NUTRITIONAL COMPOSITION AND CONSUMER ACCEPTABILITY STUDY OF DIFFERENT PREPARATIONS OF EDAMAME SOY BEANS

BY

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DECLARATION OF ORIGINALITY

I, Leandra Antoinette Taylor, hereby declare that:

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I, Frederick Veldman, supervisor of this candidate, agree to the submission of this dissertation.

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ABSTRACT

The aim of this study was to determine the nutritional composition and physical properties of dry mature and roasted mature Edamame beans and to compare, through sensory evaluation, the consumer accessibility of these products in grade 5 learners. Soy beans have been known and recognised for centuries as a plant food that, when compared with other plants, is high in protein. For this reason, soy beans have historically been called ‘meat of the field’. The overall energy content of the Edamame soy beans remained unchanged after undergoing oven and microwave roasting. Even though the microwave roasted soy bean samples appeared to have a higher macronutrient content when compared to oven roasted soy bean samples, it is important to recognize the fact that microwave roasting causes more water loss, which has a concentrating effect on the macronutrients. Forty-one grade 5 learners participated in a sensory evaluation, conducted at Cato Crest Primary School in Durban, KwaZulu-Natal. In this study, learners preferred the Edamame above their usual sweet-flavoured snacks. The learners however, preferred samples that had strong "sweet" and monosodium glutamate flavours. Results from this study suggest that the different roasting methods of Edamame beans do not yield products that are significantly different in terms of nutritional quality. Yet, microwave roasting caused more fluid loss. This makes microwave roasting ideal to process Edamame soy beans due to improved shelf life. Edamame soy beans are a healthier source of protein in comparison to peanuts as it provides good quality protein with a lower fat content. It provides all of the essential amino acids for adults and children and would be a good alternative source of protein if made more available to those at risk of malnutrition.

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DEDICATION

This thesis is dedicated to my four-year-old daughter, Miané Taylor, who is our little miracle, my new-born son, Julian Lucardo Taylor and to my late grandfather, Mr Johannes Cornelius Coetzee.

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LIST OF ABBREVIATIONS

AgriLASA	Agricultural-laboratory Association of Southern Africa
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists International
CBS	Corn-based Supplement
DOE	Department of Education
FAO	Food and Agriculture Organization
HPLC	High Performance Liquid Chromatography
IAR&T	Institute of Agricultural Research & Training
INP	Integrated Nutrition Programme
KZH-DOE	KwaZulu-Natal Department of Education
KZN-DOH	KwaZulu-Natal Department of Health
MDG	Millennium Development Goals
MIYCN	Maternal, Infant and Young Child Nutrition Working Group
NDOH	National Department of Health
NE	Niacin equivalent
NFCS	National Food Consumption Survey
NFCS-FB	National Food Consumption Survey Fortification Baseline
NIH	National Institute on Aging
NSP	Nutrition Supplementation Programme

LIST OF ABBREVIATIONS (CONT'D.)

PEM	Protein energy malnutrition
P&K	Peryam & Kroll Scale
PMB	Pietermaritzburg
RDA	Recommended daily allowance
RE	Retinol equivalent
RUF	Ready-to-use food
RUSF	Ready-to-use supplementary food
RUTF	Ready-to-use therapeutic food
SAGL	South African Grain Laboratory
SANAS	South African National Accreditation Services
SANHANES	South African National Health and Nutrition Examination Survey-1
SD	Standard deviations
UKZN	University of KwaZulu-Natal
USDA	United States Department of Agriculture
WHO	World Health Organization

CHAPTER 1
INTRODUCTION

1.1 Background to the importance of the study on Edamame

The term nutrition is used in three ways. In general, "nutrition" is used to refer to the food that we eat. "Nutrition" also refers to the science that describes and explains the processes involved in consuming and utilising food and its essential nutrients. Thirdly, nutrition can be seen as an outcome and provides information regarding the health status of either an individual or a group of individuals (Pamplona-Roger, 2010). The term malnutrition commonly implies undernutrition, but also includes over nutrition (Cunningham, 2015). The effects of malnutrition may not be apparent immediately, but it has significant effects on mortality, morbidity, the potential to be educated and productivity (Vorster *et al*., 1999). In populations where undernutrition is a chronic problem, a cycle of malnutrition exists that weakens the development of a healthy productive population (Vorster *et al*., 1999). Protein-energy malnutrition (PEM) refers to a condition characterised by an increased vulnerability to infection (Hoang *et al*., 2015). This then can result from long-term ingestion of inadequate energy and protein to meet the metabolic needs of an individual. It needs to be kept in mind that the body will use nutrients to first meet its energy requirements and not supplying the protein functions first, giving rise to PEM. Most PEM is not immediately obvious and can only be detected by measuring different parameters of growth such as the weight and height (Alaverdashvili *et al*., 2015).

The National Food Consumption Survey (NFCS) was conducted in South Africa in 1999. The focus of this survey was on the nutritional status and dietary intake of children aged 1 to 9 years. The survey reported that 23% of South African children were stunted (i.e. height-for-age below 2 standard deviations (SD) when compared to the mean of the WHO reference population). This implied that 23% of the population was too short for their age, which is an indication of widespread chronic undernutrition. The prevalence of stunting was higher in rural areas (26.3%) and especially high in commercial farming areas (30.8%). Children between the ages of 1 and 3 years were more (25.5%) affected by stunted growth when compared to older children. About 6%

of the children were affected by severe stunting (i.e. height-for-age below 3SD of the WHO reference population) (Steyn *et al*., 1999).

In 2012, the World Health Assembly has set nutrition targets for a reduction in stunting, wasting and overweight. When economies grow, the rate of population growth slows down, which results in the improvement of cognitive performance and psychological functioning in the workforce. Another generation was made less productive by the fact that the 165 million children with stunted growth in 2011 have compromised cognitive development and physical capabilities. When intervention strategies incorporate the promotion of nutrition, child development benefits are expected to be greater. More than 3 million child deaths each year occur due to undernutrition, which means that undernutrition contributes to 45% of deaths amongst children 5 years and younger (Shisana *et al.*, 2013). "Overweight in adults, and increasingly in children, constitutes an emerging burden that is quickly establishing itself globally, affecting both poor and rich populations" Black *et al.,* 2013).

The energy-containing nutrients carbohydrates, lipids and proteins, also known as macronutrients, are required in large amounts in the diet (Brundage, 2015). The NFCS assessed the nutrient intake of children from the ages of 1 to 9 years in South Africa and outcomes of this study indicated that 50% of these children had an inadequate energy intake (Steyn *et al.*, 1999). Fish, poultry, meat, milk and milk products along with legumes such as beans, peas, lentils and soy are all different sources of protein (Brundage, 2015). Protein can also be provided by grains, but only in smaller amounts. It is true that protein is very important in the diet and is needed for growth and maintenance of body structures as well as to regulate body processes (Veith, 1998). Dietary lipids include fats and oils, which are found in meat, fish, milk, vegetable oil, margarine, butter, nuts, seeds and avocado pears. Fat is the stored form of energy in the human body and provides heat and insulation (National Institute on Ageing, 2010). Carbohydrates include both starches found in vegetables and grains as well as sugars found in fruit. Carbohydrates are a readily available source of energy (Pamplona-Roger, 2010).

Vitamins and minerals (micronutrients) are only required in small amounts in the diet. A healthy balanced diet provides sufficient amounts of all three these macronutrients and a sufficient variety of foods that also provide an adequate spread of minerals and vitamins (Pamplona-Roger, 2010).

When addressing malnutrition, available data suggest that nutritional challenges are a significant and increasing public health problem globally. This is also true regarding the prevalence of malnutrition in South Africa. The prevalence of stunting in South Africa is high, particularly among African and Coloured children. Malnutrition is the highest in provinces which include former homeland areas, with persistent low socio-economic status (Shisana *et al*., 2013).

According to SANHANES (2013) 39% of 5 972 participating households indicated that they did not have enough money for basic essentials such as food and clothing in their households, whilst 18% indicated that although they had most of the essentials, they did not have luxury goods. It was reported that most households in informal communities did not have enough money available for food and clothes. This was true for 58% of the households in urban informal communities and 51% in rural informal communities. This was not only prevalent in informal communities, as the outcomes showed that 29% of households in urban formal areas has also not enough money available for food and clothes (Shisana *et al.,* 2013). Households particularly in the Northwest (58%) and Gauteng (29%) provinces did not have enough money for food and clothes. Within the nine provinces, Mpumalanga (46%) followed by North West (40%), Eastern Cape (43%) and Northern Cape (41%) had the most people reporting no income. A total of 90% of the participants indicated that they did not have access to daily necessities such as food and clothing, of which 44% was black African participants, 28% Coloured participants, 12% Indian participants and 6% white African participants (Shisana *et al.,* 2013). KwaZulu-Natal (32%), North West (31%) and Eastern Cape (30%) had the most respondents indicating pensions, grants and UIF as contributing to their earnings (Shisana *et al.,* 2013). Deriving their income from salaries and wages, whites had the largest proportions of all race groups as only 14.2% did not have any income.

The Eastern Cape province has the third largest population which contributes to 13.5% of the South African populations, yet at the same time it is the second poorest province in the country with food poverty as high as 36%. Following this food poverty in the Eastern Cape, is estimated that food poverty in KwaZulu-Natal is 33%. It should be noted that KwaZulu-Natal has the largest population in South Africa, which contributes to 21% of the total population (Statistics SA, 2013).

According to the Statistics South Africa (Statistics SA, 2013) poverty trends report, "the Eastern Cape and Limpopo have remained among the poorest provinces since 2011", while KwaZulu-Natal's poverty levels have reduced since 2001, but remain consistently high to put the province in third poorest place (Statistics SA, 2013).

Because of this, there may be a great need for good nutrition in KwaZulu-Natal (KZN). As a result of the need for adequate nutrition there is a need to promote high quality health and this can be done by means of relevant and affordable community-based strategies. Thus there must be an introduction to affordable food, containing high protein as well as other essential nutrients.

To accommodate a high-protein, low-fat and high-carbohydrate diet, soy beans have been promoted as a healthy substitute for meat (Henkel, 2000 & Pamplona - Roger, 2010). Soy protein products, unlike other beans, offer a 'complete' protein profile which enables soy to be a good substitute for animal products (Henkel, 2000). According to Henkel (2000), "soy protein products can replace animal-based foods which also have complete proteins but tend to contain more fat, especially saturated fat without requiring major adjustments elsewhere in the diet". A diet high in protein and carbohydrates and low in fat, has long been considered suitable for those with a Western lifestyle, which is characterised by a high intake of animal protein (associated with saturated fat) and fat (Vorster *et al*., 1999). In contrast to animal protein is soy bean which is a substance rich in protein. Soy beans have a protein content of about 40% and approximately 20% fat. The protein content of soy beans is contained in the soy bean seeds (Kolapo, 2011).

Soy beans can help with the fight against undernutrition due to the fact that it provides adequate amounts of carbohydrates, digestible fibres, minerals and vitamins (Kolapo,

2011). In addition to its high food value, it is one of the least expensive sources of protein when compared to eggs, milk, beef and cowpea (IAR&T, 1988; Kolapo, 2011). The Mediterranean diet, on the other hand, which contains less fat, less protein and more carbohydrates than the typical Western diet, is now recommended by the WHO. This diet is much healthier than the typical meat diet of industrialised countries (Pamplona - Roger, 2010).

The nutritional quality of food is affected by processing such as cooking, drying, and preservation of natural raw food material, irrespective of whether it is on household or industrial scale (Khattab & Arntfield, 2009). Some cooking techniques might be less expensive, easier or more readily available. The down side to these cooking techniques is that it can render a product that might not be of an adequate nutritional quality. Some nutrients are sensitive to external factors like for example heat and heat-sensitive nutrients can be easily destroyed during processing or cooking (Esveld, 2004). New processing techniques are continuously developed in order to preserve the nutritional quality of food. It is therefore extremely important that with the manufacturing of new food products, the nutritional quality of those products must be monitored in order to assess its impact on the raw material. The evolution of food systems reflects innovations in food production, delivery, preservation and preparation, changing economic conditions, social norms and expectations regarding food availability, safety, variety, and knowledge. Government policies and food industry actions affect the food supply, consumer behaviour (demand), and ultimately the diet and health of a population (Ng & Popkin, 2012).

The current study was designed to compare two roasting methods, namely dielectric roasting and oven roasting, on the nutritional composition and physical characteristics of Edamame soy beans. The Edamame soy bean is versatile and can be consumed in its raw form or as a roasted product. Edamame is high in protein, contains no cholesterol, and can be used to introduce and promote a new healthy element to the food industry in Southern Africa (Trader Joe's, 2015). The health benefits of Edamame consumption have been widely published and supported by the scientific community. It has been reported to contain a balanced vital amino acid profile in an appropriate ratio for human consumption (Messina & Messina, 1994). Edamame also:

- contains high levels of essential fatty acids along with various vitamins and minerals (Kolapo, 2011);
- contains agents such as isoflavones that are suspected to have cancer fighting and other beneficial properties (Kolapo, 2011); and
- is a source high in dietary fibre (Kolapo, 2011).

Edamame has a larger seed, is reported to taste better, is easily digestible and contains a lower percentage of trypsin inhibitor and gas-producing starches when compared to other soy strains (Zhang & Kyei-Boahen, 2007). According to records, Edamame has been consumed as early as 2838 BC in China as one of five sacred grains (Shibles *et al*., 1987).

Despite the reported benefits of soy, there is some concern about the presence of aflatoxins, lectin and oestrogen. Aflatoxins are poisonous and cancer-causing chemicals that are produced by certain molds. Peanuts also contain aflatoxin. In large quantities these toxins are poisonous to humans. Soy must therefore be extensively processed to remove toxins. Seeds are the natural medium through which plant species produce new offspring. Many seeds protect themselves by containing toxins, anti-nutrients such as lectins, chemicals such as plant oestrogens, acids that interfere with mineral metabolism or proteins that damage the eater's intestines (De Vany, 2012).

Within a developing context, the benefits of soy consumption outweigh the risk of developing any symptoms of poisoning, mainly due to the fact that soy is only consumed in small quantities. Today Edamame is commercially produced in many countries outside of the Far East, including Argentina, Australia, New Zealand, Israel and the USA (Konovsky *et al*., 1994). Like field-dried soybeans, the seeds of Edamame varieties are rich in protein and highly nutritious (Konovsky *et al*., 1994).

In the United States, Edamame has potential as an easier-to-grow, better tasting, more nutritious substitute for lima beans. As it is served in the pods, it might appeal to consumers interested in natural foods, especially if it were grown organically (Cook, 1988). Due to its prudent nutritional characteristics, Edamame is considered a suitable product to be promoted in low-income settings where malnutrition remains rife, because in a hungry world, with research and education, Edamame could be a very

nutritious, savory, and inexpensive addition to local diets, especially in calorie, protein and vitamin deficient regions of the world (Konovsky *et al*., 1994).

Yet, more research is required to evaluate consumer acceptability and different processing methods to establish the specific conditions under which, if any, Edamame can be utilised as a means to address poor nutrition, especially in low-income communities following a very conservative traditional diet.

1.2 Statement of the problem

As reported by the latest SANHANES study (2014), 45.6% of the South African population were food secure, 28.3% were at risk of hunger and 26.0% experienced hunger (were food insecure). Thirty-two percent (32.4%) of participants who reported to experience hunger resided in an urban informal locality, whereas 37.0% of the study population resided in rural formal localities. The highest prevalence of being at risk of hunger was amongst those that lived in the urban informal and rural informal areas with 36.1% and 32.8%, respectively. Nineteen percent (19.0%) of hunger was reported in the urban formal areas. According to Statistics SA (2013) a total of 45% of all female-headed households live below the poverty line. There is a need to promote access to sustainable food sources in these households. The development of new and alternative products is inexpensive, accessible and that requires limited storage resources, but provides a healthy spread of nutrients should receive priority. The consumption of soy beans, food-source rich in protein and low in fat, has been promoted for a long time, especially in communities known for a high prevalence of PEM. Ethekwini municipality in KwaZulu-Natal (KZN) has initiated a project in which the cultivation of Edamame soy beans is promoted not only as a means to address the high levels of malnutrition in its rural communities, but also to generate a means of income for small-scale farmers. Processing of Edamame can be done by means of Dielectric or microwave roasting, infrared heating, and oven roasting (hot air) (Esveld. 2004). It is unknown to what extent each of these methods will impact the nutritional value of the Edamame. In addition, it is also important to know whether consumers find the differently processed products acceptable.

1.3 Objectives

The objectives in this study were:

1.3.1 to determine the difference in nutritional composition and physical properties of dry mature, dielectric or microwave- roasted, infrared- roasted, and oven (hot air) roasted mature Edamame beans; and

1.3.2 to compare, through sensory evaluation, consumer acceptability between dry mature and roasted mature Edamame amongst grade 5 learners.

1.4 Type of study

Samples of the raw, dielectrically roasted, microwaved and air-dried roasted Edamame along with raw and roasted peanuts used as the control were analysed and compared for macronutrient and certain micronutrient contents, using validated and standardised laboratory techniques. A qualitative survey in children aged 9 to 12 years of age was used to determine the consumer acceptability of Edamame beans processed using different drying techniques. A group of grade 5 learners were selected to evaluate the taste, colour, smell and overall liking of the different flavours of roasted Edamame using a five-point facial hedonic scale.

1.5 Study constraints

Study constraints were experienced when the teachers went on strike a few times and then it was impossible to go to the school. It was necessary to go to the school every time a new flavoured Edamame sample had to be introduced and due to the strikes and school holidays there were thus a delay when it came to collecting the required data at those specific times.

The learners received consent forms to give permission that they could volunteer for this study. Only grade 5 learners could participate. Absenteeism was a problem due to the fact that not all the learners were always present for the days that consumer acceptability testing took place.

1.6 Study parameters

The nutritional composition of the Edamame beans as measured in this study included the following: energy, fat, protein, percentage of moisture, amino acid and ash analysis, while the carbohydrate content was calculated. This study only included consenting participants who did not have a nut allergy and were from Cato Crest Primary School in Durban, KZN. The children used in this study were all grade 5 learners from the ages of 9 to 12 years and of different genders.

1.7 Assumptions

For the purpose of this study the following was assumed to be valid:

- The Edamame samples were all safe for human consumption;
- The Edamame samples were all of the same quality;
- The instruments used for nutritional composition and physical properties of the Edamame soy beans were accurate;
- The study participants understood the questions and were honest with their replies; and
- None of the participants had a nut allergy.

1.8 Definition of terms and concepts

Allergy:	A damaging immune response by the body to a substance, especially a particular food, pollen, fur, or dust, to which it has become hypersensitive.
Age:	The number of years lived since birth.
Consumer food acceptability:	The degree of liking or disliking a food (Lawless & Heyman, 1999). In this study acceptability was defined

	as the degree of liking or disliking roasted Edamame. This was measured through the use of the 5-point facial hedonic scale with Kroll writing ranging from "super good" to "super bad" (Kroll, 1990).
Di-electric/ microwave drying method:	For the purpose of this study dielectric drying method refers to the use of microwaves with a frequency between 300-3000 MHz and wavelength between 1mm and 1m.
Edamame:	Immature green soy beans, usually in the pod.
Extrusion:	For the purpose of this study extrusion is a process by which mixtures of ingredients are forced through an opening in a perforated plate with a food specific design. It is then cut to specified size by blades.
Fluidized bed drying:	For the purpose of this study this method involves the suspension of solid particles caused by thorough mixing between solids and media which increases heat and mass transfer rates.
Healthy person:	A person, who had not been ill in the preceding seven days, was not on medication and did not suffer from any chronic disease such as diabetes, asthma and/or HIV/AIDS.

