temperature (temp)	1	0.3116	0.6258	0.6097	0.2376	0.7363
Potato Variety (var)	3	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
temp x var	3	0.4160	0.8474	0.4244	0.1518	0.6462
Nutritional Information (info)	1	0.1810	0.5876	0.7887	0.3294	0.4683
Eaten Taewa Before (ebef)	2	0.3814	0.1040	0.2136	0.6249	0.1189
info x ebef	2	0.7363	0.1577	**0.0935**	0.3994	**0.0973**

Key: df = degrees of freedom; P value <0.1 equates to a 90% confidence in significant difference; <0.0001 equates to > 99.9% confidence in significant difference.

6.4.1. *Effect of Serving Temperature on Consumer Hedonic Ratings*

Serving temperature appeared to have no significant effect on the participants hedonic ratings (see Tables 6.1 and 6.2). Further investigation of the means adjusted scores (Model 2) for each of the sensory attributes, where scores for all potato varieties are combined (see Table 6.3), showed that all hedonic attribute ratings, except for appearance and texture, scored slightly higher for the samples served warmed (55°C) rather than at room temperature (18°C) and aftertaste scored lowest in both temperature groups (6.1 at 18°C and 6.2 at 55°C).

Table 6.3 Hedonic Profile of All Potato Varieties Combined when served at 18°C and 55°C to all subjects.

N = 56 (Results of the combined means adjusted sensory attribute ratings (± SEM) of consumers who tasted samples from Huakaroro, Moemoe, Tūtaekuri and Nadine potato cultivars and at two serving temperatures using statistical Model 2)

Serving Temperature	Sensory Attribute				
	Overall Acceptance	Appearance	Texture	Flavour	Aftertaste
18°C	6.2 ± 0.2	6.4 ± 0.2	6.3 ± 0.2	6.4 ± 0.2	6.1 ± 0.2
55°C	6.3 ± 0.2	6.4 ± 0.2	6.3 ± 0.2	6.5 ± 0.2	6.2 ± 0.2

6.4.2. *Effect of Taewa Variety on Consumer Sensory Ratings at Two Serving Temperatures*

Potato variety had a highly significant effect ($p < 0.0001$) on participant sensory attribute rating irrespective of the subject having access to nutritional information or not, or having eaten Taewa before (Model 2).

6.4.2.1. *Differences Between Acceptable Sensory Ratings*

Mean liking ratings for sensory attributes of 6.75 or above are regarded as acceptable (Grigor, 2013, pers. com.). Huakaroro and Tūtaekuri (two Taewa varieties), were the only varieties which achieved ratings at or above this level. Huakaroro achieved this in regards to overall acceptance (6.9), appearance (6.9), flavour (6.8), and texture (7.1) for the 18°C serving temperature and for texture (6.8) at the 55°C serving temperature. The Tūtaekuri appearance (6.8), was also rated as being at an acceptable level at room temperature (18°C). Mean preference scores (± SEM) for the three Taewa varieties (Huakaroro, Moemoe, Tūtaekuri) and the modern variety (Nadine); at both serving temperatures (18°C and 55°C) are shown in Table 6.4.

Table 6.4 Mean Attribute Rating (± SEM) of Four Potato Varieties at 18 °C and 55 °C Serving Temperatures.

(Means adjusted sensory attribute ratings (± SEM) of 56 participants who tasted samples from 4 potato cultivars and at two serving temperatures)

Attribute	*Temperatures Combined*	*Served at 18 °C*	*Served at 55 °C*
Appearance			
Huakaroro	**6.8** ± 0.2 [a]	**6.9** ± 0.2 [a]	**6.7** ± 0.2 [a]
Moemoe	5.3 ± 0.2 [b]	5.5 ± 0.2 [c]	5.2 ± 0.2 [b]
Tūtaekuri	6.7 ± 0.2 [a]	6.8 ± 0.2 [ab]	6.5 ± 0.2 [a]
Nadine	6.4 ± 0.2 [a]	6.3 ± 0.2 [b]	6.6 ± 0.2 [a]
Flavour			
Huakaroro	**6.8** ± 0.2 [a]	**6.8** ± 0.3 [a]	**6.7** ± 0.3 [a]
Moemoe	5.4 ± 0.2 [b]	5.4 ± 0.3 [b]	5.4 ± 0.3 [b]
Tūtaekuri	6.5 ± 0.2 [a]	6.4 ± 0.3 [a]	**6.7** ± 0.3 [a]
Nadine	6.5 ± 0.2 [a]	6.5 ± 0.3 [a]	6.5 ± 0.3 [a]
Texture			
Huakaroro	**7.0** ± 0.2 [a]	**7.1** ± 0.23 [a]	**6.8** ± 0.2 [a]
Moemoe	6.0 ± 0.2 [b]	5.8 ± 0.2 [b]	6.2 ± 0.2 [b]
Tūtaekuri	6.4 ± 0.2 [b]	6.4 ± 0.2 [b]	6.4 ± 0.2 [ab]
Nadine	6.3 ± 0.2 [b]	6.3 ± 0.2 [b]	6.4 ± 0.2 [ab]
Aftertaste			
Huakaroro	**6.6** ± 0.2 [a]	**6.6** ± 0.3 [a]	**6.5** ± 0.3 [a]
Moemoe	5.5 ± 0.2 [c]	5.4± 0.3 [c]	5.5 ± 0.3 [b]
Tūtaekuri	6.1 ± 0.2 [b]	5.8 ± 0.3 [bcx]	**6.5** ± 0.3 [ay]
Nadine	6.4 ± 0.2 [ab]	6.4 ± 0.3 [a]	6.4 ± 0.3 [a]
Overall Acceptance			
Huakaroro	**6.8** ± 0.2 [a]	**6.9** ± 0.3 [a]	**6.7** ± 0.2 [a]
Moemoe	5.5 ± 0.2 [c]	5.5 ± 0.3 [c]	5.5 ± 0.2 [b]
Tūtaekuri	6.5 ± 0.2 [ab]	6.3 ± 0.3 [ab]	**6.7** ± 0.2 [a]
Nadine	6.3 ± 0.2 [b]	6.3 ± 0.3 [b]	6.4 ± 0.2 [a]

Key: Values in bold text represent the greatest mean score for the attribute. Values underlined represent the scores that have achieved acceptable consumer ratings (scores above 6.75) (Grigor, 2013, pers. com).

Pair-wise differences: Values down a column but within the same attribute that have the same letter (a, b, c, d), did not differ significantly ($p < 0.05$) between cultivars; values within the same attribute and cultivar that have a different letter (x,y) across the two serving temperatures (18 °C and 55 °C) were significantly different ($p < 0.05$) between temperatures.

6.4.2.2. *Differences Between Appearance, Flavour, Taste and Aftertaste of Cultivars at 18°C or 55°C Serving Temperatures*

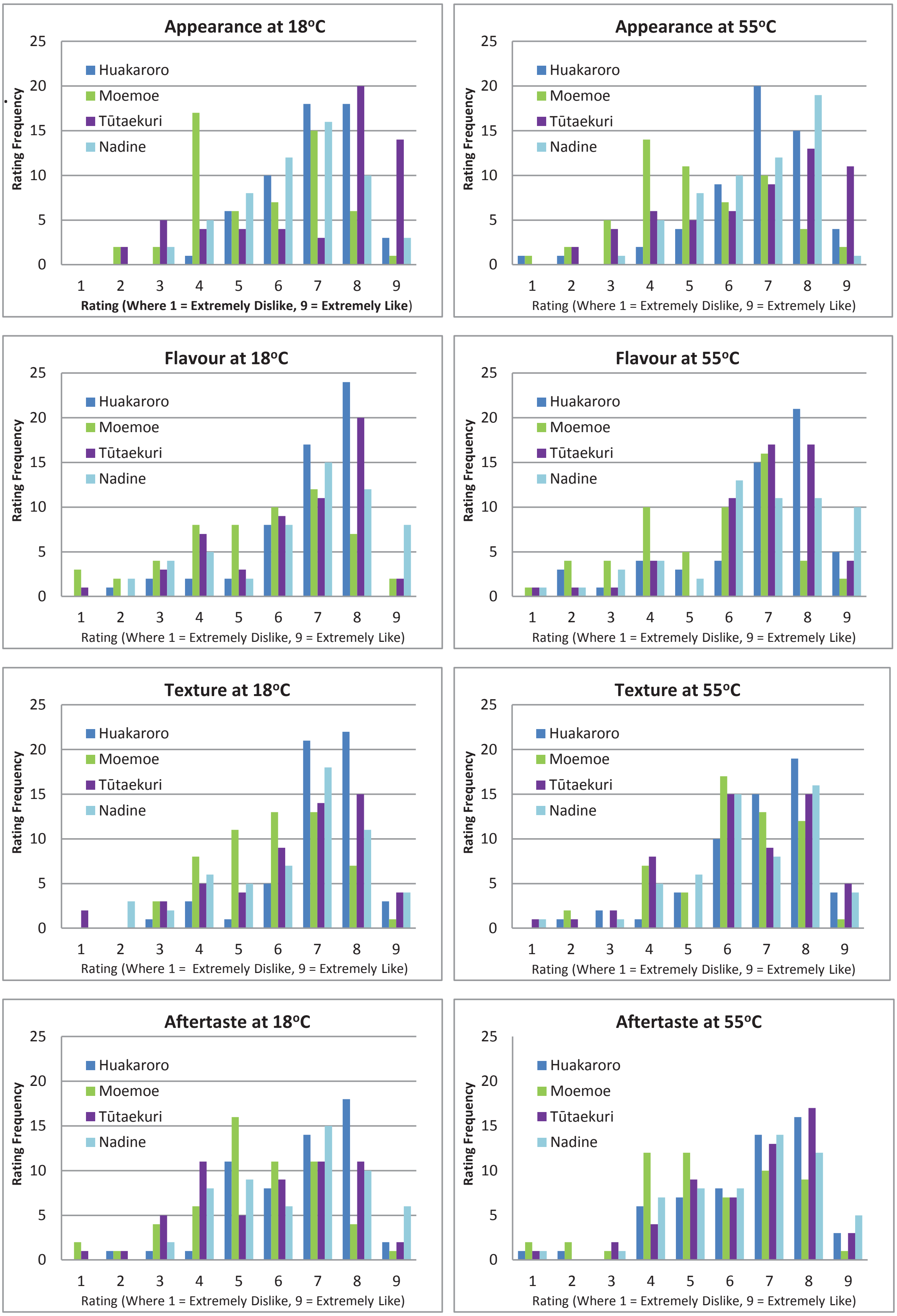
In terms of appearance, when looking at both temperatures combined, Huakaroro was the most highly rated cultivar (6.8 ± 0.2) followed by Tūtaekuri (6.7 ± 0.2) and Nadine (6.4 ± 0.2), with all three cultivars preferred ($p < 0.05$) to Moemoe (5.3 ± 0.2) (see Table 6.4). This order of preference was also demonstrated at the individual serving temperatures of 18°C and 55°C. At 55°C, Huakaroro, Tūtaekuri and Nadine were preferred ($p < 0.05$) to Moemoe, while at 18°C, Huakaroro was preferred ($p < 0.05$) to Nadine and Moemoe, and Tūtaekuri and Nadine were preferred ($p < 0.05$) to Moemoe. Serving temperature had no effect on preference ($p >0.05$), however, the Huakaroro, Tūtaekuri and Nadine cultivars achieved numerically higher sensory appearance ratings at 18°C (compared to 55°C), whereas the appearance of Moemoe was rated higher at 55°C (compared to 18°C). By looking at the frequency distribution of appearance ratings (Figure 6.1), it is clear that Huakaroro, Tūtaekuri and Nadine were given higher ratings (6-9) by a greater number of people than Moemoe.

Huakaroro also achieved the highest mean rating for flavour at both temperatures combined (6.8 ± 0.2), followed by Tūtaekuri and Nadine (6.5 ± 0.2), with all three cultivars again preferred ($p < 0.05$) to Moemoe (5.4 ± 0.2). This order of cultivar preference was maintained at 55°C with Huakaroro, Tūtaekuri and Nadine again receiving a greater frequency of higher ratings to Moemoe at both temperatures. However at 18°C Nadine received a slightly higher mean flavour rating compared to Tūtaekuri at (6.5 ± 0.3 vs 6.4 ± 0.3, respectively) (see Table 6.4 and Figure 6.1).

Huakaroro rated highest for texture at both temperatures combined (7.0 ± 0.2), and was preferred ($p < 0.05$) to Tūtaekuri (6.4 ± 0.2), Nadine (6.3 ± 0.2) and Moemoe (6.0 ± 0.2). This order of preference was maintained at 18°C with Huakaroro again preferred ($p < 0.05$) to Tūtaekuri, Nadine and Moemoe, however at 55°C the texture of Tūtaekuri rated similarly to Nadine and the only significant preference demonstrated was for Huakaroro versus Moemoe ($p < 0.05$). Serving temperature had no effect on textural preference between cultivars ($p > 0.05$). However, the Huakaroro variety achieved a greater frequency of higher ratings for texture at 18°C (compared to 55°C), and Moemoe and Nadine achieved a greater frequency of higher ratings at 55°C (compared to 18°C) (see Table 6.4 and Figure 6.1).

Figure 6.1 Frequency Distribution of Sensory Ratings Between Four Cultivars at 18°C and 55°C

N = 56. (Frequency of sensory attribute ratings of consumers who tasted samples from Huakaroro, Moemoe, Tūtaekuri and Nadine potato cultivars at two serving temperatures)



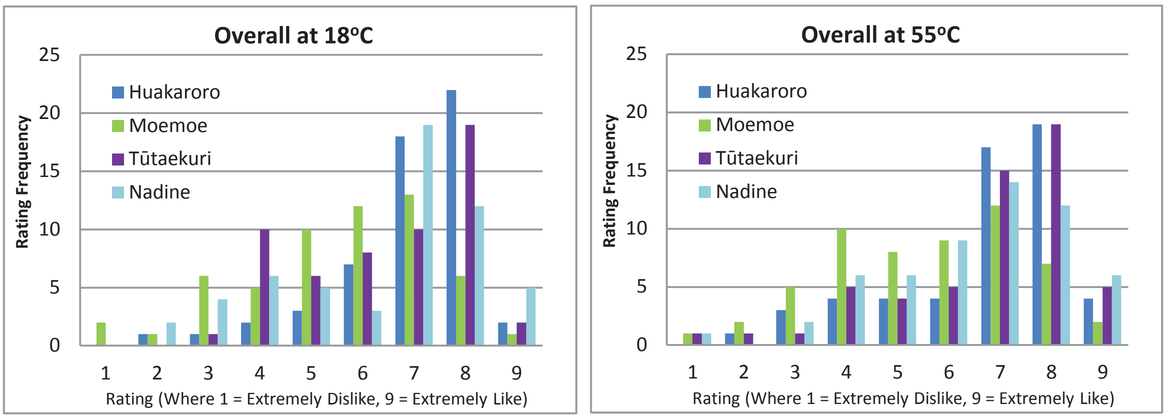
Again Huakaroro's mean rating for aftertaste was highest of the four cultivars at both temperatures combined (6.6 ± 0.2) followed by Nadine (6.4 ± 0.2), Tūtaekuri (6.1 ± 0.2) and Moemoe (5.5 ± 0.2). Huakaroro was preferred ($p < 0.05$) to Tūtaekuri and Moemoe, while Nadine and Tūtaekuri were preferred ($p < 0.05$) to Moemoe. This order of preference was maintained at the individual serving temperature of 18°C with Huakaroro and Nadine preferred ($p < 0.05$) to Tūtaekuri and Moemoe, and Tūtaekuri preferred ($p < 0.05$) to Moemoe. However at 55°C, both Tūtaekuri and Huakaroro achieved the highest mean rating for aftertaste (6.5 ± 0.3) followed by Nadine and Moemoe, with all three preferred ($p < 0.05$) to Moemoe. Looking at the frequency distribution of scores for aftertaste, all cultivars seemed to be rated more evenly between 4-8 and there were a fewer number of high ratings (7-8) compared to the other sensory attributes. Serving temperature had no effect on preference ($p < 0.05$), in three of the four cultivars, however the aftertaste of Tūtaekuri was preferred ($p < 0.05$) at 55°C (compared to 18°C) (see Table 6.4 and Figure 6.1).

6.4.2.3. Differences Between Overall Acceptance of Cultivars

After having rated appearance, flavour, taste and aftertaste, sensory participants were asked to give an "overall acceptance" rating of the sample. Huakaroro received the greatest "overall acceptance" rating at both serving temperatures combined (6.8 ± 0.2), followed by Tūtaekuri (6.5 ± 0.3), Nadine (6.5 ± 0.2) and Moemoe (5.5 ± 0.2). Huakaroro was preferred ($p < 0.05$) to Nadine and Moemoe, while Tūtaekuri and Nadine were preferred ($p < 0.05$) to Moemoe. By looking at the frequency distribution of scores for "overall acceptance" (Figure 6.2), again it is clear that Huakaroro, Tūtaekuri and Moemoe achieved a greater frequency of higher ratings (6-9) and a lower frequency of low ratings (1-4) in comparison to Moemoe. Serving temperature had no effect on preference ($p > 0.05$), however, the Huakaroro variety achieved a numerically higher overall acceptance rating at 18°C (compared to 55°C), with Tūtaekuri and Nadine preferred at 55°C (compared to 18°C) (see Table 6.4 and Figure 6.2).

Figure 6.2 Frequency Distribution of "Overall" Rating Between Four Cultivars at 18°C and 55°C

N = 56. (Frequency of "overall" sensory ratings of consumers who tasted samples from Huakaroro, Moemoe, Tūtaekuri and Nadine potato cultivars at two serving temperatures)



6.4.2.4. Preferred Sensory Attributes Within Cultivars

What can be seen in both the frequency distribution and mean scores of sensory ratings is that different cultivar's appeared to have differences with regards to the most liked and least liked attributes, but the attribute most or least preferred appeared to be dependent on the serving temperature.

