Resolving problems affecting the processing of dried marrowfat peas for fried foods:

Hard-seededness and cooking temperature and time

A thesis

submitted in partial fulfilment of the requirements

for the degree of

Masters of Food Technology

Massey University

Palmerston North, New Zealand

Froilan T. Ayaquil

September 2017

ABSTRACT

The Midland Seed Ltd, a top agricultural seed producer in New Zealand, wishes to increase their level of technical knowledge regarding the processing of peas to assist with solving production problems. In this study, analyses were conducted to resolve if hard-seeded peas or the frying parameters caused the textural irregularities in fried marrowfat peas. Marrowfat peas (*pisum sativum cv*. Midichi and Midlea) from 16 different harvest locations and years (2014 to 2017) were subjected to tests such as hydration capacity, and sizing of peas were examined to ascertain how much hard-seeded peas were surfacing in a line batch and in different sizes (<6.7mm, 6.7-7.1 mm, 7.1 – 8.0 mm, and > 8.0mm) upon soaking (in different soaking times 12, 18 and 24 hours) and frying at 160°C for 12 minutes. Furthermore, frying conditions including, oil temperature, pea to oil ratio, were explored at a laboratory scale to obtain the most suitable frying parameters capable of producing fried marrowfat peas with consistent and highly acceptable organoleptic properties. It can be concluded from this study that the very low frequency of hard seeds found in marrowfat peas was not the cause of texture inconsistency generally. However, it was shown that cooling the oil to below 130°C, when peas were added to the oil, slowed temperature recovery of the oil and significantly increased pea hardness to unacceptable levels. Marrowfat peas fried at 160°C for 12 minutes, with a pea to oil ratio of between 1/20 and 1/40 resulted in peas consistently fried to a highly acceptable quality.

ACKNOWLEDGEMENTS

First of all, I would like to thank our Lord Jesus Christ for giving me an opportunity to do this research project and Master's programme.

I would also like to thank the New Zealand Ministry of Foreign Affairs and Trade and New Zealand Aid Development program for offering the opportunity and scholarship support to the whole Master's program.

Massey University International Student Support Support Office Sylvia, Dave, Jamie, Logan, Dianne, Tina, and Saba; they are our second family here in New Zealand, and have never stopped caring for us.

Midland Seeds Ltd, Brett Colgan and Krystyna Krivanek, for the research opportunity, trust, and support.

Allan Hardacre, for his constant guidance, support, great advice in academic and personal life, and his limitless patience especially in checking my writing.

I would also like to thank:

Steve Glasgow, Warwick Johnson, Michelle Tamehana, Peter Jefferies, Sue Nicholson, Byron McKillop, Gary Radford, Chris Hall, Michael Parker for their technical assistance and support in my study.

Ericka Ramirez and Edgar Santos for helping me in analysing my data and statistics.

Ruth Mortimer for proofreading and guiding me.

Sunny George Gwanpua, for his help and his mini-lecture to enable me to understand the topic easily.

My colleagues, Grace Ng, JieHong, TeckAnn, Zitong, Maheeka, Jessie, Peter, Zhenghao, Echo for sharing each other's lives in dealing with the struggles and challenges of postgraduate studies.

My friends Dominic Lomiwes, Spencer Secretario, Marc Icaro, Tracy Decena, Fem Socorro, Marvin Novio, Kaye Nono, Francis and Joanna Vattiprolu, and Vision Church for the unending support encouragement and great memories.

Our family, friends and relatives, Dr. Rosario Sagum , Tito Ansel and Tita Nenita Leonardo and family, Tito Ron and Babe Icaro and family, and Ayaquil, Tec and Cuico family.

And especially to my wife and life partner, Michelle Cuico, her never ending patience, support and love the keeps me going and reaching for success.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Grain legumes or, more generally, pulse crops, including soy, lentils, beans and peas, are one of the earliest crop plants cultivated by humans, and genera have evolved and been cultivated throughout the world. Lentils and chickpeas are cultivated in East Asia, phaseolus beans and lupins are from Central and South America, and fava beans from Northern Africa and India were an important source of protein in Europe prior to the 17th century. While peas are a more recent crop in the western world, they have been cultivated in the Fertile Crescent of the Near East for millennia (Smýkal et al., 2015).

According to Food and Agriculture Organization (2016), legumes provide a much cheaper and abundant source of protein globally than protein from meat sources, while the less human palatable varieties such as lupine and some bean species are important sources of proteins for farmed animals. Furthermore, all legume crops are capable of fixing atmospheric nitrogen and adding up to 150kg of N/ha and are therefore doubly beneficial to farmers. Nearly 85 million hectares of pulses were grown worldwide in 2014, producing 60-72 million tonnes of grain and fixing 3-6 million tonnes of nitrogen (Food and Agriculture Organization, 2016).

In the last 30 years, Llgumes have emerged as and improtant food source (Sinha, 1977). Simple calculations show that soy and bean crops can produce upwards of 1000kg of protein/ha/year compared with cereal crops of about half this, while animals produce less than 150kg/ha in the absence of supplementary feed (Chadd, Davies, & Koivisto, 2004; Dairy NZ, 2010). Although providing a little less digestible protein compared to meat (approximately 95% when cooked) much of the world's current protein shortage could be ameliorated by better exploitation of this resource. An important component of this shift in protein source is in providing foods that are more acceptable in organoleptic terms for delivering plant protein into our diets. Peas contain about 27% protein, and 60-65% of carbohydrate along with useful levels of fat, fibre and micronutrients (Troy, Ojha, Kerry, & Tiwari).

Peas were believed to have originated in northwest Asia and have been found in archaeological sites in Egypt dating from more than 6000 years ago ("Fried Pulses," 2016). Peas were a significant part of the diet in Europe during the Middle Ages. By the 1600-1700s, peas had become popular in their 'green' or fresh form ("Fried Pulses," 2016). Nowadays, peas are one of the major legumes used as human food, either as a fresh or dried crop. Cooked peas (per 100g) contain about 24% protein on a dried basis, 58% carbohydrates which have 2% resistant starch and 2% soluble and 23% insoluble fibre, all of which are

attractive for addressing lifestyle diseases such as obesity and diabetes mellitus (de Almeida Costa, da Silva Queiroz-Monici, Pissini Machado Reis, & de Oliveira, 2006; de Ron, 2015).

Pea product opportunities exist as peas are being utilised as an ingredient for different commercial food applications such as stabilizers for beverages, dessert and dairy and incorporation of pea flour to gluten-free baked products and meat product applications (Boye & Ma, 2015; Kigel, Rosental, & Fait, 2015). Aside from their acceptable taste, functionality and nutritional properties, pea products are popular in developing countries because they are easily transported, do not require special storage, and can be easily produced in an extensive variety of snack products (Malcolmson et al., 2014; Zhu, Zhang, & Wang, 2015).