Infrared drying method:	For the purpose of this study infrared drying method refers to the transfer of heat from the hot surface of a heating element to the soybean.
Malnutrition:	Lack of proper nutrition, caused by not having enough to eat, not eating enough of the right things, or being unable to use the food that one does eat. Under nutrition caused by insufficient consumption of essential nutrients or the rapid excretion before they can be replenished.
Nutritional composition:	The amount and type of nutrients such as proteins, fats, carbohydrates, water, vitamins and minerals found in food products (FAO, 2011).
Oven drying method:	For the purpose of this study oven drying method is a process by which an oven is used to reduce the moisture content in soybeans to extend its shelf life.
Recommended daily dietary allowance:	The intakes that is sufficient to meet the nutrient needs of almost all healthy people in a specific life stage and gender group.
Spouted bed:	For the purpose of this study spouted bed drying is an efficient drying method for drying soybeans with a medium to high moisture content.

1.9 Summary

This chapter highlights the background for a study in which the nutritional and consumer acceptability was tested for a specific non-genetically modified strain of soy beans, which was dried using different techniques. In this chapter, it is motivated why soy beans could potentially play an important role in alleviating the nutritional problems posed in especially rural areas of the country, where PEM remains rife.

1.10 Organisation of the thesis

This thesis contains six chapters, and in this chapter (Chapter 1) the importance of the study was emphasised and parameters and objectives of the study were given. In the next chapter (Chapter 2), a review of literature is presented and it provides the current knowledge on properties, acceptability and feasibility of using Edamame and the methodologies used. Chapter 3 presents the methodologies used in the study and their validation in research. Chapter 4 provides the results generated from the study along with the discussion and interpretation of the results in association with the current knowledge (Chapter 2) provided. In Chapter 5 the recommendations based on the findings of the study are made and discussed and, finally, Chapter 6 contains the conclusion of the study.

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CHAPTER 2
REVIEW OF RELATED LITERATURE

2.1 Introduction

Soy beans have been known and recognised for centuries as a plant food that, when compared with other plants, is high in protein. Protein is the reason that soy beans have historically been called ‘meat of the field’ or ‘meat without bones’ (The George Metaljan Foundation, 2001-2015). Some interesting conclusions have been drawn when researchers took a closer look at especially the protein content of soy beans. Soy protein is a plant protein which is lower in certain amino acids when compared to animal proteins like those that are found in hen’s eggs or in cow’s milk. Yet, once adjustments have been made for digestibility and other metabolic factors, soy beans amazingly turn out to receive a protein quality rating that is equal to those of hen’s eggs or cow’s milk. Very small and unique peptides in soy have also been discovered. Examples of these unique peptides in soy beans include defensins, glycinins, conglycinins and lunasin. Some of these peptides have been proven to provide humans with health benefits, such as improved blood pressure regulation, better control of blood sugar levels and improved immune function. These benefits make soy an attractive food (The George Metaljan Foundation, 2001-2015).

2.2 Nutrition situation in South Africa

The South African population is characterised by both over- and undernutrition (Shisana *et al.*, 2013). The 2005 National Food Consumption Survey-Fortification Baseline (Labadarios, 1999) indicated that 18% of children between the ages of one and nine years were stunted. Furthermore, children below the age of nine years had a high prevalence of underweight (at 9% of the study sample) (Shisana *et al.*, 2013). The common nutritional deficiencies observed amongst South African children are not only limited to protein and energy deficiency, but also micronutrient deficiencies, such as vitamin A, iron and zinc deficiency (Shisana *et al.*, 2013). At the same time, sub-Saharan Africa, particularly South Africa, currently has the highest incidence of HIV/AIDS-infected children in the world (Shisana *et al.*, 2013) The need for

appropriate nutrition intervention in these population groups underlines the importance of developing appropriate food sources that can address these deficiencies. Yet, the situation is complex, as it is also true that in countries of the sub-Saharan region, additional factors, such as storage, cooling, food hygiene, lack of safe water, etc. have a major impact on the viability and sustainability of food products. It is therefore important to (i) focus all attention on the development of specific products that fit into the requirements of a demanding environment; and (ii) make sure that the products that is delivered, are of a high nutritional quality so that the community benefits from it (Shisana *et al.*, 2013).

The integration of nutrition in child health plays an important role in both individual and national development. Nutrition targets aimed to reduce stunting, wasting and overweight were set in 2012 by the World Health Assembly (Shisana et al., 2013). Economic growth and the rate of population growth are inversely proportional to one another. Where approaches can promote nutrition and child development, greater benefits can be expected. Forty-five percent (45%) of deaths is due to undernutrition of children younger than the age of 5, leading to more than 3 million deaths per year in South Africa. Stunted growth was found in 165 million children in 2011, which made another generation less productive in South Africa than they would have been (Shisana *et al.*, 2013). Adding to this is the increase of obesity amongst children, which causes a global developing concern amongst both poor and rich populations (Black, 2013; Shisana *et al.*, 2013).

2.3 A historical perspective on soy consumption

The consumption of soy beans has a long history, especially in the East, where the processing of the raw bean has introduced a broad variety of products, including sauces and soy milk. Some of these products have been in use for centuries, with others that we developed by means of contemporary industrial technologies (For goodness sake, 2005-2015).

2.3.1 Consumption of soy beans in the East

For many years, soy beans made up a crucial part of the Asian diet, long before the Western countries even gave thought to soy beans. Approximately 30 years ago health statistics in studies started to suggest it is due to the typical Asian diet, that they enjoyed much better health than people in Western countries (For goodness sake, 2005-2015). The outcomes of a number of research studies conducted amongst the Asian population, have reported lower incidence of cancer, less menopausal and –related hormonal symptoms, better heart health and lower incidences of osteoporosis (Vincent, A[1] & Fritzpatrick, LA, 2000; Nahas *et al*., 2003; Dijsselbloem *et al.*, 2004; Cho *et al.*, 2010; Sacks *et al*., 2014; Wong, 2004). Soy protein received substantial attention for its potential role in improving risk factors for cardiovascular disease (CVD) (Sacks *et al*., 2014), especially in the Asian population. Clinical studies showed that at least 25g of soy protein per day can lower total- and LDL cholesterol significantly (Sacks *et al.*, 2014).

When too much unfermented soy is consumed for more than 3 times per week, it may lead to the soy beans exerting a negative effect on health. According to Mercola (2012), it is suspected that the main reason for this negative effect on health is because most soy beans in the United States are genetically modified. However, this aspect requires more research in the future. Thus, in this case, soy may lead to malnutrition, digestive distress, immune system breakdown, thyroid dysfunction, cognitive decline, reproductive disorders and infertility – even cancer and heart disease (Mercola, 2012).

2.3.2 Consumption of soy beans in the West

There is a difference in the consumption of soy amongst Eastern and Western populations (For goodness sake, 2005-2015) as described in table 2.1.

Table 2.1 The difference between the West and the East in terms of soy consumption

West	East
Soy is consumed in large quantities.	Soy is consumed in small quantities.
Soy is eaten on a regularly – daily in small quantities (10 g per day).	Soy is not often consumed frequently – more than 10 g per day.
Soy is an important part of the diet which has a much lower proportion of animal food (dairy, meat).	Replace whole food groups with soy (i.e. replace beef, chicken, milk with processed soy equivalents).
Soy is typically consumed as tofu, miso, natto, tempeh, Edamame, soy bean sprouts or soy sauce.	Soy milk on cereal, vegetarian burgers, soy ice cream (Pure Western mutations).
Fermented soy – Beneficial to your health when used in small quantities of not more than 10 g per day.	Unfermented soy – can be unfavourable to your health.

(For goodness sake, 2005-2015).

Western populations mainly consume fermented soy products whilst Eastern populations mainly consume unfermented soy products. The levels of genistein, an isoflavone, are significantly higher in Japanese and other Eastern soy products than those in American and Western European countries. When comparing the consumption of these levels of genistein, it should be noted that mortality rates for cancer are lower amongst Japanese and Eastern populations who consume higher levels of genistein (Fukutake *et al*., 1996).

2.3.3 How much soy is consumed in the East?

By now it is known what type of soy is consumed by the eastern countries. “What quantity of soy foods is considered a reasonable intake?” is a frequently asked question, especially when children are concerned. Other questions also include a desire to know the amount of soy required to develop potential health benefits with respect to decreasing the risk of chronic diseases, or lessening hot flushes. It is generally not easy

to give specific answers to some of these questions, but a strong basis is provided as a guideline for the intake of soy foods. The United States Food and Drug Administration (FDA) concluded in 1999 that 25 g / day of soy protein as part of a diet low in saturated fat may reduce the risk of coronary heart disease. This figure may not be relevant to all consumers since it is aimed specifically at reducing cholesterol (Messina *et al*., 1994).

Because the Western diet traditionally does not include soy, very little guidance is provided. Legumes generally play a limited role in North American diets, thus making daily consumption of any bean product unusual for many. The recommended dietary guideline for the consumption of soy is three cups (six servings) of beans per week (Messina, 2014a). A recent review that included five studies involving older adults in Japan, reported that soy protein intake in women ranged from as low as 6.0 g / day to as high as 10.5 g / day, whilst it ranges between 8.0 to 11.3 g / day in males. Soy foods contributed 6.5 to 12.8% of the total protein intake of these participants. For comparison, one serving of a traditional soy food provides anywhere between 7 and 20 gram of protein per serving (Messina, 2014a).

2.3.3.1 The optimal soy intake

A number of foods provide many phytonutrients and all nutrients, but soy foods are in essence one of the richest sources of isoflavones. At the moment there is no fixed recommended isoflavone intake. Approximately 8 or 9 gram of soy protein and about 30 to 35 mg / day could be recommended if the median Asian intake is used as a guide. A substantial number of epidemiological studies show that a higher soy and isoflavone intake is associated with a lower risk of diseases associated with a western lifestyle (Messina *et al.*, 1994). The physiological intake of a dietary compound is a daily consumption that is no more than two to three times the average intake of that compound in a respective population (Messina, 2014a). By accepting this definition, an upper intake of about four servings of soy foods per day is recommended for adults. Similarly, about 100 milligram isoflavones and 25 g soy protein is thus recommended, once again if accepting the definition above. No clinical evidence has yet proved that exceeding this level is or can be harmful though (Messina, 2014a).

Table 2.2 The daily total protein intake based on soy protein consumption per day

For most adult Americans:	Consumption of 25 g soy protein per day would imply that soy foods would provide about 25%+ of the daily total protein intake
For young children:	Two servings of soy foods per day seem reasonable as their overall calorie and protein intake is reduced in comparison to adults.

(Messina, 2014c; Messina, 2014d)

Besides flavonoids and isoflavonoids, soy beans also offer a number of unique nutrients, including: phenolic acids, phytoalexins, phytosterols, proteins and peptides, and saponins (The George Metaljan Foundation, 2001-2015).

According to table 2.3. below, it can be seen that there are many different soy foods. The total amount of isoflavones per serving size is also reflected in this table. As seen in table 2.3. cooked, yellow soy beans and plain, roasted soy contain the most isoflavones per serving whilst soy crumble the least.

Table 2.3 Isoflavone content of soy foods

Soy food	**Serving size**	**Total (mg) isoflavone/serving**
Soy beans, Yellow, Cooked	1/2 cup	78
Soy beans, Roasted, Plain	1/4 cup	78
Soy Protein Isolate Powder, Plain	1/3 cup	53
Tempeh	1/2 cup	53
Soy beans, Green, Cooked	1/2 cup	50
Soy Flour, Low-fat	1/4 cup	50
Soy milk, Plain, Fortified	1 cup	43
Soy Flour, Defatted	1/4 cup	42

Table 2.3 (cont'd.) Isoflavone content of soy foods

Soy food	Serving size	Total (mg) isoflavone/serving
Soy beans, Black, Cooked	1/2 cup	40
Soy Flour, Full-fat	1/4 cup	33
Textured Soy Protein, Dry	1/4 cup	33
Tofu	1/2 cup	25
Soy milk, Plain, Unfortified	1 cup	10
Soy Crumbles	1/2 cup	9
Miso	1 Tbsp	7

(Messina, 2014a; Messina *et al*., 2006).

2.4 Nutritional value and value of soy in a malnourished diet

Malnutrition, especially in young children is a serious public health problem in South Africa and the rest of sub-Saharan Africa. In fact, malnutrition is the underlying cause of death in 64% in children below the age of five (Schermbrucker, 2013). In 2008, the prevalence of underweight, stunting and wasting amongst South African children under the age of five years was 8.7%, 23.98% and 4.7%, respectively. These figures had declined since 1993 as measured against the Millennium Development Goals (Millennium Development Goals, 2013). However, in an effort to combat malnutrition, the South African government has developed policies to fortify certain foods regarded as staples. These products include wheat flour and maize flour. As a result, eight important micronutrients would now be added to those foods consumed most by the South African population (Schermbrucker, 2013). Although South Africa has been deemed food secure on a national level, many households do not qualify as food secure (Aliber, 2009). It is believed that in a developing country such as South Africa, there is a need for introducing inexpensive, safe and nutritious foods to alleviate hunger and its acute and chronic consequences. A number of attempts have been made in the past in identifying appropriate foods that can be used for this purpose. For some time now, researchers have believed that soy and soy products might pose the necessary qualities to provide excellent nutrition in general (Messina *et al*., 1994). "In a hungry world, with

research and education, Edamame could be a very nutritious, savoury, and inexpensive addition to local diets, especially in calorie, protein, and vitamin deficient regions of the world" (Konovsky *et al*., 1994).

2.4.1 Nutritional composition of soy beans

Soy beans could be compared with some of the richest natural foods, when taking into consideration the high levels of protein, vitamins and minerals, along with containing valuable phytochemicals. The extraordinary capacity of soy to nourish and prevent disease can be better understood when reviewing its composition in terms of protein, fat, carbohydrates, vitamins, minerals and fibre. The amino acid contents also meet most needs of the body for both adults and children. In contrast to other legumes such as beans or lentils that contain less than 1% fat, soy can have as much as 19.9%, primarily containing unsaturated fats. Carbohydrates constitute approximately 20.9% and are composed of a variety of oligosaccaharides, saccharose and a small amount of starch. One hundred grams (100 g) of soy provides half of the daily requirements for vitamins B_1 and B_2 and 20% for vitamins B_6 and E. Soy is however, poor in vitamin C and contains very little provitamin A (Pamplona-Rodger, 2013).

Study outcomes estimate that an individual can lower total cholesterol intake by approximately 125 mg / day and saturated fat by an estimated 2.4 g / day when meat and dairy are replaced with soy (The George Metaljan Foundation, 2001-2015; Jenkins *et al*., 2011). A person can ingest 10 g of fibre and 25 to 30 g of high-quality protein for every 1 cup of soy beans, which will provide a total energy of 1 255.2 kJ. This amount of energy represents 16 to 17% of the total energy required by an individual who consumes a total of 7 531.2 kJ per day. This implies that up a sixth of an individual's required daily energy, can be provided through one cup of soy beans, which in return will also provide 40% of the daily required fibre and 50 to 60% of the daily required protein for a healthy individual (The George Metaljan Foundation, 2001-2015). In its unrefined state, soy contains approximately 9.3% fibre, of which most of this is soluble fibre. Unfortunately, processed soy products contain less fibre (Pamplona-Rodger, 2013).

Thus when investigating the soy protein quality, it shows that soy foods provide high-quality protein and is generally low in saturated fat (Rand *et al*., 2003; Astrup, 2005). The nutrient composition of soy bean is demonstrated in table 2.4 (Pamplona-Rodger, 2013).

Table 2.4 Soy bean composition per 100 g of raw edible portion

Parameter (Nutrient)	Unit of Measurement	Value
Energy	kJ	1.74
Protein	g	36.50
Carbohydrates	g	20.90
Total Fat	g	19.90
Saturated Fat	g	2.88
Cholesterol	mg	-
Sodium	mg	2.00
Fibre	g	9.30
Vitamin A	µg RE_1	2.00
Vitamin B1	mg	0.87
Vitamin B2	mg	0.87
Niacin	mg	10.50
Vitamin B6	mg	0.38
Folate	µg	375.00
Vitamin B12	µg	-
Vitamin C	mg	6.00
Vitamin E	mg α-TE_2	1.95
Calcium	mg	277.00
Phosphorus	mg	704.00
Magnesium	mg	280.00
Iron	mg	15.70
Potassium	mg	1.80
Zinc	mg	4.90

(Pamplona-Rodger, 2013)

1: RE = Retinol equivalent

2: α-TE = Alpha-tocopherol equivalent

Soy beans also contain high amounts of minerals. The foods with high iron content aren't necessarily the best sources of iron. By weight, soybeans have roughly twice the iron content of beef. But it is estimated that only about 7% of the iron in soybeans is absorbed. Spinach is also high in iron, but less than 2% of the iron in cooked spinach is absorbed (Scrimshaw, 1991). To absorb this non-heme iron (found in plant foods, as well as in eggs, milk and meat and is less easily absorbed by the body) effectively, substances that enhance iron absorption are required. These substances include vitamin C, poultry, salmon and, presumably, some other kinds of fish, pork and citric acid (Englemann *et al*., 1998; Hurrell *et al*., 2006; Navas-Carretero *et al*., 2008; Engle-Stone *et al*., 2005; Teucher *et al*., 2004; Fidler *et al*., 2009; Hallberg & Rossander, 1984). Fidler *et al*., (2009) reported that adding just 63 mg of vitamin C to a meal rich in non-heme iron yielded a 2.9-fold increase in iron absorption. Research also suggests that by adding 50 to 85 g of meat to a meal results in a 1.5- to 4-fold increase in iron absorption (Baech *et al.*, 2003; Baynes & Bothwell, 1990; Cook & Monsen, 1976; Engle-Stone *et al*., 2005; Navas-Carretero, 2008). Vitamin C derived from fresh fruits and vegetables ingested in the same meal, significantly increases absorption of iron from soy. Overall, soy is well tolerated, and recommended as a dietary substitution for higher-fat animal products (Michelfelder, 2009). A study conduct amongst adults in the U.S.A. has shown by replacing meat and dairy intake with soy, there is a significant increase in an individual's intake of folate, calcium, iron and fibre (Tucker *et al*., 2010). Soy is also rich in phosphorus, whereas it contains virtually no sodium (Pamplona-Rodger, 2013). It is also a good source of copper, zinc, manganese, molybdenum, riboflavin and omega-3 fatty acids, in the form of alpha-linolenic acid (The George Metaljan Foundation, 2001-2015).

2.4.2 Benefits of soy consumption

The benefits of soy consumption are a controversial issue. Yet, in most instances, the foods people include in their diet rely heavily on personal choice and soy is now widely consumed all over the world (Wellness Today, 2004). Things to consider when wanting to incorporate soy into an individual's diet are:

- Whether the body tolerates the soy well or not;
- The acceptable quantity of soy that can be consumed, especially when a vegan or vegetarian diet is followed;

- Labels on packaged soy foods should always be read; and
- products chosen must be the ones with the least amount of added ingredients (Wellness Today, 2004).

Soy has been and should remain a nutritious part of any well-balanced diet. It should be emphasised again that in moderation, the right quantities and consumed properly, soy is an excellent source of a number of important nutrients (For goodness sake, 2005 - 2015). When incorporating soy beans in a diet however, it should be kept in mind that it is best to use the wholefood forms. Fermented products such as tempeh, tofu and soy miso are also highly recommended soy products (The George Metaljan Foundation, 2001-2015).

In general, it is postulated that populations with diets high in soy protein and low in animal protein have lower risks of prostate and breast cancers than other populations (Michelfelder, 2009). Increasing dietary whole soy protein lowers levels of total cholesterol, low-density lipoproteins, and triglycerides; may improve menopausal hot flashes; and may help maintain bone density and decrease fractures in postmenopausal women (Michelfelder, 2009).