In Huakaroro, texture was the most favoured attribute, whereas aftertaste was the least favoured at both temperatures. In Moemoe, texture was also the most favoured attribute at both temperatures, and when served at 55°C appearance appeared to be the least favoured of the four attributes.

The highest attribute ratings for Tūtaekuri were for appearance (at 18°C) and flavour (at 55°C). Tūtaekuri's lowest ratings were for aftertaste (at 18°C). The appearance of both Tūtaekuri and Moemoe did not score as highly when served warmed (55°C) compared to when they were served at room temperature (18°C). Typical comments from the participants regarding the appearance of Moemoe and Tūtaekuri were similar for the respective cultivars at both temperatures and indicated that the appearance of the flesh of Moemoe or skin of Tūtaekuri were not appealing (see Appendix 6.6 for typical comments regarding Tūtaekuri and Moemoe).

The greatest difference in rating between serving temperatures for all sensory attributes within the same potato variety occurred in the perceived aftertaste of Tūtaekuri samples, where the warmed Tūtaekuri samples scored 0.7 points higher compared to those Tūtaekuri samples served at room temperature (6.5 *cf* 5.8 served warmed or at room temperature respectively.

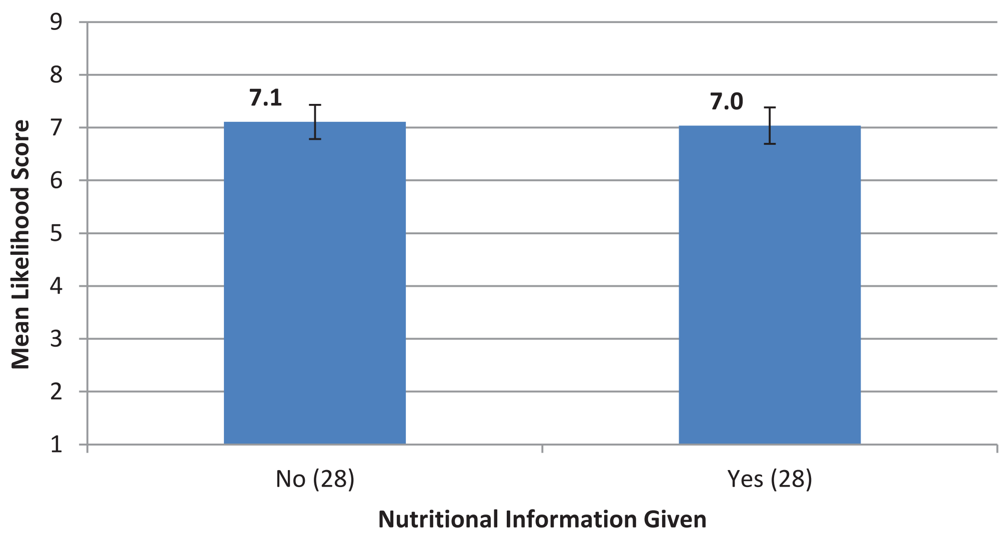
6.4.3. *Effect of Nutritional Information on Likelihood of Future Taewa Purchase*

Twenty eight of the fifty six participants (50%) undertaking the sensory evaluation were given information about the potential health benefits of (a) eating cooked potato that had been cooled for a period prior to consumption due to an increase in resistant starch (RS) content; and (b) consuming red, blue or purple-coloured potatoes due to their increased potential antioxidant content. Participants were told that certain Taewa that had been tested had a greater potential RS (Section 5.3.4.1.) and anthocyanin (ACYN) content (Section 2.4.5.1.) than the modern Nadine variety used.

In the final section of the sensory questionnaire, all 56 sensory participants were asked to rate their likelihood of purchasing Māori potatoes in the future on a nine-point category scale anchored with "extremely unlikely" through to "extremely likely" and a central neutral point of "neither likely or unlikely". Based on the results, it appears that both groups, (those who did receive the information (n=28) and those who did not (n=28)) may be likely to purchase Taewa in the future as the likelihood of future Taewa purchase were scored at 7.0 ± 0.4 and 7.1 ± 0.3 respectively (Figure 6.3).

Figure 6.3 Likelihood of Future Taewa Purchase vs Nutritional Information Given.

(N = 56; Mean likelihood score for future Taewa purchase between 1-9 where 1 = extremely unlikely, 5 = neither likely or unlikely and 9 = extremely likely)



Key: Values in bold represent the groups mean score for likelihood of future Taewa purchase. Bars indicate standard errors.

6.4.4. *Evaluation of the Effect of Previous Taewa Consumption on Various Aspects of the Sensory Trial Data*

All survey participants (n=56) were asked to indicate whether or not they had previously eaten Māori potatoes. Twelve participants indicated that they had never eaten Taewa before (NEB group); twelve participants indicated that they were unsure if they had eaten Taewa (UEB group) and thirty two participants indicated that they had eaten Taewa previously (EB group).

6.4.4.1. *Effect of Previous Taewa Consumption on Sensory Scores*

No significant difference ($p > 0.05$) was found between the three groups in the mean liking scores for combined cultivar and serving temperature ratings for any of the sensory attributes (see Table 6.2). However significant pair-wise differences ($p < 0.05$) were found in combined cultivar and serving temperature ratings depending on the participants' previous Taewa consumption and ratings for each of the attributes was scored lower by those who had not eaten Taewa before (NEB group), compared to those who had eaten Taewa (EB group). The greatest significant pair-wise difference was found with regards to the combined cultivar overall acceptance rating ($P=0.040$). Overall acceptance was scored 6.6 ± 0.2 by the EB group and 5.9 ± 0.3 by the NEB group. Differences were also found between the EB and NEB groups with regards to flavour (6.3 ± 0.2 (EB) and 5.9 ± 0.3 (NEB); $P=0.036$), and approached a trend for texture (6.2 ± 0.2 (EB) and 5.9 ± 0.3 (NEB); $P=0.098$).

6.4.4.2. *Effect of Previous Taewa Consumption on Cultivar Preference*

Taewa cultivar eating preferences were previously identified among Taewa consumers in both the Group Discussions (Section 3.4.1.4.) and among the 209 participants who responded to the survey of Taewa cooking and consumption practices (Section 4.4.2.3). It was therefore of interest to see whether the Taewa cultivar preferences of the 24 sensory trial participants, who selected "no" and "not sure" for having eaten Taewa before (43% of the total), were similar to those found among survey participants who had previously eaten Taewa. Having previously eaten Taewa appeared to have no effect on the liking scores ($P >0.05$), however significant differences ($P <0.05$) were found between the liking of Moemoe and liking of the other three potato cultivars. Based on the highest mean liking scores for all attributes, Huakaroro was both the Taewa cultivar, as well as the overall cultivar most preferred when served at $18^{o}C$ by those who had never or weren't sure if they had previously eaten Taewa (NEB + UEB group), as well as for those who had eaten Taewa before (EB group) .

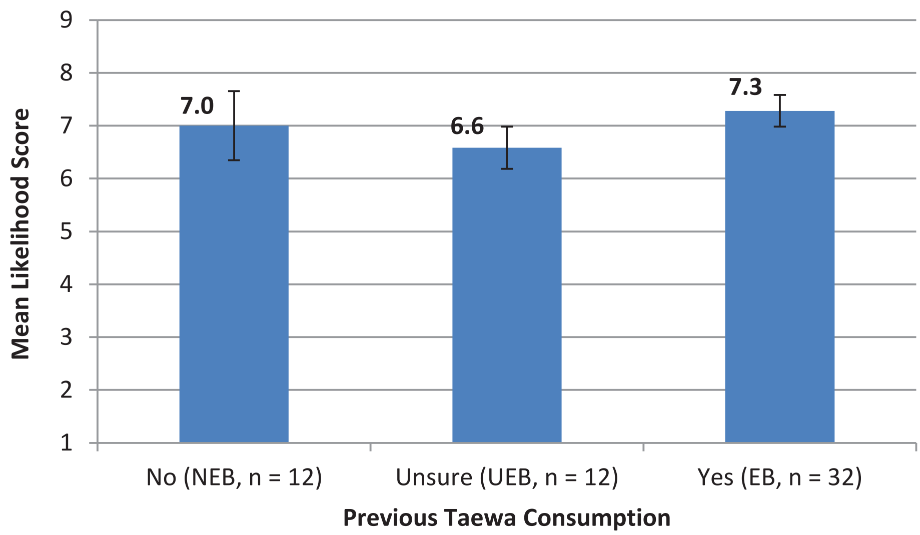
The rating achieved by Huakaroro for each attribute was also similar irrespective of whether participants had eaten Taewa before or not. Moemoe was the cultivar least preferred of all four cultivars for all sensory attributes both by those had eaten Taewa and those who had not eaten Taewa previously.

A slightly different preference for cultivars was found between the NEB + UEB group and EB group when the potatoes were served at 55^{o}C. Huakaroro again appeared to be the most preferred cultivar overall by those who had eaten Taewa before (EB group), as it achieved the greatest liking score for each of the sensory attributes. Moemoe was the least preferred cultivar by all groups based upon its lowest liking ratings for each sensory attribute.

6.4.4.3. Effect of Previous Taewa Consumption on Likelihood of Future Taewa Purchase

Previous exposure to Taewa did not appear to effect the likelihood of participants purchasing Māori potatoes in the future, as the mean likelihood ratings for all groups suggested they would likely purchase Taewa in the future (Figure 6.4), as scores were similar ($p > 0.05$) irrespective of whether they had, hadn't or were unsure if they had previously eaten Taewa.

Figure 6.4 Likelihood of Future Taewa Purchase According to Previous Taewa Consumption. (N = 56. Mean likelihood score for future Taewa purchase between 1-9 where 1 = extremely unlikely; 5 = neither likely or unlikely and 9 = extremely likely)



Key: Values in bold represent the mean group score for likelihood of future Taewa purchase according to previous Taewa consumption. Bars indicate standard errors.

6.5. Discussion

The major aims of the current sensory trial were to carry out a preliminary investigation as to whether pre-boiled, 24 h-cooled Taewa potato products, (which were shown in Section 5.3.4.1. to accumulate greater resistant starch than the modern variety Nadine), might be acceptable to potato consumers. In addition, to investigate whether there might be a preference for serving temperature of the pre-boiled, 24 h-cooled Taewa potato products; and whether providing nutritional information after testing, might influence the future purchasing of Taewa products.

It was also of interest to investigate whether a participant's previous consumption of Taewa influenced the sensory rating and preference for a Taewa cultivar; or might be expected to influence future consumption of Taewa potato products with improved health benefits; or future purchasings of Taewa. While conclusions regarding the effect of nutritional information or prior Taewa consumption on the likelihood of future purchases of Taewa is subject to error due to the low power in numbers, the positive results (mean scores greater than 6.6 for all groups) suggest that people may be more likely than not to want to purchase Taewa.

6.5.1. Analysis of Overall Fixed Effects

Statistical analysis (Table 6.2) of effect on sensory ratings from serving temperature, potato variety, nutritional information and previously exposure to Taewa showed that only potato variety had a significant effect ($p< 0.05$), on any of the sensory attribute ratings.

No apparent effect on sensory ratings for the combined effects of serving temperature and potato variety were of significance, however, the combined effects of nutritional information as well as previous exposure to Taewa were approaching a significant effect with regards to flavour ($p = 0.0935$) and overall acceptance ($p = 0.0973$). However, this result may be due to a bias from low participant numbers within the relevant groups rather than a real effect on liking scores.

6.5.2. *Effect of Serving Temperature on Consumer Sensory Ratings*

The finding that there were no differences in preference ($p > 0.05$) between serving temperatures for any of the potato varieties was surprising because a clear preference for eating Taewa hot or warm was indicated in both the group discussions (Chapter 3) and the survey of Taewa cooking and consumption practices (Chapter 4). The majority of the group discussion participants (21 of 25; 84%) preferred to eat cooked Taewa hot or warm (Section 3.4.1.4.) and of 209 survey participants, 51% preferred eating Taewa hot; 35% warmed; and only 3% preferred to eat Taewa cold (Section 4.4.2.3.b.).

One possible reason for this difference could be the perception of what was considered a “cold” sample by participants in the Taewa survey. Survey participants may have construed “cold” to mean a potato eaten straight from the fridge, and had they been asked their perception of consuming a potato sample served at room temperature their preference could well have been different. In addition, the sensory participants were a different subset of people to those who participated in the Taewa survey which was undertaken using a different method of analysis (memory recall versus immediate sensory reaction) and so for these reasons direct comparisons between the two groups are not necessarily valid.

A lack of preference difference between serving temperatures may also have been due to a study bias from participants who wanted to score samples similarly for the benefit of the researcher; or that the warmed samples had cooled closer to room temperature by the time the participant had time to evaluate the later warmed samples, thus minimizing any potential effect of serving temperature. Additionally, although the thought of eating cold potatoes may not be preferable (as shown by the Group Discussion and Potato Survey of Chapters 3 and 4), there was only one occasion out of the four cultivars and 4 sensory attributes measured where there was a significant preference for serving temperature (aftertaste in Tūtaekuri scored a significantly higher rating at 55^{o}C compared to 18^{o}C; $P > 0.05$).

The general lack of temperature preference may simply show that in reality, potatoes served at room temperature may not be less desirable or less flavoursome than those served at a warmer temperature. However, the Huakaroro variety appeared to be preferred at 18°C (compared to 55°C) and Tūtaekuri and Nadine preferred at 55°C (compared to 18°C), due to a numerically higher overall acceptance rating at the relevant serving temperatures.

Repeating the sensory trial again under the same conditions, but with more subjects would help clarify whether there is no significant difference between serving temperature preferences for these potato cultivars.

The lack of preference between serving temperature and mean ratings that were consistently greater than the neutral central point of 5, (“neither like nor dislike”) for each of the sensory attribute suggests that pre-boiled, 24 h-cooled potatoes may have the potential to be used in future products served at 18^{o}C (such as in a pre-prepared potato salad served at a restaurant at room temperature) or at 55^{o}C (such as par-boiled or pre-boiled potato destined for further cooking or warming by the consumer).

When all of the sensory attribute ratings for all potato varieties were combined, “appearance” received the highest rating of 6.4 at 18^{o}C; while at 55^{o}C “flavour” received the highest rating of 6.5. “Aftertaste” scored lowest at both serving temperatures (6.06 at 18^{o}C and 6.23 at 55^{o}C), suggesting this may be the attribute that may limit acceptability for pre-boiled and 24 h-cooled potato served in this manner.

6.5.3. Effect of Taewa Variety on Consumer Sensory Ratings

A potato cultivar effect on sensory liking ratings was expected due to the differences in the inherent tuber characteristics of each potato variety (such as the differences in tuber skin and flesh colouring; differences in cooked textures; taste / flavour differences; range in glycoalkaloid content) which all contribute to the overall evaluation of the sensory appeal of the variety.

Significant cultivar differences have been found in relation to various texture descriptors (Van Marle *et al.,* 1997; Thybo and Martens, 2000) and score of flavour and texture in boiled potatoes (Pardo *et al.,* 2000). A study by Arvanitoyannis and colleagues in 2008 found significant sensory differences between boiled Spunta and Agria cultivars, particularly relating to the odour intensity and taste sweetness (Arvanitoyannis *et al.,* 2008).

Clear Taewa varietal preferences were apparent in both the 25 group discussion participants (Section 3.4.3.1.) and 132 Taewa survey respondents (Section 4.4.4.2.a.). Huakaroro was mentioned most frequently by the 25 group discussion participants as being the preferred variety, however, Tūtaekuri was identified as being the most preferred Taewa variety by 34.8% (46/132) of survey respondents compared to the preference for Moemoe by 9.1% (12/132) of respondents and Huakaroro by 7.6% (10/132) of respondents.

Due to the greater number of participants involved in the Taewa survey compared to the group discussions, and the greater percentage of survey respondents who preferred Tūtaekuri compared to the other two Taewa varieties, it was expected that Tūtaekuri would be the preferred variety in the sensory trial.

As expected, significant differences in liking scores for appearance, flavour, texture, aftertaste and overall acceptability occurred between potato cultivars overall, as well as between cultivars served at the different temperatures. Significant differences in rating most often occurred between the three varieties Huakaroro, Tūtaekuri and Nadine, and Moemoe and with the preferred ranking between the cultivars generally being Huakaroro first, Tūtaekuri and Nadine second or third and Moemoe achieving the lowest for each sensory attribute.

The low rating scores for Moemoe may be explained by the fact that although it was harvested at the same time as the other Taewa varieties, it had been stored under different conditions to the Huakaroro and Tūtaekuri tubers. At the time of the sensory trial, the Moemoe tubers did not seem as firm as the other varieties and some had just begun to sprout. Also, a greyish appearance of the cooked Moemoe flesh near to the skin (possibly due to the aging of the potato or related to a transfer of pigments from the purple skin into the white flesh associated with the Moemoe cultivar) was more apparent in the Moemoe samples and a number of participants commented that this was not appealing. Hence these factors may have impacted on the sensory qualities of Moemoe and thus its sensory ratings.

Due to the clear preference of 85% (170/200) previously demonstrated by Taewa survey participants for eating warm or hot Taewa (Section 4.4.2.3.b.), it was not surprising that the sensory attribute ratings for Moemoe, and Tūtaekuri generally scored higher when served warmed (55^{o}C). However, it was of interest to discover that the appearance of Tūtaekuri and Moemoe and all sensory attribute ratings for Huakaroro scored higher when served at room temperature (18^{o}C) rather than when served warmed (55^{o}C).