Despite the popularity of peas, hard seeds have caused problems for food processors for more than 100 years (Argel & Paton, 1999; Ross, Arntfield, Beta, Cenkowski, & Fulcher, 2008). Hard-seeded peas (or stone peas) are the seeds that are slow or unable to absorb water when steeped or during cooking in water. The hard-seeded fault also results in non-uniformity of germination. Two categories of hard seeds have been reported: the first type is the hard seed induced by growing conditions and is found in recently harvested seed, and the second is the type that can occur in storage at >25°C and >60% RH (Pirhayati, Soltanizadeh, & Kadivar, 2011). The first type of hard seed is due to the seed coat's impermeability, while the second type is a characteristic attributable to sclerema or cotyledon impermeability.

Marrowfat peas are large irregular-sized peas that have green cotyledons, an appealing flavour profile and are therefore grown as a human food (Kigel et al., 2015). They may be sold as dry seeds, ground as flour, canned in water, or processed into snacks such as fried or wasabi peas. Midlands Seed Ltd, in New Zealand, contracts farmers to produce dry marrowfat peas and has been exporting the crop to countries such as Japan and Singapore. In the frying of peas, texture inconsistencies have been noticed by Midlands Seed clients. With the goal of increasing the quality of marrowfat peas, and strengthening the relationship with their clients, Midlands wish to increase their level of technical knowledge regarding the processing of peas to assist with solving production problems. Midlands Seed Ltd requested assistance from Massey University to investigate if hard-seeded peas caused the textural irregularities in fried peas. Furthermore, the frying process itself was researched to understand the critical process control points in the frying process.

Objectives

General Objective

To identify if the frequency of hard-seeded peas in various seedlines of marrowfat peas harvested from the Canterbury region during 2017 affects the texture of fried marrowfat peas.

Specific Objectives

- Identify the frequency of hard-seeded peas in various populations of field peas.
- Attempt to assess possible causes of hard-seeded peas in the crop
- Determine how the hydration capacity, protein content and starch-pasting properties differ between normal and hard-seeded peas.
- Establish the appropriate frying parameters to obtain a consistent texture in fried peas.

CHAPTER 2: LITERATURE REVIEW

2.1 LEGUMES AND PULSES

Legumes are defined as plants in which the fruits (dry grains) are enclosed in a pod and which can fix nitrogen from the atmosphere (Asif, Rooney, Ali, & Riaz, 2013; Pulse Canada, 2012). The word 'pulse' is derived from the Latin word *puls* or *pultis*, meaning thick slurry, and is applied to legume seeds harvested solely for their value as an animal or human food. It excludes crops used for oil extraction such as soybeans (Asif et al., 2013; Dahl, Foster, & Tyler, 2012; Food and Agriculture Organization, 1994). Pulses are further defined as the mature grain legumes that are marketed as dry products. Beans, lentils, chickpeas, broad beans, dry field peas and lupins are some examples (Arntfield & Maskus, 2011; Tiwari, Gowen, & McKenna, 2011).

The Leguminosae, or sometimes called the Fabaceae family, has an enormous global distribution (Smýkal et al. 2015). Altogether, they consist of 650-750 genera and have around 16,000-19,000 species (Liu, Wang, Copeland, & Wang, 2015; Smýkal et al., 2015; Tiwari et al., 2011). It covers an extensive range of plant species from arctic alpine herbs and temperate or tropical perennial shrubs to annual xerophytes and giant equatorial trees. Fabaceae includes several economically important and versatile species, with most providing grains and pulses. Categorised by their distinct fruit, the Fabaceae family was termed 'legume'. Traditionally, it has been divided into the following three sub-families which includes Caesalpinioideae (148 genera and 4000 species) which is mainly found in tropical areas; Mimosoideae (80 genera and ~3200 species) located mostly in tropical and warm temperate regions of Asia and America; and Papilionoideae (503 genera and ~14000 species) and cosmopolitan distribution (Azani et al., 2017; Smýkal et al., 2015). The family of Fabaceae now has six sub-families Mimosoideae, a former sub-family, is now under Caesalpinioideae, while Cercidoideae (12 genera and ~335 species) is mainly tropical, Detarioideae (84 genera and ~760 species) mostly tropical, Duparquetioideae (1 genus and 1 species) from west and central Africa, and Dialioideae (17 genera and ~85 species) widespread through the tropics was added to the sub-family (Azani et al., 2017). Most of the major food and feed legumes are found in the sub-family of Papilionoideae (Kigel et al., 2015).

Humans first cultivated legumes over 6000 years ago in Asia, the Middle East and Africa (Tiwari et al., 2011). Amongst the grain legumes are several of humanity's earliest crop plants, soybeans and mung beans. Faba beans, lentils and chickpeas are located in East Asia, peas are from the Fertile Crescent of the Near East, and the common beans or lupins are from Central and South America (Smýkal et al., 2015). Despite a large number of species

in this family of legumes, only 12 are widely used in the food industry and, of these, the most important include peas, lentils, beans (fava and phaseolus) and chickpeas (Liu et al., 2015).

Legumes, as a crop, also improve soil fertility due to their ability to fix nitrogen from the atmosphere and this can lead to an increase in soil nitrogen of up to 150 Kg N/ha/year (Greenwood, Aves, & Catherwood, 2008). Legumes are used as an intercrop, or break crop, that growers use to reduce disease carry-over between subsequent crops of other grains such as wheat or barley. The limited availability of animal protein and its cost promotes the demand for pulses as a source of protein and improvement of the diet in developing nations such as South East Asia and Africa (Tiwari et al., 2009). Pulses are one of the solutions in innovative gluten-free products. Since the addition of legumes as a replacement for wheat flour gluten, it has added structure to meals made with other gluten-free ingredients such as rice, tapioca or potato starches ("Fried Pulses," 2016). Legumes have become the second most important food source globally, next to cereals.

2.1.1 Structure of legume seed

The legume seeds are composed of the embryo and the cotyledons that are enclosed in a tough seed coat or testa. As shown in Figure 1, the seed structure of french beans and pea seeds is composed of two cotyledons and enclosed by testa. The micropyle, the hole through which the pollen tube entered the ovule, remains as a hole in the testa and is an important route for the entry of water during germination. The hilum is the scar left where the seed was attached to the pod (Thomas, 2013).

Figure 1. Seed Structure of (a) French Bean and (b) Pea
(Finch-Savage & Leubner-Metzger, 2006; Thomas, 2013)

Most species of the Fabaceae family including peas, garden beans, and soy beans, have non-endospermic seeds. These non-endospermic seeds have the cotyledons as food

storage organs. Throughout the growth of the embryo, the food reserves are absorbed from the endosperm to the cotyledon. Once the legume seeds mature, the embryo is almost degraded (Finch-Savage & Leubner-Metzger, 2006; Leubner).