Pamplona-Roger (2013) commented that ingestion of soy has been linked to a possible reduction in the risk of various cancers, including breast cancer, prostate cancer and colon cancer. Regular soy consumption is also believed to be associated with a decrease in the development of arteriosclerosis, reduces the risk of coronary thrombosis and heart attack, increases calcium density and may prevent osteoporosis because of the estrogenic action of the isoflavones in the soy. The consumption of soy provides proteins and seems to be easily digested and absorbed. Possible relief of unpleasant symptoms of menopause may be experienced. Soy also proves to contain no cholesterol, and is rich in unsaturated fatty acids. Beyond that, soy milk also occurs fit to be used to replace cow's milk in infant formulas for lactose intolerant children (Pamplona-Roger, 2013).

The Edamame soy bean in specific is harvested as a vegetable when the seeds are still at an immature stage (80% maturity). They are speciality soy beans, abundant in protein and highly nutritious. They were first recorded in China over 200 years ago. Although

this soy bean variety is not popular around the world it is commonly consumed in East Asia. As a vegetable it can be included in soups, added to salads, stir-fried and combined with other mixed vegetables. It can also be eaten as a snack. The Edamame soy bean itself has a hint of sweetness with a mild flavour and nutty texture. Distributors and consumers determine the quality of the Edamame soy bean based on appearance, aroma, flavour and firm texture after it has been cooked (Konovsky *et al*., 1994).

The metabolic effects of soy consumption seem to exert gender-specific outcomes (Messina, 2014a, Messina, 2014b, Messina, 2014c, Messina, 2014d).

2.4.2.1Metabolic effects of soy consumption in men

Significant health benefits may be obtained by men from soy foods. These health benefits include lowering the risk for prostate cancer and heart disease (Lai *et al*., 2013). Soy foods have been hypothesised to protect against heart disease in the following ways:

- Removing higher saturated fat foods from the diet (Hegsted *et al*., 1993; Mensink *et al*., 1992);
- Modestly lowering LDL-cholesterol (Jenkins *et al*., 2010);
- Lowering of blood cholesterol (Zhan *et al*., 2005).

So far, research has shown that soy is safe for men to consume and that they may benefit by including soy foods in their diet. Soy foods can play an important role in the diets of men. These foods provide high quality protein and are generally low in saturated fat. This fact makes the majority of soy foods great choices for men who want to increase their protein intake from healthy foods. Soy foods also have a beneficial fatty acid content. The soy protein modestly lowers levels of cholesterol (Messina, 2014c).

Isoflavones promote prostate health as they may play a role in preventing and / or treating benign prostatic hyperplasia and prostate cancer (Liu, 2004; Messina *et al*., 2001; Dagnelie *et al*., 2004). No meaningful clinical evidence has been obtained to suggest that soy protein lowers serum testosterone levels or even exerts any estrogen-like or feminising effects in men (Hamilton-Reeves *et al*., 2010). From clinical research it is evident that no hormonal disturbances or semen abnormalities occur in response to

reasonable soy exposure. There are two primary isoflavones in soy beans. One is genistein and the other is daidzein. The average isoflavone intake among older Japanese men is about 40 mg / day (Messina, 2014c).

This amount can be provided by 10 to 12 g of soy protein from traditional soy foods. Each serving (could be 1 cup soy milk or ½ cup tofu or Edamame) of minimally processed soy food provides about 25 mg of isoflavones or 3.5 mg isoflavones per gram protein (Messina *et al*., 2006). Soy foods that have been processed have a generally lower isoflavone concentration per gram of protein (Messina, 2014c).

Table 2.5 Global comparison of soy intake among men in general

	Daily soy intake in g / day	% of total protein intake
United States	1 – 2	$^{+}/_{-}2$
Japan	$^{+}/_{-}10$	>10
China	12 – 13	$^{+}/_{-}15$

(Messina, 2014c).

2.4.2.2 Metabolic effects of soy consumption in women

Isoflavones have a limited distribution in nature. Diets that does not comprise of soy foods are lacking isoflavones (Franke *et al*., 1998). In Japan and China, the average intake of isoflavone among adult's ranges from about 30 to 50 mg / day (Messina et al., 2006). In contrast to this, is the intake of isoflavones less than 3 mg / day in the United States and other Western countries (Horn-Ross *et al*., 2003; Goodman-Gruen & Kritz-Silverstein, 2001; De Kleijn *et al*., 2001; Van Erp-Baart *et al*., 2003; Van Der Schouw *et al*., 2005; Boker *et al*., 2002; Bai *et al*., 2014). Using weighted, 2-day food consumption data for the American population collected as part of the National Health and Nutrition Examination Survey (NHANES) 2007-2008, the American Department of Agriculture more recently estimated that the daily per capita isoflavone intake for women is 0.68 mg (Soyconnection.com, 2014).

Soy foods are a distinctive dietary source of isoflavones, a phyto-estrogen that are believed to offer women the following benefits:

- Heart-health benefits (Soy foods may offer protection against heart disease, as they are low in saturated fat and high in polyunsaturated fats) (Slavin *et al*., 2009);
- Help lessen hot flushes during menopause (Adlercreutz *et al*., 1992; Nagata *et al*, 2001). In most clinical trials, hot flush relief is achieved by ingesting approximately 50mg total isoflavones daily (Adlercreutz *et al*., 1992; Nagata *et al*, 2001);
- Lower the odds of osteoporosis as fortified soy milk is a good source of isoflavones and also contains calcium, vitamin D and protein, which offer additional bone health benefits (Brandi & Gennari, 1993; Ross *et al*., 1991);
- Improves bone mass in peri- and postmenopausal women (Potter *et al*., 1998);
- Lower rates of breast cancer (Wu *et al*., 2008). According to the American Cancer Society (Crouse *et al*., 1999), breast cancer patients can consume up to 3 servings of soy foods daily; and
- Meaningfully reduces cholesterol levels in hypercholesterolaemic subjects (Crouse *et al*., 1999).

In a prospective epidemiological study involving Seventh-day Adventists (a religious domination that includes a high proportion of vegetarians) soy milk intake was significantly inversely related to the presence of osteoporosis (Matthews *et al*., 2011). This specific study involved 337 postmenopausal women. The women who participated had their bone health assessed using broadband ultrasound attenuation of the calcaneus two years after completing a lifestyle and dietary questionnaire at enrolment. Compared to women who did not drink soy milk, women drinking soy milk once a day or more had 56% less chance of osteoporosis (defined as a T-score < -1.8).

The protective effect of soy milk was likely due to its calcium instead of the isoflavone content since dairy product intake was similarly protective (Messina, 2014d). Coming back to cancer, clinical evidence indicates that neither soy foods nor isoflavones adversely affect breast tissue. Human data has suggested that isoflavones do not exert stimulatory effects on breast tissue. These include tissue density or cell proliferation *in vivo*, which are both markers of breast cancer risk (Messina, 2014d).

2.4.2.3 The effect of soy consumption in infants and children

Eating habits can have a big impact on chronic diseases in adults from early in life. It is extremely important to establish good healthy eating habits early in an individual's life. Childhood eating habits are carried over into adulthood. It is easier to change eating habits during childhood than changing adult dietary behaviour. Dietary habits seem to may affect the likelihood of developing breast cancer during adulthood (Shu *et al*., 2001; Lee *et al*., 2009). Also, a major global concern currently is childhood obesity. This is associated with increased mortality from cardiovascular disease in adulthood, independent of the weight of the adults (Must *et al.*, 1992). These observations are important as 20% of children in the United States are obese. Diseases generally associated with obesity, such as hypertension and type 2 diabetes mellitus primarily seen in adults previously, are now also more present in childhood (Messina, 2014b).

Soy protein can meet the protein needs of growing children. Soy foods help children meet the 2010 Dietary Guidelines for Americans (Thomas & Lutz, 2001; Ashraf *et al*., 1990). Short-term studies show that soy foods support normal growth, support the development of children and improve growth (Kay *et al*., 1975; Mathew & Raut, 1981) when substituted for legumes in the diets of malnourished pre-schoolers (Messina, 2014b; Kay *et al*., 1975; Mathew & Raut, 1981). Therefore, soy foods can play a very important role in a healthy and varied diet of a child (Messina, 2014b). In 2000, the American Department of Agriculture removed limits on the amount of soy protein that can be used in the National School Lunch Program. Providing healthful sources of protein without excessive saturated fat content is important for children (Messina, 2014b).

The perspective on the public health benefit of modest soy ingestion during childhood and adolescence cannot be more over-elaborated (Endres *et al*., 2003; Reilly *et al*., 2006); thus all in moderation. Data suggest that when children reach the age of 10, approximately only one out of every 1 000 children are allergic to soy protein (Cordle, 2004).

The effect of soy on puberty has not been studied. A remarkable body of research, consisting of both epidemiological and animal data (Lamartiniere *et al.*, 2000; Peng *et al*., 2009; Mishra *et al.*, 2011), indicates that soy consumption in adolescence reduces the risk of breast cancer later in life. This evidence is coherent with rising data that the risk of breast cancer is hugely impacted by early life events (Russo *et al*., 2005). The first 20 years of life seems to be of great importance. The epidemiological data suggest that approximately one serving of soy consumption during the early years would be sufficient to reduce the risk of breast cancer later on in life (Shu *et al*., 2001; Lee *et al.*, 2009). It is unclear when it comes to the period of exposure to soy that is most protective against the risk of breast cancer. Most studies have focused on the teenage years (Wu *et al*., 2009), but a little study by Korde *et al.*, (2009) showed results that suggested that soy intake during childhood can provide an even greater protection against breast cancer.

2.4.3 Other postulated health benefits of soy-derived isoflavone consumption

Phyto-oestrogens are compounds found in floras that could act like the hormone oestrogen when consumed. Foods high in phyto-oestrogens include soy products such as soy milk, yoghurt, tofu and tempeh. Flaxseed, legumes and whole grains are also very high in phyto-oestrogens. The phyto-oestrogens in soy foods are also known as isoflavones. The structure of phyto-oestrogens is similar to the body's own oestrogen structure. It is believed that the phyto-oestrogens may act like weak oestrogen in some situations, but also block the actions of oestrogen in others (Cancer Council NSW, 2014).

The highest incidences of hormone-related cancers, menopausal symptoms as well as cardiovascular diseases are typically found in populations with Western lifestyles. This Western lifestyle is high in fat, is meat-based and low-fibre (Bingham & Riboli, 2004). Asian populations with eastern habits who consume plant-based diets which are rich in phyto-oestrogens are believed to be less at risk for the above mentioned conditions (Rosenberg *et al.*, 2002). Asian people have a low cancer risk, but when migrating to the America, their risk rises to that of the American rates. This occurs generally in the same (prostate cancer) or for some cancer types in the next generation (breast cancer). Therefore, the large contribution to the occurrence of these pathophysiologies is

hypothesised to include diet-related factors, rather than pure genetic factors, but requires further elucidation. It has been pointed out however, after considerable research and analyses that dietary soy as the major source of isoflavones might lower cancer risk (Dijsselbloem *et al*., 2004).

Furthermore, soy appears to postpone and protect against chemically induced mammary tumour formation in rodents (Jin & MacDonald, 2002). Some reports propose effective protection against breast cancer if soy intake is spread over a lifetime. The period before puberty and during adolescence may be particularly important (Dijsselbloem *et al*., 2004).

A question arose as to whether phyto-oestrogens and soy foods can give protection against breast and prostate cancer. In some Asian countries, where soy is very common in the diet, lower rates of breast and prostate cancer led scientists to investigate the link between the eating of soy foods and the protection against breast and prostate cancer. It is difficult to determine whether it is the soy in the diet or some other factor that lowers the risk of these cancers. What makes it slightly difficult are the different amounts and types of food intakes, and also different genetics of individuals. Large studies done on people gave the impression that a high consumption of soy foods may lower the risk of breast and prostate cancers. Animal and test tube studies do support an anti-cancer effect. From the existing proof, it is believed that a moderate consumption of soy foods (e.g. 1-2 servings of soy foods / day) along with an overall healthy eating plan is unlikely to have opposing effects. This is coherent with the Cancer Council's recommendations and dietary guidelines to eat a diet rich in plant foods (Cancer Council NSW, 2014).

Currently there is no proof that high doses of soy or soy isoflavones are effective in preventing cancer; this is therefore not recommended at present. It is best to eat soy foods in moderation as part of an overall healthy eating plan. Individuals are advised not to suddenly increase the amount of soy phyto-oestrogens in their diet. The Cancer Council of Australia (Cancer Council NSW, 2014) recommends that women with breast cancer avoid soy and phyto-oestrogen supplements. Evidence is starting to show that by maintaining a healthy weight, eating a low-fat diet with plenty of fruit and vegetables and being physically active can improve the survival and overall health of breast cancer

survivors (Cancer Council NSW, 2014; Mercola, 1997-2014). The new FDA ruling does not allow any claims about cancer prevention on food packages, but has also not restrained industry and marketers from making these claims in promotional literature (The World Vision Portal Forum, 2004; Cancer Council NSW, 2014).

2.4.4. Postulated disadvantages of soy consumption

Soy poses as a nutritious alternative claiming to have excellent properties, but some disadvantages of soy consumption have also been reported. Within this context, soy remains classified as a super food and consumption of it should not be discouraged (Pamplona-Roger, 2013).

- All legumes produce uric acid, with soy producing the most uric acid (380 mg / 100 g), beef producing 130 mg / 100 g (variety meat more) and milk producing no uric acid. Soy's uric acid poses limited health risks, especially if the diet is rich in vegetables, which is reported to alkalize the urine and facilitate excretion;
- A diet rich in soy should always be consumed supplemented with fruits, vegetables and even meat as soy contains low concentrations of pro-vitamin A and vitamin C;
- The dust from soy beans can provoke serious respiratory allergies;
- Soy lacks vitamin B_{12};
- Soy, as all other raw legumes, contains toxic substances, also described as anti-nutritive factors. These factors interfere with the absorption of specific nutrients, such as iron. These substances in soy partially or completely break down during processing. Different ways of processing soy in order to destroy these substances include soaking in water, cooking, sprouting, fermentation and industrial processing;
- Soy stimulates digestive flatulence. This can be prevented to some degree when soy is soaked and then cooked.

2.4.4.1 Anti-nutritional factors

There are a number of components present in soybeans that exert a negative impact on the nutritional quality of the protein. The negative impact of these anti-nutritional factors is demonstrated in table 2.6 below. Amongst those factors that are destroyed by

heat treatment are the protease inhibitors and lectins. Protease inhibitors use their anti-nutritional effect by causing pancreatic hypertrophy or hyperplasia, which leads to an inhibition of growth. The lectin has the ability to bind to glycoprotein receptors on the epithelial cells lining the intestinal mucosa, but on the negative side inhibits growth by interfering with the absorption of nutrients (Liener, 1994).

Khattab & Arntfield (2009) reported that different types of treatments applied to legumes, drastically reducing the anti-nutritional load of the seeds with moist heating – moist heating being: boiling, microwave cooking and autoclaving. Thus moist heating is the most effective heating method. Legume seeds being part of the human diet, any of these treatments mentioned are highly advocated to be applied to pulse seeds prior to their consumption. This is necessary to ensure their safety and quality in the food and feed (Khattab & Arntfield, 2009). When deciding on a technique, or a combination thereof, to be applied to bulk quantities the economic considerations should be looked at (Khattab & Arntfield, 2009).

Table 2.6 Anti-Nutritional Factors (ANFs)

Tannins	Phytic acid	Trypsin inhibitors
Inhibit digestive enzymes, thus lowering digestibility of most nutrients, in particular proteins and carbohydrates (Reddy *et al.*, 1985).	Ability to bind essential dietary minerals along with starch and proteins. Reduce bioavailability of these minerals, starches and proteins in humans (Khattab & Arntfield, 2009; Urbano *et al.*, 2000).	Sturdily inhibit trypsin activity. Reducing digestion and absorption of dietary protein (Khattab & Arntfield, 2009).

2.4.5 Soy bean consumption in Africa

2.4.5.1 History of soy in Africa

According to Shurtleff and Aoyagi (Shurtleff & Aoyagi, 1911; Shurtleff & Aoyagi, 2007) a comprehensive study about soy beans and soy foods in Africa have been made. It has been compiled one record at a time over a period 34 years, in an attempt to document the history of soy in this region. A summary of the history of cultivation of soy beans in Africa can be seen in table 2.7 below.

Table 2.7 History of cultivation of soy beans in Africa and close-by countries

Area	Year	Producer
Algeria	1896	French agronomist Trabut
Cedara in Natal and in the Transvaal (now known as Gauteng)	1903	Burtt-Davy and Sawer
Ghana (Previously known as Gold Coast)	1909	
Egypt (SA's leading soy bean producing country)	1920	
Ethiopia (Yields very low)	1950	
Nigeria	1965	Ezedinma (Reviewed history of crop) and Onochie (First Nigerian to study the use of soy foods
Morocco	1974	Wheat-soy blend accepted in school lunch programmes

(Shurtleff & Aoyagi, 1911; Shurtleff & Aoyagi, 2007).

The interest in growing soy beans in Africa originated in 1908. This was due to Europe importing large quantities of soy beans for the first time from Manchuria in response to

severe shortages and high prices of oil in Europe. African colonies were the potential areas for soy bean cultivation of European nations. The colonies most actively involved were the English colonies (Shurtleff & Aoyagi, 1911; Shurtleff & Aoyagi, 2007). A scientific experiment began in September 1909 when soy bean seeds were shipped from Liverpool to Bathurst, Gambia. These seeds were grown out and then in January 1910 the Bathurst Trading Company sent its first crops back to Liverpool for analysis. The seeds were found to have an oil content of 17.5% (Pynaert, 1920; Shurtleff & Aoyagi, 1911; Shurtleff & Aoyagi, 2007). Cultivation of beans took place in Ghana in 1909 (Snow, 1961). In the summer of 1910 Sir Alfred Jones shipped soy beans to West Africa for culture trials. AG Turner had to encourage soy bean cultivation in West Africa. He later reported that they could be successfully grown throughout Gambia, Sierra Leone, Nigeria and the Gold Coast (Ghana) (Shurtleff & Aoyagi, 1911; Shurtleff & Aoyagi, 2007).

Later results, compared to the previous results, were "phenomenally successful" (Sawer, 1911), as soy beans were grown in all these areas and in Mauritius. Extensive investigations were made on all the British governmental experiment farms in Africa. By 1910, when looked at the present demand and prices, the colonies could compete very successfully with imported Manchurian soy beans. The most dynamic and broad cultivation work was done in South Africa, which led to a number of detailed reports that were published on this work, starting in 1910. It is known that soy bean culture failed to become established in Africa because the soy bean varieties were poorly adapted to local conditions. Also the domestic market was not developed, and the European market became small and unpredictable (Shurtleff & Aoyagi, 1911; Shurtleff & Aoyagi, 2007).

The earliest known commercial soy food in Africa was soy flour. It was introduced in South Africa in 1937 by a popular milling company and used by a number of gold mines on the Rand to strengthen the diets of mine workers. The interest in soy beans and soy foods in Africa had started in approximately 1973. There were two main reasons for the strong interest in Africa (Shurtleff & Aoyagi, 1911; Shurtleff & Aoyagi, 2007):

- The sudden rise in world soy bean prices; and

- The work of The International Soybean Program (INTSOY), headquartered at the University of Illinois, America.

There was a fast development of soy bean varieties that yielded well under African conditions due to INTSOY's soy bean variety trials that started in 1973. This was tested by co-operators in different African countries. For the first time it made economic sense for African farmers to grow soy beans because of (i) the high yields; (ii) the high prices, and (iii) the domestic interest in food uses (Shurtleff & Aoyagi, 1911; Shurtleff & Aoyagi, 2007).

2.5 PROCESSING OF NATURAL RAW FOOD MATERIALS

2.5.1 Introduction

Some cooking techniques might be less expensive, easier, or readily available, but render a product that is not necessarily of a sufficient nutritional quality. Some nutrients are more and others less sensitive to external factors, such as heat. These nutrients could easily be destroyed during processing. Industry is therefore continuously on the lookout for new processing techniques that do not destroy the beneficial constituents of a raw product. It is therefore very important when new products are formulated that the nutritional quality of the products be measured against that of the raw material.