Of the four sensory attributes (appearance, flavour, texture and aftertaste), texture received the highest sensory attribute rating in Huakaroro (at 18^{o}C) and in Moemoe (at 55^{o}C), whereas appearance received the highest rating for Nadine (at 55^{o}C) as well as for Tūtaekuri (at 18^{o}C) . Interestingly, all sensory attribute ratings for Huakaroro scored higher when served at room temperature (18^{o}C), whilst the sensory attribute ratings for the other three varieties (Moemoe, Tūtaekuri and Nadine), generally scored higher when served warmed (55^{o}C).

Previous research into consumer behaviour of New Zealanders in relation to fresh and processed potatoes found that the visual appearance of the potatoes had the greatest influence when selecting which potatoes to buy (Horticulture New Zealand, 2006). Jemison and colleagues (2008) found that when 275 American participants were able to see the colour of the potato flesh, it significantly affected variety selection such that white or yellow-fleshed varieties were preferred, and greater than 10% of the participants indicated that they would not purchase "blue" potatoes (a colour category Tūtaekuri would likely fit under) (Jemison *et al.*, 2008).

However, appearance may not have as great an effect on consumer acceptance once tasted. Leksrisompong *et al*. (2012) evaluated the sensory characteristics (appearance, texture, flavour, overall acceptability) of twelve sweet potatoes with varying flesh colours (yellow, orange, purple) and the impact of flesh colours on consumer acceptance (90 subjects). Although visual appearance positively impacted liking scores of yellow, orange and purple sweet potato when products were not well liked, the authors found that appearance had a lower impact on scores when the sweet potato was well liked, suggesting that flavour and texture rather than appearance were the driving attributes for liking (Leksrisompong *et al*., 2012).

In this sensory trial, it was of interest to learn that the uncommon, strikingly different appearance of Tūtaekuri (deep purple skin and flesh) did not appear to negatively affect appearance liking ratings overall (mean combined score of appearance at both serving temperatures; 6.7); when compared to the more the common brown-skinned, white-fleshed appearance of the Nadine variety (overall appearance rating; 6.4). In fact, when served at room temperature, the mean appearance score of Tūtaekuri was 6.8, which was higher (p = 0.08) than the mean appearance score of Nadine (6.3).

6.5.4. Effect of Nutritional Information on the Likelihood of Purchasing Taewa in the Future.

A number of studies have shown that providing favourable nutritional information can positively influence consumer willingness to consume, purchase or to try novel foods (Pelchat and Pliner, 1995; Kozup *et al*., 2003; Luckow *et al*., 2006; Baixauli *et al.*, 2008). Thus, the purpose of including a question about the likelihood of future Taewa purchasings in the sensory trial was to discover whether providing information on the nutritional properties of potatoes might increase the likelihood of purchasing Māori potatoes in the future compared to those who had not received the nutritional information.

Receiving information regarding the potential health benefits of eating cooked potato that had a potential increase in resistant starch (RS); or an increased potential antioxidant value, did not appear to affect the likelihood of purchasing Māori potatoes in the future irrespective of whether the participants had received the information or not.

Both groups (those who had and hadn't received nutritional information) awarded a likelihood of purchasing Taewa in the future above 7 (score of 7 = moderately likely to purchase Taewa in the future), therefor provision of information did not affect future likelihood of purchase. This is a positive result with regards to the indication that the survey participants would be more than likely to purchase Taewa in the future if the opportunity presented itself.

6.5.5. Effect of Previous Taewa Consumption on Various Aspects of the Sensory Trial Data

The purpose of this part of the study was to see whether familiarity with Taewa and/or previous consumption of Taewa cultivars might positively affect sensory attribute liking scores, sway the preference for Taewa compared to the modern variety or increase the likelihood of consuming Taewa products with improved health benefits or increase the likelihood of purchasing Taewa in the future.

Raudenbush and Frank (1999), found that within 33 subjects, evaluations of familiar foods were generally more positive than evaluations of unfamiliar foods. Luckow *et al*. (2006) found that repeated exposure to products, or to nutritional information and receiving favourable information about juices containing probiotic cultures had a significant positive effect on the "overall liking" of juices in 116 consumers.

In the current sensory trial, having previously eaten Taewa or not, did not significantly affect overall sensory ratings in any of the sensory attributes measured (Table 6.2). The sensory ratings for all attributes were numerically higher from those participants who had eaten Taewa previously compared to those who hadn't.

Therefore it is possible that with greater numbers, both of those who had eaten Taewa, as well as those who hadn't, a significant difference may have been found between the groups. Additional exposure to the nutritional information may also result in a significant influence on ratings.

6.5.5.1. *Preferred Cultivar*

Huakaroro was the preferred cultivar when served at room temperature irrespective of previous Taewa consumption. However, when served at 55^{o}C, Nadine was most preferred by those who hadn't or were unsure whether they had eaten Taewa before (NEB + UEB group), with Huakaroro still preferred by those who had eaten Taewa (EB group).

Similarly to the subjects in the Raudenbush and Frank study (1999), it is possible that Huakaroro and Nadine were the varieties preferred by the NEB + UEB group because of their familiarity to potato varieties that are commonly eaten in New Zealand (brown skinned, white or yellow-fleshed varieties)and thus rated more favourably overall than either Tūtaekuri and Moemoe which had unfamiliar tuber characteristics.

6.5.5.2. *Likelihood for Future Taewa Purchase*

When asked to rate their likelihood for purchasing Taewa in the future, no significant difference in scores were found between the NEB group (7.0); UEB group (6.6) or EB group (7.3). In fact, all three groups were more than likely to purchase Taewa in the future (as shown by their ratings scores above 6 on the 9 point scale).

Although this result must be viewed with caution as consumers may have associated the Nadine variety as a Taewa variety, the results suggests that even consumers trying Taewa products for the first time may be more than likely to purchase Taewa in the future if the opportunity presented itself. However, a greater number of participants (both of those who had, and those who hadn't eaten Taewa) would be needed to confirm this result or show if the numerical differences observed attained actual significance.

6.5.6. *Possible Relationship of Varietal Chemical Composition in Huakaroro, Moemoe, Tūtaekuri and Nadine to Sensory Ratings*

The chemical composition of potato cultivars play a key role in parameters relating to potato quality, cooking performance and sensory appeal (Sharma *et al.,* 1959; Burton, 1989; Thybo *et al.,* 1996). Huakaroro, Moemoe and Tūtaekuri and the modern Nadine cultivar differed in regards to many nutrient, anti-nutrient and phytonutrient components (Chapter 2). These compositional differences may help explain some of the sensory results observed in this trial. Discussion of the possible influence of some of the key chemical components on sensory attribute ratings occurs in the following sections.

6.5.6.1. *Dry Matter, Sugar, Starch Content and Textural Ratings*

Dry matter content (Burton *et al.*, 1992), starch composition (Thygesen *et al.*, 2001; Kaur *et al.*, 2002) and cell wall structure (Van Dijk *et al.*, 2002b) all play key roles in potato quality and sensory perception, particularly with regards to textural perception. A potato cultivar with high dry matter content, low sugar content and high starch content is positively associated with being floury when cooked and with increased mealiness, which will thus affect textural perception and acceptance (Burton, 1989).

Nadine, Huakaroro and Moemoe generally have a lower dry matter content compared to Tūtaekuri, and analysis of boiled, 24 h-cooled, whole tubers (Section 5.3.4.1.) found that Huakaroro, Moemoe and Tūtaekuri had a much higher dry matter and starch content than Nadine (24 – 28 *cf* 15 g/100 g FW dry matter; 15 – 17 *cf* 8 g/100 g FW starch). These compositional differences suggest that Tūtaekuri is more likely to be associated with increased floury / mealiness (due to its highest dry matter and starch content).

The descriptors mealiness or flouriness are normally associated with a more in depth investigation into textural sensory analysis, than was carried out in this sensory trial, however a number of participants commented on the mealiness in the texture of Tūtaekuri samples (Appendix 6.8). Tūtaekuri's mealy / floury texture may have contributed to the fact that texture was given the second lowest rating of all sensory attributes in Tūtaekuri.

6.5.6.2. *Flavour Precursors, Fatty Acid Content and Flavour Ratings*

The inherent array of volatile and non-volatile compounds present in potatoes (Jensen *et al.*, 1999; Petersen *et al.*, 1998; Ulrich *et al.*, 2000; Blanda *et al.,* 2010; Morris *et al.*, 2010) are some of the components that are likely to affect taste and flavour perception. Flavour precursors inherent in raw potato tubers show wide variation in quantity between cultivars (Morris *et al.*, 2010), and these in turn, affect the number and intensity of volatile and non-volatile metabolites that result from Maillard reactions and Strecker degradation brought about during cooking (Ulrich *et al*., 2000; Duckham *et al*., 2002; Blanda *et al*., 2010). Cultivar differences in both the composition of flavour compounds and perceived aroma of boiled potatoes, have been reported in a number of studies (Jensen *et al.*, 1999; Petersen *et al.*, 1998; Ulrich *et al.*, 2000; Blanda *et al.*, 2010; Morris *et al.*, 2010). Ulrich and colleagues (2000), reported that more than 140 volatile compounds were identified in only 3 boiled modern potato cultivars (2 German cultivars: Adretta and Likaria and 1 breeding clone: St 1,365).

Although neither flavour precursors nor volatile and non-volatile metabolites were analysed in the current research, a desirable “buttery” flavour was mentioned a number of times by the group discussion participants (Section 3.4.3.1); survey participants (Section 4.4.5.2.) as well as by a few of the sensory participants. Desirable flavours such as the “buttery” flavour, possibly brought about by volatile or non-volatile compounds inherent in the Huakaroro variety, and released due to cooking or warming, may have contributed to Huakaroro’s highest overall rating for flavour of the four cultivars (6.8 in Huakaroro *cf* 5.4, 6.5 and 6.5 in Tūtaekuri, Moemoe and Nadine respectively). Since palmitic, linoleic and linolenic fatty acids represent more than 90% of the fatty acids present in potatoes, lipid oxidation in boiled potatoes by lipoxidase enzymes will give rise to a number of aldehydes and ketones which may give rise to fatty, fruity or floral notes (Galliard and Matthew, 1973; Petersen *et al.*, 1998). However the yellow appearance of Huakaroro may also have impacted on the perceived “buttery” flavour perception of this cultivar.

Analysis of whole tubers (Section 2.3.4.3) found that Tūtaekuri had a greater combined palmitic, linoleic and linolenic content (93.9 mg/100 g FW) compared to Huakaroro (80.9 mg/100 g FW), Moemoe (84.1 mg/100 g FW) and Nadine (45.7 mg/100 g FW). Thus fatty acid oxidation in boiled Tūtaekuri may have given rise to a greater intensity of fatty, fruity or floral notes and thus contributed to the greater overall flavour rating of Tutaekuri compared to Moemoe or Nadine.

Further, the increase in volatile components being released from the sample as it was heated (Delwiche, 2004) may have caused a greater flavour rating of Tūtaekuri served warmed compared to when it was served at room temperature.

6.5.6.3. Phenolic, Glycoalkaloid Content and Aftertaste Ratings

The concentration of compounds imparting bitter tastes such as the anti-nutrient glycoalkaloids (Friedman and Dao*,* 1992; Friedman, *et al.,* 1997; Savage *et al*., 2000), or of bitter-tasting phenolic compounds (Mondy *et al*., 1971), are both likely to affect both flavour and aftertaste perception. A potential concern associated with potato consumption is the presence of naturally occurring glycoalkaloid compounds, which have adverse effects in humans ranging from gastrointestinal disturbances at low levels (1-2 mg/kg bodyweight), to neurological disorders at higher levels (3-4 mg/kg bodyweight) to possible death at levels above 5 mg/kg bodyweight (Friedman *et al.*, 1997). Glycoalkaloids at much lower concentrations are also likely to have an effect on the bitterness or aftertaste perceived in potato samples.

In commercial potatoes (*Solanum tuberosum*), the major glycoalkaloids are α-chaconine and α-solanine, which are normally present in low concentrations (<100 mg glycoalkaloid/kg fresh weight potato), but levels can vary significantly between and within potato varieties. Levels of glycoalkaloids have been found to range from 5 – 665 mg/kg FW across modern and Andean cultivars (Hellenäs *et al.*, 1995a; Hellenäs *et al*., 1995b; Friedman *et al.,* 2003).

Phenolic compounds differ which respect to the bitterness or astringency imparted, however a greater phenolic content in potatoes may result in increased aftertaste or bitterness perception. Mondy *et al*. (1971) found significant correlation between high phenolic content (>450 mg/kg FW potato) and astringency or bitterness in 50 hybrid clones of cooked potatoes from the *Solanum tuberosum subsp. tuberosum* and *Solanum tuberosum subsp. andigenum* varieties such that increased phenolic content increased bitterness and astringency perception.

As shown in Chapter 2, total glycoalkaloid levels ranged from 11.5 mg – 70 mg/kg FW in Taewa flesh and 181 mg – 575 mg/kg FW in Taewa skin. The total phenolic content of the Taewa ranged from 196 – 4920 mg/kg FW Taewa flesh and 909 - 8575 mg/kg FW in Taewa skin). The Tūtaekuri variety (dark purple skin and flesh) had the greatest content of glycoalkaloid and phenolic compounds of the four Taewa varieties tested.

Savage *et al.* (2000), found that glycoalkaloid content ranged from 38.7 to 142.6 mg/kg FW whole potato between Taewa cultivars with the higher glycoalkaloid content found in cultivars that had purple flesh and skin (most likely Tūtaekuri). Thus it was hypothesised that Tūtaekuri might be among the least favourite of the Taewa varieties to be consumed due to a greater bitterness potentially imparted by the greater content of glycoalkaloids and phenolic compounds.

In the sensory trial, when Tūtaekuri was served at room temperature, aftertaste received the lowest mean rating of all the sensory attributes, suggesting that the greater glycoalkaloid content (likely to impart a bitter aftertaste) may have contributed to the low sensory attribute rating in the cultivar. However, the scores for aftertaste between Tutaekuri samples served at room temperature (5.8) or served warmed (6.5) were different ($p < 0.05$). It is possible that the greater scores given during the higher temperature sensory perception may have reflected enhanced flavour tones brought about by release of volatile compounds in Tūtaekuri, thus helping to mask bitter tones that might be present. Thus it may be beneficial that a pre-cooled, 24 h-cooled product made from Tūtaekuri should be designed so as warming would take place prior to consumption.

It was of interest however, that Moemoe (which had lower glycoalkaloid content compared to Tūtaekuri), was the cultivar rated lowest for aftertaste when served both at room temperature or warmed. However, when all cultivars were served warmed, the aftertaste of Tūtaekuri and Huakaroro were rated the most preferable (6.5 *cf* 6.4 and 5.5 in Nadine and Moemoe respectively). Therefore glycoalkaloid content alone cannot be used to predict sensory acceptance as there are clearly other factors impacting on preference here.

6.5.6.4. Anthocyanin Content and Appearance Ratings

Reducing sugar or asparagine content (Marquez and Anon, 1986; Rodriguez-Saona and Wrolstad, 1997; Amrein *et al*., 2003) and coloured pigments present in the tuber skin or flesh such as carotenoid (Burgos *et al*., 2009; Bradshaw and Bonierbale, 2010) or anthocyanin phytonutrients (Voss *et al*., 1999; Jemison *et al.,* 2008; Leksrisompong, 2012), are likely to affect the appearance acceptability of the tubers both prior to and subsequent to cooking.

Anthocyanins are phytonutrient compounds which give rise to the pink, red, blue and purple colourations found in both the skin and flesh of potato tubers, and have been found to a varying degree in Taewa. The demand for speciality potatoes (varieties with skin or tuber characteristics that differ from the common commercial brown/white skinned, white/creamy-fleshed varieties) appears to be on the increase (Voss *et al*., 1999), and studies have found variable preferences for potato tuber colours, in particular a greater preference for yellow-fleshed, yellow-skinned or white-fleshed, red-skinned varieties than purple-fleshed, purple-skinned varieties (Voss *et al*., 1999, Wechsler, 2011).

Tūtaekuri in particular, has a much greater anthocyanin content than Huakaroro, Nadine (43-90 mg *cf* 0-0.5 mg/100 g FW in raw potato flesh; 118-126 mg *cf* 0-18 mg/100 g FW in raw potato skin) (Section 2.4.5.1) and its combination of anthocyanins give rise to its vivid dark purple skin and flesh colouration. Thus it might be expected that due to the greater anthocyanin content and uncommon vivid purple colouration of Tūtaekuri compared to the usual white or creamy-fleshed, brown-skinned colouration of most modern potatoes such as Nadine, that the appearance of Tūtaekuri would be rated lower than Nadine or Huakaroro (creamy-yellow skin and flesh). Tūtaekuri's uncommon appearance may have affected appearance ratings as the overall rating for appearance in Tūtaekuri was 6.4 compared to 6.7 in Nadine and 6.8 in Huakaroro. However, the appearance of Tūtaekuri was rated higher than the purple-skinned, creamy-fleshed Moemoe. Additionally, a lower rating in Tūtaekuri for appearance didn't appear to preclude a lower rating for flavour as overall, Tūtaekuri received the second highest rating for flavour (higher than Nadine and Moemoe).