2.1.2 Composition of legumes

The chemical composition of legume seeds is dependent on the species. Shown in Table 1 are the differences between the compositions of pulses compared to wheat and maize. The carbohydrates of food legumes variy from 24% (winged beans) to 68% (cowpeas) (Ratnayake, Hoover, Shahidi, Perera, & Jane, 2001). The protein content generally ranges from 20 – 40% and, commonly, are twice higher than cereal grains. Lipids in pulses are mostly composed 1.5% of dry matter, except for some beans such as winged bean and soy bean. Most beans are very low in fat, except for chickpeas, lupin seeds, and soybeans, which contain 15 to 47% fat. A ½ cup of cooked pulses contains 2–4 g of fibre and 7–8 g of protein. Pulses also contain considerable amounts of the vitamin B and minerals, as well as phytochemicals: bioactive compounds, including enzyme inhibitors, lectins, oligosaccharides, and phenolic compounds (Rebello, Greenway, & Finley, 2014).

Table 1. Nutrient composition of pulses, wheat and maize (in %, dry basis).

	Pulses			Wheat	Maize
	Peas	**Cow Peas**	**Beans/Soy Beans**		
Protein	19-32	21-23	37-44	11	10-14
Carbohydrate					
-Starch	34-47	49	10-11	60-70	50-70
-Fibre/NSP	14-26	3	23-32	2.2-2.4	2-3
Fat	1-4	1-4	15-22	1.9-2	3.5-12
Ash	2-4	1-4	3-5	2	1.3-1.6

2.1.2.1 Carbohydrates

Pulses generally contain 60-65% carbohydrates as energy storage of which the primary component is starch. Starches are the primary carbohydrate reserve in most plants and are a major source of energy for humans. Similar to cereals and root crops, the starches of legumes are comprised of amylose and amylopectin, packed in granules. Pulse starch granules may be oval, round, spherical, irregular or polygonal in shape (Shen et al., 2016).

The structure and packing of amylose and amylopectin within granules vary among starches from different species.

Amylose consists of α-(1-4) linked D-glucopyranosyl residues with a slight degree of branching (9-20 α-(1-6) branch points per molecule). The amylose content of pulse starch ranges from 24-65% (Hoover & Sosulski, 1991; Liu et al., 2015) and varies depending on the variety, physiological state of the seed, and environmental conditions (Bogracheva, Morris, Ring, & Hedley, 1998; Fabbri & Crosby, 2016; B. K. Singh, Hotti, Singh, & Mandal, 2016; Tiwari et al., 2011). The degree of polymerisation of starches from pulse ranges from 1000-1900 (Hoover & Sosulski, 1991).

Amylopectin is composed of linear chains of (1-4) α- D-glucopyranosyl connected through (1-6)-α-linkages on 5-6% of the sugar residues. It has a molecular weight ranging from 50-500 million and degree of polymerisation of 300,000 to millions depending on the plant species (Eastman, 1995).

Gelatinisation is the term used when starches are heated in the presence of excess water; it undergoes transition from order to disorder over a temperature range characteristic of starch source (Alcázar-Alay & Meireles, 2015; Tiwari & Singh, 2012). This phase transition of starch is linked with the water diffusion into the granule, heat uptake, loss of birefringence due to the breaking of the double helix in the crystalline region and the leaching of amylose (Alcázar-Alay & Meireles, 2015; Donovan, 1979; Evans & Haisman, 1982; Stevens & Elton, 1971; Tiwari & Singh, 2012). Once the amorphous area swells, it imparts stress on the crystalline region and this effect strips polymer chains from the surface of starch crystallites (Adebowale & Lawal, 2003).

The gelatinization process is represented by gelatinisation transition temperature (T_o, onset; T_p peak; T_c, conclusion) and enthalpy of gelatinisation (ΔH_{gel}) in the paste, and these measures are characteristic for each species. Cook and Gidley (1992) suggests that ΔH_{gel} is an indicator of the loss of molecular order within the granule and it gives an overall crystallinity quality and quantity measure (Tiwari & Singh, 2012). Shown in Table 2, pulses with high transition temperatures correspond to a high degree of crystallinity, high stability and resistance of the granule structure to gelatinization (Alcázar-Alay & Meireles, 2015; Tiwari & Singh, 2012). The longer amylopectin chains would require a higher temperature to dissociate compared to the shorter double helices.

Table 2. Thermal properties of starch from different pulses and corn (Pulse Canada, 2012; Tiwari & Singh, 2012).

Starch	T_o onset (°C)	T_p peak (°C)	T_c conclusion(°C)	ΔH (J/g)
Beans	60-73	64-77	70-82	9-17
Peas	55-64	60-71	73-80	10-14
Chickpeas	58-65	63-72	70-81	11-18
Lentils	47-68	57-76	69-82	2-14
Corn	~62	~75	~85	13

2.1.2.2 Dietary Fibre and Non-Starch Polysaccharides

Dietary fibre (DF) is defined by the American Association of Cereal Chemists as the "edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine" (Tiwari et al., 2011, p. 20). Included as DF are polysaccharides, oligosaccharides, lignin, and associated plant substances. The non-starch polysaccharides (NSPs) are groupings of the several types of polysaccharides that do not contain the α-1-4-linked glucose that is characteristic of starch (Englyst, Liu, & Englyst, 2007; Khattak & Ali, 2002).

2.1.2.3 Proteins

Pulses are an important source of food proteins, and most pulse legumes contain between 17-30% (dry weight basis) of storage proteins. The major classes of proteins found in pulses are globulins and albumins. Albumins are water soluble and comprise enzymatic proteins, protease inhibitors, amylase inhibitors and lectins. Globulins are the most abundant class of proteins in grain legumes and are salt soluble (Boye, Zare, & Pletch, 2010; McCrory, Hamaker, Lovejoy, & Eichelsdoerfer, 2010).

Globulins are the major seed storage of dicotyledonous plants (Tiedemann, Neubohn, & Müntz, 2000). Among the four major types – 2S, 7S, 11S and 15S – the globulins 7S (vicilin) and 11S (legumin) are classified as the major fractions (A. Singh, Meena, Kumar, Dubey, & Hassan, 2015; Tiwari et al., 2011). The 11S globulin is solely a storage protein and has no physiological activity (A. Singh et al., 2015).