2.5.2 Methods of processing

2.5.2.1 Introduction

Options for utilising soya would include a roasted soy bean snack food. Several methods exist for heat treatment (Esveld, 2004; Tromp, 1992), each based on a different way that heat is being transferred. Methodology for roasting could include convection heating, infrared heating or dielectric heating. It is necessary to know the impact of each on the nutritional value, the cost and acceptability of the method (Esveld, 2004; Tromp, 1992).

The three techniques therefore that can be considered when roasting soy beans are:

- Infrared heating provides a very direct means of heat transfer from the heat source to the soy bean (Esveld, 2004; Tromp, 1992);
- Dielectric roasting, which is a medium-wave infrared dryer / Microwaving (a microwave-assisted, fluidised bed, where a combination of hot air and microwaves are used) (Esveld, 2004; Tromp, 1992); and
- Oven roasting (A hot-air, fluidised bed) (Esveld, 2004; Tromp, 1992).

Trypsin inhibitors and lipoxygenase must be inactivated in order for the soy beans to become nutritional. Trypsin inhibitors interfere with the proper digestion of the soy bean protein and therefore full-fat soy beans require heat treatment to denature the trypsin inhibitors. Heat treatment has made it possible to denature the trypsin inhibitor in the whole soy bean. Having said this, it must be mentioned that heat treatment may also destroy other proteins in the soy bean, such as the amino acid lysine in particular. Due to this, heat treatment must carefully balance the desired destruction of trypsin inhibitor with the undesirable destruction of amino acids. Considerable amounts of research have been done into the preferred methods and levels of treatment in order to produce heat-treated whole soy bean of limited anti-nutritive activity and maximum protein availability (Tromp, 1992). The three techniques mentioned are used in the industry to roast whole soy beans as well as legumes such as peanuts (Esveld, 2004).

2.5.2.2 Infrared heating

Infrared lamps emit light with a wavelength longer than the wavelength of visible light to heat the surface of the beans. These long waves are used because they penetrate roughly 1mm into the bean before being entirely absorbed. The browning of crusts at the end of baking cycles on baked products are sometimes done by infrared systems. Infrared heating is an indirect method that relies on heat being generated externally, then applied to the surface of the food, mostly by radiation, by convection and, to a lesser extent, conduction (Esveld, 2004).

Micronisation is the infrared heating of seeds. It is applied to cereal grains to (Hutton & Foxcroft, 1975):

- Improve digestibility;

- Reduce trypsin inhibitors; and
- Improve palatability.

Where food processing is concerned micronisation is used to prepare cooked, flaked cereals and toasted products (Murray, 1987). It has been reported by Arntfield *et al.*, (2001) that micronisation of lentils, previously tempered to 33 g / 100 g moisture for 16 hours, up to an internal temperature of 138℃, was done. This has increased the gelatinised starch and pectic substances, but lowered the phytic levels when compared to the unprocessed lentils (Arntfield *et al.*, 2001).

2.5.2.3 Microwaving or dielectric roasting

Microwave heating uses an even longer wavelength than infrared heating so that it can penetrate further into the product. The heating efficiency is very high and surface burning does not occur, because the energy is evenly distributed over the volume of the product (Yoshida & Takagi, 1997).

Microwave cooking is the most multipurpose method in the world today. It is energy-effective and decreases cooking time when compared to conventional heating (Yoshida & Takagi, 1997). The microwave cooking method is preferred because of its speed and short cooking time. Microwaves are used in the food industry for warming, drying, thawing and baking. It also has other applications such as:

- Pasteurising and sterilising many food types;
- Many more advantages are provided by microwave heating than through conventional food processing methods; and
- Microwave ovens are easy to use (Yoshida & Takagi, 1997).

The food is exposed to high temperatures for a shorter time period. Due to this fewer heat-sensitivity nutrient may be lost, which will result in improving the nutritive value of electronically cooked products, although this point is being debated (Yoshida & Takagi, 1997). Drying of food at high temperatures and for long periods of time by conventional heating results in the damage of quality of the end dried or roasted product (Workneh & Oke, 2013). This may be due to the fact that fruit and vegetables, when

being dried, are subjected to low drying rates during the falling drying rate period in many of the conventional drying methods such as airflow drying, vacuum and freeze-drying (Workneh & Oke, 2013).

Microwaves hold a lot of advantages and hence the increase in the number of domestic microwave ovens. People benefit from the advantages such as:

- Convenience;
- Economy; and
- Time saving.

Yoshida and Kajimoto (Yoshida & Takagi, 1997) reported that microwave heating was not only effective for the inactivation of trypsin inhibitor in whole soy beans, but also for making high vitamin E and full-fat soy flour from raw soy beans. Yoshida & Takagi, (1997) stated that microwave treatment was more effective for inactivating lipoxygenase in beans with higher moisture contents, but now and then consumers are alarmed by reports that noxious compounds are produced in microwaved food. Yoshida & Takagi (1997) stated that triacylglycerols in saturated soy beans were already hydrolysed into diacylglycerols and free fatty acids during soaking and were further hydrolysed by microwaves. According to a study by Yoshida & Takagi (1997), intensive membrane degradation occurs in lipid bodies isolated from soy beans at the molecular level. The outcomes of this study indicated that phospholipase D was converted to phosphatidylethanolamine (PE) and phosphatidylcholine (PC) to phosphatidic acid relatively swiftly at 30°C (Yoshida & Takagi, 1997). Heat treatment with live steam or microwave treatment, however, resulted in more complete extraction of phosphatides (Mullin, 1995). Microwave ovens are indorsed with rapid heating rates and high effectiveness, because of their high penetrating power (Ren & Chen, 1998). The phospholipids in soy beans are the major constituents of cell membranes, and they have a high degree of unsaturation, although little has been reported on how microwave roasting affects the composition and positional distribution of fatty acids of the phospholipids in soy beans (Yoshida & Takagi, 1997). Microwave drying has become very popular in the last couple of years as an alternative drying and roasting method for many food products. The focus of microwave drying so far has been mainly on the fundamental aspects rather than industrial application.

Many researchers have investigated the combination of fast heating or roasting by microwaves and low temperature convective drying (Workneh & Oke, 2013; Al-Harahsheh *et al*., 2009; Zhang *et al.*, 2003; Mullin, 1995). Zhang *et al.*, (2006) wrote a review in which there was stated that a combination of drying methods leads to better drying processes than using microwave or conventional drying methods only. Microwave heating works by means of the transformation of alternating electromagnetic field energy into heat energy by effecting the polar molecules of the material. Microwave heating can more easily heat bulk amounts of food than conventional heating can (Mullin, 1995; Zhang *et al*., 2006; Workneh & Oke, 2013). The electromagnetic energy of the microwaves travel in high frequency waves with wavelengths of between 1mm and 1m, which are corresponding frequencies to between 300 Ghz and 300 MHz (Al-Harahsheh *et al.*, Schiffmann, 1995). Because of these wavelengths, microwave heating can largely reduce the drying time of products without degradation of the quality of products (Workneh & Oke, 2013).

2.5.2.4 Oven roasting

Since the beginning of time, man has been drying food for preservation. Man has thus depended on the sun as the main drying source, which has been greatly influenced by the weather. Besides the disadvantage of the fluctuation in the weather patterns from day to day, this natural drying process remained a popular way for preserving food up until the twentieth century, when mechanical drying replaced it (Workneh & Oke, 2013).

As mentioned by Zhang *et al*., (2003), (Workneh & Oke, 2013), hot-air ventilation drying of products at high temperature for extended periods of time causes substantial damage to nutritional value. The physical quality of fruit and vegetables are also harmed. By using this method, the following happens (Al-Harahsheh *et al.*, 2009; Warchalewski *et al*., 1998; Krokida & Maroulis, 2001; Maskan *et al.*, 2002; Workneh & Oke, 2013):

- Food materials are exposed to increased drying temperatures;
- This leads to an increase in the shrinkage and toughness of the product; and

- There is a reduction in the bulk density and rehydration volume of the dried product, causing severe damage to colour, flavour and nutrient content.

A disadvantage of the convective hot-air drying method coming from an energy point of view, is that it has a longer drying period as well as higher drying temperature, which leads to high energy usage, being as high as 6 000 kJ / kg of water evaporated (Mujumdar & Menon, 1995; Alibas, 2007; Workneh & Oke, 2013). To reduce or minimise the above disadvantages along with the desire to achieve quick and effective thermal processes has led to the usage of microwave and dielectric heating methods for the drying of food (Bondaruk *et al.*, 2007).

2.5.3 Comparison between microwave and infrared radiation

Two forms of electromagnetic energy are microwave heating and infrared (radiant) heating. Similarities between microwave and infrared heating include (Workneh & Oke, 2013):

- Both are transmitted as waves;
- Both penetrate food; and
- Both convert to heat.

The main differences between microwave and infrared heating is discussed in Table 2.8 (Workneh & Oke, 2013).

Table 2.8 The main differences between microwave and infrared heating

Process	Microwave heating	Infrared (radiant) heating
	Microwaves are produced at specified specific frequency bands.	Radiant heat is less controlled and has a wider range of frequencies.
	Microwaves penetrate more deeply than radiant (infrared) energy.	The depth of penetration into a food is directly related to frequency.

Table 2.8 (cont'd.) The main differences between microwave and infrared heating

Process	Microwave heating	Infrared (radiant) heating
	The extent of heating by microwaves is determined in part by the moisture content of the food.	The extent of heating by radiant energy depends on the surface characteristics and colour of the food.
	Microwaves induce molecular friction in water molecules to produce heat.	Infrared energy is simply absorbed and converted to heat.
		The lower penetration of infrared energy means that the thermal conductivity of the food is more important in infrared heating than in microwave heating.
	Microwaves are used to preserve foods.	Infrared radiation is mostly used to alter the eating qualities of foods by changing: • The surface colour; • Flavour; and • Aroma
Heat production	Energy is absorbed and converted to heat.	Induces molecular friction in water molecules to produce heat.
Heating	Is determined in part by the moisture content of food.	By radiant energy depending on surface characteristics and colour of food.

Table 2.8 (cont'd.) The main differences between microwave and infrared heating

Process	Microwave heating	Infrared (radiant) heating
Reason for method	To preserve foods.	Used to alter the eating qualities by changing the surface colour, flavour and aroma.
Thermal conductivity of food	Not so important in dielectric.	Limiting factor in infrared heating.

(Workneh & Oke, 2013; Esveld, 2004).

2.5.4 The differences between microwave and conventional hot-air ventilation drying

High temperature efficiency, shorter drying time, healthier product quality, heat that is generated throughout the material, faster heating rates and the heating of bulk foods more easily are the advantages of Microwave drying above conventional hot-air ventilation drying of food (Mubarak, 2005).

2.5.5 The effect on the nutritional quality of legumes by some physical treatments

Protein, calories, minerals and vitamins are limited in a moderately high amount in legumes and the use of it in food and feed is being limited by the presence of some anti-nutritional factors (ANFs) (Mubarak, 2005).

The nutritional quality and value of food legumes have been enhanced to different extents by the use of different processing methods and traditional treatments such as dehulling, soaking, cooking, fermentation and germination (Mubarak, 2005). Tannins, phytic acid, Trypsin inhibitor activity (TIA) and oligosaccharides have been remarkably reduced after boiling, autoclaving and microwave cooking. The reduction of the previously mentioned took place in Mug beans, Cowpeas and Black gram, red and white kidney beans (Mubarak, 2005; Udensi *et al*., 2007; Rehman & Shah, 2005).

2.6 SUMMARY

For over 200 years, along with rice, soy beans have formed the basic diet of the people of the East and Southeast Asia where very little meat, milk and eggs are consumed. For some years now, a number of attempts have been made to introduce soy as a cost-effective, high-protein complement to the diet of those affected by malnutrition, in specific under-nutrition. Soy beans have natural qualities that provide individuals a healthy spectrum of nutrients.

Soy beans are processed in many different ways. Each method of processing has its unique effect on the nutrient quality of the end-product. In some cases, such as when the beans are fermented to produce soy sauce, the end product is void of protein and very high in sodium and also other products that may not promote good health. So far, it seems that the beans themselves when undergoing limited processing, provide the best option for consumption.

Limited processing would be defined as drying, since the raw bean is not readily consumed and could potentially contain high levels of aflatoxin. Limited data is available to investigate the impact of different drying techniques on the nutritional quality of the soy bean. Also, consumer acceptability of different preparations of dried soy beans is not known.

The objectives of this study were to investigate (i) whether different drying techniques produce products with varying nutritional contents and (ii) to determine whether these products can be served in a palatable form which is acceptable to the consumer.

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CHAPTER 3
MATERIALS AND METHODS

3.1 Introduction

In this chapter the research processes, techniques, tools and methods used to analyse the collected data will be described. An essential part of the methodology serves as a tool for accuracy and the validity of the research problem and how it was solved.

The aims of this study were to investigate the nutritional properties and acceptability of Edamame among grade 5 learners by keeping the following objectives in mind:

- To determine the nutritional composition and physical properties of dry mature and roasted mature Edamame beans; and
- To compare, through sensory evaluation, dry mature and roasted mature Edamame for grade 5 learners.

A combination of research approaches was used in order to investigate these aims.

3.2 Study design

The research process used for this study was of a mixed (quantitative and qualitative) descriptive nature. In using this method, the researcher had no control over any of the variables and can only report what the participants, through their questionnaires, has made evident (Kothari, 2004), in addition to the laboratory analyses that were performed by a private, independent laboratory. This study was performed in two phases:

Phase 1: A laboratory-based quantitative study, to determine the nutritional composition of mature Edamame beans prepared using different roasting methods and techniques.

Phase 2: A qualitative study using questionnaires, for the measurement of the consumer acceptability of different preparations of Edamame beans.

3.3 Research methodology

3.3.1 Sample description.

Mature Edamame seeds from variety VegsoyYgP083 cultivated by farmers that participates in the Edamame Development Programme, Durban, South Africa, were used. The Edamame beans were roasted by Delphius Commercial and Industrial Technologies (Pty) Ltd in Lynwood Ridge, Pretoria. Raw and roasted peanuts obtained from Manoli's, Pinetown, were included in the analyses, for the sake of reference and also familiarity. The three techniques that were used for roasting the soy beans were:

- *Dielectric roasting, through a medium-wave infrared dryer/Microwave-assisted fluidised bed*

  Microwave heating is a heat source that uses longer wavelengths than infrared heating to penetrate further into the product. Heating efficiency is very high and surface scorching does not occur, because the energy is dispersed over the volume of the product.

  Microwave assisted fluid bed roasting uses microwave energy to evaporate the moisture from the centre of the bean and to roast the interior. The process is faster and much more energy efficient than hot air only. The colour change in the beans is the smallest of the procedures evaluated. The temperature profile through the bean shows that the interior is roasted by the microwaves while the outer surface is roasted by the hot air. The roasted beans were brittle and crispy with no signs of over- or under processed product. The texture was superior to the beans roasted with hot air.

- *Infrared heating*

  Infrared heaters or lamps emit light with a long wavelength (longer than visible light) to heat the surface of the beans and the long waves penetrate approximately 1mm into the bean before being completely absorbed. Infrared systems are

Figure 3.1 Colour range and roasting profile of microwave plus hot air roasting

sometimes used for the browning of the crust on baked products at the end of the baking cycle. The quality of the product was adjustable, the colour of the roasted beans in a single trial varied from green to black, as shown in figure 3.2 below. When an infrared roasted soy bean is split, the colour profile indicates that infrared roasting occurs near the product surface and the interior is heated by heat conduction. The taste of the beans varied from still raw and moist, to over-processed and in some cases, even burnt.

- *Oven roasting (a hot-air fluidised bed)*

Hot air heating is a common method for the roasting of peanuts and soy beans. It can be in the form of trays in a batch oven, continuous conveyor systems or fluidised bed systems. The beans are heated by convection to the bean surface and heat conduction from the surface to the interior of the bean.

Figure 3.2 Colour range and roasting profile of infrared roasting

This method provides good product temperature control, because of the individual beans that are suspended in the constant temperature air stream; thus being consistently heated. Figure 3.3 below shows the range of colours found in beans from the same trial. The temperature profile shows that the heating occurs at the product surface, but scorching is less than with the infrared roaster. The beans were brittle and crispy with no signs of over- or under processed product.

A 100 g sample of the seed was sent to CPM Wolverine Proctor Ltd, UK. This seed was roasted in the following way: The Batch Nut Roaster provides efficient and economical through-draft tray roasting technology for product development, low to moderate batch quantity processing, samples for test marketing and direct commercial operation scale up.

Nutritional analysis was performed on the different preparations of Edamame soy beans, the raw soy beans, as well as a sample of raw and commercially roasted peanuts.

Figure 3.3 Colour range and roasting profile of hot air roasting

For the consumer acceptability tests, the following preparations of roasted Edamame beans were formulated:

- Himalayan rock salt coated roasted Edamame; and
- Roasted Edamame mixed with other seeds, raisins and dried cranberries.

There was no specific reason as to why the different flavours of roasted Edamame were introduced. The main purpose of the consumer acceptability tests was to investigate whether the Edamame soy beans would be acceptable and palatable to the community or not. More research is required to establish a specific healthy formulation.

3.3.2 Laboratory analysis of the nutritional composition and physical properties of unflavoured roasted Edamame

3.3.2.1 Micro-nutrient composition analyses

Soy samples were sent to the SA Grain Laboratories (SAGL, Pretoria) for analysis. The SAGL is a SANAS (South African National Accreditation System) accredited laboratory. Standardised methods were used to analyse the following:

- Protein bound amino acid profile (analysis method was not SANAS accredited)
- Tryptophan, (as is) (HPLC In-house analysis method IH 007)
- Methionine & Cysteine, (as is) (HPLC In-house analysis method IH 0015)
- Remaining protein bound amino acid profile (HPLC In-house analysis method IH 9): Aspartic acid, Glutamic acid, Serine, Glycine, Histidine, Arginine, Threonine, Alanine, Proline, Tyrosine, Valine, Isoleucine, Leucine, Phenylalanine, Lysine.
- Free Amino Acids (In-House analysis method 008 - Not SANAS accredited): Phosphoserine, Aspartic Acid, Glutamic Acid , Alpha-Aminoadipic Acid, Hydroxyproline, Phosphoethanolamine, Serine, Asparagine, Glycine, Beta-Alanine, Taurine, Histidine, Gamma-Aminobutyric Acid, Citrulline, Ammonia, Threonine, Alanine, Beta-Amino-isobutyric Acid, Carnosine, Arginine, Proline, 1-Methyl Histidine, 3-Methyl Histidine, Alpha-Aminobutyric Acid, Tyrosine, Valine, Methionine, Cystathionine, Cystine, Isoleucine, Leucine, Hydroxylsine 1, Hydroxylysine 2, Phenylalanine, Tryptophan, Ornithine, Lysine (results were reported as mg / 100 g).

3.3.2.2 Physical properties (density or brittleness, colour, etc.)

The physical properties of the different samples were tested in the Food Science-Laboratory of the Programme of Dietetics and Human Nutrition, Scottsville, University of KwaZulu-Natal.

3.3.2.3 Macro-nutritional composition analysis

The nutrient analysis was conducted by the following outsourced laboratories:

- UKZN animal science laboratory, a member of AGRI-LASA, and
- SAGL, a SANAS-accredited laboratory.

A 100 g sample of the Proctor roasted, dielectric roasted, raw Edamame, raw peanuts and roasted peanuts was sent off to each laboratory. In Table 3.1 the methods and instrumentation used for the analyses are listed.