6.5.7. *Summary of Results*

A primary aim of the sensory trial was to provide a preliminary investigation to see whether pre-boiled, 24 h-cooled potato products might be acceptable to potato consumers. Given the lack of difference in sensory attribute scores between serving temperatures for potatoes prepared in this way and that the combined mean attribute liking scores of all cultivars were above 6 when they were served at either 18°C or 55°C, may suggest that pre-boiled, 24 h-cooled potato products served at these temperatures might indeed have a place in the market. Pre-boiled, cooled potato products served at room temperature might have potential for use in potato salads, whereas partially-cooked, cooled potato products served at 55°C might have potential for consumers that prefer to eat potato warmed (par-boiled potato products could be stored under refrigeration at the supermarket, then the cooking completed by the consumer at home). Both of these products could be marketed as having the added benefit of an increased resistant starch and slowly digestible starch content and therefore may be useful for those with diabetes or glucose intolerance concerns.

Results from the group discussions and survey suggested that Huakaroro was one of the commonly eaten varieties (Sections 3.4.1.2. and 4.4.2.2.c), a preferred variety for eating (Sections 3.4.3.1. and 4.4.4.2.a). and also one of the varieties that was suggested as a suitable variety to be eaten cold (Sections 3.4.4.2. and 4.4.5.2).

Results from the current trial suggest that Huakaroro would likely be more popular among potato consumers than Moemoe, Tūtaekuri or even the modern variety Nadine. Sensory ratings measured (flavour, appearance, texture, aftertaste, overall acceptance) generally scored higher in Huakaroro than the other three varieties at both serving temperatures. Sensory ratings for Huakaroro were also more likely to consistently score above 6.8, suggesting a greater likelihood for consumer acceptance.

Tūtaekuri might also be considered as a Taewa variety with potential to be used in pre-boiled, 24 h-cooled products since combined temperature sensory ratings for Tūtaekuri were greater than Nadine in appearance, texture and overall acceptance, and sensory ratings for Tūtaekuri were often the second highest at both temperatures.

Although Moemoe scored the lowest for all sensory ratings at both temperatures out of the four cultivars tested, the sensory evaluation of Moemoe may have been affected by a lower overall quality of the tubers compared to the other three cultivars. It would be advisable to rerun the sensory trial but this time with Moemoe tubers that had been stored under similar conditions to the other three cultivars.

The intense purple colour of the Tūtaekuri samples was not lost during cooking and was obvious in the samples tasted. Huakaroro has a much yellower flesh colour than other potato varieties commonly available in New Zealand, and also retains its buttery-yellow colour following boiling. Smooth, brown/creamy-skinned and white/creamy-fleshed potato varieties such as Nadine are the most common varieties in the New Zealand market, however the results of this trial suggests consumers may find potatoes with alternate flesh or skin colours acceptable, as the appearance of both Huakaroro and Tūtaekuri scored higher or were equivalent to that of Nadine at both serving temperatures, and achieved appearance scores at, or above 6.5.

Neither receiving nutritional information on the potential health benefits of consuming Taewa, nor previous exposure to Taewa had any significant effect on likelihood ratings for purchasing Taewa in the future. Results showed that there was a strong trend/ high likelihood (score above 7) of purchasing Taewa anyway and provision of nutritional information did not improve the already high score further. However, due to the low power in numbers, a repeat of this experiment with greater participant numbers –and particularly those unfamiliar with Taewa would be advisable to ascertain greater validity of Taewa purchasing intent.

Sensory results suggest that familiarity with the characteristics associated with Taewa, (particularly the visual and aftertaste) may predispose consumers to greater acceptability of Taewa and therefore explain the higher sensory ratings of those who had eaten Taewa before compared to those who hadn't. Although participants were not informed as to which of the samples were Taewa varieties and which was the modern variety Nadine, Nadine achieved the highest liking scores of all four cultivars for overall acceptance, flavour and aftertaste and was just below Huakaroro's highest liking scores for appearance and texture in those who hadn't previously eaten Taewa. Therefore it may be suggested that familiarity with the sensory characteristics of Nadine led to preference for Nadine. Within the Taewa varieties which had been boiled, then cooled for 24 h, Huakaroro was the cultivar preferred when served at room temperature (18^{o}C), however, Tūtaekuri appeared to be preferred when warmed to 55^{o}C by those participants who had not previously eaten Taewa.

The sensory attributes of Huakaroro that may be most likely to appeal to those who have not eaten Taewa before include its texture and appearance, whereas Huakaroro's aftertaste is least likely to be acceptable. Again, due to the low power in numbers, a repeat of this experiment with greater participant numbers –particularly of those unfamiliar with Taewa would be advisable to ascertain greater validity of Taewa vs Nadine preferences.

Based on the results of this trial, a pre-boiled, 24 h-cooled Huakaroro product incorporated into a potato salad and served 18^{o}C may help to emphasize Huakaroro's firm, waxy texture; buttery-yellow appearance and minimize any aftertaste effect brought about by warming. Tūtaekuri's flavour and texture are likely to appeal to consumers (particularly at 55^{o}C), whereas Tūtaekuri's aftertaste (particularly at 18^{o}C) is least likely to be acceptable. Whole, medium-sized Tūtaekuri that had been par-boiled, 24 h-cooled and designed for cooking and being served at 55^{o}C, may help to emphasize Tūtaekuri's flavour and minimize an aftertaste effect.

In this trial, sensory analysis was carried out on three Taewa varieties, and the information obtained has led to suggestions for preferred applications which maximise the potential for each particular variety. Since chemical composition varies between cultivars, and is likely to strongly influence sensory attributes and descriptors, the approach used here is a viable one to use for future product development work with Taewa. Therefore, further sensory evaluations with greater participant numbers, chemical and physical-chemical composition analysis with the full range of Taewa varieties, along with simultaneous analysis of possible sensory descriptors from a range of Taewa varieties could help to predict and then align Taewa varieties with appropriate end uses with regards to future applications.

CHAPTER 7

General Discussion

7.1. Taewa Should Be More Widely Eaten

Modern potato varieties have recently been highlighted as having significant levels of key nutrients that are often inadequate in diets (Storey and Anderson, 2013b), and therefore potatoes have been recognised as one of the foods that achieves a high nutrient rich food index (i.e. foods that contain high amounts of key nutrients relative to their energy contribution per 100g) (Drewnoski, 2010). However, few investigators have studied the nutritional or potential health properties of Taewa. Research that has been carried out in Taewa has included an analysis of anthocyanin, phenolic, flavonoid content or antioxidant potential (Lewis *et al.,* 1998; 1999; Lister, 2001; Cambie and Ferguson, 2003; Gould *et al.,* 2006; Philpott *et al.,* 2009; Chong *et al.,* 2009; Chong *et al.,* 2013); glycoalkaloid content (Savage *et al.,* 2000) and starch characteristics (Singh *et al.,* 2006; 2008a; 2008b; 2009). In contrast to Taewa, the chemical and nutritional composition of today's mainstream modern potato varieties has been extensively researched (Burton, 1989; Lisinska and Leszcynski, 1989; Rama and Narasimham, 1993; Burlingame *et al.,* 2009; Bradshaw and Bonierbale, 2010)

7.1.1. Taewa Have Excellent Potential for Nutritional Value

One of the major aims of this research was to provide a preliminary investigation of the nutrient composition of Taewa cultivars and to compare these results with that of Nadine, a modern potato cultivar, commonly eaten in New Zealand. The results of this research suggest that fresh, raw tubers, as well as par-boiled tubers from four Taewa (Huakaroro, Karuparera, Moemoe, Tūtaekuri) show promising potential with regards to nutritional benefits compared to Nadine due to the apparent greater content of a range of nutrients. These included a greater energy contribution from starch; greater fibre content (total, insoluble and soluble fibre); higher protein content (particularly with regards to the essential amino acid (EAA) content and amino acids likely to be limiting in modern potato varieties: methionine, cysteine, leucine or lysine); higher mineral content (e.g. K, P, Mg, Fe, Zn and Cu) and higher amounts of the vitamins (e.g. thiamine (B1), niacin (B3), pyridoxine (B6) and folic acid (B9)). Results also suggest these four Taewa varieties show promise for a comparable if not greater nutritional value to other reported NZ cultivars (Athar *et al.,* 2003) as well as some of the cultivars reported in international reviews of modern and traditional Andean potato cultivars (Lisinska and Leszcynski, 1989; Burlingame *et al.,* 2009).

Potatoes with highly coloured tuber skin or flesh are likely to have greater bioactive total phenolic content and as such, have greater potential for improved health benefits such as anti-inflammatory, antibacterial, antimutagenic and especially antioxidant functions (Rahal *et al.,* 2014). Taewa are known for their variable flesh and skin colourations. This research as well as other research (Lewis, 1998; Lister, 2001), has shown that coloured Taewa cultivars, (Tūtaekuri in particular), show promise for greater antioxidant potential compared to Nadine other modern NZ cultivars with regards to total phenolic content or antioxidant potential even after boiling, cooling and then reheating to 18°C or 55°C.

When cooked potatoes are subjected to a period of cooling after cooking, the *in vitro* digestibility of the starch decreases. This is likely due to a decrease in rapidly digestible starch (RDS) accompanied by an increase in slowly digestible starch (SDS) and resistant starch (RS) (Mishra *et al.,* 2008). Increasing SDS and RS in cooked potato has potential health benefits with regards to reducing the glycaemic potency and increasing the dietary fibre component (Monro *et al.,* 2009; Slavin, 2013). This research suggests that over a 24 to 48 h cooling period, RS content may double in comparison to just boiled potato and appears to accrue to a greater extent and at a greater rate in the four Taewa than in Nadine. In addition, although this research found that reheating cooled potatoes for 1 min in a microwave, or reheating 24 h-cooled potatoes to 18°C or 55°C reduced RS content compared to the unreheated counterpart, the reduction was relatively minor, and the RS content was still generally 1.5-2 times greater than that found in just boiled potatoes.

7.2. Taewa Should Be More Widely Grown

If people are to be encouraged to eat Taewa because of their inherent nutritional and other health benefits, then it follows that they should also be encouraged to grow Taewa. There are several arguments favouring the production of Taewa as a commercial food crop.

7.2.1. Marketable Traits

Taewa possess a number of qualities that make them very marketable. One of these is the potential nutritional value that Taewa could offer if they were included in the diet of New Zealand consumers. Should further nutritional analysis of Taewa confirm the results of this study, a number of general level health claims could be communicated to customers and consumers through food labelling, packaging and promotional material. General health claims can be made if the nutrient content of a food reaches certain criteria as specified in the FSANZ Standard 1.2.7.

Based on the compositional data for fresh and par-boiled Taewa shown in this research, these four Taewa varieties may qualify for nutrition claims to be made in regards to dietary fibre, vitamin C, niacin, thiamine, pyridoxine, potassium and potentially iron and copper. This is due to the fact that the content of these nutrient in an average portion of potato (150 g FW) of whole Taewa tubers (raw or par-boiled or both) is likely to be near or greater than 10% of the AusNZ Recommended Dietary Intake (RDI) for 19-30 year old adults.

A knowledge of nutritional benefits does not necessarily translate to greater consumption of a food product however. Research has shown that there are a wide range of factors affecting food choice, and that factors such as cost, age and sensory perception (such as taste, appearance and texture) may have a greater influence on consumer food choice than health knowledge (Drewnowski, 1997; Clark, 1998).

Research within this thesis suggests that Taewa also possess marketing potential for their sensory qualities. Results from the qualitative and quantitative research (Chapter 3 and 4) found that many research participants familiar with Taewa stated that they ate Taewa because they enjoyed the taste, some preferring the unique flavour of Taewa to the blandness of more common, commercially available varieties.

Results from the sensory trials (Chapter 6), that included participants both familiar and non-familiar to Taewa, indicated that in terms of sensory qualities, Taewa may appeal to a wider market than is currently being tapped. Generally, Huakaroro scored higher in terms of flavour, appearance, texture, aftertaste and overall acceptance than the more common variety, Nadine. Sensory ratings for Tūtaekuri were also greater than Nadine in terms of appearance, flavour, texture and overall acceptance. These results suggest that consumers may find potatoes with alternative flesh or skin colours attractive, as the scores for appearance for both Huakaroro and Tūtaekuri were equivalent or higher to those of Nadine when served at both 18^{o}C and 55^{o}C temperatures.

As highlighted in chapter 3 and 4, one of the marketable qualities that Taewa have is the fact that they are a uniquely New Zealand product, carrying intrinsic cultural and historical value as a heritage food crop. Because of this value, extensive efforts have been made by a number of organisations such as Tahuri Whenua, Koanga NZ Institute and Te Waka Kai Ora to preserve, promote and disseminate Taewa seed crops to growers throughout New Zealand, and to preserve this food source for future generations.

Potentially, this quality as a unique taste of New Zealand is one that could be promoted within the hospitality and tourism industries. Recent research has shown that potential markets for fresh Taewa and Taewa-derived products already exist (Roskruge, 2007), and therefore, growing Taewa commerically is a potentially viable enterprise.

7.2.2. Social and Cultural Value

In addition to being a food source, Taewa carry significant social and cultural value for many New Zealanders, and for Māori in particular. Growing Taewa would be particularly appropriate for Māori growers for whom the act of growing Taewa is also, and perhaps more importantly, a way to enhance wellbeing and connect with tupuna (ancestors, relatives) and whenua (land).

Due to the ease with which Taewa can be cultivated throughout New Zealand, growing Taewa could provide New Zealanders with a number of social benefits. As it has for Māori in the past, growing Taewa may enable people to re-establish traditional values in growing food for the family and community, thus promoting pride in this accomplishment, skills in self-reliance, sustainable practice, working together for the benefit of many, and re-connecting with the land. Furthermore, growing Taewa may also help to address food security concerns whilst providing cheap, nutritional food for the family.

7.2.3. Taewa Promote Holistic Health For Māori

As discussed in section 1.6.4., Taewa are regarded by Māori as a taonga, and although they have been largely replaced in the Māori diet by modern potato cultivars, the cultivation and consumption of Taewa remains intricately linked with cultural, historical, spiritual and emotional aspects of Māori life and can thus contribute to the holistic wellbeing of both individual and whānau. This research found that the cooking and eating practices associated with Taewa were indeed linked with cultural, historical, spiritual and emotional aspects for Māori as encapsulated in these quotes from the research participants:

> *“... with this Nanny that we lived with, that the Māori potato was definitely something special like even though we had it all the time at her place, it was like a delicacy, a spoil herself thing and she's always said that when people would come over and stuff, it's about manaakitanga (hospitality), having kai(food) available so it's just like how you would say maybe when you'd have guests, you would offer them a biscuit, that she’d have Māori potatoes available there”.*

"I like the idea of continuing something that has been a traditional practice. I like the idea of sharing that kind of thing with my kids so that it's something that's familiar with them, not something that was in the past that's not a living practice anymore. Appeal of Taewa is that they come with a story. They have cultural significance, are unique to this country. You can't find exact replicas elsewhere. They have been grown by our own people and have been used by Māori for years".

"I think like the feelings and that it brought back memories, family memories of being together and that it was a special occasion for us when we had them and I can always recall fond memories of how we'd walk in the door and we'd ask what was for dinner and she'd say 'Oh there's Moemoes on the stove' and how excited we used to be and feel about it and not wanting to share them with anybody else. But she would always ring other family members up and they'd come over and we just have fun as a family. We'd sing a lot of music. So those are the sort of feelings that it brought back when I think about Moemoe - as a family coming together to share".

Although not explored extensively in the Taewa survey, results obtained from the over 200 Taewa survey participants also indicated that an emotional or spiritual value was associated with the reason for why a favourite Taewa variety was eaten. This association of cultural, historical, spiritual or emotional value is not surprising given the over 200 year history of Māori in cultivating, eating and supplying Taewa.

7.3. Recommendations and Future Research

In order to facilitate the social and cultural benefits of improved nutrition and health outcomes, opportunities for commercial development, the enhancement of self-reliance, sustainable practice and increased food security which may be derived from the increased consumption and production of Taewa, the following key recommendations are suggested.

Key Goal: Improve and extend the availability of Taewa

Results from the group discussion (Chapter 3) and Taewa survey (Chapter 4) identified that significant barriers to eating Taewa included factors relating to the lack of availability or accessibility to Taewa (not knowing where to obtain Taewa for eating or growing; limited numbers of people growing, or with the knowledge to grow Taewa and a lack of land or economic base required for cultivating, supplying or purchasing Taewa compared to that previously enjoyed).

Therefore, although the number of Taewa growers and suppliers may be increasing (thanks to a concerted effort by Tahuri Whenua, Koanga NZ Institute, Te Waka Kai Ora and others), knowing where to source Taewa and having Taewa available year-round from an easily accessible source, are major barriers to people being able to eat Taewa. These accessibility factors appeared to be more important than the purchasing cost, knowing how to grow Taewa, or knowing a Taewa variety's nutritional value. Given that this is indeed the case:

- Government, potato research, the NZ Potato Industry or other research or funding agencies should increase funding support to organisations (such as Tahuri Whenua, Koanga NZ Institute, Heritage Potato, Te Waka Kai Ora) that are already involved in maintaining, preserving and disseminating Taewa seed in order to extend the capacity for growing Taewa;

- Government, potato research, the NZ Potato Industry or other research or funding agencies should work with, and support Māori and other organisations already growing Taewa to further investigate potential commercial ventures with Taewa;

- Further research is needed to identify optimal conditions with regards to agronomical practice, climate and growing regions, post-harvest and processing practices and the development of year-round Taewa production that retains the full nutritional benefit of their harvests for commercial growers of Taewa crops;

- Analysing market research information from the introduction of "Purple Passion" and "Purple Heart" modern varieties into the New Zealand market, may be useful in terms of introducing coloured fleshed and skinned Taewa varieties onto the market.