2.1.3 Nutritional benefits of legume consumption

Legumes and pulses are known as an excellent source of protein as they have in-vitro protein digestibility ranging from 55-72%, thus making them attractive for new foods with

possible increases in nutritional value (Chitra, Vimala, Singh, & Geervani, 1995; Fabbri & Crosby, 2016). Furthermore, cooked pulses from Canada such as red kidney beans, split green peas and yellow peas, navy bean and chickpeas have high protein digestibility-corrected amino acid score (PDCAAS) of >0.50-0.65. The United States consider PDCAAS as an evaluation of protein quality whereas > 0.5 is considered a good source of protein (Tavano, Neves, & da Silva Júnior, 2016). Pulse grains are a good source of dietary fibre and include both insoluble fibre from the seed coat, and internal cell wall seed structures and various soluble fibres.

Table 3 shows the differences between the micronutrient compositions of pulses compared to wheat and maize. The pulses have higher contents of minerals than wheat and maize. Pulses are also regarded as excellent sources of water-soluble vitamins, as well as a rich source of minerals like calcium, phosphorus, potassium, magnesium, iron, and zinc (Fabbri & Crosby, 2016).

Table 3. Micronutrient comparison of pulses, wheat and maize (in %, dry basis).

Minerals, µg/kg					
	Pulses			Wheat	Maize
	Peas	Cow Peas	Beans/Soy Beans		
Ca	521-2257	660-2010	1280-1990	540 - 770	154-178
Mg	995-1797	1902-2767	1050-1320	1170-1400	985-1125
P	2471-6013	4643	5100-5140	3450-5000	1970-2000
K	7553-12954	7330-7411	1139-1234	4740-5500	2915-3471
Fe	37-71	98-109	35-49	29-38	20-27/38-56
Zn	31-65	14	43-47	24-46	37-52

Data compiled from journal articles published by various researchers (Black, Brouwer, Meares, & Iyer, 1998; Carver, 2009; Chaudhary, Kumar, & Langyan, 2014; Kruger, Minnis-Ndimba, Mtshali, & Minnaar, 2015; Y. Ma et al., 2017; Rachoñ, Palys, & Szumilo, 2012; ŠtěrbovÃ¡ et al., 2016; Stevenson, Doorenbos, Jane, & Inglett, 2006; Tosh & Yada, 2010; N. Wang & Castonguay, 2013).

2.2.4 Quality standards and evaluation of pulses

The definition of the quality of pulses is not standardised globally for the following reasons: (1) the problem of language, (2) variation in organoleptic preferences, (3) differences in national specifications, and (4) import/export specifications. Three organisations are working on the consolidation of quality parameters for pulses: the International Pulse Quality Committee (IPQC), the Codex Alimentarius Commission (CAC) and the American Association of Cereal Chemists (AACC) Pulse and Grain Legume Technical Committee.

Table 4. Quality parameters commercial quality pulses (Tiwari et al., 2011).

Extrinsic quality parameters			**Intrinsic quality parameters**	
Presence of impurities	**Grain defects**	**Contaminants**	**Technological**	**Physicochemical criteria**
Broken kernels Sprouted kernels Foreign matter impurities Inorganic matter Weed seeds Other grains Dead insects	Mouldy grains Insect damaged Sprout damaged Shrivelled kernels Diseased kernels Heat-damaged Visual defects	Pesticide residues Mycotoxins Heavy metals Noxious seeds Radioactivity	Moisture Test weight 1000 – kernel weight Grain size Colour Hard-seeded	Protein content Starch content Starch quality Lipids Fibre Total ash content Enzyme activity

The CAC is an inter-governmental body with 170 members, operating within the structure of the joint FAO and the WHO Food Standards programme, with the purpose of protecting the health of consumers and ensuring fair practices in the food trade Codex Standard (CODEX STAN 171-1989) covers pulses.

The AACC is a non-profit international organisation that specialises in the use of cereal grains in food. The AACC was established to develop new methods and revise existing testing and analytical methods for pulses. Testing methods developed by the IPQC will be verified by the AACC to validate the methods internationally.

Lastly, the IPQC was created to develop methods of testing and quality parameters and standardise nomenclature to meet client requirements and their quality specifications for common pulses as shown in Table 5 and is comparable with the parameters outlined in Table 4.

Table 5. Quality parameters identified by IPQC (Tiwari et al., 2009).

S. no.	Parameters
1	Seed size
2	Moisture content
3	Crude protein
4	Fibre
5	Starch
6	Water absorption
7	Split yield and dehulling efficiency
8	Cooking quality and time
9	Trypsin inhibitor activity (TIA)
10	Seed coat integrity
11	Tannins

In New Zealand, the Pea industry Development Group (PIDG) is responsible for addressing poor profitability, increasing yields, farmers' decreasing interest to grow peas and sustainability of the pea industry. The PIDG is composed of farmers, processors, seed companies, industry organisations and researchers who have decided to collaborate in exploring strategies to bring advances to the pea industry (Greenwood et al., 2008).

2.2.5 The hard seed phenomenon in legumes

Environmental factors such as soil type and crop agronomy alter the quality of pulses (Kigel et al., 2015). One of the well-known difficulties in legume grain is the hard seed characteristic that causes problems for food processors by restricting water uptake during processing (Argel & Paton, 1999; Ross et al., 2008). The disadvantage of legumes is their long cooking time and the presence of hard seed (N. Singh, Kaur, Rana, & Sharma, 2010). This issue is known by many names including stone seed, hard seed, hardseededness, hard shell (HS), hard-to-cook (HTC), seed coat dormancy, seed coat-impermeability. All forms of impermeable seeds delay water uptake for hours, days or longer. However, once the moisture uptake begins it proceeds at a rate comparable to that of permeable seeds (F. Ma, Cholewa, Mohamed, Peterson, & Gijzen, 2004). The characteristic is likely beneficial biologically and may provide protection from adverse environmental germination and growing conditions. This phenomenon also lengthens the life span of viable seeds. Seed hardness also protects the inner parts of the seed from injury and increases the likelihood that at least part of the seed population in the soil will emerge under favourable conditions (Woodstock, 1988). Hard seeds are also protected during the passage through the digestive tract of animals. However, it is not beneficial for the food processing industry as fast, and consistent hydration is desirable.

Different views of early researchers surfaced as to the reason for the impermeability of seeds. Woodstock (1988) notes that hard seed may be due to a compact arrangement of cellulose microfibrils in the cell wall involving the changes resulting in the micellar structure during maturation and dehydration of the seed. Some researchers attribute the water impermeability to the structure of the seed's strophiole, hilum, micropyle and the cuticularised layer and consider it to be genetically controlled. The permeability can be influenced by thickening of the outer surface of the walls of the epidermal palisade cells that subtend the cuticle (Spurný, 1964; Woodstock, 1988). In addition, it is suggested that cells may also be be impregnated with water impermeable substances such as lignin, fats, suberin or tannin (Spurný, 1964; Woodstock, 1988).