Table 3.1 Methods and instrumentation used for the nutritional composition analysis

Analysis	Method	Instrument	Laboratory
Gross energy	Bomb calorimetry	LECO AC500 automatic bomb calorimeter	
Crude protein	Dumas Combustion method, AOAC official method 990.03	LECO Truspec Nitrogen analyser	UKZN animal science laboratory, member of AGRI-LASA
Crude fat	Soxhlett procedure, AOAC official method 920.39	Buchi 810 Soxhlett fat extractor	
Ash	AOAC official method 942.05	Furnace	
Moisture percentage	AOAC official method 934.0.	Air-circulated hot oven	
Amino acid analysis	High Performance Liquid Chromatography (HPLC) method.	HPLC	SAGL, SANAS-accredited laboratory

The nutrient composition of raw and two types of roasted Edamame was analysed and compared to that of raw and roasted peanuts.

3.4 Consumer acceptability of different preparations of roasted Edamame beans

The purpose of this part of the study was to determine whether Edamame beans would be acceptable for young consumers, focusing on different flavours of the bean. The purpose of this part of the study was not to formulate a recipe for producing an

acceptable product, but rather to test the palatability of the soy beans in its roasted form. The following flavours where introduced as part of the study: Himalayan rock salt coated roasted Edamame (savoury) and roasted Edamame mixed with other seeds, raisins and dried cranberries (sweet). The flavoured Edamame beans that were used for consumption by the participants were all prepared using the di-electric roasting method.

The participants were grade 5 learners from Cato Crest Primary School in Cato Crest, Durban, a mid-level school in Durban, KZN. The school was approached to participate in this study and the learners voluntarily participated. Prior to the study, informed consent was obtained from the school management and from the parents of the learners. This is an ideal age group as learners ages ranged between 9 and 12 years. This then, to a certain degree, rules out the risk of learners being allergic to soy protein as data are suggesting that approximately only one out of every 1 000 children are allergic to soy protein by the age of 10 years (Messina, 2014). This school qualifies as a Quintile 3 school (KwaZulu-Natal Department of Education, 2011). The socioeconomic status of schools can be grouped into five quintiles, according to the National Department of Education (2008). Quintiles are often used to create cut-off points for schools, with Quintile 1 being the poorest and Quintile 5 being the least poor schools.

Recruitment of the learners participating was done by the teachers. Children were of ages 9-12 years. The learners' age (years), mass (kg), height (m), gender and BMI were recorded / calculated. Confirmation from either teachers or parents was given that none of the participants were allergic to peanuts.

3.5 Data collection

3.5.1 Phase 2: Consumer acceptability of roasted Edamame beans

Of the three main types of descriptive methods – observational methods, case-study methods and survey methods – it was the survey method that was used so that participants could answer questions administered through questionnaires. After the participants had answered the questions, the responses were analysed and interpreted (Appendix D). The questions were clear and easy to comprehend and thus constructed properly, in order for the survey to be both reliable and valid. Rating-scale questions

were included (Jackson, 2009), the advantages being that they are very easy to analyse statistically. It is referred to as a Likert-type scale. This part of the survey was selected to determine if the participants preferred the Edamame above other snacks, if they would like to have the Edamame more than once a week, if they would eat the Edamame rather than other snacks if they knew that it was good for their health, if they wanted to be healthy, and if they still felt hungry after eating the Edamame. The Likert-type scale was also used to find out what the participants' favourite food was and what food they ate the most of.

Another part of the survey included the standards described by Lawless and Heymann (1998), using a five-point facial hedonic scale which consist of a P&K scale ranging from "super bad" to "super good", as indicated in Figure 3.1, to measure the food acceptability. Children have been shown to perform better with facial scale due to their limited linguistic and cognitive development which limits their ability to understand and complete tasks and thus the five-point facial hedonic scale was selected. It has been found that the hedonic scale can be misinterpreted by children and thus the results could indicate how the children felt while testing the product and not what their perceptions were towards the product (Lawless & Heymann, 1998). To eliminate this problem, the meaning of the five faces on the scale was thoroughly explained at the beginning of each session before the participants started tasting the Edamame. What helped to improve the understanding of the hedonic scale was the use of the P&K scale with wording, as mentioned, ranging from "super bad" to "super good". The five-point hedonic scale was used for this part of the survey to measure acceptability of the taste, smell, colour and overall liking of the Edamame. Additional information was gathered on the age, grade and gender along with attributes most and least favoured by the participants (Appendix D).

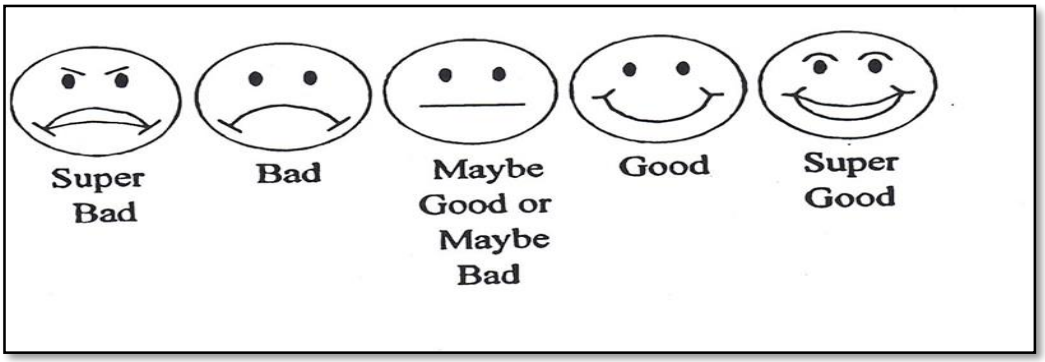

Figure 3.4 Five-point facial scale used in the questionnaire in the study

3.5.2 Procedure

On arrival at the school, teachers had organised the children into the respective groups. Each group was placed in a venue. Attendance was registered upon arrival. The sample or samples were placed on a desk along with the questionnaires. Each child received a chance to approach the table where two data capturers were seated. The data capturers would ask the questions and then write down the answer or choice of each child for that specific question. Children were not influenced in any way. After answering the first few questions on what their name, age and gender were, each child was asked to taste the specific sample. After he or she tasted the sample, the rest of the questionnaire was completed. This part of the questionnaire included the use of the five-point facial hedonic scale. Thereafter, only yes or no questions were asked. After completing the questionnaire, each child received his or her own 250 g packet of the specific sample to be tasted that day with fruit juice. Once all questionnaires were completed, children were allowed to go home. Questionnaires were collected from the two data capturers and processed later that day. This process was repeated as there were different coated flavours of the roasted Edamame. On the very first day children were also weighed, measured and their BMI-calculated, using the equation:

- weight / (height x height) or
- kg / m^2.

These measurements were not repeated on other days.

3.6 Data analysis

Data were analysed using the IMB SPSS 23 (New York). Means and standard deviations for different preparations of Edamame beans and peanut butter samples were calculated using the replicate values. Due to the small sample size, no comparative statistics were performed between the nutritional composition of the different samples. However, for the anthropometric and sensory evaluations categorical data was presented using frequencies and percentages, and means and standard deviations for continuous data, after using the Kolmogorov–Smirnov test (K–S test or KS test) for evaluation of the normal distribution of continuous data. The Chi-square test was used to compare group-statistics, whereas the independent t-test was used for continuous data. A p-value of < 0.05 was considered as significant. Due to the large sample size (>40) of the sensory evaluation and anthropometric data, the sampling distribution always tends to be normal, regardless of the shape of the data and means of samples from any distribution will themselves have normal distribution.

3.7 Ethical considerations

- The issue of consent versus assent was addressed
- The following was added:

The participants were grade 5 learners from Cato Crest Primary School in Cato Crest, Durban, a mid-level school in Durban, KZN. The school was first approached to participate in this study. Prior to the study, informed assent was obtained from the parents of the learners. Participation was voluntary and participants were explained their right to withdraw from the study at any point of time, without the need to provide a reason. Participants nowhere indicated their identity (a number was assigned to each participant in order to link anthropometric data with sensory evaluation questionnaires).

Confidentiality was addressed in the assent form:

1. I understand that the information collected about my child will remain strictly confidential and on a voluntary basis. I also understand that my child may withdraw from participating in this study at any point should he/she wish to do so, without fear of any negative or undesirable consequences.

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CHAPTER 4
RESULTS

4.1 Introduction

The aim of this study was to determine the nutritional value, best roasting method and the consumer acceptability of Edamame. In this chapter the results generated from the study are provided and interpreted in the order of the objectives.

The results of various experiments conducted are outlined in this chapter. These have been illustrated in the form of figures in order to compare the results of the raw, oven and microwave roasted Edamame soy beans, and raw and roasted peanuts. Results for nutritional composition, colour and texture analysis are also provided in this chapter.

4.2 Sample characteristics

Three samples of 100 g soy beans were used for this study. These samples were comprised of soy beans obtained from a single batch from the Ethekwini Municipality.

The three samples consisted of 100 g raw Edamame soy beans, 100 g oven roasted Edamame soy beans and 100 g di-electric/microwave roasted Edamame soy beans. Drying techniques used was conducted by Dolphius Commercial and Industrial Technologies (Pty) Ltd in Lynwood Ridge, Pretoria.

Two 100 g samples of commercially available peanuts were used as reference to compare with the soy bean samples. The peanuts were included more for the sake of familiarity than serving as control or standard. These samples comprised of 100 g raw peanuts and 100 g roasted peanuts.

4.3 Nutritional composition results

4.3.1 Macro-nutrient contents

The nutritional composition results were compiled by comparing the nutrients of soy beans with those of peanuts. Different roasting methods was used as shown in Table 4.1. The results of the roasted soy beans and roasted peanuts was also compared with the raw samples of both soy beans and peanuts. The nutrient analysis took the moisture percentage, gross energy, carbohydrates (CHO), protein and fat per 100 g sample into consideration. The Edamame legume contains all three the macro-nutrients required for good nutrition: protein, carbohydrates and fat, as well as vitamins, minerals and phytonutrients (Appendix C).

Table 4.1 Nutrient analysis of soy bean and peanut samples

	Soy beans			**Peanuts**	
	Oven roasted	**Microwave**	**Raw**	**Roasted**	**Raw**
Moisture (%)	7.2	6.6	9.5	4.4	5.4
Gross energy (MJ / kg)	23.6	23.5	23.3	28.1	30.2
Carbohydrates (g / 100 g)	14.6	16.0	10.2	18.1	15.3
CHO(g) : Protein(g) : Fat(g) Ratio	2:2:1	2:2:1	2:2:1	1:2:3	1:2:3
Protein (g / 100 g)	14.9	17.2	11.5	33.2	27.8
Fat (g / 100 g)	6.1	8.2	4.9	62.8	52.8

Carbohydrates are abbreviated as “CHO” from this point forward

CHO: Protein: Fat Ratio

In terms of macronutrient ratio, soy beans have 2 parts CHO, 2 parts protein and 1-part fat, relative to each other. Peanuts, in contrast, have 1 part CHO, 2 parts protein and 3

parts fat. Comparisons of moisture, gross energy and macronutrients are represented in figures 4.1 to 4.5.

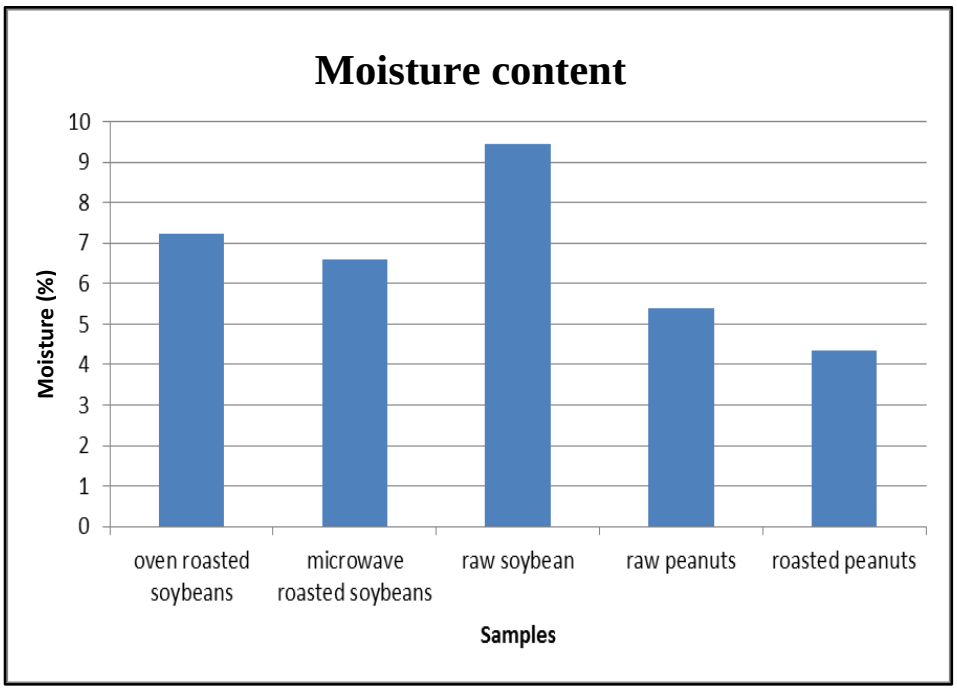

Figure 4.1 Comparison of moisture content (%) for each soy bean and peanut sample

Raw soy beans have the highest amount of moisture (9.5%) (see figure 4.1 and Table 4.1). Oven roasted and microwave roasted soy bean samples have less moisture than the raw soy bean sample. The moisture % in oven roasted and microwave roasted soy bean samples were 7.2% and 6.6%, respectively. The soy bean sample with the least moisture was the microwave roasting method (6.6%). In comparison to soy beans, the raw peanut sample had less moisture (5.4%). The % moisture was the lowest in the roasted peanut sample (4.4%).

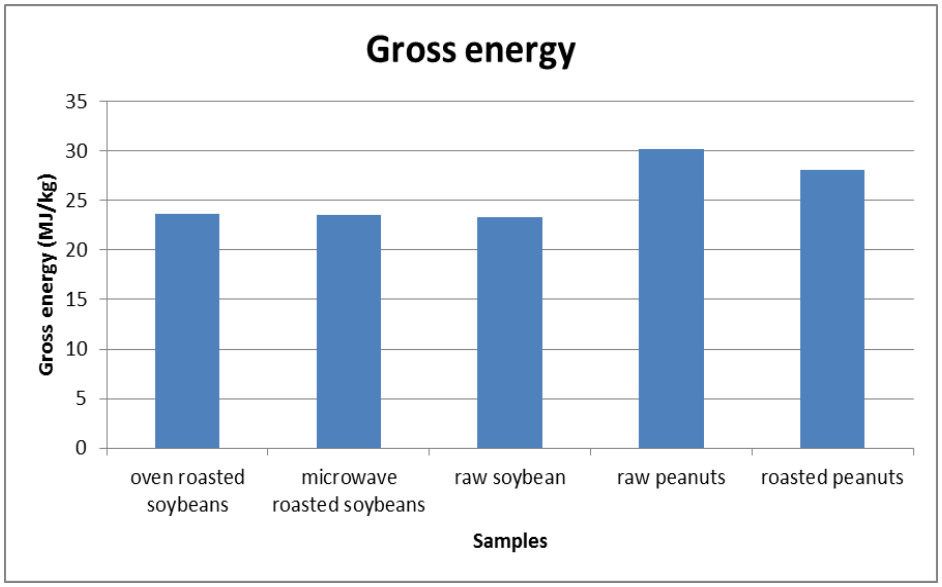

Figure 4.2 Comparison of gross energy (MJ / kg) for each soy bean and peanut sample

As illustrated in figure 4.2, the gross energy of roasted soy beans is very similar to that of oven and microwave roasted soybeans. Gross energy in raw soy beans and raw peanuts were 23.3 and 30.2 MJ / kg, respectively. In comparison to soy beans, peanuts therefore, have a higher gross energy. Gross energy was lower in roasted peanut samples than in raw peanut samples.

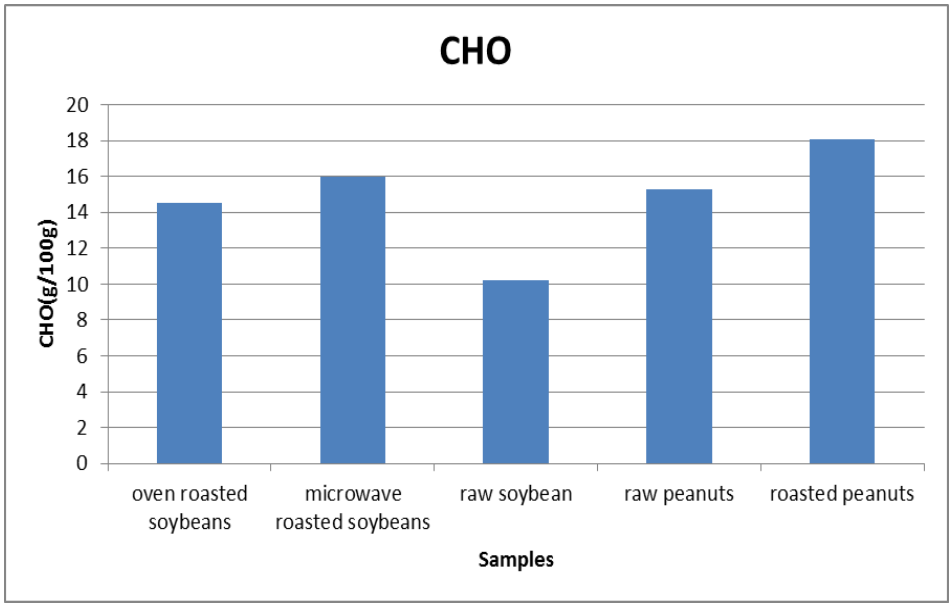

Figure 4.3 Comparison of carbohydrates (CHO) (g) for each soy bean and peanut sample

The CHO content of the various samples that was tested is reflected in figure 4.3. The CHO content of oven roasted soy beans, microwave roasted soy beans and raw soy beans were 14.6 g / 100 g, 16.0 g / 100 g and 10.2 g / 100 g respectively. In comparison to raw soy beans, roasted soy beans had a higher CHO content. Microwave roasted soy beans have the highest CHO content of all 3 soy bean samples (16.0 g / 100 g). CHO content of peanut samples was 15.3 g / 100 g for raw peanuts and 18.1 g / 100 g for roasted peanuts. In comparison to raw soy beans, raw peanuts have a higher CHO content (10.2 g / 100 g compared to 15.3 g / 100 g). Roasted peanuts have a higher CHO content than raw peanuts.

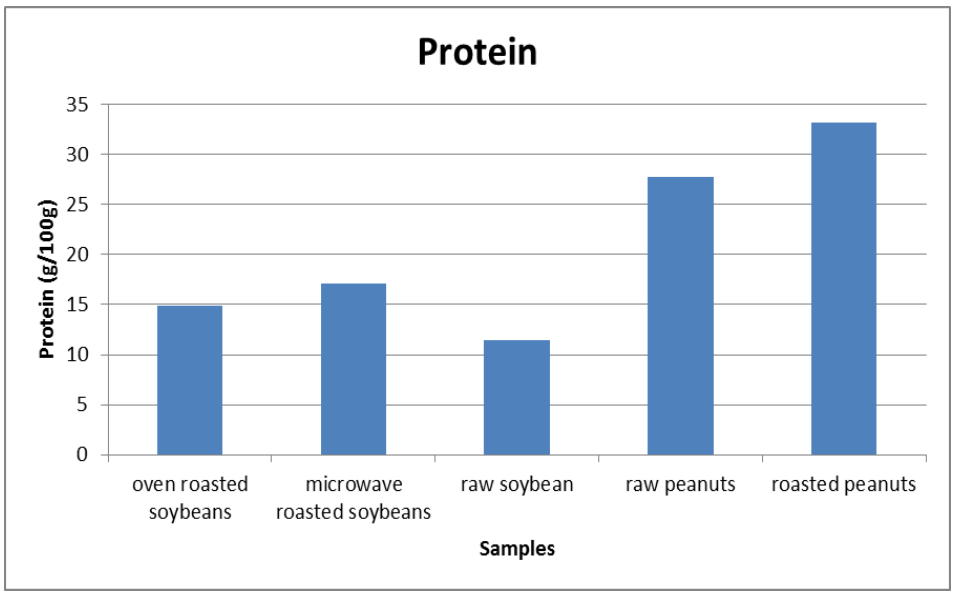

Figure 4.4 Comparison of protein (g) for each soy bean and peanut sample

Protein content for oven roasted soy beans, microwave roasted soy beans and raw soy beans were 14.9 g / 100 g, 17.0 g / 100 g and 11.5 g / 100 g, respectively. As seen in figure 4.4, the protein content of the roasted soy bean samples was higher than that in the raw soy bean sample. The microwave roasted soy bean sample had the highest protein content of all 3 soy bean samples (17.1 g / 100 g). Protein content of peanut samples was 27.8 g / 100 g for raw peanuts and 33.2 g / 100 g for roasted peanuts. It can be seen that raw peanuts have significantly higher amounts of protein than raw soy beans (27.8 g / 100 g compared to 11.5 g / 100 g). Roasted peanuts have significantly higher amounts of protein than roasted soy beans (33.2 g / 100 g in roasted peanuts compared to 14.9 g / 100 g in oven roasted soy beans and 17.1 g / 100 g in microwave

roasted soy beans). The protein content of roasted peanuts is higher than the protein content of raw peanuts.