Key Goal: Increase consumer awareness of Taewa

Lack of familiarity with and differences in tuber characteristics were also mentioned by the group discussion participants as possible barriers to those unfamiliar with Taewa (Chapter 3). Even among those who had eaten Taewa, 37% (78/209) of the survey participants were unaware or did not specify varietal names of the Taewa they had eaten and 57% (115/209) specified they had only eaten 1-2 Taewa varieties (Chapter 4). Hence it is recommended that:

- Government, potato research, the NZ Potato Industry or other research or funding agencies should support community organisations and Marae-based community gardens facilitating “grow your own Taewa” initiatives;

- Upon confirmation of the preliminary Taewa nutritional value findings of this research, New Zealand populations that may have food security concerns, or nutrient inadequacies with regards to dietary fibre, niacin, thiamine, pyridoxine, potassium, iron, copper, and zinc may find Taewa to be of particular benefit. Thus Nutrition and Health promoting educational agencies could include Taewa as being a nutrient rich food with high nutritional value for money.

- Based on the historical and cultural value Māori already associate with Taewa, educational and health promotional materials encouraging the growing, purchasing and consumption of Taewa is likely to be well received among Māori. As such, Taewa should be included in all Ministry of Health Food and Nutrition guidelines for all New Zealanders, but especially those targeted for Māori.

- Distribution of Taewa recipe books, Taewa recipe pamphlets, and cooking demonstrations that show how Taewa might be used could be circulated throughout supermarkets, community organisations, marae and other providers or sellers of Taewa.

- Encouragement should be given to the development and promotion of innovative Taewa-based cuisine as part of New Zealand’s culinary culture through food festivals, television cooking programmes and within the hospitality and tourism industries of New Zealand.

Key Goal: Further explore the nutritional or health value of Taewa

- This research suggested that the iron content of the an average portion (150 g) of par-boiled Taewa tubers may provide greater than 10% of the adult RDI, however little is known of Taewa iron bioavailability. Therefore, studies into Taewa iron bioavailability and how to maximise iron throughout Taewa crop production, processing and after would be nutritionally beneficial for the consumer.

- While this study analysed vitamins likely to be of value in potatoes (thiamine, pyridoxine, niacin, folic acid and vitamin C), and which were present in uncooked skin, flesh and whole tuber samples of the four Taewa, the scope of the study only allowed vitamin C to be measured in Taewa after they were cooked. As Taewa are not eaten raw, and it is likely that processing or cooking will significantly impact the actual vitamin content of Taewa following cooking or processing, it would be important to reinvestigate these and the content of other vitamins after processing or cooking.

- Cooked, then cooled potatoes may have improved health benefits due to the increased ratio of slowly digestible starch (SDS) or indigestible resistant starch (RS) to rapidly digestible (RDS) starch. Increasing the SDS or RS ratio of foods is of benefit to those who may need to choose foods lower in rapidly digestible glucose in order to monitor blood glucose levels. In addition, RS can contribute to bowel health by acting as a metabolic substrate for beneficial colonic bacteria. However the potential for the development of RS and SDS has been shown to vary with cultivar. Further research could be carried out on a range of cooked and cooled Taewa in order to ascertain their propensity for RS and SDS formation.

Key Goal: Explore the potential for Taewa product development.

- New Zealand based industries such as Heinz Wattie's Ltd., New Zealand vegetable producers, AirNZ, NZ hospitality and tourism markets could be encouraged to utilise and incorporate Taewa into their products and marketing.

- Incorporating Taewa varieties analysed in this research into products already available on the market could provide a means by which the nutritional qualities of Taewa might be used to advantage. One particular product that might be explored is using Taewa with kūmara as a base for New Zealand-made introductory weaning foods or in formulating infant food products.

- This research suggested that par-boiling was a good option with regards to retaining nutritional and health value. In addition, resistant starch content (RSC) as well as antioxidant potential may be improved in cooked Taewa after 24 h cooling and reheating to 18^{o}C and 55^{o}C compared to just boiled Taewa.

- Par-boiled, 24 h-cooled potato products with additional RSC and antioxidant health benefits when heated to 18^{o}C and 55^{o}C could translate to convenience potato products as part of a potato salad or warmed in the microwave prior to consumption (such as pre-cooked, refrigerated potato cubes destined to be reheated at home in the microwave prior to consumption). Acceptability of such products among consumers could be explored with Taewa.

- Sensory evaluation was only carried out on three Taewa, yet the preliminary results in Chapter 6 suggest preferences with regards to cultivar, and serving temperature of the Taewa as well as a type of Taewa product they might be most appropriate for. Based on results of the sensory research, Huakaroro may be more suited for cold potato salad type products such as those served in the delicatessen part of a supermarket, whereas Moemoe and Tūtaekuri may be more suitable for pre-cooked, cooled products that are then taken home and heated by the householder before consumption. Further research should be undertaken with these Taewa varieties to test this hypothesis.

- In addition, further sensory evaluation amongst consumers unfamiliar and familiar with Taewa should be carried out on a wider range of Taewa and with a greater number of participants in order to broaden the pool of information regarding potential acceptability of Taewa and the type of products they might be better aligned with, as the three Taewa used in the sensory trial were only three of the six favourite eating varieties previously identified in the Taewa survey (Chapter 4).

- Research could be undertaken to compare the sensory acceptability of just-cooked versus 24 h-cooled potatoes and extended cooling periods of 7days, 14days or 21days in order to investigate the maximum shelf life period whilst still maintaining consumer acceptability.

- Potato snacks such as potato crisps or extruded snacks are a huge market. Finding ways to utilise Taewa as a snack food may have potential commercially. Exploring a range of processing methods to create a Taewa-based snack food which has minimised nutrient losses and the addition of salt or fat, while maximising marketability would therefore be useful.

Comments from the group discussions (Chapter 3) and the survey of Taewa cooking and consumption practices (Chapter 4) suggested Taewa might have potential with regards to specialty breads and pasta, particularly in relation to Tūtaekuri. Combining the unique colours of the Taewa together and with other modern cultivars in the same dish (such as Tūtaekuri and Huakaroro or Dragia in a potato salad with watercress) was also suggested. Viability and experimentation of such products could also be further explored.

"Ka titiro whakamuri, kia ahu whakamua, ka neke"

"By looking into the past, our current practice can be informed to create a pathway forward."

In conclusion, Taewa have great potential for future development as a marketable food product. Taewa production also has the potential to contribute in useful ways to Māori development goals in health, economic development and the sustainable use of whenua Māori. However the way forward must be tempered with constant reference to traditional knowledge, experience and cultural considerations with regards to the use of this taonga, as encapsulated in the above whakatauki (Māori proverb). This is important, to ensure the preservation of the integrity of this traditional food source and Māori cultural icon.

Given that Māori already have over 200 years of experience and knowledge in cultivating Taewa, it would make sense that Māori growers with cultural knowledge and expertise are involved in any future developments for commercial Taewa ventures from inception to conclusion, from cultivation through to product development, marketing and retail. This would ensure that cultural concerns and expectations in the development and appropriate use of this taonga are met.

The findings of this research suggest that Taewa should be among other New Zealand potato varieties such as Nadine and other common New Zealand potato cultivars that are served in restaurants and on the plates of New Zealanders at home. Taewa, (especially home-grown Taewa), have the potential to provide the consumer with a wide range of nutritional and holistic health benefits, particularly so for Māori, and could help to support a uniquely New Zealand product which has rich historical, cultural and spiritual value.

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Chapter 3 Appendices

3.1 Group Discussion Consent form

3.2 Group Discussion Information Sheet

3.3 Advertisement for Participation in Group Discussion

3.4 Māori Potato Identification Chart

3.5 Group Discussion Protocol

Appendix 3.1

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

TAEWA COOKING AND CONSUMPTION PRACTICES

FOCUS GROUP PARTICIPANT CONSENT FORM

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

Please circle those that apply.

I agree to the interview being sound recorded	Yes / No
I wish to have my recordings returned to me	Yes / No
I agree to the recording, sharing and use of favourite or family Maori potato recipes I provide	Yes / No
I wish to have my name associated with any favourite or family Maori potato recipes I provide	Yes / No
I wish to have data placed in an official archive	Yes / No
I agree to not disclose anything discussed in the Focus Group	Yes / No
I agree to participate in this study under the conditions set out in the Information Sheet	Yes / No

Signature: ______________________ **Date:** __________

Full Name - printed ______________________

Te Kunenga
ki Pūrehuroa

Institute of Food, Nutrition and Human Health
Private Bag 11222, Palmerston North 4442, New Zealand T 64 6 350 4336 F 64 6 350 5657 http://ifnhh.massey.ac.nz

Appendix 3.2

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

TAEWA COOKING AND CONSUMPTION PRACTICES
INFORMATION SHEET FOR PARTICIPANTS

Kia ora, my name is Zirsha Wharemate. I am a PhD student at Massey University. The purpose of this information sheet is to provide you with details about the research I would like you to help me with.

What is the aim of the project?
This project is being undertaken as part of a Doctorate programme in Human Nutrition at Massey University. The major aim of this project is to consolidate information gained from previous group discussions regarding consumers' experiences and common practices in cooking and eating Taewa (Māori potatoes). A secondary aim is to collate recipes of popular ways to eat Māori potatoes to be later used as a free resource for current or potential Māori potato consumers.

What will participants be asked to do?
Should you agree to take part in this survey, you will be asked to fill out a questionnaire about your current practices and traditional knowledge concerning cooking and eating Māori potatoes, which we expect will take no more than 15-20 minutes. In order to know the demographics of the study's population group, you will also be asked to fill out a brief questionnaire identifying your gender, age group, iwi affiliations, ethnic groups and geographical region of residence. The questions I will be asking have been peer reviewed by staff of the Institute of Food, Nutrition and Human Health at Massey University.

You will also be invited to write down any favourite Māori potato recipes you would like to share. You will then be asked to return your completed forms in an addressed envelope provided.

All interested participants who return their questionnaires will go into a draw to win a free copy of a recently published, photographically illustrated book on Pests and Diseases of Māori Potato Crops.

What use will be made of the information collected?
Information collected about Taewa cooking and consumption practices will be used in designing a nutritious meal for a subsequent sensory evaluation study using Māori potatoes. The information will also be summarised and reported in my PhD thesis. It is also hoped that this information will contribute to later published articles and be a useful resource for those growing, marketing and promoting the use of Māori potatoes. It is also my intent that any recipes shared will contribute towards a resource that can be later accessed by the public via electronic copy or a free webpage.

Your rights
Completion and return of the consent form and questionnaire implies consent. However, you have the right to decline to answer any particular question.

Project Contacts
Researcher: Zirsha Wharemate.
Institute of Food, Nutrition and Human Health; Research Centre for Māori Health and Development
Telephone 06 356 9099, x 7423, email Z.R.Wharemate@massey.ac.nz

Chief Supervisor: Dr Kay Rutherfurd-Markwick
Institute of Food, Nutrition and Human Health
Telephone 09 4140800; x 41141, email K.J.Rutherfurd@massey.ac.nz

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher named above is responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email: humanethics@massey.ac.nz.

Zirsha Wharemate
PhD Student
Massey University

Appendix 3.3

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

Māori Potatoes: How do YOU have them?

Group Discussion on Taewa Cooking and Consumption Practices

Massey University invites you to take part in a research project investigating the common, traditional and popular methods of cooking and eating Māori potatoes.

WHO?

We are looking for adults who enjoy eating, cooking and sharing Māori potato recipes. If this sounds like you then we would love to hear from you.

WHY?

In this study we want to learn more about the qualities you think makes Māori potatoes great and how you like to cook and eat them. Combined with our recent nutritional analysis of four Māori potato cultivars, we hope to provide Māori potato growers and enthusiasts with information that will help them market or cook their Māori potatoes in products that will be both popular and nutritious.

HOW?

If you would like to participate, you will be asked to join others on one of four dates in a small facilitated group discussion to share experiences and preferences in cooking and eating Māori potatoes. You will be invited to bring along favourite or family recipes featuring Māori potatoes you would like to share. The discussion group is expected to take no more than two hours from 10am -12 noon on the specified day. A light luncheon will be provided following.

If you are interested please contact

Zirsha Wharemate: (06) 356 9099 extn 7423 or email Z.R.Wharemate@massey.ac.nz
Kay Rutherfurd: (09) 4140800 extn 41141 or email K.J.Rutherfurd@massey.ac.nz

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Appendix 3.4

MAORI POTATO IDENTIFICATION CHART –PAGE 1/3

Huakaroro, "White Maori" / Ngateuteu?

Very knobbly, slightly elongated, sometimes very large tubers with yellow skin, sometimes splashed with pink and covered with tiny black dots; Yellow flesh; Waxy, excellent for boiling

Karupārera / Kanohi Pārera

Purple skin with yellow around eyes; Creamy-yellow flesh; Floury, tends to disintegrate when boiled. Virus-free samples (right photo) may loose some of the purple skin colour

Karupoti

Round-oval tubers; Dark-red skin, Dark-reddish purple flesh surrounded with white; Floury when cooked; Tend to disintegrate when boiled

Kohatuwhero / Red Rock

Red skin, White flesh, smoother surface. Doesn't fall apart when boiled, very waxy and dense. Whalers potato, from Chatham Island.

Kowiniwini / Kaupari

Purple skin with yellow around eyes; Creamy-white flesh; Generally waxy, but has known to be floury

Maori chief / Rangatira

Oval shaped tubers with yellow skin, splashed with red; White flesh with purple flecks; Floury, disintegrates if boiled too much

Moemoe / Muimui / Nga Toko

Round-elongated tubers; Yellow-red mottled skin, Yellow flesh, purple flecks around vascular ring; Waxy; –firm after boiling

Nga Oti Oti / Nga Outi Outi

Yellow-red mottled skin, White flesh, red flecks outside vascular ring; Disintegrates if boiled

MAORI POTATO IDENTIFICATION CHART –PAGE 2/3

Ngaupere

Pink-yellow mottled skin, similar to moemoe but generally smaller and rounder. Yellowy flesh, sometimes with purple flecks. Generally waxy.

Parareka

Small, elongated tubers with shallow eyes. Pink skin with yellow markings; White flesh; Floury

Pāwhero / Black Kidney / Old Red

Long dark red tubers, narrower at one end; white flesh sometimes with red flecks; remains reasonably firm when boiled

Peruperu

Slightly elongated tubers; yellow skin splashed with purple; creamy-white flesh sometimes with yellow streaks; Floury; - not so good boiled

Pink Fir

Long yellowy-pink tubers, Similar shape to tutaekuri. Creamy flesh. Very waxy

Poiwa

Yellow-red mottled skin, White flesh; More on the waxy side, reasonably firm when boiled.

Raupi

Yellow skin, often with purple splashes or blotches; Yellow flesh-sometimes with purple dots around vascular ring; waxy -reasonably firm when boiled.

Rokeroke

Round, regular shape. Pink-yellow mottled skin; White waxy flesh -remains reasonably firm when boiled.

MAORI POTATO IDENTIFICATION CHART –PAGE 3/3

Te Maori

Uniformly round shaped tubers , shallow eyes with red, rough skin; White flesh; Floury when boiled.

Tutaekuri / Urenika / Keretewha /Rongo Blue / Tuarua Waikato

Elongated tubers with dark purple skin and flesh, sometimes with white flecks. Very floury when boiled.

Uwhi / Uwhiwhero

Pink to orange-pink tubers with waxy, white flesh. Remain firm after boiling

Wakaora / Whakaora

Yellow skin; yellow flesh. Smaller than Huakaroro. Waxy

Whanako

Round, regular shape. Pink-yellow mottled skin; White waxy flesh - reasonably firm when boiled.

Waiporoporo

Dark-purple skin; White flesh, sometimes with purple specks around vascular ring. More waxy –firmer when boiled

Whataroa

Slightly elongated tubers with pink-yellow mottled skin; Yellow flesh; remains reasonably firm when boiled.

Wherowhero

Round shaped tubers with pinky-red skin; Yellowy flesh; Floury –tends to disintegrate when boiled.

Taewa photographs used in the identification chart were either adapted from Harris, G. and Niha, P.P. (1999), pp 41-42 or were provided courtesy of Dr Nick Roskruge, Agricultural Scientist at Massey University, Palmerston North, NZ.

Appendix 3.5

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

INSTITUTE OF FOOD, NUTRITION AND HUMAN HEALTH;
TE PUMANAWA HAUORA (Research Centre for Maori Health and Development)

TAEWA CONSUMPTION STUDY 2010

Group Discussion Protocol: Taewa Cooking and Consumption Practices

INTRODUCTIONS. RIGHTS, CONSENTS

HABITS AND INTEREST IN EATING MAORI POTATOES

These questions are designed to explore your experiences and preferred practices in eating and cooking Maori potatoes. I have some photos of common taewa varieties if you are not sure of the taewa names.

1. How do you or your whanau use Maori potatoes and why is it done in this way?
    - Uses –general, special occasions or events, frequency of consumption
    - Common practices vs preferences:
        - Methods of cooking
        - Condiments
        - Temperature
        - Cultivar varieties used
        - Serving size
        - Meal times
        - Favourite recipes

2. Which Maori potato variety is easiest to cook? – best to eat? – why?

3. What do you know about how Maori Potatoes were used traditionally?
    - Uses – general, special occasions or events in life, healing or heath benefits
    - Common practices vs preferences:
        - Customs in methods of cooking, serving
        - Condiments
        - Cultivar varieties used

COLD POTATOES

What about cooking and eating Maori potatoes cold?

Te Kunenga
ki Pūrehuroa

Institute of Food, Nutrition and Human Health
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4. What would be the best way to cook and serve cold Maori potatoes?
    - Why would these practices be preferable?
    - What factors would encourage someone to eat them? –discourage someone from eating them?