2.2.5.1 Factors that lead to hard seed phenomenon

2.2.4.1.1 Growing Conditions

A reversible hard-shelled (HS) characteristic occurs in the freshly harvested seed which disappears during storage. The development of hard seed in freshly harvested legumes can be attributed to several factors: genetics, climatic conditions, crop husbandry, seed size and degree of ripeness. A climatic condition, such as cold weather at germination and hot, dry climate during pod filling and harvesting, increases the hard seed in beans. Removing small seeds from beans removes most of the hard texture seeds. Late sowing, water stress and early harvesting increase the percentage of hard texture in fava beans. These factors are attributed to the shortened maturity and production of raw seeds (El-Tabey Shehata, 1992) .

2.2.5.1.2 Storage Conditions

The second type of hard seed characteristic (Sclerema) or hard-to-cook seeds differs from the first, and rather than being present at harvest, it develops during storage and is a property of the storage tissue of the cotyledons and, like other forms of hard seeds, is characterised by the inability of cotyledons to soften during the cooking process (Yi et al., 2016). The phenomenon is complicated and affects properties of the cell wall polymers, phenolic compounds and the starch granules (Jackson & Varriano-Marston, 1981; Pirhayati et al., 2011). The degree of sclerema depends upon the moisture content of the seeds and storage conditions, such as temperature, relative humidity (RH), atmospheric gas composition and storage time (El-Tabey Shehata, 1992). As early as 1928, the hard seeded peas and beans due to storage at elevated temperatures (> 25°C) were reported. The storage of peas under humid (> 60% RH) or arid conditions (< 1% RH) have been associated with the hard-seeded phenomenon (Powell & Matthews, 1977). Decreases in hydration capacity and in the percentage of hard-seeded beans (over 50%) were encountered when the bean variety Roshina G2 was stored at 25°C and 65-75% RH over two months (El-Tabey Shehata, 1992).

Legume starches show reduced enzymatic hydrolysis, with increased storage time, particularly at high temperatures and high RH, and this was correlated with increases in the proportion of hard to cook seeds El-Tabey Shehata (1992) . The storage conditions (22°C; no air control) of adzuki beans, influenced the starch gelatinisation of stored beans (one year storage) compared to the fresh beans (11% moisture). The fresh beans boiled in water for 60 minutes attained 50% starch gelatinisation compared to 18% for the one-year stored beans. Significant increases of starch gelatinisation enthalpy was observed in 1986 black bean samples stored at 15°C, 35 RH and 30°C, 80% RH with 4.22 to 5.96 J/g. The 1987 samples

also replicate an increase in gelatinisation enthalpy with 2.05 to 3.91J/g (Garcia-Vela & Stanley, 1989). Moreover, the research on adzuki bean starch stored at elevated temperatures of (30°C) for six months showed an increase in both onset (59.7-61.9°C) and gelatinisation peak (59.5-61.7°C) temperatures (Yousif et al., 2003). The changes in the gelatinisation enthalpy of the studies discussed above were attributed to the changes in the crystallinity of the starches (Hohlberg & Stanley, 1987; Yousif et al., 2003).

2.2.5.2 Alleviating hard seed

The hard-to-cook phenomenon of legumes has been a problem for food manufacturers, who have resorted to different processing methods to improve texture before processing legumes. Many artificial methods have been developed such as mechanical, chemical scarification to rupture, and remove the impermeable portions of the seed coat to stimulate water absorption. However, most of these studies are used for germination of seeds. The treatments found that are related for food processing are the hot water soaking, soaking with sodium or monovalent solutions and rupturing of seed coat. It is discussed by Argel and Paton (1999) rupturing of the seed coat will resume the normal water absorption of the seeds. In Figure 2, hydration rate of control, stabbed and split marrowfat peas was soaked in water for 24 hours. The control peas absorbed 131 % water (dry weight basis) compared to the stabbed peas which absorbed 132%, and split peas 162%. The increase in water uptake of stabbed and split peas was due to the increase in accessible points where water can be absorbed.

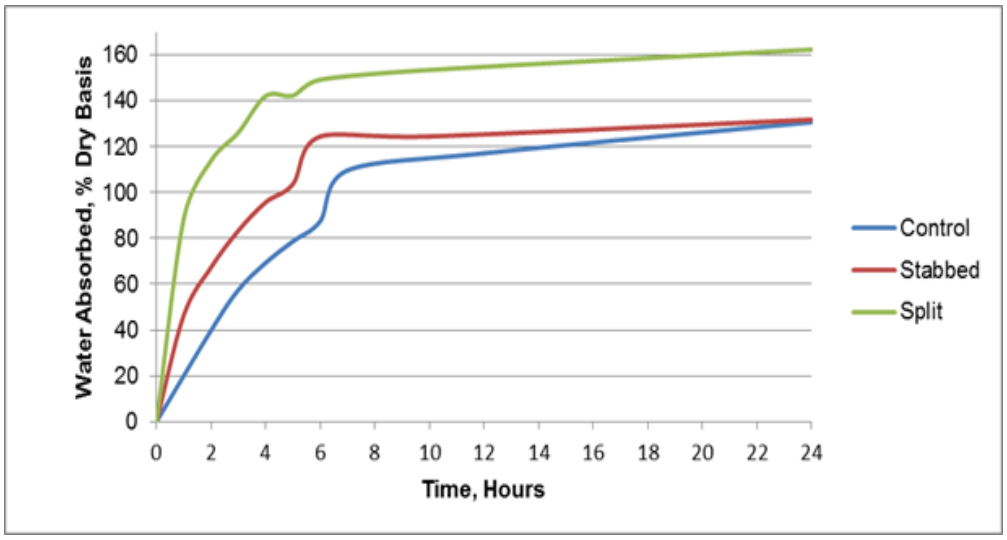

Figure 2. Hydration rate of marrowfat peas stabbed, split and normal peas (Ayaquil, 2016)

The suggestion of Ross et al. (2008) that seed coat and blocked strophiole are causing the delayed water uptake of stone peas is the probable explanation for the increased water uptake. Hard seed was not encountered on the stabbed peas and split peas even if there was a high frequency (14%) of seed hardness in the small sized (< 6.7 mm) marrowfat pea sample. This result shows that the hard seeds was not induced by storage and can be resolved if the seed coat is tampered and an increase in water uptake can be done by piercing through the seed coat of the peas (Ayaquil, 2016).