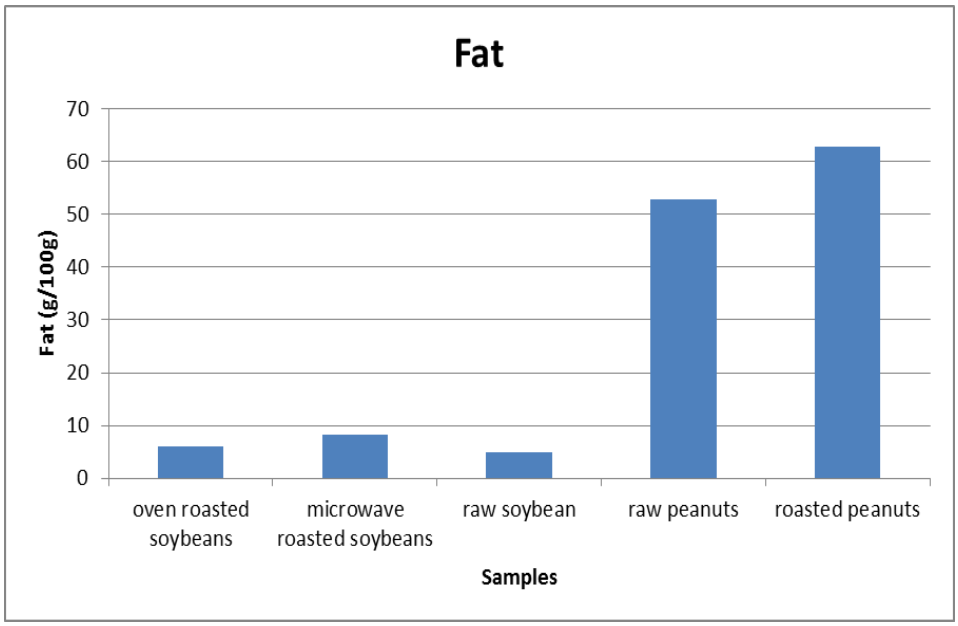

Figure 4.5 Comparison of fat (g) for each soy bean and peanut sample

Fat content for oven roasted soy beans, microwave roasted soy beans and raw soy beans were 6.1 g / 100 g, 8.2 g / 100 g and 4.9 g / 100 g, respectively (refer to figure 4.5). Fat content was higher in roasted soy bean samples than in the raw soy bean sample. The microwave roasted soy bean sample had the highest fat content (8.2 g / 100 g). Fat content in peanut samples were 52.8 g / 100 g for raw peanuts and 62.8 g / 100 g for roasted peanuts. It is seen that raw peanuts have significantly higher amounts of fat than raw soy beans. Raw peanuts have 47.9 g / 100 g more fat than raw soy beans. Roasted peanuts have significantly higher amounts of fat than roasted soy beans (62.8 g / 100 g in roasted peanuts compared to 6.1 g / 100 g in oven roasted soy beans and 8.2 g / 100 g in microwave roasted soy beans). The fat content of roasted peanuts is higher than the fat content of raw peanuts.

4.3.2 Selective macro-nutrient test results

Table 4.2 Comparison of proteins and amino acids between differently roasted Edamame and peanuts

		Raw Edamame soy beans	Oven roasted Edamame soy beans	Di-electric roasted Edamame soy beans	Raw peanuts	Roasted peanuts
Amino Acids Amino Acids	Tryptophan, g / 100 g	0.469	0.504	0.519	0.239	0.204
	Methionine, g / 100 g	0.482	0.498	0.492	0.521	0.248
	Cystine, g/100g	0.681	0.641	0.647	0.373	0.349
Protein Bound Amino Acids	Aspartic Acid, g / 100 g	3.809	3.885	4.483	2.636	2.561
	Glutamic Acid, g / 100 g	6.388	6.622	7.345	4.667	4.564
	Serine, g / 100 g	1.820	1.901	2.085	1.247	1.197
	Glycine, g / 100 g	1.457	1.522	1.666	1.468	1.461
	Histidine, g / 100 g	0.880	1.026	1.000	0.578	0.594
	Arginine, g / 100 g	2.704	2.712	3.152	2.598	2.433

Table 4.2 (cont'd.) Comparison of proteins and amino acids between differently roasted Edamame and peanuts

		Raw Edamame soy beans	Oven roasted Edamame soy beans	Di-electric roasted Edamame soy beans	Raw peanuts	Roasted peanuts
Bound Amino Acids	Threonine, g / 100 g	1.331	1.381	1.539	0.673	0.663
	Alanine, g / 100 g	1.463	1.521	1.693	0.936	0.939
	Proline, g / 100 g	1.779	1.842	2.045	1.089	1.089
	Tyrosine, g / 100 g	1.197	1.244	1.311	0.899	0.882
	Valine, g / 100 g	1.653	1.753	1.902	0.951	1.064
Protein Bound Amino Acids	Isoleucine, g / 100 g	1.478	1.501	1.696	0.805	0.794
	Leucine, g / 100 g	2.586	2.621	2.970	1.527	1.533
	Phenylalanine, g / 100 g	1.695	1.739	1.955	1.253	1.212
	Lysine, g / 100 g	2.202	2.028	2.157	0.840	0.537

The essential amino acid profile did not vary significantly between the two methods of roasting. The amino acid content of raw soy beans was slightly higher than both roasted samples. It is also evident that Edamame soy beans have a higher content of all the essential soy beans when compared with that of peanuts.

For the following amino acids, the results showed differences between different preparations:

- There was 0.641 g / 100 g of cystine in the oven roasted soy sample, 0.647 g / 100 g in the Dielectric sample and 0.681 g / 100 g in the raw Edamame sample. There was 0.373 g / 100 g of cystine in the raw peanut sample and 0.349 g / 100 g in the roasted peanut sample.

For the protein-bound amino acid content:

- 6.62 g / 100 g glutamic acid in the oven roasted sample, 7.34 g / 100 g in the Dielectric sample and 6.39 g / 100 g in the raw Edamame sample. There was 4.67 g / 100 g glutamic acid in the raw peanut sample and 4.56 g / 100 g in the roasted peanut sample.
- 1.84 g / 100 g proline in the oven roasted sample, 2.045 g / 100 g in the Dielectric sample and 1.779 g / 100 g in the raw Edamame sample. There was 1.09 g / 100 g proline in the raw peanut sample and 1.09 g / 100 g in the roasted peanut sample.
- 2.62 g / 100 g leucine in the oven roasted sample, 2.97 g / 100 g in the Dielectric sample and 2.59 g / 100 g in the raw Edamame sample. There was 1.53 g / 100 g leucine in the raw peanut sample and 1.53 g / 100 g in the roasted peanut sample.
- 2.03 g / 100 g lysine in the oven roasted sample, 2.16 g / 100 g in the Dielectric sample and 2.20 g / 100 g in the raw Edamame sample. There was 0.84 g / 100 g lysine in the raw peanut sample and 0.54 g / 100 g in the roasted peanut sample.

4.3.3 Physical properties of Edamame beans and peanut samples

4.3.3.1 Colour analysis of Edamame soy beans and peanut samples

Table 4.3 Colour analysis of Edamame soy beans and peanut samples

	Raw Edamame soy beans	Oven roasted Edamame soy beans	Di-electric/ microwave roasted Edamame soy beans	Raw peanuts	Roasted peanuts
L	57.62	58.25	46.46	40.02	40.71
a	4.29	7.33	12.70	17.08	15.31
b	25.18	26.31	28.23	20.24	22.78

L = Measure of lightness (0 = black to 100 = white)

a = Measure of redness (+a = redness; -a =greenness)

b = Measure of yellowness (+b = yellowness, -b = blueness)

Table 4.4 Colour difference (Sample-Standard)

	Oven roasted Edamame soy beans	Di-electric / microwave roasted Edamame soy beans	Roasted peanuts
Δ L	0.63	-11.16	0.69
Δ a	3.04	8.41	-1.77
Δ b	1.13	3.05	2.54

The Hunter L, a, and b values of the Edamame soy bean samples varied slightly from one another (Table 4.3 and 4.4). Delta L of the Edamame soy bean samples was negative after Di-electric/microwave roasting indicating the sample became darker and positive after oven roasting indicating the sample became lighter. Delta a and b for both roasting methods of the soy beans remained positive. This means that the samples became redder and more yellow. Delta L and b of the roasted peanuts were positive

while delta a was negative. The peanut sample lightened after roasting and became less red and more yellow.

4.3.3.2 Texture analysis results

Hardness and fracturability / brittleness results are tabulated in Table 4.5. There was a significant change in the hardness of the raw Edamame soy bean and both roasted samples. While both methods of roasting had an impact on hardness, oven roasting (766.28 g) appeared to harden the soy bean more than Di-electric/microwave roasting (434.56 g). Roasted peanuts were less hard than both roasted soy bean samples. Raw peanut samples were dramatically harder than raw Edamame soy bean samples. The raw peanut sample was the most easily broken (1.06 mm), while the microwave roasted soy bean sample was the least easily broken (0.19 mm). The oven roasted (0.41 mm) soy bean sample was more easily broken than the microwave sample.

Table 4.5 Texture analysis of Edamame soy beans and peanut samples

	Raw Edamame soy beans	**Oven roasted Edamame soy beans**	**Di-electric/ microwave roasted Edamame soy beans**	**Raw peanuts**	**Roasted peanuts**
Hardness 1= most hard 5= least hard	5 52.40 g	2 766.28 g	3 434.56 g	1 2743.62 g	4 264.29 g
Fracturability / Brittleness 1 = most fracturable 5 = least fracturable	3 0.64 mm	4 0.41 mm	5 0.19 mm	1 1.06 mm	2 0.71 mm

4.4 Consumer acceptability of different preparations of roasted Edamame

As seen in Table 4.6, most of the Grade 5 learners that participated in the sensory evaluation were female (61%). The majority of the group was 10 years of age.

All the volunteers were selected from the same grade and the same school. They were all in grade 5 learners.

The anthropometric measurements of the study group are presented in Table 4.7. The minimum weight (kg) of the volunteers was 22.6 kg and the maximum was 62.0 kg. The average weight for the total group of volunteers was 33.1 kg. The minimum height, thus the shortest volunteers, was 1.25 m and the tallest volunteers were 1.52 m
The average height for the volunteers was 1.36 m. The body mass index (BMI) showed that the lowest was 13.8 kg / m^2 and the highest was 31.0 kg / m^2. The average for BMI was 17.8 kg / m^2.

Table 4.6 Age and gender of study volunteers

		Frequency	Percentage (%)
Gender	Male	`16	39.0
	Female	25	61.0
Age	9	1	2.4
	10	17	41.5
	11	10	24.4
	12	7	17.1
	Total	35	85.4

Table 4.7 Anthropometric results of the study group

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Weight of Volunteers/ kg	41	22.6	62.0	33.1	7.7
Height of Volunteers/ m	41	1.25	1.52	1.4	0.1
Body Mass Index (BMI)/ kg / m^2	41	13.8	31.0	17.8	3.6

Each time a new flavour was introduced to the volunteers, they were asked what their favourite food was. They could choose between meat, vegetables, fruit, sweets, French fries and pasta. According to the data presented in Table 4.8, for that day 48.8% of the volunteers chose meat as their favourite food. Fruit was the choice of only 2.4% of the volunteers and another 48.8% of the volunteers chose pasta.

Table 4.8 Favourite food of volunteers

		Frequency	**Percentage (%)**
Meat	1	20	48.8
Vegetables	2	0	0
Fruit	3	1	2.4
Sweets	4	0	0
French fries	5	0	0
Pasta	6	20	48.8
	Total	41	100.0

Table 4.9 Food eaten most frequently by volunteers

		Frequency	Percentage (%)
Meat	1	23	56.1
Vegetables	2	0	0
Fruit	3	0	0
Sweets	4	0	0
French fries	5	0	0
Pasta	6	18	43.9
	Total	41	100.0

In contrast to what the volunteers' favourite food was, the next question was what food they ate the most. The options stayed the same as they could choose from meat, vegetables, fruit, sweets, French fries and pasta. From the results presented in Table 4.9 it can be seen that 56.1% of the volunteers consume mostly meat, followed by pasta (43.9%).

The volunteers had the opportunity to taste a sample of the Himalayan rock salt flavoured roasted Edamame beans. A total of 80.5% of the participants favoured this specific flavour, compared to 19.5% who did not like this flavour (see Table 4.10).

Table 4.10 Consumer acceptability of the Himalayan rock salt flavour Edamame roasted soy beans

		Frequency	Percentage (%)
Flavour	Like	33	80.5
	Dislike	8	19.5
	Total	41	100.0

Table 4.11 Satisfying of volunteers' hunger by the sample of Edamame beans coated with Himalayan rock salt

		Frequency	Percentage (%)
Hunger	Satisfied	14	34.1
	Not Satisfied	27	65.9
	Total	41	100.0

Each of the volunteers received a 25 g pack of Edamame beans coated with Himalayan rock salt. A question was designed around the idea of how much of the Edamame sample is sufficient for consumption and relief of hunger. It is obvious that the question is highly subjective, but nevertheless included in the questionnaire. A total of 34.1% of the volunteers reported that the sample of soy nuts had satisfied their hunger compared to 65.9% who said that the sample did not satisfy their hunger.

Table 4.12 Preference of the Himalayan rock salt flavoured soy nuts to other snacks

		Frequency	Percentage (%)
Preference	Himalayan flavored soy nuts	28	68.3
	Other snacks	13	31.7
	Total	41	100.0

Volunteers were asked if they had preferred the Himalayan rock salt flavoured soy nuts to the snacks that they normally eat. The results in Table 4.12 showed that 68.3% preferred the Himalayan rock salt soy nuts to the snacks that they normally consumed. There were only 31.7% of the volunteers who said that they still prefer their usual snacks above the Himalayan rock salt flavoured soy nuts.

Table 4.13 Receiving of these soy nuts more than once a week

		Frequency	Percentage (%)
Receiving of soy nuts	Yes	22	53.7
	No	19	46.3
	Total	41	100.0

Even though 68.3% of volunteers reported that they preferred the soy snack above their usual snacks, only 53.7% said that they would like to receive these soy nuts more than once a week. Compared to the 31.7% who reported that they did not prefer the soy nuts over their usual snacks, 46.3% of the volunteers reported that they also would not like to receive these soy nuts more than once a week (refer to Table 4.13).

Table 4.14 Awareness of a healthy lifestyle

		Frequency	Percentage (%)
Want to be healthy	Yes	39	95.1
	No	2	4.9
	Total	41	100.0

It was explained to the volunteers the importance of caring for their health and to live a healthy lifestyle. Table 4.14 showed a very positive result of 95.1% of volunteers who cared about their health while 4.9% reported not to care about their health.

The volunteers were asked if they would prefer to receive these soy nuts in the Himalayan rock salt flavour rather than their usual snacks, if the soy nuts were good for their health. As seen in Table 4.15, the outcome showed that 92.7% of the volunteers would consume the soy nuts knowing that it was healthy and good for them. The other 7.3% still did not want to choose the soy nuts above their usual snacks, even knowing that the soy nuts would be healthier for them.

Table 4.15 Preference of the Himalayan rock salt flavoured soy nuts as a healthy food choice

		Frequency	Percentage (%)
Willingness to eat this flavor if they knew it was good for them	Yes	38	92.7
	No	3	7.3
	Total	41	100.0

Table 4.16 Favourite food of volunteers

		Frequency	Percentage (%)
Volunteers absent		11	26.8
Meat	1	9	22.0
Vegetables	2	8	19.5
Fruit	3	9	22.0
Sweets	4	0	0
French fries	5	1	2.4
Pasta	6	3	7.3
	Total	41	100.0

The second flavour that was introduced to the volunteers was the roasted Edamame that was mixed with other seeds, raisins and dried cranberries.

On that day they could once again choose between meat, vegetables, fruit, sweets, French fries and pasta. According to the table above (Table 4.16), for that day 26.8% of the volunteers were absent. 22.0% of the volunteers chose meat as their favourite food. Vegetables were the choice of 19.5% of the participants and another 22.0% chose fruit. 2.4% (one person) chose French fries as their favourite food and another 7.3% chose pasta.

Table 4.17 Food eaten most frequently by volunteers

		Frequency	Percentage (%)
Volunteers absent		11	28.8
Meat	1	14	34.1
Vegetables	2	6	14.6
Fruit	3	7	17.1
Sweets	4	1	2.4
French fries	5	1	2.4
Pasta	6	1	2.4
	Total	41	100.0

In contrast to what the volunteers' favourite food was, the next question was what food they ate most frequently. The options stayed the same as they could choose from meat, vegetables, fruit, sweets, French fries and pasta. From the results in Table 4.17, it can be seen that 34.1% of the volunteers consume meat the most, another 14.6% consumed vegetables the most and 17.1% consume fruit the most. 2.4% of the volunteers consumed sweets the most; while another 2.4% consumed French fries the most and 2.4% consumed pasta the most.

The volunteers had the opportunity to taste a sample of the roasted Edamame that was mixed with other seeds, raisins and dried cranberries. A total of 65.9% of the participants favoured this specific flavour, compared to 7.3% who did not like this flavour (see Table 4.18).

Each volunteers received a 25 g pack of the roasted Edamame that was mixed with other seeds, raisins and dried cranberries. A question was designed around the idea of how much of the Edamame sample is sufficient for consumption and relief of hunger. It is obvious that the question is highly subjective, but nevertheless included in the questionnaire.

Table 4.18 Consumer acceptability of the roasted Edamame that was mixed with other seeds, raisins and dried cranberries flavour

		Frequency	Percentage (%)
Volunteers absent		11	26.8
Flavour	Like	27	65.9
	Dislike	3	7.3
	Total	41	100.0

A total of 53.7% of the volunteers reported that the sample of soy nuts had satisfied their hunger compared to 19.5% who said that the sample did not satisfy their hunger (refer to Table 4.19).

Table 4.19 Satisfying of volunteers' hunger by the sample of roasted Edamame that was mixed with other seeds, raisins and dried cranberries

		Frequency	Percentage (%)
Volunteers absent		11	26.8
Hunger	Satisfied	22	53.7
	Not Satisfied	8	19.5
	Total	41	100.0

Volunteers were asked if they had preferred the roasted Edamame that was mixed with other seeds, raisins and dried cranberries flavoured soy nuts to the snacks that they normally eat. The results in Table 4.20 showed that 58.5% preferred the mixed sample soy nuts to the snacks that they normally consumed. There were only 14.6% of the volunteers who said that they still prefer their usual snacks over the mixed sample flavoured soy nuts.