MAORI POTATOES VS NON-MAORI POTATOES

Now I'd like to get some insight into how Maori Potatoes might compare with non-Maori potato varieties

5. If you had to choose between your favourite Maori potato variety or your favourite non-Maori potato variety to cook and eat, which would you choose and why?
    - Significance or barriers to eating Maori potatoes
    - Attributes of Maori vs non-Maori potatoes

6. Imagine you are contestants on the NZ Top Chef show. You need to impress the judges with a winning dish using Maori potatoes. Other contestants have non-Maori potatoes to use. What would you do and why?
    - Cooking method, condiments, temperature, cultivar used, serving size, meal time
    - Marketing potential of Maori vs non-Maori potatoes

Finally, I'd like you to complete a very short questionnaire about yourself.

**INSTITUTE OF FOOD, NUTRITION AND HUMAN HEALTH;
TE PUMANAWA HAUORA (Research Centre for Maori Health and Development)**

TAEWA CONSUMPTION STUDY 2010

1. What is your age? (please circle one)

18 to 25   26 to 35   36 to 45   46 to 55   56 to 65   66 and above

2. Are you male or female? (please circle one)

3. What ethnic group or groups do you belong to?

____
____
____
____
____

4. Which iwi do you affiliate with?

____
____
____
____
____

5. Have you ever grown Maori potatoes? (please circle one)   Yes / No

THANK YOU VERY MUCH FOR YOUR HELP

Chapter 4 Appendices

4.1 Survey Consent form

4.2 Information sheet for mail-out participants

4.3 Information sheet for online participants

4.4 General Email Taewa Survey Advertisement

4.5 Quantitative Survey Questionnaire

4.6 Frequency of Taewa Variety Selection Within Respondent Residential Region (Taewa Identified by Name and Description Combined)

4.7 Te Hikoi o nga Taewa 2008 – 2011.

Appendix 4.1

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

TAEWA COOKING AND CONSUMPTION PRACTICES

PARTICIPANT CONSENT FORM - INDIVIDUAL

I have read the Information Sheet and understand the details of the study. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

Please circle those that apply.

I agree to participate in this study under the conditions set out in the Information Sheet Yes / No

I agree to the recording, sharing and use of favourite or family Māori potato recipes I provide Yes / No

I wish to have my name associated with any favourite or family Māori potato recipes I provide Yes / No

Signature: ______________________________ **Date:** ____________

Full Name - printed ____

Please circle those that apply

*(If you circle **Yes** to any of the questions below – please clearly write the name, postal address and / or email address you would like us to send the information to in the spaces provided below).*

I wish to receive a copy of the study's findings Yes / No

I wish to receive a copy of the shared recipes Yes / No

Please tick (✓) your preferred option

I wish to have information I provide placed in an official archive ☐

OR

I wish to have my questionnaire returned to me ☐

Name ____

Postal Address ____

____

____

Email Address ____

Please enclose and post this completed form along with your completed questionnaire in the addressed envelope provided. Thank you.

Te Kunenga ki Pūrehuroa

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Private Bag 11222, Palmerston North 4442, New Zealand T 64 6 350 4336 F 64 6 350 5657 http://ifnhh.massey.ac.nz

Appendix 4.2

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

TAEWA COOKING AND CONSUMPTION PRACTICES
INFORMATION SHEET FOR MAIL-OUT PARTICIPANTS

Kiaora, my name is Zirsha Wharemate. I am a PhD student at Massey University. The purpose of this information sheet is to provide you with details about the research I would like you to help me with.

What is the aim of the project?
This project is being undertaken as part of a Doctorate programme in Human Nutrition at Massey University. The major aim of this project is to consolidate information gained from previous group discussions regarding consumers' experiences and common practices in cooking and eating Taewa (Māori potatoes).

What will participants be asked to do?
Should you agree to take part in this survey, you will be asked to fill out a paper questionnaire about your current practices and traditional knowledge concerning cooking and eating Māori potatoes, which we expect will take no more than 10-15 minutes. In order to know the demographics of the study's population group, you will also be asked to fill out a brief questionnaire identifying your gender, age group, iwi affiliations, ethnic groups and geographical region of residence. You will also be invited to write down any favourite Māori potato recipes you would like to share. You will then be asked to return your completed forms in an addressed postage-paid envelope provided.

Alternatively, you can complete the survey online, by typing the following URL into the web address bar.

http://tph.ac.nz/limesurvey/index.php?sid=72843&lang=en

The questions I will be asking in the survey have been peer reviewed by staff of the Institute of Food, Nutrition and Human Health at Massey University.

What use will be made of the information collected?
Information collected about Taewa cooking and consumption practices will be used in designing a nutritious meal for a subsequent sensory evaluation study using Māori potatoes. The information will also be summarised and reported in my PhD thesis. It is also hoped that this information will contribute to later published articles and be a useful resource for those growing, marketing and promoting the use of Māori potatoes. It is also my intent that any recipes shared will contribute towards a resource that can be later accessed by the public via electronic copy or a free webpage.

Your rights
Completion and return of the consent form and questionnaire implies consent. However, you have the right to decline to answer any particular question.

Project Contacts
Researcher: Zirsha Wharemate.
Institute of Food, Nutrition and Human Health; Research Centre for Māori Health and Development
Telephone 06 356 9099, x 7423, email Z.R.Wharemate@massey.ac.nz

Chief Supervisor: Dr Kay Rutherfurd-Markwick
Institute of Food, Nutrition and Human Health
Telephone 09 4140800; x 41141, email K.J.Rutherfurd@massey.ac.nz

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher named above is responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email: humanethics@massey.ac.nz

Zirsha Wharemate
PhD Student
Massey University

Te Kunenga ki Pūrehuroa

Institute of Food, Nutrition and Human Health
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Appendix 4.3

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

TAEWA COOKING AND CONSUMPTION PRACTICES
INFORMATION SHEET FOR ONLINE PARTICIPANTS

Kia ora, my name is Zirsha Wharemate. I am a PhD student at Massey University. The purpose of this information sheet is to provide you with details about the research I would like you to help me with.

What is the aim of the project?
This project is being undertaken as part of a Doctorate programme in Human Nutrition at Massey University. The major aim of this project is to consolidate information gained from previous group discussions regarding consumers' experiences and common practices in cooking and eating Taewa (Māori potatoes).

What will participants be asked to do?
Should you agree to take part in this survey, you will be asked to fill out a questionnaire about your current practices and traditional knowledge concerning cooking and eating Māori potatoes. We expect this will take no more than 10 minutes. In order to know the demographics of the study's population group, you will also be asked to fill out a brief questionnaire identifying your gender, year of birth, iwi affiliations, ethnic groups and geographical region of residence. The questions I will be asking have been peer reviewed by staff of the Institute of Food, Nutrition and Human Health at Massey University.

You will also be invited to record any favourite Māori potato recipes you would like to share.

All interested participants who complete the survey will go into a draw to win a free copy of a recently published, photographically illustrated book on Pests and Diseases of Māori Potato Crops.

What use will be made of the information collected?
Information collected about Taewa cooking and consumption practices will be used in designing a nutritious meal for a subsequent sensory evaluation study using Māori potatoes. The information will also be summarised and reported in my PhD thesis. It is also hoped that this information will contribute to later published articles and be a useful resource for those growing, marketing and promoting the use of Māori potatoes. It is also my intent that any recipes shared will contribute towards a resource that can be later accessed by the public via electronic copy or a free online site.

Your rights
Completion of the questionnaire implies consent. However, you have the right to decline to answer any particular question.

Project Contacts
Researcher: Zirsha Wharemate
Institute of Food, Nutrition and Human Health; Research Centre for Māori Health and Development
Telephone 06 356 9099, x 7423, email Z.R.Wharemate@massey.ac.nz

Chief Supervisor: Dr Kay Rutherfurd-Markwick
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This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher named above is responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email: humanethics@massey.ac.nz.

Zirsha Wharemate
PhD Student
Massey University

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Appendix 4.4

General Email Advertisement For Taewa Survey

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<

Maori potatoes are potatoes that have been cultivated in New Zealand, mostly by Maori, since the early 1800s. They have excellent nutritional potential, unique culinary attributes (taste, flavour, cooking) and a distinct appearance, as can be seen in the photo attached.

Zirsha Wharemate is a researcher at Massey University who is conducting a survey to discover popular ways of cooking and eating Maori potatoes.

We invite all adults who have cooked and eaten Maori potatoes to assist us in this research.

If you would like to participate in this survey.....

You can access the survey online by clicking on this link:
http://tph.ac.nz/limesurvey/index.php?sid=72843&lang=en

OR we can send you a copy of the survey by post to fill out and return in a pre-paid envelope.

Please email Zirsha Wharemate on Z.R.Wharemate@massey.ac.nz to request a copy to be sent by post.

The survey should take no longer than 10 minutes to complete.

If you would like to know further information about this survey please contact Zirsha on 06 356 9099, extn 7423 or via email at: Z.R.Wharemate@massey.ac.nz

We look forward to hearing from you!
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<

Appendix 4.5

TAEWA COOKING & CONSUMPTION PRACTICES 2011 QUESTIONNAIRE

The purpose of this survey is to gather information about the current and historical practices of cooking and eating Māori potatoes so as to discover popular ways of eating them, and potential ways to market them.

Thank you for your willingness to participate in this survey.

1. **Where were the Māori potatoes you have eaten, sourced from?**

PLEASE TICK AS MANY OR AS FEW AS APPLY

	✓
Supermarket	☐
Roadside stall	☐
Market	☐
Private contact	☐
Own garden	☐
Don't know	☐

2. **Which geographical area(s) were they grown in?** Please tick (✓) in the box if **not known** ☐

a) **If known**, please circle the regional names of the area(s) they were grown on the map below.

3. **Have you ever eaten Māori potatoes you have grown yourself?**

(please tick one) Yes ☐ No ☐

4. **Using the scale from 1 to 5 described below, please tick (✓) a box to show how strongly each of these factors would encourage or enable you to eat Māori potatoes more often.**

(Scale: 1 = not at all, 2 = a little, 3 = moderately, 4 = strongly, 5 = very strongly)

	1	2	3	4	5
Knowing what varieties are available locally	☐	☐	☐	☐	☐
Knowing how to grow them	☐	☐	☐	☐	☐
Knowing where to source them from	☐	☐	☐	☐	☐
Favourite variety being available	☐	☐	☐	☐	☐
Purchasing cost is within budget	☐	☐	☐	☐	☐
Knowing different recipes for preparing them	☐	☐	☐	☐	☐
Knowing what nutritional or health-promoting benefits they have	☐	☐	☐	☐	☐

5. We are interested to know of traditional or other practices associated with Māori Potatoes that may have been used for traditional, healing, nutritional benefit or health-promoting reasons.

Have you, or others you know of, practised any of the following with relation to Māori potatoes?

PLEASE TICK AS MANY OR AS FEW AS APPLY

	(✓)
Purposes Other Than Eating:	
Potato flesh or skin used for medicinal or healing purposes	☐
Potato flesh or skin used for health-promoting purposes	☐
Using raw potato flesh on wounds or other ailments	☐
Using cooked potato flesh on wounds or other ailments	☐
Consumption of:	
Potatoes with purple skin or flesh to promote health	☐
Cold, cooked potato to promote health	☐
Raw potato for medicinal or health-promoting purposes	☐
Raw potato juice as a drink or tonic	☐
The boiled potato water as a drink or tonic	☐
Other Practices:	
Storing potatoes in a particular way to prevent deterioration	☐
Potato flesh or skin used for ceremonial purposes (please describe below)	☐
Other (please describe below)	☐

____

____

____

____

____

6. **Now we'd like to know ALL the Māori potato varieties you have eaten.**

If you *KNOW THE NAMES*, please place a tick (✓) in the box beside each of the names of the varieties you have eaten in the list below. If you're not sure of the names, please go to the table below. NEXT, please identify the *ONE* variety that you *MOST PREFER TO EAT* by either circling the variety's name in the list, OR description in the box below.

- Huakaroro / Karoro / "White Māori" ☐
- Karupoti ☐
- Kowiniwini / Kaupari ☐
- Moemoe / Muimui / Nga Toko ☐
- Ngaupere ☐
- Pawhero / Black Kidney / Old Red ☐
- Pink Fir ☐
- Raupi ☐
- Te Māori ☐
- Wakaora / Whakaora / Ngauteuteu / Matariki ☐
- Waiporoporo ☐
- Karuparera / Kanohi Parera ☐
- Kohatuwhero / Red Rock ☐
- Māori Chief / Rangatira ☐
- Nga Oti Oti / Nga Outi Outi ☐
- Paraketia / Parareka ☐
- Peruperu (see * below if purple skin & flesh) ☐
- Poiwa ☐
- Rokeroke ☐
- Uwhi / Uwhiwhero ☐
- Whanako ☐
- Whataora ☐
- Tutaekuri / Urenika / Keretewha / Rongo Blue / Tuarua Waikato / *Peruperu (purple skin & flesh) ☐
- Other variety name (please describe) ☐ ____________________

If you're *NOT SURE OF THE NAMES*, place a tick (✓) inside the box in the table below that corresponds to your best recollection of the potato skin and flesh colour *for each* of the varieties you have eaten. Next, please identify the *ONE* variety that you *MOST PREFER TO EAT* by either circling the variety's name in the list, OR description in the box below.

Māori Potato Description Table		MAJOR POTATO SKIN COLOUR						
		Purple	Purple with Cream/White around eyes	Pink / Red	Pink / Orange	Creamy Yellow	Mottled Creamy yellow and Pink/Red	Mottled Creamy yellow and Purple
POTATO FLESH COLOUR	Purple							
	Creamy/yellow							
	Creamy/yellow with purple, red or pink flecks							
	White							
	White with purple centre							
	White with purple, red or pink flecks							

➢ Questions 7 to 13 relate to the ***Māori potato variety you MOST PREFER TO EAT*** (***The one you circled above***). We would like to explore the reasons why you might prefer this variety.

7. **Is your favourite Māori potato variety commonly grown in the area where you live?**

   (please tick one) ☐ Yes ☐ No ☐ Don't know

8. **Which of the reasons below best explain *WHY* you prefer to eat this variety?**

PLEASE TICK AS MANY OR AS FEW AS APPLY

	✓
My parents or grandparents cooked it / I grew up with it	☐
I have cooked it for myself or for my family	☐
It is the only variety I have eaten or been able to access	☐
It holds personal significance to me	☐
I have eaten it on a special occasion	☐
I am able to easily access it	☐
I like the taste or flavour of this variety	☐
I like the colour qualities of this variety	☐
I like the size attributes of this variety	☐
I like the nutritional benefits of this variety	☐
It performs best in the Māori potato dishes/recipes I like to eat	☐

➢ For the next five questions, please think of the ***WAY YOU MOST PREFER TO EAT*** your favourite Māori potato variety.

9. **Is it with or without the skin on?**

PLEASE TICK ONE ONLY

	✓
With the skin on	☐
Without the skin on	☐
No preference	☐

10. **How is your favourite Maori potato variety prepared for cooking or eating?**

PLEASE TICK ONE ONLY

	✓
Kept whole	☐
Cut in halves	☐
Cubed or sliced	☐
As for chips or wedges	☐
Cooked then mashed	☐
No preference	☐

11. **Which of the *COOKING METHODS* below best describes how you *MOST PREFER* your favourite Māori potato variety to be cooked.**

PLEASE TICK ONE ONLY

	✓
Boiled in water on their own	☐
Steamed over boiling water on the stove top	☐
Steamed in a microwave	☐
Steamed in a hangi	☐
Baked in an oven	☐
Baked in a microwave	☐
Baked/Roasted in oil, fat or butter	☐
Fried in oil, fat or butter	☐
Cooked in moist heat with other ingredients such as in a boil-up, soup, casserole, stir-fry or stew	☐
No preference	☐

Think of the way you MOST PREFER to eat your favourite Maori potato variety.

12. **Which of the following condiments or meal accompaniments would be used to eat with your favourite Māori potato variety?**

PLEASE TICK YOUR MOST PREFERRED CHOICE OR COMBINATION

	✓
Nothing, I prefer to eat them on their own	☐
Salt or other salt-based seasoning	☐
Pepper	☐
Butter or margarine	☐
Cream	☐
Sour cream	☐
Cheese	☐
Tomato sauce / ketchup	☐
Chilli sauce	☐
Mayonnaise	☐
Dried or fresh herbs	☐

13. **At what *TEMPERATURE* do you *MOST PREFER* to eat your favourite Māori potato variety?**

PLEASE TICK ONE ONLY

	✓
Hot	☐
Warm	☐
Cold	☐
No preference	☐

14. **Of all those Maori potato varieties you have eaten, which one would you prefer to eat in a cold potato salad and why?**

____

____

____

____

➢ Finally, I'd like you to answer a few questions about yourself....

15. What is your age group? (please tick one group)

18 to 25 ☐ 26 to 35 ☐ 36 to 45 ☐ 46 to 55 ☐ 56 to 65 ☐ 66 and above ☐

16. Are you male or female? (please tick one)

male ☐ female ☐

17. What ethnic group or groups do you belong to?

____

____

18. Which iwi do you affiliate with?

____

____

19. Which geographical region do you reside in? (please circle the region's name on the map below)

We would be interested in any other comments you have about Māori potatoes in general, or how you prepare, cook or eat them, or if you have any favourite Māori potato recipes you would like to share. If you do, please describe them below or send in on a separate sheet.

____

____

____

____

____

____

Please enclose and post this completed questionnaire, along with the completed consent form, in the addressed envelope provided.

Thank you. Your time and consideration has been much appreciated.