Additionally, the research of Kinyanjui et al. (2015) (Figure 3) on whole and dehulled beans supports the idea of Ross et al. (2008) with regard to the water absorption and seed coat. The whole beans had an initial lag phase in the water absorption which was not seen with dehulled beans. Dehulled beans soaked in water at 20°C had no initial lag phase and began absorbing water at an exponential rate (Kinyanjui et al., 2015). After the free capillary and intermolecular spaces, or the void between the seed coat and cotyledon were filled, the whole beans continued to absorb water similar to the dehulled beans at an exponential increase in water content, and lastly both are in a plateau phase.

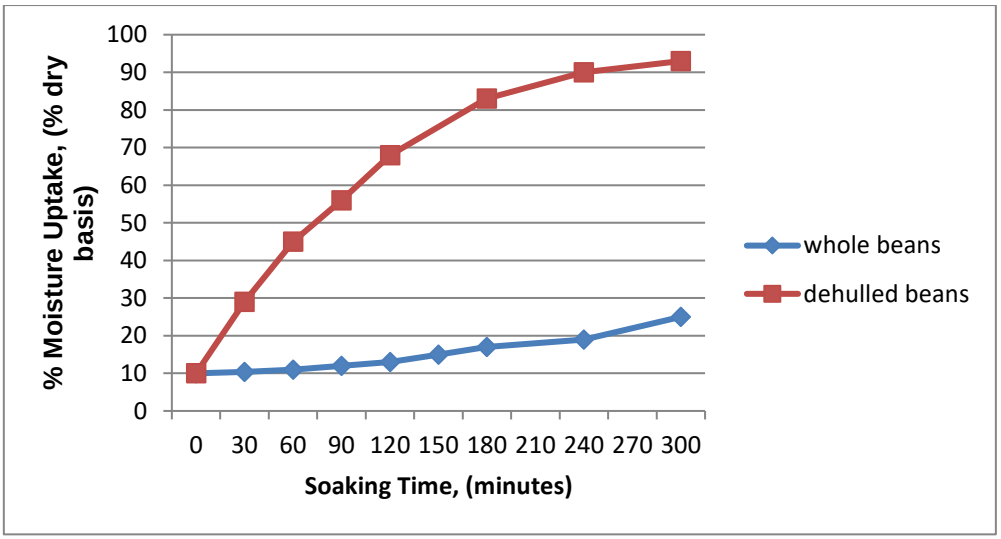

Figure 3. Percent moisture uptake of whole and dehulled HTC pinto beans (Kinyanjui et al., 2015).

In addition to the dehulling or physical damage on seed coat, it is suggested that heat and water are required to induce physicochemical changes in the seed coat, thus improving the water uptake of seeds (Ross et al., 2008). The hot-water treatment is a simple and reproducible method, which does not require special equipment. In Figure 4, the easy-to-cook and hard-to-cook beans display differences in water absorption when the beans were soaked at different temperatures (Kinyanjui et al., 2015). The rate of water absorption of both the easy to cook and hard to cook peas increases as the temperatures of soaking water increases (20, 35 and 50°C). The rate of water absorption increases with water temperature up to 50°C for both ETC and HTC (Kinyanjui et al., 2015). The reason behind the greater water uptake on the increase of water temperature is due to an increased water diffusion rate (Sopade, Ajisegiri, & Badau, 1992).

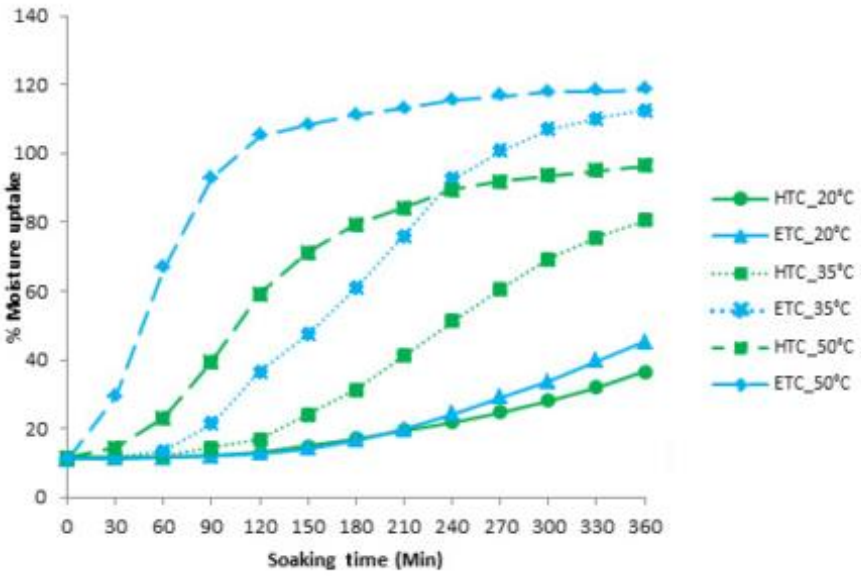

Figure 4. Percentage moisture uptake (dry basis) of ETC (Rose Coco) and HTC (Pinto) beans (Kinyanjui et al., 2015)

Besides the approaches reviewed above on treating hard seeds, Pirhayati et al. (2011) suggests that the soaking of seeds in sodium salts such as sodium bicarbonate and sodium citrate or monovalent cation solutions, storage of legumes at desirable conditions (low temperature, low humidity), radiation and extrusion causes an increase in water absorption and digestibility. Soaking of seeds in 1% sodium carbonate had the most effect in softening the texture of lentils and beans compared to tap water (Pirhayati et al., 2011).

Additionally, the use of sodium carbonate and sodium bicarbonate increased the cookability of the peas and made them softer than those soaked in water (Kinyanjui et al., 2015). The ETC and HTC beans in Figure 5 were soaked in different pH and cooked for 30, 60 and 90 minutes at 96°C. Beans soaked in 8.0-8.5 have a significantly lower average cutting force than the other soaking media (Kinyanjui et al., 2015). Furthermore, the behaviour of the beans upon soaking in an alkaline salt solution (pH 9 & 12) resulted in improved hydration rates than pH < 6 as shown in Figure 6. It has been suggested by Potter (1973) that the breakdown of proteins, polysaccharides and pectin substances occurs in alkaline solutions where the pH is above 8 tenderises the tissue (Kinyanjui et al., 2015).