Table 4.20 Preference of the roasted Edamame that was mixed with other seeds, raisins and dried cranberries

		Frequency	Percentage (%)
Volunteers absent		11	26.8
Preference	Mixed flavored soy nuts	24	58.5
	Other snacks	6	14.6
	Total	41	100.0

Even though 63,4% of participants reported that they preferred the consumption of the soy snack above their usual snacks more than once a week, only 9,8% said that they would not like to receive these soy nuts more than once a week (refer to Table 4.21).

Table 4.21 Receiving of these soy nuts more than once a week

		Frequency	Percentage (%)
Volunteers absent		11	26.8
Consumption of the Mixed flavored Soy nuts more than once a week	Yes	26	63.4
	No	4	9.8
	Total	41	100.0

It was explained to the volunteers what it meant to care about their health and why it was important to live a healthy lifestyle. Table 4.22 showed a very positive result of 73.2% of volunteers who cared about their health while 0% reported not to care about their health. 26.8% of the volunteers were absent on this day.

Table 4.22 Awareness of a healthy lifestyle

		Frequency	Percentage (%)
Volunteers absent		11	26.8
Want to be healthy	Yes	30	73.2
	No	0	0
	Total	41	100.0

The volunteers were asked if they would prefer to receive these soy nuts in the roasted Edamame that was mixed with other seeds, raisins and dried cranberries flavour rather than their usual snacks, if the soy nuts were good for their health. The outcome showed that 63.4% of the volunteers would consume the soy nuts knowing that it was healthy and good for them. The other 9.8% still did not want to choose the soy nuts above their usual snacks, even knowing that the soy nuts would be healthier for them.

Table 4.23 Preference of the roasted Edamame that was mixed with other seeds, raisins and dried cranberries as a healthy food choice

		Frequency	Percentage (%)
Volunteers absent		11	26.8
Willingness to eat this flavor if they knew it was good for them	Yes	26	63.4
	No	4	9,8
	Total	41	100,0

4.5 Comparison of the different results obtained

4.5.1 Comparing the preference of the two different flavours to each other as well as the preference of the Edamame to other snacks

Twenty-six percent (26.8%) of the volunteers were absent. From the rest of the results it can be seen in figure 4.9 that, when testing the respective flavours, 68.3% and

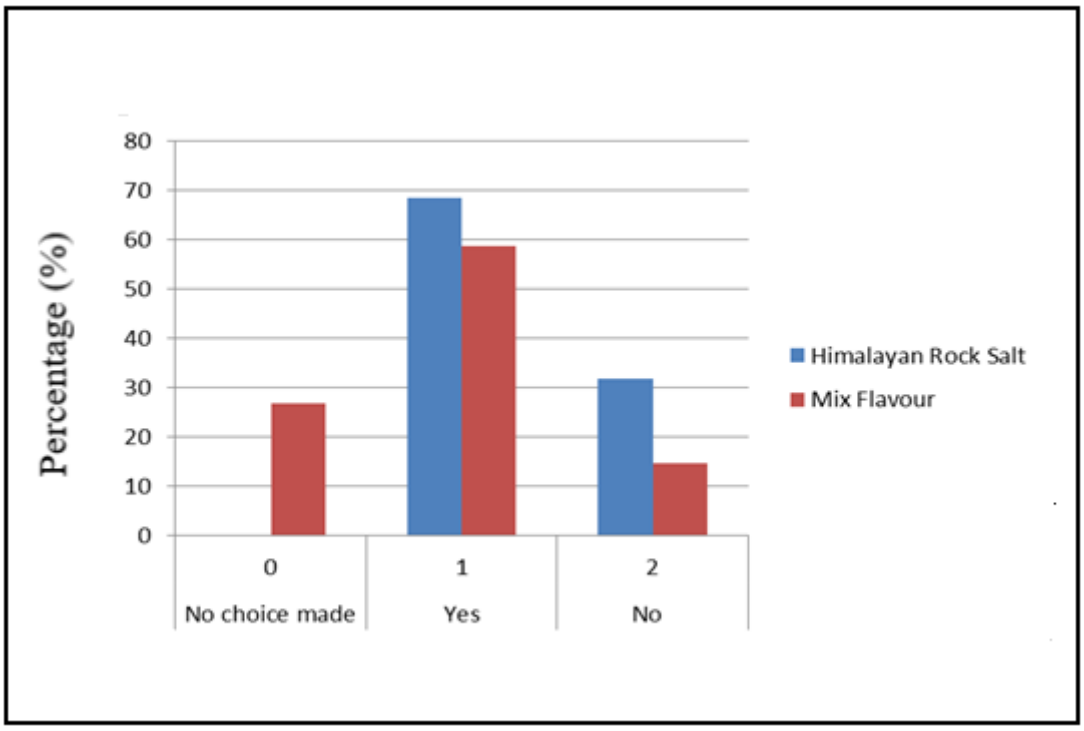

Figure 4.6 The preference of the different flavours of Edamame

58.5% reported that they would prefer the soy nuts rather than other snacks, while only 31.7% and 14.6% respectively reported that they still preferred other snacks above the soy nuts.

4.6 Conclusion

The macronutrient ratio of raw peanuts is very similar to that of roasted peanuts. In terms of macronutrient ratio, raw soy beans contain 2 parts CHO, 2 parts protein and 1-part fat. Peanuts, in contrast, have 1 part CHO, 2 parts protein and 3 parts fat. The gross energy in soy beans did not change significantly after soy bean samples were roasted.

In comparison to soy beans, peanuts have a higher gross energy. Protein content was higher in roasted soy bean samples when compared to the raw soy bean samples. The microwave roasted soy bean sample had the highest protein content of all 3 soy bean samples (17.1 g / 100 g). Protein content of peanut samples were 27.8 g / 100 g for raw peanuts and 33.2 g / 100 g for roasted peanuts. Roasted peanuts have significantly higher amounts of protein than roasted soy beans.

Fat content was higher in roasted soy bean samples than in the raw soy bean sample. The microwave roasted soy bean sample had the highest fat content. Fat content in peanut samples were 52.8 g / 100 g for raw peanuts and 62.8 g / 100 g for roasted peanuts. It is seen that raw peanuts have significantly higher amounts of fat than raw soy beans. Roasted peanuts also have significantly higher amounts of fat than roasted soy beans. When testing the respective flavours of roasted Edamame soy beans, a sensory evaluation indicated that 68.3% of school children aged 9 to 12 years would prefer the Himalayan Rock salt flavoured Edamame soy beans to the 31.7% who reported that they would rather prefer other snacks. Also 58.5% of the same group reported that they would prefer the Edamame soy beans mixed with other seeds, raisins and dried cranberries to the mere 14.6% who reported that they would rather still prefer other snacks above the soy nuts.

CHAPTER 5
DISCUSSION

5.1 Introduction

This chapter will highlight and discuss significant findings of the study. This includes the difference in nutritional composition and physical properties of dry mature, dielectric or microwave- roasted, infrared- roasted, and oven (hot air) roasted mature Edamame beans and also a comparison, through sensory evaluation, the consumer acceptability of dry mature and roasted mature Edamame in grade 5 learners.

5.2 Significant findings

5.2.1 The nutritional composition of dry mature and dielectric or microwave- roasted, infrared- roasted, and oven (hot air) roasted mature Edamame beans.

Overall, the macronutrient breakdown of raw Edamame soy beans indicates that it is a good source of protein while being low in fat. In terms of processing, the protein content of the Di-electric/ microwave roasted soy bean sample was higher than the oven roasted sample. This could possibly be due to the lower moisture content that renders the protein more concentrated in the microwaved soy bean sample. However, this also inflates the fat content of the microwaved soy beans, albeit not to such an extent that it can be considered unhealthy when compared. Carbohydrate content was also higher in the microwave roasted soy bean sample. It was noted however, that raw peanuts have significantly higher protein content than raw Edamame soy beans. However, it was also significantly higher in fat thus making soy beans a healthier alternate source of protein than peanuts. A study was done on the effect of microwave roasting and microwave-assisted hot air roasting processes on protein concentration of hazelnuts (Kalkan *et al*., 2015). The initial level of protein concentration of unroasted hazelnuts was 154.99 µg of BSA / ml of extract. The levels of protein concentrations for roasted hazelnuts were higher than those of unroasted hazelnuts for all the roasting conditions studied (Kalkan *et al*., 2015). The highest protein concentration (243.34 µg of BSA / ml of extract) was obtained using the microwave roasting process at 110°C for 21 min. This concentration

was 57% higher than the protein concentration of unroasted hazelnuts (Kalkan *et al*., 2015). This increase was for the highest level of protein concentration using the MW-assisted hot air roasting process. In this context, Locatelli *et al*. (2010) reported that the protein content of medium roasted hazelnuts was lower than that of dark roasted hazelnuts, which supported our results. Higher levels of protein in roasted hazelnuts compared to unroasted hazelnuts may be explained by the protein digestibility. Kong and Singh (2009) emphasized in their study that the roasting process caused an increase in protein digestibility. In recent studies conducted by Vanga *et al*. (2015) similar results were observed where processing of peanuts increased the protein digestibility. It was also reported by Holter and Reid (1959) that there was a relationship between level of protein concentration and level of protein digestibility of some forages.

In summary, both roasting methods appeared to have no significant negative impact on the nutritional composition of the Edamame soy bean.

Essential amino acids are obtained from the diet. Leucine, isoleucine, valine, threonine, methionine, phenylalanine, tryptophan and lysine are all classified as essential amino acids. Histidine is only essential in children. By providing all the essential amino acids soybeans are therefore a suitable protein alternative (Pamplona-Rodger, 2013). The amino acid composition of Edamame soybeans was higher than that of peanuts before and after the different roasting techniques. Due to the higher moisture content of the raw Edamame soybeans, the amino acid concentration in the roasted samples measure higher; this serves as a warning when interpreting the results. Hence, peanuts have a higher protein content overall. Di-electric/microwave roasting appears to have cause less structural damage to amino acids than oven roasting.

In terms of the amino acids, it can be seen that from the 5 samples, which included infrared roasted Edamame, dielectric prepared Edamame, raw Edamame, raw peanuts and roasted oven-peanuts; the sample that contained the most tryptophan after being roasted was the dielectric roasted sample. The infrared sample contained the most methionine after roasting. The raw Edamame sample contained the most cystine and then after roasting the dielectric sample contained the most cystine. The dielectric sample was the one that contained the most aspartic acid, glutamic acid, serine, glycine, arginine, threonine, alanine, proline, thyrosine, valine, isoleucine, leucine,

phenylalanine and lysine. Only histidine was the highest in the infrared sample after roasting. A general conclusion that can be drawn is that the dielectric/microwave method resulted in a product with the most favourable micro-nutrient composition.

A thin layer of tomato slices was taken to be dried, using microwaves together with air ventilation and hot-air drying. According to this study of a 'Thin Layer Modelling of Microwave-Convective Drying of Tomato Slices', it was observed that the tomato slices dried faster using the microwave heating joined with the hot-air ventilation. As microwave power density along with hot-air temperature was increased, the drying time had remarkably decreased. The microwave drying had upheld superior colour quality of the tomato slices compared to the other two methods. In general, tomato slices were exposed to long drying times when dried by means of hot-air ventilation. The microwave-supported hot-air drying treatment significantly reduced the drying time of the tomato slices by more than 84% when compared with the drying at 50°C drying air temperature. It was shown to be a cost- and energy-saving method when the lower activation energy for moisture diffusion of tomato slices, compared to some agricultural food such as paddy rice, wheat, barley, pistachio nut and tiger nut, indicated that drying of tomato slices required less energy compared to the drying of other products (Workneh & Oke, 2013).

In another study by Boge *et al*., (2009) on the composition of five raw soy bean cultivars, and the effects of oil- and dry-roasting methods on the quality of the beans, the results showed an overall decrease in the moisture content after roasting, whereas oil-roasted soy beans had considerably lower moisture content than the dry-roasted soy beans. Oil-roasted soy beans had considerably higher lipid content compared to the raw and dry-roasted soy beans, as a result of the absorption of oil. There was no major difference in the sugar and free amino acids contents of the five soy bean cultivars. During roasting it was noted that there occurred a decrease in the contents of free amino acids, but not soluble sugars. Due to higher roasting temperatures, larger reductions in oil-roasted soy beans were measured. The authors concluded that it is the roasting method, instead of the cultivar, that has the greatest effect on the composition of the bean (Boge *et al*., 2009).

5.2.2 Physical properties of Edamame soy beans

5.2.2.1 Colour of Edamame soy beans

After Di-electric roasting the Edamame soy bean sample was darker in colour, while the oven roasted sample became lighter. Both roasted soy bean samples became redder and more yellow in colour. The peanut sample also lightened in colour and was less red and more yellow after roasting. Colour changes in general were not undesirable and would not drastically impact the quality of the end product. The oven roasted sample had the lowest ΔL, Δa and Δb values indicating the least amount of colour change.

Peanuts are roasted to achieve desirable colour and flavour characteristics in peanut products. Roasting methods can be identified to save time, money or energy, while at the same time producing the same or better flavour and colour. There is a relationship between roast colour and flavour development. Due to this relationship the colour is used as a control parameter for commercially roasted peanuts (Smyth *et al*., 1998). "The ideal CIELAB L∗ value for roasted peanuts, in order to achieve the optimum roasted peanut attribute response with a trained sensory panel, ranged from 58 to 59 ± 2 (Pattee *et al*., 1991). In roasted peanuts, the Maillard reaction, Strecker degradation, caramelization of sugars, and lipid oxidation are responsible for volatile formation (Neta *et al*., 2010; Smith & Barringer, 2014). Roasted peanut colour and volatiles were evaluated for different time and temperature combinations of roasting in this study, *Colour and Volatile Analysis of Peanuts Roasted*. Microwave and oven technologies were used. Raw peanuts were oven-roasted, microwave-roasted, or combination-roasted by microwave and oven roasting for various times and temperatures (Smith & Barringer, 2014). Peanuts were categorised as under-roasted, ideally roasted, and over-roasted. The complete roasting time in order to achieve supreme colour was not shortened by most of the combination treatments compared to their oven-roasted equivalents. Oven before microwave roasting compared to microwave before oven roasting was found to considerably increase the Lightness (L∗) value. Peanuts with different volatile levels had the same colour (Smith & Barringer, 2014). Hexanal concentrations decreased and then increased with roasting. An increase in roasting time showed an increase in pyrazine levels even though oven treatments had the highest levels and the microwave treatments had the lowest. There was a general increase in

the volatile levels as the roasting time and temperatures increased. Oven treatments in general had the highest level of volatiles among the roasting treatments that were tested. Analogies based on volatile levels showed that raw peanuts were the most different, commercial samples were the most similar to each other, and oven, microwave, and combination roasting were all similar in volatile profile (Smith & Barringer, 2014).

Cocoa beans (Theobroma cacao) were roasted using a superheated steam oven (Healsio, AV-1500V, SHARP) in superheated steam mode and convection mode operated at three sets of temperatures (150℃, 200℃ and 250℃) for 5 to 35 minutes in the study of the *Effect of Superheated Steam and Convection Roasting on Changes in Physical Properties of Cocoa Bean* (Theobroma cacao) (Zzaman & Yang, 2012). There were changes observed in the physical properties. The colour values were more affected during the steam roasting than during the convection roasting. The convection roasting had affected the hardness of the cocoa beans more than the superheated steam had while, on the other hand, the fracturability values were more affected in superheated steam mode as compared to convection roasting. The superheated steam roasting showed lower moisture losses compared to convection roasting, but the heating rate inside the cocoa beans was higher in superheated steam (Zzaman & Yang, 2012).

5.2.2.2 Texture of Edamame soy beans

The soy bean samples became significantly harder after roasting. Oven roasted soy bean samples were harder than Di-electric/microwave roasted samples. This means that Di-electric/microwave roasted soy beans would be easier for the consumer to bite and chew. This type of soy bean would also be easier to process into other products such as soy flour as less energy would be required for milling.

According to the generated results the raw peanut sample was noted to be the hardest of all the samples and this was not expected. The peanut sample became less hard after roasting.

Fracturability or brittleness is the ease with which the samples broke. The raw peanut sample broke with the most ease and therefore had the highest fracturability. The oven roasted soy bean sample broke with greater ease than the microwave roasted soy bean sample. Oven roasted soy beans would therefore be easier to chew. This was not

expected as the sample with the lower moisture content would be expected to be more brittle. This indicates there may be other structural changes that occur during roasting.

5.2.3 Comparison through sensory evaluation of dry mature and roasted mature Edamame in grade 5 learners

Forty-one grade 5 learners, volunteers in a sensory evaluation, conducted for a period running in 2015 at Cato Crest Primary School in Durban, KZN. This consumer acceptability was done to determine consumer perceptions and acceptance of dry mature and roasted mature Edamame.

The volunteers were recruited to rate two Edamame flavours based on taste, smell, colour and overall liking. Other questions were asked to determine if the participants' hunger was satisfied, if they wanted to be healthy and if they would prefer the Edamame above other snacks.

Regardless of which flavour of Edamame was tasted, the majority of participants still preferred the Edamame above other snacks.

Of the two samples of Edamame flavoured beans, one was raw and the other a salt flavour and according to the 5-point hedonic facial scale the grade 5 learners still preferred the Edamame above their usual sweet-flavoured snacks. When comparing this to the Doenjang study (Kim *et al*., 2010), the consumers preferred samples that had strong "sweet" and "MSG (monosodium glutamate)" tastes according to consumer acceptability. Salty, meju, traditional Korean soy sauce and fermented fish caused the consumers to dislike the Doenjang (Kim *et al*., 2010). External preference mapping was done to establish the relationships between the sensory characteristics and consumer acceptability in each cluster.

Cookies were evaluated by n=75 consumers for colour, flavour, texture and overall liking using a 9-point hedonic scale in the study done by Chen *et al*. (2003) on consumer evaluation of soy ingredient-containing cookies. In this study something that seemed to have played a role also was age, as different age groups had preferred different cookies using the 9-point hedonic scale. For example: "There were significant interactions

between the degree of colour liking of cookies and gender (p-values < 0.01) and overall liking of cookies and age (p-values < 0.01)" (Chen *et al*., 2003). A minor gender difference in opinion occurred between the cookie colour, but not between other treatments. This could have been something to have considered and looked further into in the study of consumer acceptability of the Edamame to see which flavour was preferred by each gender. This could potentially relate flavour to gender preference. The mean scores for colour, texture, flavour and overall liking evaluation for all four flavours of cookies were between 6 (like slightly) and 7 (like moderately) on a 9-point scale. This indicated that the panel, in general, preferred the cookies (Chen *et al*., 2003).

College students participated in a consumer acceptability evaluation to see what their acceptance and preference of five flavours of soy nuts were by making use of a 9-point hedonic scale (Kandiah & Laird, 2001). Areas that were focussed on were appearance, texture, flavour and overall acceptability. Once again, gender did not show a specific preference although females and older students rated the overall appearance of the nuts higher than males and younger students. Different preferences were observed by the different age groups, for example: "Simple effects tests showed mean ratings of the nuts for texture and flavour were significantly different for the younger and the older age groups" (Kandiah & Laird, 2001). Based on the 9-point hedonic scale that was used, it was observed that the college students' acceptability of soy nuts was based on flavour, texture, appearance as well as age of the students (Kandiah & Laird, 2001).

5.3 Limitations of the study

Limitations of the study included the fact that there was a small sample size and that there were learners absent during the course of the consumer acceptability evaluations. In addition, nutrient analyses are very expensive, but additional funding would have allowed for more of the micro-nutrients to be tested. If a greater variety of roasted Edamame flavours could have been tested and given to the volunteers for consumer evaluation then a better comparison could then also have been made, using the study done by Kandiah *et al*. (2001).

In general, there were a few problems with the groups used for the acceptability evaluation. Absenteeism was already mentioned; other issues included the timing of

data collection, because learners were only allowed to participate after school until parents came to collect them or until they had to walk home. The learners could not have been left at their desks to complete the questionnaires as they would have tried to copy their friends' answers. Thus, data capturers (teachers) had to step in and ask the questions and then write down the learner's answers.