Appendix 4.6

Frequency of Taewa Variety Selection Within Respondent Residential Region (Taewa Identified by Name and Description Combined)

N = 195 (Respondents that specified an eaten Taewa variety by name and/or description and provided a NZ residence)

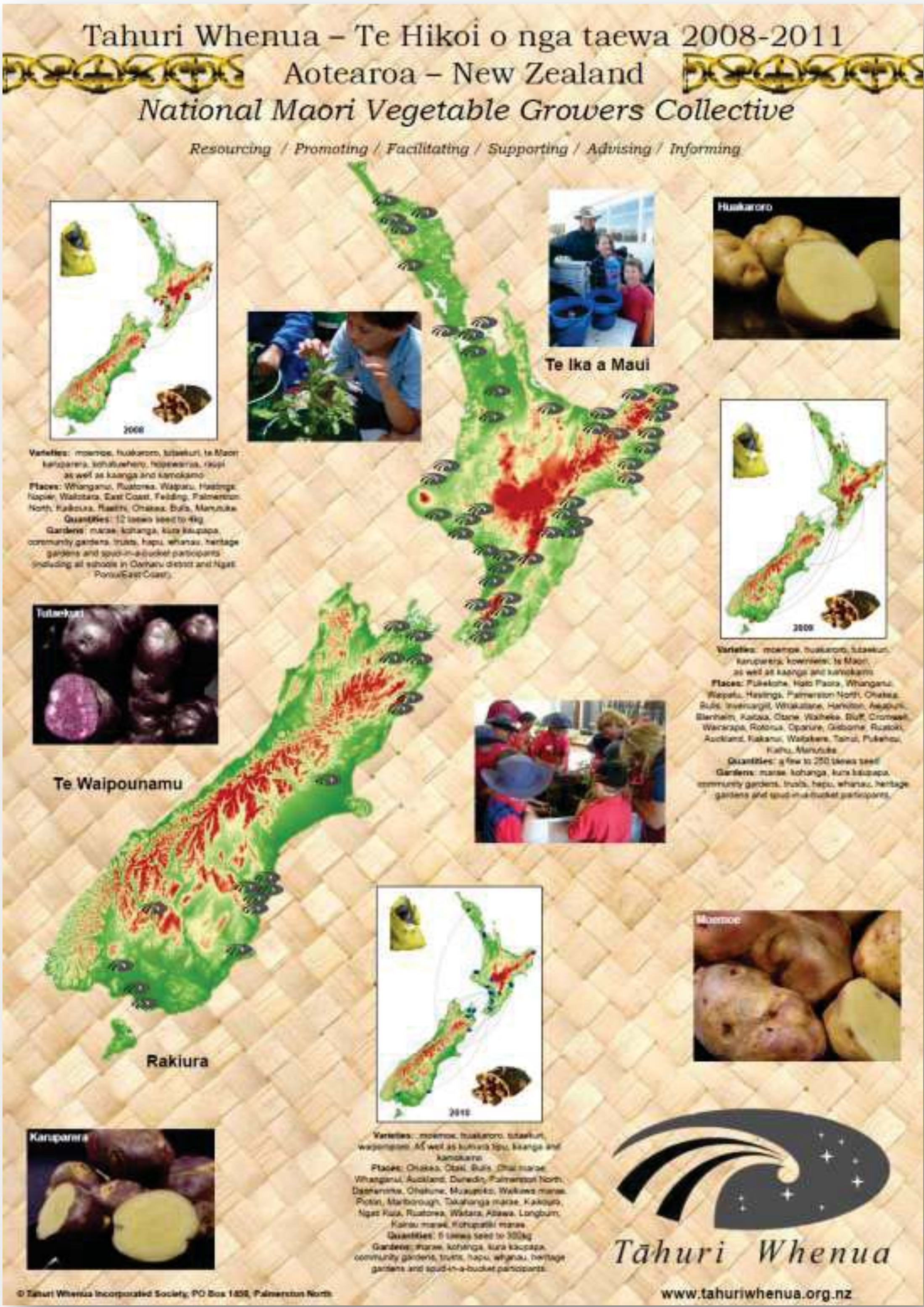
RESIDENTIAL AREA OF RESPONDENTS

TAEWA VARIETIES	Northland	Auckland	Waikato	Bay Of Plenty	East Coast	Hawkes Bay	Central Plateau	Taranaki	Wanganui / Manawatu	Wairarapa	Wellington	Marlborough	West Coast	Canterbury	Otago	# Regions Variety Eaten In
Tutaekuri type	11	18	10	9	1	10		5	58	3	10	1	1		3	**13**
Pawhero type	6	12	4	9		7	1	2	34	1	6				2	**11**
Peruperu *	8	6	5	1		2		1	15	2	3		1		1	**11**
Moemoe type	5	12	7	6		3		1	30		7				1	**9**
Huakaroro type	2	9	4	7	1	4		1	29		3					**9**
Karuparerā type	2	10	7	12					11	1	2			1	2	**9**
Kohatuwhero type	3	1	2	2		1			9	1	1					**8**
Karupoti		3	4	2		1		1	5		1					**7**
Nga Oti Oti type	1		2	5					6	2	2					**6**
Uwhiwhero type	3		1	1		1			6		1					**6**
Raupi		1	1	3					3		1					**5**
Unknown 3	1		1	1					1		1					**5**
Unknown 1			1	1					1		2					**4**
Unknown 2		2							1							**2**
# of Taewa Variety Types Eaten In Region**	**12**	**14**	**15**	**17**	**2**	**9**	**1**	**6**	**18**	**6**	**14**	**1**	**2**	**1**	**6**	
# of 195 Respondents Residing In Region	**14**	**24**	**12**	**13**	**1**	**13**	**1**	**6**	**85**	**4**	**15**	**1**	**1**	**1**	**4**	

Key: Peruperu * = Could relate to a number of Taewa varieties but does not have purple skin and flesh. ** = Taewa cultivars identified by name (Table 4.5) as well as new variety types identified by description (Table 4.7).

Appendix 4.7

Te Hikoi o nga Taewa 2008-2011.   (Used with permission)



Chapter 6 Appendices

6.1. Sensory Consent form.

6.2. Information sheet for participants.

6.3. Sensory Email Advertisement.

6.4. Sensory Evaluation Form.

6.5. Nutrition Information Sheet.

6.6. Typical Comments Regarding Appearance of Tūtaekuri and Moemoe.

6.7. Differences in Sensory Attribute Ratings of Modern and Taewa Cultivars based on Previous Taewa Consumption.

6.8. Sensory Participant Comments.

Appendix 6.1

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

PREFERENCES FOR DIFFERENT COOKED AND COOLED POTATOES

CONSENT FORM

THIS CONSENT FORM WILL BE HELD FOR 12 MONTHS FROM DATE OF SIGNING

- I have read and understood the Information Sheet and have had the details of the study explained to me. Any questions I may have had have been answered to my satisfaction, and I understand that I may ask further questions at any time.

- I agree to voluntarily participate in this study under the conditions set out in the Information Sheet.

- I understand I have the right to withdraw from the study at any time and to decline to answer any particular questions

- I have been advised about the objectives of the study and have discussed with the researcher any potential relevant cultural, religious or ethical beliefs that may prevent me from consuming the foods under consideration

- I have been advised about any potential allergens in the products I am about to taste and see no reason why I cannot participate in the sensory panel.

Participants Signature: ______________________________ **Date:** __________

Full Name - printed ____

Te Kunenga ki Pūrehuroa
Institute of Food, Nutrition and Human Health
Private Bag 11222, Palmerston North 4442, New Zealand T 64 6 350 4336 F 64 6 350 5657 http://ifnhh.massey.ac.nz

Appendix 6.2

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

INFORMATION SHEET FOR PARTICIPANTS

TITLE OF WORK: Preferences for different cooked and cooled potatoes

Researcher(s) Information

Researchers Name:	Zirsha Wharemate	**Supervisors Name:**	Dr Kay Rutherfurd-Markwick
Contact Details:	06 356 9099, extn 81740 Z.R.Wharemate@massey.ac.nz	**Contact Details:**	09 4140800, extn 41141 K.J.Rutherfurd@massey.ac.nz

Adults aged 18 and above, who eat boiled potato are invited to take part in a consumer sensory evaluation for a PhD study being conducted on cooked, cooled potatoes.

This project aims to compare consumer acceptability of cooked, cooled potato with regards to sensory and potential nutritional attributes from four different varieties of potato.

You will be asked to taste a total of eight 5-10g cooked and cooled potato samples –half of which will be served at room temperature and the other half, served warm. We would like you to tell us which one(s) you prefer with regards to various sensory and potential nutritional attributes, on an answer form that will be provided.

In order to record the demographics of the study population, you will also be asked to fill out a brief questionnaire identifying your gender, age group and previous consumption of Māori potatoes.

Your participation in this study will take approximately 15-20 minutes.

The potatoes you will be tasting contain the following components that can be harmful or cause allergic reactions with certain groups of people. You are requested not to undertake the study if you may be adversely affected by the following:

- Patatin (potato protein)
- Anthocyanins (natural plant pigments)

The information collected in this study will contribute towards partial fulfillment of a Doctorate in Human Nutrition at Massey University and will be summarised and reported in my PhD thesis. The information will be published in a scientific paper and be a useful resource for Tahuri Whenua (National Māori Growers Collective) who have supplied Māori potatoes for the PhD research. No data linked to an individual's identity will be collected.

If you have any questions about this work, please contact one of the people indicated above.

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher named above is responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email: humanethics@massey.ac.nz.

Te Kunenga ki Pūrehuroa

Institute of Food, Nutrition and Human Health
Private Bag 11222, Palmerston North 4442, New Zealand T 64 6 350 4336 F 64 6 350 5657 http://ifnhh.massey.ac.nz

Appendix 6.3

Sensory Trial Email Advertisement

>>>

Maori potatoes have been cultivated in New Zealand, mostly by Maori, since the early 1800s.

They have excellent nutritional and culinary attributes (taste, flavour, cooking) and a distinct appearance.

We are looking for adult volunteers (aged over 18years), to help us develop healthier potato products by participating in a sensory evaluation trial designed to assess cooked Maori and non-Maori potato samples.

If you would like to participate, a 10 minute sensory evaluation trial is being held on Friday, 16th September from 12-2pm at the Massey University Sensory Evaluation Labs.

If you would like more information, please contact us.

Zirsha Wharemate: email z.r.wharemate@massey.ac.nz or Catherine Lever: c.lever@massey.ac.nz; ext. 2653

We appreciate your cooperation.

>>>
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Appendix 6.4

EVALUATION FORM – COOKED, COOLED POTATO

ID no________

We would like to ask your opinion about eight cooked potato samples.

The first tray will include four samples that will be served at room temperature. After these four have been evaluated, you will be given a second tray of four samples of the same potato varieties that will be served warmed.

EVALUATION INSTRUCTIONS

1. Please start with the cup labelled________, then proceed from left to right. Please check you are only eating the sample that matches the number labelled on the top of each progressive evaluation sheet.
2. First you will be asked to evaluate the **appearance** of the sample. Please tick in the box that best fits your opinion.
3. Next please eat an entire piece of the sample in the cup.
4. While eating the sample, please consider the **flavour**, any **aftertaste** and the **mouthfeel** / **texture** of the sample.
5. Following consumption, take your time to evaluate the sample by ticking in the box that best fits your opinion for each listed attribute.
6. Pause for 20 seconds, take a bite of cracker, and rinse out your mouth by taking a sip of water ***before*** proceeding on to the next sample.
7. When you have completed your evaluation of the first four samples, please pass your tray through the front wall of your booth and wait for the next four samples to be passed through.
8. When all eight samples have been evaluated, please pass your tray through the booth, then ensure you have answered all the questions on all the pages before handing in your form for checking.

THANK YOU FOR YOUR TIME

Page **1** of **18**

POTATO 1 EVALUATION FORM **ID no**____________

SAMPLE ☐

Please look at the potato sample

How much do you like or dislike the appearance of the potato sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely

Do you have any comments about the appearance of the potato sample?

____

____

____

Please eat one entire piece of the potato sample

How much do you like or dislike the flavour of the potato sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely

Do you have any comments about the flavour of the potato sample?

____

____

____

How much do you like or dislike the mouthfeel or texture of the potato sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely

Do you have any comments about the mouthfeel of the potato sample?

____

____

____

Page **2** of **18**

SAMPLE ☐ continued.... **ID no**____________

How much did you like or dislike the aftertaste of the potato sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely

Do you have any comments about the aftertaste of the potato sample?

____
____
____

Overall, how much do you like or dislike this sample?

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like Slightly	Like Moderately	Like Very much	Like Extremely

Do you have any additional comments about the product that you would like to make?

____
____
____

Please take a bite of cracker and rinse out your mouth by taking sips of water before tasting the next sample

Page **3** of **18**

DEMOGRAPHICS **ID no____________**

Have you eaten Māori potatoes before ? **Please tick (✓) one.**

Yes ☐ **No** ☐ **Not sure** ☐

How likely are you to purchase Māori potatoes in the future?

Please tick (✓) one.

☐ Extremely Unlikely	☐	☐	☐	☐ Neither likely or unlikely	☐	☐	☐	☐ Extremely Likely

Gender **Please tick (✓) one.** **Male** ☐ **Female** ☐

Age group **Please tick (✓) one.**
18-25 ☐ **26-35** ☐ **36-45** ☐ **46-55** ☐ **56+** ☐

PLEASE HAND IN YOUR FORM WHEN COMPLETED.

THANK YOU VERY MUCH FOR YOUR TIME.

Appendix 6.5

HEALTH AND NUTRITIONAL INFORMATION

ID no______________

- Warm, just-cooked potato is a source of highly digestible carbohydrate. As potatoes cool following cooking, more carbohydrate in the potatoes converts into resistant starch as time progresses. Resistant starch does not contribute to the rise in blood glucose that normally occurs after eating. Instead, it passes through into the large bowel, becoming potential fuel for beneficial bacteria growing there.

  Manipulating the resistant starch in foods has potential health benefits for diabetics, those concerned with blood glucose management and those seeking to improve lower bowel health. Cooled, pre-cooked potato has greater resistant starch content than warmed, or just-cooked potato.

- Anthocyanins are naturally-occurring antioxidant compounds found in plant pigments. They are generally responsible for the purple, blue, and red colours found in fruits or vegetables. The photos below depict potato varieties with high anthocyanin content (far left), to those with minimal anthocyanin content (far right).

- Certain Māori potatoes I have tested had significantly more resistant starch and anthocyanin content than the modern variety used.

ANTHOCYANIN CONTENT

High anthocyanin content >> moderate anthocyanin content >> minimal anthocyanin content

How likely are you to consume pre-cooked and 24hr-cooled potato in the future?

Please tick (✓) one.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Extremely Unlikely				Neither likely or unlikely				Extremely Likely

How likely are you to consume purple-fleshed or purple-skinned potatoes in the future?

Please tick (✓) one.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Extremely Unlikely				Neither likely or unlikely				Extremely Likely

Page 1 of 1

Appendix 6.6

Typical Participant Comments Regarding Appearance of Tutaekuri and Moemoe Served at 18°C and 55°C

Cultivar	Temperature	Mean Liking Score	Like	Typical Comments
Moemoe	18°C	5.51		
			✓	Looks like a common, usual-looking potato;
			✓	Dark purple skin colour attractive
			✓	Purple tinges interesting
			X	Dark; grey flesh colour near skin unappealing
			X	Dislike that it looks old; dirty; brown; watery
			X	Dislike black spots on skin
			X	Dislike inconsistent colour
			X	Pale flesh and very dark skin unappealing
			X	Looks a bit floury
Moemoe	55°C	5.17		
			✓	Looks like pre-cooked potato
			✓	Dark purple skin colour attractive
			X	Dark, odd, greyish flesh colour near skin unappealing
			X	Not fresh looking; looks rotten; old
			X	Gritty; dirty; grainy looking
			X	Dislike watery, soggy appearance
			X	Dislike slightly brown and soft appearance
			X	Skin looks unwashed - slightly off-putting
			X	Dislike that flesh colour is affected by skin colour
			X	Dislike black spots on skin
Tutaekuri	18°C	6.83		
			✓	Purple flesh colour attractive; vibrant; appetising; -exotic; unique; interesting; unusual
			✓	Haven't seen potato of this colour
			X	Prefer white colour
			X	Dislike dark skin –makes it look hard/dry/tough
			X	Dislike unusual; intense colour; colour looks fake; - colour reminds me of chemicals or pharmaceuticals
			X	Skin unattractive but flesh colour appealing
			X	Looks floury
Tutaekuri	55°C	6.49		
			✓	Purple flesh colour attractive; vibrant; appetising; -exotic; unique; interesting; unusual; spectacular
			X	Skin colour unappealing; dull; unattractive
			X	Dislike cracked, dull, white flesh
			X	Dislike mushy and mouldy appearance

Appendix 6.7

Differences in Sensory Attribute Ratings of Modern and Taewa Cultivars based on Previous Taewa Consumption (Means adjusted sensory attribute ratings of 56 participants who tasted samples from 4 potato cultivars served at 18˚C and 55˚C)

	Taewa Varieties						Modern Variety	
	Huakaroro		Moemoe		Tutaekuri		Nadine	
Sensory Attribute	*18°C*	*55°C*	*18°C*	*55°C*	*18°C*	*55°C*	*18°C*	*55°C*
Overall Acceptance								
NSN	**6.79**	6.17	5.25	5.00	6.13	6.29	6.29	**6.79**
EB	**7.09**	**7.19**	5.81	6.00	6.69	7.09	6.44	6.25
Appearance								
NSN	**6.96**	**6.42**	5.79	4.92	6.33	5.92	6.42	6.33
EB	7.00	**7.09**	5.41	5.47	**7.31**	7.03	6.34	6.87
Flavour								
NSN	**6.71**	6.08	5.25	4.83	5.25	6.42	5.75	**6.92**
EB	**7.00**	**7.38**	5.72	6.00	6.66	7.03	6.66	6.41
Texture								
NSN	**7.29**	**6.58**	6.42	6.04	6.46	6.17	6.17	6.50
EB	**7.03**	**7.09**	6.00	6.41	6.56	6.59	6.41	6.50
Aftertaste								
NSN	**6.67**	6.08	6.21	5.33	5.71	6.29	6.21	**6.58**
EB	**6.63**	**6.78**	5.56	5.69	5.84	6.66	6.34	6.28

Key: NSN = 24 participants who had not and weren't sure if they had eaten Taewa before; EB = 32 participants who had eaten Taewa before. Highest cultivar attribute score at 18°C within each previous Taewa consumption group are in blue highlighted text. Highest cultivar attribute score at 55°C within each previous Taewa consumption group are in red highlighted text.