Figure 5. Effect of soaking on (A) ETC and (B) HTC beans (Kinyanjui et al., 2015)

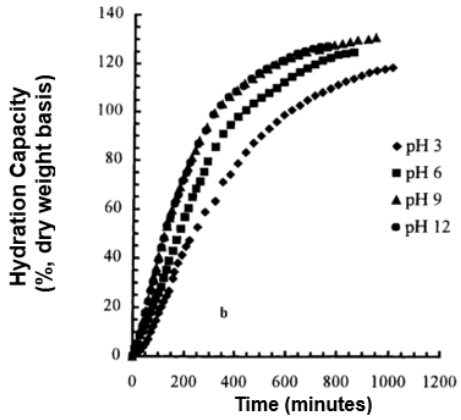

Figure 6. Hydration rates of faba bean soaked at different pH levels (Haladjian et al., 2003)

2.2 PEAS

In this section, the Pea (Pisum spp.) is discussed in detail with special relevance to the processing of the dry seed into fried peas with good organoleptic properties. Peas are from the family of Leguminosae, a sub-family of Papilionoideae and are of the order dicotyledons, Rosales (Boye & Ma, 2015; Ratnayake, Hoover, & Warkentin, 2002). Peas are one of the five most important pulse crops (beans, soy beans chick peas and lentils) (Boye & Ma, 2015; Kigel et al., 2015). Like other legumes, they are used as a break crop for disease control in cereal-based cropping systems, and they fix useful amounts of atmospheric nitrogen. Peas are an economically viable crop where the environment is favourable both as food for humans and feed for animals (Dung, 2012; Martin et al., 2008).

Peas are categorised into three major genotypes; snow or sugar peas (*Pisum sativum* var. macrocarpon), snap peas (*Pisum sativum* var. saccharatum) and garden or field peas. A snow pea pod is slab-sided and consumed before the string develops (Beckingham, 2001). Snap peas produce oval to round pods, and their varieties have strings in the pods that peel off easily. Snap peas were developed by crossing a garden pea with a snow pea (Fernando & Dimsey, 2009).

2.2.1 Garden and field peas

Field and garden peas are classified by their seed characteristics with the following classes used: Austrian winter, yellow, green, dun and marrowfat peas; the distinction garden peas (variety: sativum) and field peas (variety: arvense) can also be made. (Canadian Grain Commission, 2016; Comstock & Lothrop, 2012; Pulse Canada, 2012). Other classifications are also used, but will not be discussed here. Field peas are harvested dry while the garden peas are collected in their immature state and eaten fresh or frozen before cooking. The characteristics of field peas and garden peas are summarised in Table 6 (Logan & Jermyn, 1985).

Garden peas are also known as vegetable peas or vining peas and are mostly used fresh, but dried, frozen and canned products are also accessible. Garden peas have a wrinkled mature seed phenotype (genetically rr). They include freezer peas, snow and snap peas (Asif et al., 2013; Logan & Jermyn, 1985).

Field peas are known as dry or combining peas that have a round mature seed phenotype (genetically RR) and include yellow, green and red cotyledon varieties. There are several cultivars of field peas grown in New Zealand, but only one or two types are commonly cultivated. The significant cultivars are blue boiling, marrowfat, maple and white peas.

Table 6. Type of peas, seed characteristics and colour of cultivar (Logan & Jermyn, 1985)

Type of pea	Cultivar	Seed characteristic/colour
Field peas	White or yellow pea	Yellow cotyledons
	Green or blue	Green cotyledons
	Black, brown, maple and partridge pea	Mottled brown seed coat
	Marrowfat or grey peas	Large green wrinkled seed
Garden peas	Green peas	Green
	Processing peas	Green

The blue pea cultivars have medium-to-short straw length and have the average maturity that is appropriate for spring sowing in crop rotation. The blue peas were represented by the old European cultivar Rovar, and Blue Prussian (Logan & Jermyn, 1985). White peas are early maturing, and very erect white peas are used for splitting, and other human food end uses. The high-quality and high-yielding Huka superseded the cultivars White Prolific and Pamaro. Maple peas are smooth or wrinkled yellow cotyledon peas with a brown flecked or mottled seed coat. They are also used for bird seed mixtures (Kigel et al., 2015; Logan & Jermyn, 1985). Maple peas have long straw and are sown in autumn and traditionally grown on dryland cropping farms (Logan & Jermyn, 1985).

2.2.2 Growth and development

Peas are grown as a cool season crop in subtropical areas and at higher elevations in tropical areas (Logan & Jermyn, 1985; Ratnayake et al., 2001). Peas require specific soil and temperature conditions to grow well since they are sensitive to disease, water stress, and weed competition (Dung, 2012). Furthermore, pea plant growth depends on and varies according to the geographical condition of growth such as the type of soil, weather conditions, culture and plant location (Makasheva, 1983). Hence, the yield of peas is affected by the time of sowing, plant structure, soil conditions, irrigation and abortion (White, Jermyn, & Wratt, 1987).

It has been known that peas are more sensitive to poor soil aeration and water-logging than other crops. The problem occurs in the field when there has been impeded drainage, but poor soil structure, heavy irrigation to above-field capacity, or field capacity irrigation followed by rain. Water-logging for two days would kill the roots of the plant with a small chance of recovery, while as little as 12 hours of water may reduce the yield of the peas (White et al., 1987)

Peas can be planted in a diverse series of soil types from clay to sandy soil. The best soil for the peas is deep, well-drained clay loam because (as with sandy soil) lower yields are recorded, so potassium fertilisers are a requirement (James et al., 2005; Khan & Zimmer, 1989; Schatz & Endres, 2009). Moreover, the cultivation area and cultivation year (climate condition) affect the nutrient composition of field pea seeds (Nikolopoulou, Grigorakis, Stasini, Alexis, & Iliadis, 2007).

2.2.3 Adaptation

Peas have adapted well in New Zealand, as the climate has a similarity to Canada's in which peas thrive in cool weather (Schatz & Endres, 2009). Most of the pea production in New Zealand is located in the South Island, especially in the Canterbury region where most of the year the temperate climate is available for growing. Plant and Food Research (NZ) Ltd is responsible for breeding peas such including marrowfat, green, yellow, maple, forage and sprouting (Plant and Food Research NZ Ltd, 2010)

The pea crops that are sown early in the spring season (late September and early October) have the greatest potential for high yield as they experience cooler temperatures, develop more slowly, grow for more days and intercept more solar radiation (Dung, 2012). There are different suggestions about the base temperature, but 0-5°C is commonly used (Dung, 2012). The best harvesting time to gather the field pea is when its moisture content is in the range of 16-20% (Arnaudin & Pyke, 2013).

Peas in New Zealand are grown under a contracting system where merchants contract the areas of the peas needed to meet orders from international buyers (Logan & Jermyn, 1985). Since peas are under a contracting system, farmers have different agronomic practices that affect the pea plant growth. Careful planning, freedom from stress through the growing season and good timing of harvest can result in maximum yields of peas. Recommendations for high-yielding spring pea crops in Canterbury such as preparations before sowing of peas, sowing, development, weed and disease control, and harvest and storage were suggested by

Jermyn (1984) to help and guide farmers. Some suggestions are seed bed preparation, timing, drilling and use of fertilisers sowing seeds in free-draining soil as peas are more sensitive to impeded drainage than any other crop. The pea harvest is suggested to commence once the moisture of the peas goes down to 14-16%. Compared to cereal, a pea loses quality such as bleaching or colour loss and has to shatter once harvesting is delayed. In a challenging harvest season, windrowing and defoliation may be beneficial. In the storage of peas, it should be ensured that augers and silos are clean to prevent contamination from other crops and pea types (Jermyn, 1984; Jermyn & Batey, 1982).