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CHAPTER 6

CONCLUSION

6.1 Summary of the main findings

This study indicates that raw Edamame soy beans are a good source of protein while low in fat. In terms of processing, the protein content of the Di-electric/ microwave roasted soy bean sample was higher relative to the oven roasted sample. This difference is ascribed to the fact that the dielectric method caused more water loss. Raw peanuts showed to have significantly higher protein content than raw Edamame soy beans, but also revealed to be significantly higher in fat. Consumer acceptability tests showed that regardless of which flavour of Edamame was tasted during the consumer acceptability test; the majority of participants preferred the Edamame above other snacks.

6.1.1 The importance of the findings of this study of Edamame soy beans

The objectives in this study were to determine the difference in nutritional composition and physical properties of dry mature, dielectric or microwave- roasted, infrared-roasted, and oven (hot air) roasted mature Edamame beans and to compare, through sensory evaluation, the consumer acceptability of dry mature and roasted mature Edamame in grade 5 learners.

In chapter one the background for this study was highlighted in which the nutritional and consumer acceptability was tested for a specific non-genetically modified strain of soy beans, which was dried using different techniques. In this chapter it was also motivated why soy beans could potentially play an important role in alleviating the nutritional problems that was posed in especially rural areas of the country, where protein energy malnutrition remains rife.

Rice along with soy beans have formed the basic diet of the people of the East and Southeast Asia where very little meat, milk and eggs are consumed. For some years now, attempts have been made to introduce soy as a cost-effective, high-protein supplement to the diet of those affected by malnutrition, in specific under-nutrition. A

healthy range of nutrients are provided to individuals by soy beans even though soy beans are processed in many different ways. Each method of processing has its unique effect on the nutrient quality of the end-product. In some cases, the end product is void of protein and very high in sodium. So far, it seems that the beans themselves when undergoing limited processing provide the best option for consumption. Limited processing would be defined as drying, since the raw bean is not readily consumed and could potentially contain high levels of aflatoxin. The impact of different drying techniques on the nutritional quality of the soy bean has been investigated, but data is restricted. Also, consumer acceptability of different preparations of dried soy beans is not known. In this study, research was undertaken to investigate whether different drying techniques produce products with varying nutritional contents and also to see whether some of these products can be served in a palatable form.

6.1.2 The most preferred roasting method

Three methods, dielectric; infra-red and oven roasting, disclosed the best results concerning nutritional content. From this study it was observed that the preferred method was the dielectric method as it produced the best results in the majority of the tests. Dielectric, air ventilation and hot-air drying was also compared by drying tomato slices. A tomato slice dried faster when it was subjected to dielectric heating coupled with hot-air ventilation. The study showed a lower activation energy, which indicated that the dielectric drying of tomato slices requires a smaller amount of energy (compared to other methods) and is therefore a cost- and energy-saving method. Dielectric drying also maintained superior colour quality of the tomato slices. Dielectric drying has become popular as an alternative drying method for a diverse assortment of food and agricultural products.

6.2 Recommendations for future research

- Research should be done to investigate the viability of introducing Edamame soy nuts in school feeding programmes; Introducing Edamame beans as a means of income-generation through cultivation;

- Compare the density and shelf-life of the roasted Edamame with other available products (i.e. peanuts); and
- Measure the by-products (and toxicity thereof) that form as a result of drying.

6.3 Implications for further research

- This study focused on the once-off consumer-acceptability of Edamame by a group of grade 5 learners. A long-term study using additional year groups of school children would add value to the results of this study; and
- Future studies should aim to monitor baseline dietary intake of subjects and the increase in overall energy intake that supplementation with Edamame provided in order to identify whether it is possible to improve energy intake and achieve a healthy body weight.

APPENDIX A: Consent forms

PARENT/GUARDIAN OF CHILD

Dear Sir / Madam

RE: REQUEST FOR PERMISSION TO ASK YOUR CHILD FOR HIS or HER OPINION ABOUT EDAMAME (SOY BEANS)

I am a student of Dietetics and Human Nutrition at the University of KwaZulu-Natal, Pietermaritzburg. I am studying towards a master's degree and my research topic is entitled "Nutritional composition and consumer acceptability study of Edamame". This study aims to determine the nutritional composition and physical properties of dry mature and roasted mature Edamame beans and to compare, through sensory evaluation, dry mature and roasted mature Edamame in grade 5 learners. Sensory evaluation is a method during which the individual is given a specific food or product and has to give feedback about its taste, texture, and whether he or she likes it or not.

I am hereby requesting permission to provide the Edamame soy bean products to your child once a week until he/she has tasted all the beans roasted by various methods. This will take place over a period of approximately 6 weeks. Your child will be required to complete a questionnaire after each sample he/she has consumed. Any information collected about/by your child will remain strictly confidential and on a voluntary basis. Your child may withdraw from participating in my study at any point/given time should he/she wish to do so. The participating children will not face any negative or undesirable consequences should they choose to withdraw.

Should you have any queries regarding my research, please feel free to contact me on 079 513 8343.

I would be most grateful if you could sign the attached form and return it to your child's teacher, who in turn will return it to me as soon as possible.

Yours sincerely

Leandra Taylor	*Professor Frederick Veldman*
Master's Student	**Master's Supervisor**

INFORMED CONSENT FROM PARENT/GUARDIAN

1. I hereby confirm that I have been informed by UKZN master's student Leandra Taylor about the nature of her study "Nutritional composition and consumer acceptability study of Edamame", which investigates whether the nutritional composition and physical properties of dry mature and roasted mature Edamame beans is favoured by my child and to compare through sensory evaluation dry mature and roasted mature Edamame in grade 5 learners.
2. I have also received, read and understood the written information in the letter requesting permission for my child to participate in this study.
3. I understand that I may contact Mrs Taylor (079 513 8343) at any time if I have any questions about the research.
4. I understand that the information collected about my child will remain strictly confidential and on a voluntary basis. I also understand that my child may withdraw from participating in this study at any point should he/she wish to do so, without fear of any negative or undesirable consequences.

I hereby consent to my child's participation YES:_____ NO:_____

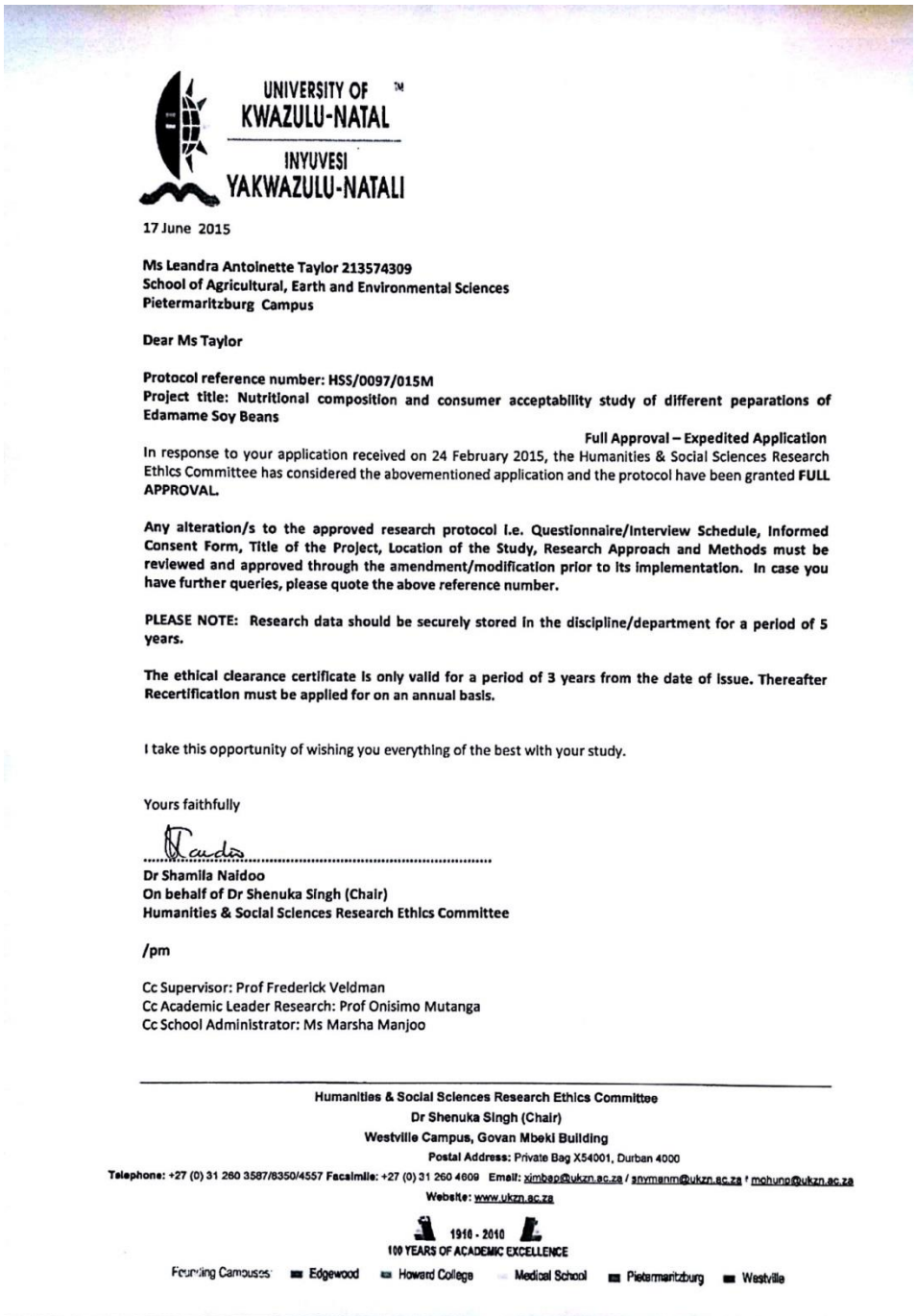
Name: _____

Signature: _____

Child's Name: _____

Date: _____

APPENDIX B: Ethical clearance



UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

17 June 2015

Ms Leandra Antoinette Taylor 213574309
School of Agricultural, Earth and Environmental Sciences
Pietermaritzburg Campus

Dear Ms Taylor

Protocol reference number: HSS/0097/015M
Project title: Nutritional composition and consumer acceptability study of different peparations of Edamame Soy Beans

Full Approval – Expedited Application

In response to your application received on 24 February 2015, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol have been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

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Dr Shamila Naidoo
On behalf of Dr Shenuka Singh (Chair)
Humanities & Social Sciences Research Ethics Committee

/pm

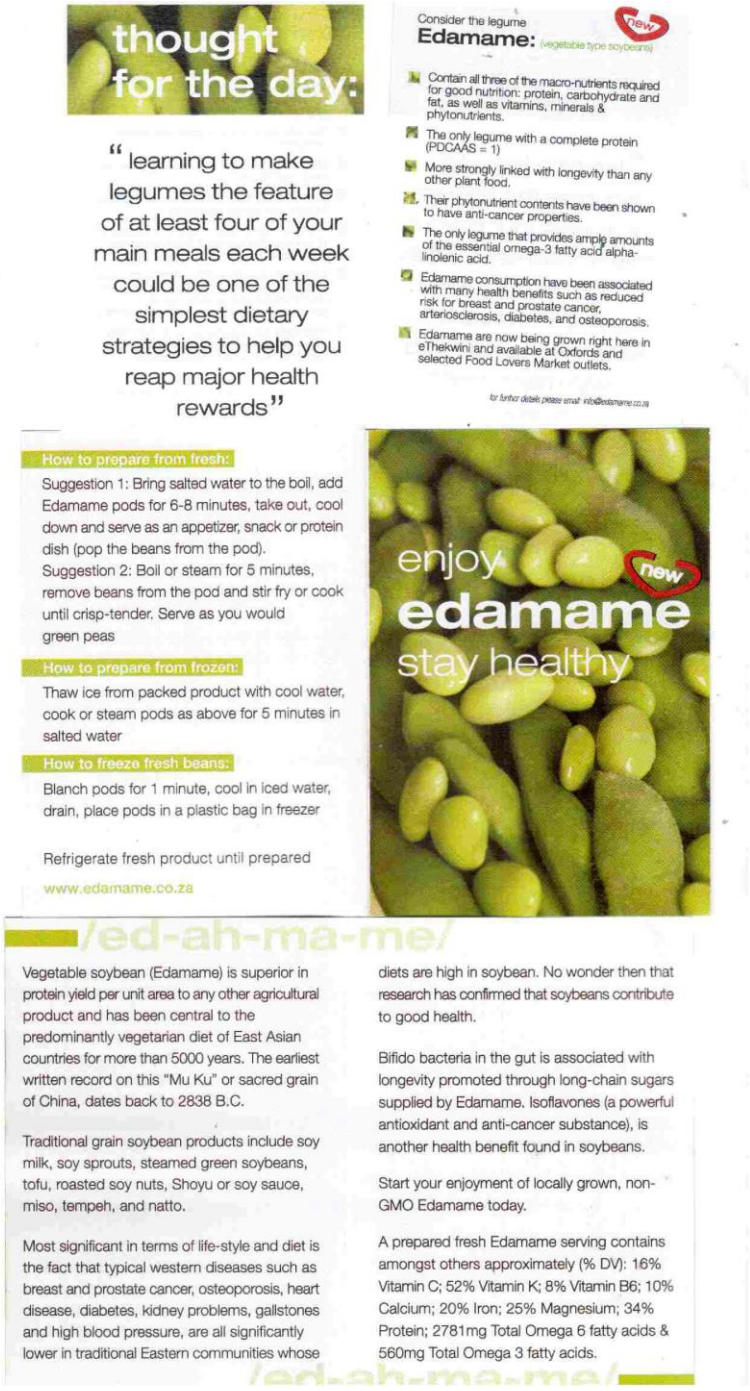
Cc Supervisor: Prof Frederick Veldman
Cc Academic Leader Research: Prof Onisimo Mutanga
Cc School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood, Howard College, Medical School, Pietermaritzburg, Westville

APPENDIX C: Edamame pamphlets



APPENDIX D: Questionnaire

Questionnaires used

Questionnaire/Interview response sheet

Group number: _____

Date: _____

Grade: _____

Age: _____

Gender:  _____  _____

Today's flavour is: _____

Instructions

Please taste the soy nut sample that you have received and then answer the questions by drawing a cross (X) over the answer that you have chosen.

Questions

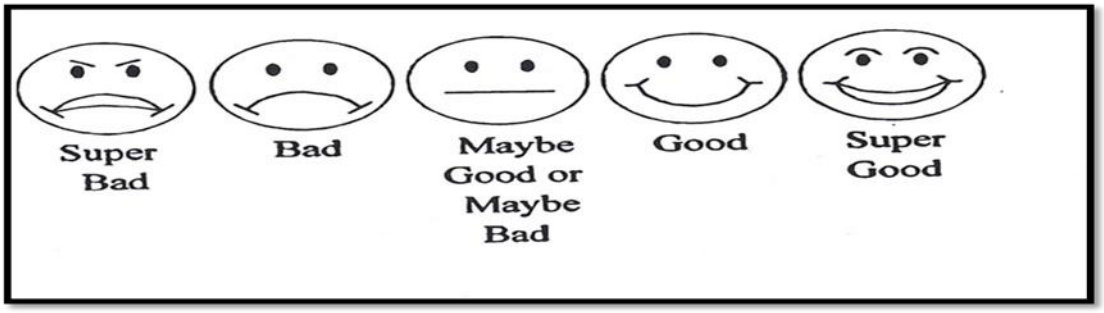
1. **What is your favourite food?**

MEAT VEGETABLES FRUIT SWEETS CHIPS PASTA

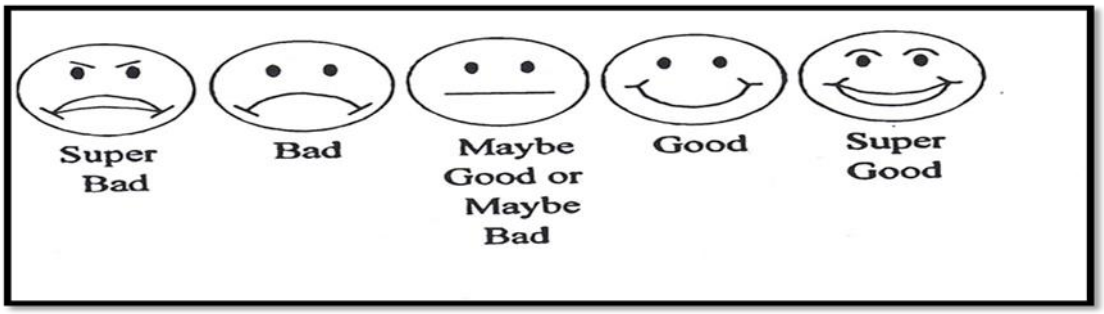
2. **What food do you eat the most?**

MEAT VEGETABLES FRUIT SWEETS CHIPS PASTA

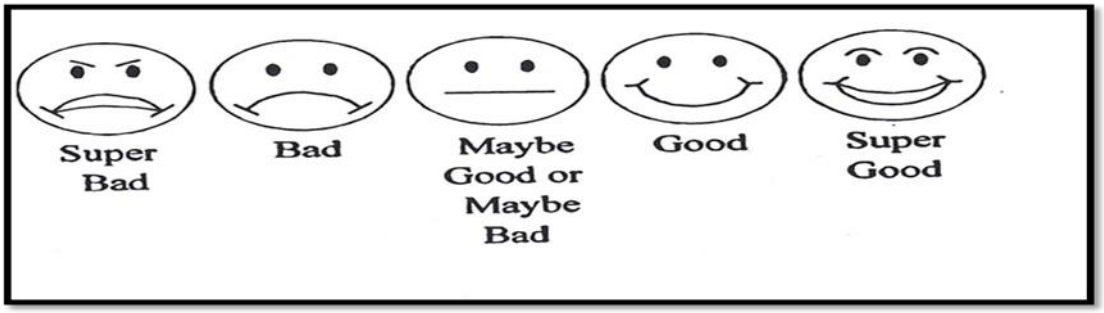
3. **Taste**



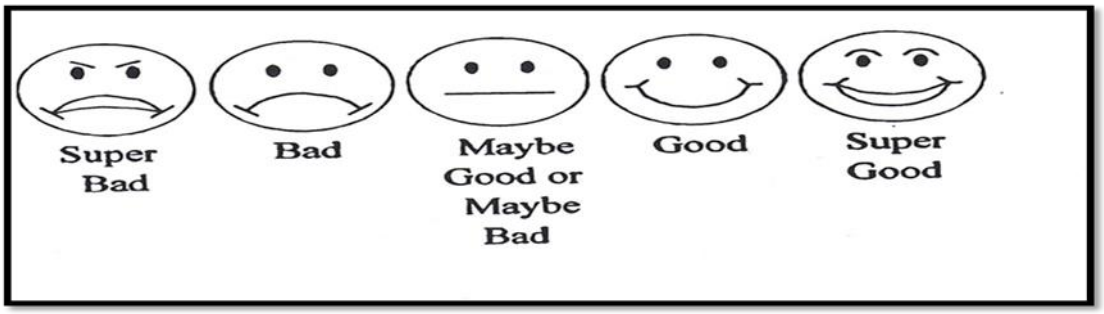
4. **Smell**



5. **Colour**



6. **Overall liking**



7. **Do you still feel hungry after eating the soy nuts?**

   YES **NO**

8. **Would you eat these soy nuts rather than other snacks?**

   YES **NO**

9. **Would you like to have these soy nuts more than once a week?**

   YES **NO**

10. **Do you want to be healthy?**

    YES **NO**

11. **Would you rather eat these soy nuts than other sweets or snacks if you knew that it was good for your health?**

    YES **NO**

12. **Did you like today's flavour of soy nuts?**

    YES **NO**