Appendix 6.8

Sensory Participant Comments

Served at 18°C	Served at 55°C	Served at 18°C	Served at 55°C	Served at 18°C	Served at 55°C	Served at 18°C	Served at 55°C	Served at 18°C	Served at 55°C
029, Tutaekuri	**635, Tutaekuri**	**029, Tutaekuri**	**635, Tutaekuri**	**029, Tutaekuri**	**635, Tutaekuri**	**029, Tutaekuri**	**635, Tutaekuri**	**029, Tutaekuri**	**635, Tutaekuri**
Appearance	Appearance	Flavour	Flavour	Texture	Texture	Aftertaste	Aftertaste	Overall	Overall
don't like the colour Score: 6	Score: 6	Score: 8	Score: 6	Score: 9	Score: 6	Score: 6	Score: 7	Score: 6	Score: 7
Score: 3	Score: 4	quite hairy Score: 4	Score: 4	Score: 4	Score: 4	Score: 6	Score: 4	Score: 6	Score: 4
the colour boosts appetite Score: 9	appetising colour Score: 9	has unique taste Score: 9	good flavour Score: 9	the texture is good and feels the mouth Score: 9	texture is good and high dry matter content Score: 9	the flavour remains for sometime in the mouth Score: 9	aftertaste remains good Score: 9	it seems the sample has high dry matter which is good for feeling the stomach Score: 9	Score: 9
appearance good, size not good Score: 9	good appearance Score: 9	flavour very good Score: 8	Score: 8	floury and tasty Score: 9	Score: 9	no bitterness Score: 8	Score: 8	sample is good and I like it very much for its colour and floury Score: 9	good appearance Score: 8
beautiful and colourful Score: 9	beautiful and colourful Score: 8	tasteful and yummy Score: 8	flavour tastes good Score: 8	really good and not too hard or soft Score: 8	feels good Score: 8	tastes good Score: 8	tastes good Score: 8	Score: 8	Score: 8
such a vibrant looking colour Score: 8	still a vibrant looking potato Score: 8	bit floury for my taste Score: 6	tastes wonderful warm Score: 8	still a bit floury for me but still nice Score: 5	beautiful tasting potato Score: 8	not really much of an aftertaste, but what was there was ok Score: 6	warm potato tastes so much better Score: 8	nice sample. Score: 6	has to be my favourite. Score: 8
Score: 4	Score: 7	Score: 6	Score: 7	Score: 6	Score: 7	Score: 6	Score: 7	Score: 6	Score: 7
beautiful purple "exotic" well it isn't) Score: 8	I love purple Score: 9	flavourful, slightly sandy texture. Not unpleasant Score: 7	beautiful spud. Sandy texture. Not same as 029? Score: 8	yum Score: 7	potato-like. Pleasing Score: 8	very pleasing, I would like more Score: 7	assurance that I've eaten a potato Score: 7	very yummy. A beautiful spud Score: 8	purple spuds rule! Subjective eh! Score: 8
Score: 6	Score: 5	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8
Score: 7	Score: 5	Score: 6	Score: 7	not very moisture Score: 6	skin is quite thick Score: 7	skin tastes a little bit bitter Score: 4	Score: 7	Score: 4	Score: 7
Score: 9	Score: 7	Score: 8	Score: 7	Score: 8	Score: 6	Score: 8	had sour aftertaste Score: 7	Score: 8	Score: 7
skin ugly but purple colouring lovely	love inside, ugly black skin	yum	yum. Definitely better when warm	good, starchy	less starchy than when cold	slightly bitter	bitter after taste not so noticeable		awesome colour

Score: 7	Score: 7	Score: 7	Score: 9	Score: 7	Score: 9	Score: 4	Score: 8	Score: 4	Score: 9
the flesh looks like you could use it for colouring dyes Score: 7	stunning colour, too many eyes Score: 8	creamy, smooth texture, slightly bitter skin Score: 7	creamy, sweet, smooth Score: 8	smooth Score: 8	firm to the bite. Will hold its shape Score: 8	bitter aftertaste from skin Score: 4	yummy Score: 8	Score: 7	Score: 8
love the purple flesh but not the black skin Score: 9	love appearance of flesh, probably wouldn't buy on outside appearance though Score: 9	Score: 5	not nice Score: 1	flash a lot thicker than others, skin was chewier too Score: 4	tough and dry Score: 1	aftertaste better than initial taste Score: 6	sour aftertaste Score: 1	might be ok with seasoning? Score: 5	wouldn't buy Score: 1
Score: 8	Score: 7	Score: 8	Score: 7	Score: 7	Score: 7	was sweet Score: 8	Score: 7	Score: 8	very nice Score: 7
like the colour Score: 8	love the colour Score: 7	Score: 8	sweet tasting Score: 6	Score: 8	Score: 6	Score: 5	Score: 6	Score: 8	Score: 6
Score: 8	Score: 8	Score: 4	Score: 4	Score: 4	Score: 4	Score: 6	Score: 5	Score: 6	Score: 4
Score: 6	Score: 4	Score: 3	Score: 6	Score: 5	Score: 6	Score: 6	Score: 6	Score: 5	Score: 6
wonderfully unusual colour Score: 8	colour is beautiful Score: 8	it has a slightly nutty flavour Score: 8	had a slightly bitter taste Score: 7	smoother, somehow "fresher" Score: 8	was a bit "mealy" Score: 6	Score: 8	Score: 7	Score: 8	Score: 7
reminds me certain type of chemicals or pharmaceutical I used to use Score: 2	less purple colour this time. Once used to this colour do not think it is going to change whether I eat it or not very much Score: 5	texture is fine to me, till the last bit of taste came out as bitter, and even bitter after finishing it. It reminds me the taste when potato goes green. Flavour is fine Score: 4	slight sweet mixed with bitterness from the skin Score: 7	mouth feel (aftertaste) afterwards is the issue for me Score: 5	nice creamy texture Score: 7	bitter and unpleasant aftertaste might stop me eating it again Score: 3	warm potato does not have much bitterness taste left and bitter taste did not last long this time Score: 7	Score: 4	after warm up, this sample tastes much better Score: 7
who doesn't like purple! Although to some people it might look quite scary Score: 8	Score: 6	the skin has a bit of bitterness, the potato itself is fine Score: 6	taste like "kumara" Score: 7	softer than huakaroro. The texture of the skin is crunchy, which is quite interesting Score: 6	not too bad compared to cooled Score: 6	it has a sort of weird aftertaste, a little bit bitter, a little bit sour, lingers in the whole mouth and it numbs the tongue a bit. Don't quite like it but interesting at the same time! Score: 3	the weird aftertaste of cooled sample does not present here Score: 5	interesting product Score: 6	Score: 6
great colour									

Score: 8	Score: 6	Score: 4	Score: 7	Score: 4	Score: 6	Score: 4	Score: 4	Score: 5	Score: 6
looks like an unusual piece of potato Score: 4	an unusual looking piece of potato Score: 4	a nice flavour Score: 7	a nice piece of potato, slightly different to a standard potato Score: 7	texture was very nice Score: 8	the texture is the same as another piece of standard potato Score: 6	a nice flavour to aftertaste. Just like a standard potato, with a slightly, unusual flavour underneath very nice piece of potato Score: 6	a nice aftertaste Score: 6	Score: 7	a nice unusual piece of potato Score: 7
like the purple Score: 9	Score: 7	Score: 6	Score: 7	Score: 6	Score: 6	Score: 7	Score: 5	Score: 7	Score: 5
the skin doesn't look too appealing. The purple colour Score: 3	skin doesn't look very nice / appealing. Love the purple colour 2	the aftertaste overpowered the flavour Score: 1	better tasting when warm Score: 6	the skin was too chewy Score: 1	skin is a bit crunchy. Nice feel about the rest of the potato Score: 6	very strong aftertaste in mouth and back of throat Score: 1	the aftertaste is far nicer than when cold Score: 6	the colour is great, just the aftertaste puts you off it Score: 4	the colour is the main appeal to this potato Score: 8
Score: 9	Score: 9	Score: 5	chewy skin Score: 4	Score: 3	quite dry Score: 1	Score: 4	Score: 3	Score: 4	Score: 5
love purple colour Score: 8	Score: 8	Score: 7	Score: 8	Score: 6	Score: 8	Score: 7	Score: 8	Score: 7	Score: 8
very brilliant Score: 9	Score: 9	earthy and somewhat sweet Score: 7	buttery and sweet Score: 8	good, starchy Score: 7	nice and smooth Score: 8	slightly bitter but not too terrible Score: 4	I want more Score: 8	Score: 7	great Score: 9

Served at 18°C	Served at 55°C	Served at 18°C	Served at 55°C	Served at 18°C	Served at 55°C	Served at 18°C	Served at 55°C	Served at 18°C	Served at 55°C
029, Tutaekuri	**635, Tutaekuri**	**029, Tutaekuri**	**635, Tutaekuri**	**029, Tutaekuri**	**635, Tutaekuri**	**029, Tutaekuri**	**635, Tutaekuri**	**029, Tutaekuri**	**635, Tutaekuri**
Appearance	Appearance	Flavour	Flavour	Texture	Texture	Aftertaste	Aftertaste	Overall	Overall
I have never seen a potato with this colour Score: 8	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8	Score: 8
dislike the skin makes the potato look hard/dry/tough, but like the bright colour of the inside, looks a bit gritty Score: 5	still looks dry/hard outside but great colour inside Score: 5	gritty/floury like moemoe, taste is similar to moemoe Score: 4	too strong, skin is thick Score: 3	floury, little bits of potato came off as chewing the piece (did not get broken down in mouth in a uniform manner) Score: 3	skin thick and potato gritty Score: 4	Score: 5	strong taste faded fast Score: 5	not very nice to chew would probably give little lumps when mashing but do like the purple colour Score: 4	too strong and gritty bitter taste Score: 3
what a unique interesting colour Score: 9	brilliant colour Score: 9	not any flavour, colour makes it look really interesting Score: 3	really pleasant flavour, nice potato Score: 7	skin seemed to be tough Score: 4	good crunch and not floury Score: 6	slight floury taste left on tongue, not very tasty Score: 4	makes me want more Score: 7	needs flavour, sweetness Score: 4	good colour and with normal potato flavour, makes me want to eat more Score: 8
Score: 9	Score: 9	Score: 3	Score: 9	Score: 7	Score: 9	Score: 3	Score: 9	I do not like aftertaste, it is a bitter aftertaste for me. Do not like flavour. I felt this sample being a bit hard. It may need a little longer cooking. If it was cooked properly, all bitter taste would be gone? Score: 4	Score: 9
too intense colour Score: 4	Score: 6	strange smell Score: 4	Score: 6	Score: 5	Score: 7	Score: 3	Score: 6	Score: 4	a bit aftertaste smell Score: 6
vibrant colour, looks fresh Score: 8	purple still cool but looks a bit floury Score: 6	a bit sweeter, not too strong Score: 8	sweeter when warm, crispy skin, not as smooth Score: 8	a bit softer, smooth Score: 7	a bit floury Score: 6	pleasant, not strong, sweeter Score: 8	Score: 8	Score: 8	Score: 7

skin looks foreboding, but flesh looks great! Score: 6	skin not that appealing, but flesh looks great Score: 7	not as strong a taste as expected Score: 7	underwhelming compared with flesh appearance, but enjoyable Score: 7	its ok - probably slightly more floury than I prefer Score: 7	a little dry-ish, but ok Score: 7	enjoyable aftertaste Score: 8	Score: 7	a great looker when centre exposed. Not sure how its looks would combine with other foods Score: 7	Score: 7
attractive colour Score: 9	attractive colour Score: 8	well balanced Score: 8	balanced flavour Score: 8	not too gritty, not too floury or mealy Score: 8	medium texture Score: 8	Score: 8	Score: 8	Score: 8	Score: 8
very attractive colour Score: 8	Score: 8	nice potato flavour, less flavour-like than (No Suggestions) Score: 8	not as sweet as some other samples Score: 7	Score: 7	Score: 7	Score: 7	Score: 7	Score: 8	very attractive colour Score: 8
such a vivid purple makes it look somehow dangerous like a fungus etc. Score: 3	Score: 3	Score: 7	Score: 6	Score: 6	a little powdery Score: 4	Score: 7	Score: 5	Score: 7	Score: 4
Score: 4	skin colour not good Score: 7	little flavour Score: 5	Score: 6	floury Score: 3	too floury Score: 4	slightly sweet nice Score: 7	good Score: 8	not a good boiler potato, too fluffy, novel colour Score: 5	skin too tough Score: 7
I prefer my potato to be white or orange colour Score: 3	Score: 3	Score: 7	doesn't taste of much Score: 6	Score: 8	Score: 8	has a strange aftertaste, not bitter but a bit gritty Score: 3	not much flavour Score: 6	Score: 3	Score: 7
Score: 9	vibrant colour, spectacular Score: 9	Score: 8	Score: 7	Score: 7	Score: 6	Score: 5	skin a bit kata 4	Score: 8	Score: 7
Score: 8	Score: 7	very tasty Score: 8	sweet Score: 8	Score: 7	firm texture Score: 8	Score: 7	Score: 7	Score: 8	Score: 8
Score: 8	Score: 8	Score: 7	Score: 9	Score: 8	Score: 9	weird feeling on my tongue Score: 4	Score: 9	Score: 7	Score: 9
the skin is a bit too dark, with a bit of imperfection however, the purple colour is familiar and very skinny Score: 8	skin not very attractive, skin a bit hard Score: 4	skin really hard. Floury consistency Score: 4	Score: 7	Score: 1	Score: 8	Score: 2	Score: 7	Score: 4	Score: 7

Score: 5	Score: 4	Score: 8	Score: 7	Score: 9	Score: 8	Score: 9	Score: 8	Score: 8	Score: 8
loved the purple colour Score: 8	love the purple Score: 8	tastes nice, feels nice, feels filling in my mouth Score: 6	love it warm, though cold is nice as well Score: 8	firm Score: 8	again a filling taste, nice Score: 8	yum, would eat more Score: 8	loved the taste Score: 8	lovely Score: 8	yum Score: 8
very unusual, I haven't seen a blue-looking spud before. It looks very interesting Score: 8	looks similar to an earlier one, nice colour Score: 8	the skin has a somewhat bitter taste but the inside has a nice earthy flavour Score: 6	a good balance of flavour, not too earthy but with a good amount of taste Score: 8	the skin seemed a bit tough, I think I would like it more without the skin on Score: 6	it seemed a little floury but otherwise good Score: 6	not as good as Nadine, or (No Suggestions) for me Score: 6	Score: 8	it would be good with some seasoning Score: 6	the good colour and balanced flavour are a good combination Score: 8
its different, could look great served as part of a meal, as lots of visual appeal Score: 8	nicer looking on the inside than the outside Score: 8	tastes like a potato except slightly more acidic Score: 7	a bit acidic Score: 7	starchy Score: 7	not as much creaminess in mouth Score: 4	slightly acidic Score: 4	appearance more appealing than taste Score: 5	the colour is a big pro Score: 7	Score: 7
Score: 5	Score: 5	Score: 6	Score: 6	Score: 7	Score: 6	Score: 5	Score: 5	Score: 5	Score: 5
Score: 2	Score: 3	strong flavour Score: 9	Score: 8	crumbly Score: 7	Score: 7	Score: 7	Score: 8	Score: 6	Score: 8
it looks appealing to me Score: 9	I like the colour, want to buy if I see it Score: 9	sweet Score: 8	sweet Score: 8	quite powdery Score: 6	Score: 7	aftertaste have astringent Score: 4	Score: 5	dessert mixed potato with sugar maybe Score: 8	dessert with coconut cream Score: 8
Score: 8	cracked, white flesh dull Score: 2	very tasty Score: 8	Score: 2	Score: 8	very floury Score: 2	not much of an aftertaste Score: 5	Score: 3	Score: 8	worst one of all ate Score: 2
beautiful colour-stunning Score: 9	very nice colour Score: 9	not as exciting as it looks though-just tastes like potato Score: 8	Score: 8	not too floury / waxy Score: 8	Score: 8	neutral Score: 7	Score: 8	because of the colour I love it! Score: 8	Score: 8
Score: 5	Score: 4	a bit dry Score: 6	Score: 6	Score: 6	a bit dry Score: 4	4	Score: 6	Score: 5	Score: 5
looks fake! Score: 3	light skin Score: 6	flavoursome Score: 8	Score: 4	firm but moist Score: 8	too dry, floury Score: 3	pleasant Score: 7	floury Score: 4	good texture Score: 8	tough to eat Score: 4
I think the colour looks pretty and nice-will be cool to have in dish. Though doesn't give impression of potatoes Score: 8	look a bit mushy and look a bit mouldy a bit Score: 3	flavour is nice, quite like it Score: 8	flavour is ok Score: 6	quite crunchy, the skin texture mix well and better with flesh than moemoe Score: 7	too dry and powdery Score: 4	not as strong aftertaste as moemoe, aftertaste is ok and acceptable. But could be used as refreshing feel of potatoes Score: 7	its ok for me Score: 5	I like it Score: 7	too dry Score: 4