2.2.4 Pea seed structure and function

The pea seed which is enclosed in a hull (seed coat/testa) has a cotyledon (Hashemi et al., 2015). The pea seed consists of an embryo (embryo and two cotyledons) and the seed coat (Argel & Paton, 1999). The embryo consists of the radicle, stem and the plumule (Makasheva, 1983). The cotyledons, which are covered by the seed coat, are the largest part of the embryo. The cotyledon also stores most of the nutrients that are required in the primary phase of the growth of the embryo (Makasheva, 1983).

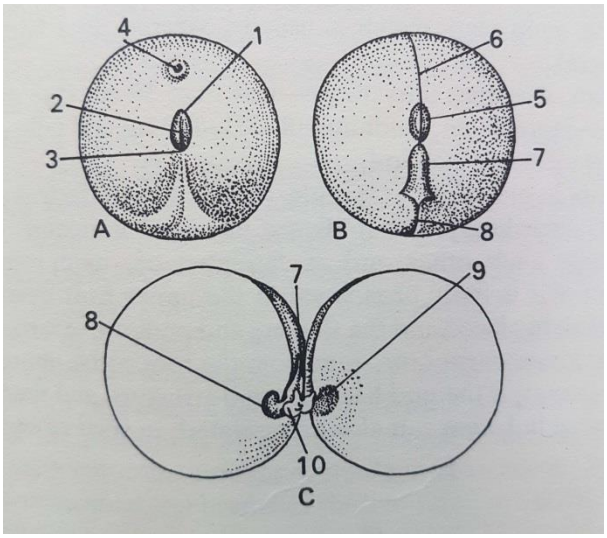

Figure 7. The Pea seed
(A - with seed coat; B- without seed coat C- two cotyeledon viewed from inner side)
1 – hilum, 2 – hilum line at contact point of cotyledon, 3 – micropyle, 4 trace of chalaza, 5 trace of hilum, 6 contact point of cotyledon, 7 –embryonic root, 8 embryonic apical bud, 9 depression in the cotyledons at the place of location of embryonic bud, 10 place of attachment of the embryoninc stem (collar) to cotyledons)

The hilum is the scar formed when the funiculus detaches from the seed at maturity. (Makasheva, 1983; Woodstock, 1988). (Figure 7 - 1). Hyde (1954) established that the hilum acts as a hygroscopic valve, opening to absorb moisture when the environmental humidity is

high, and closing to keep moisture when the environmental humidity is low (An, Arntfield, Beta, & Cenkowski, 2010).

The micropyle (Figure 7-3), found at one end of the hilum and looks like a small hole (Woodstock, 1988) and is the pore through which the radicle emerges at germination. The raphe is the slightly depressed area on the opposite side of the hilum from the micropyle (An et al., 2010; F. Ma et al., 2004). The strophiole or lens is the seed structure near the hilum and on the opposite side of the micropyle. The strophiole, or aril, is considered an outgrowth of the hilum region that is composed of tissue, which restricts water movement (Argel & Paton, 1999; Woodstock, 1988).

The outer layer of the seed coat is known to be the palisade layer and consists of macro-sclereids or malpighia cells, covered by the cuticle on the exposed wall (as shown in Figure 8) (Argel & Paton, 1999). The seed coat that surrounds and covers the seed is typically derived from the integuments around the ovule which, upon seed maturation, diminishes in thickness and becomes disorganised (Woodstock, 1988). The role of the seed coat during seed development is to supply nutrients arriving via the funiculus and distributes them to the growing embryo through a vascular net embedded in its parenchyma tissue (Kigel et al., 2015) The composition of the seed coat plays an important role in the water-absorbing properties of the seed.

Figure 8. Seed coat layers of Wild Pea (*Pisum elatius) (Mayer & Poljakoff-Mayber, 1989; Yousif, Kato, & Deeth, 2007)*

According to Woodstock (1998), it is obvious that seed size, presence and condition of the seed coat, the viability and vigour of the seed, membrane permeability and chemical

composition of the seed all play a part in water absorption, but their respective roles cannot be separated easily. The hilum, micropyle and raphe are not sites of the initial water entry (F. Ma et al., 2004). Initial entry of water are in the dorsal side of the peas wherein the seed coat is thinnest (F. Ma et al., 2004).

2.2.5 Pea size grading

Seed size depends primarily on the genotype of the variety and the conditions of cultivation (Khvostova, 1983). The physicochemical characteristics of immature yellow peas show lower seed weight and smaller seed size compared to matured yellow peas (Shen et al., 2016). The grain and flour pea's accessions with a higher grain weight have a less compact structure with a greater proportion of large-sized starch granules. Pea size classification varies in every country. For the US, pulses are considered large if less than 3% passes through a 16/64 (6.35mm) round hole, while it is considered small if 3% remains in the 16/64 round hole, but no greater than 3% passes through the 10/64 (3.97mm) slotted hole sieve. For Canada, if 95% or more remains on top of the No. 14 round-hole sieve (5.56 mm, 14/64) the sample is considered large (Canadian Grain Commission, 2016, 2017). The sorting of pulses using laboratory sieves and manually shaking them is deemed to be more helpful than the visual evaluation of size by sensory panelists (Nleya, Minnaar, & de Kock, 2014).

2.2.6 Current use and possible opportunities for peas

Peas have an appealing colour texture and shape (N. Singh et al., 2010). Currently, applications include whole pea flour, dehulled flour; finely ground hull as a fibre product, pea starch, pea protein concentrates and isolates (Arntfield & Maskus, 2011). Field peas are consumed as whole or split form; these are used in soups and stews or fried as a snack.

Field pea production in Canada and New Zealand is mostly exported to Europe, South America and used in the Asian market as snack foods (Khan & Zimmer, 1989; Plant & Food Research, 2010).

2.2.7 Marrowfat peas

Marrowfat peas are large irregular-sized field peas with a wrinkled seed coat; they are harvested at maturity at a moisture content of about 14%. Typically they have green cotyledons, (Kigel et al., 2015). and when cooked have a sweet, strong pea taste compared

to other types of cooked peas, for example dun, green peas and yellow peas (Malcolmson et al., 2014). They are capable of commercially viable yields under irrigation in New Zealand.

Marrowfat peas grown by Midlands Seeds Ltd comprise two varieties: Midichi which comprises about 90% of the crop planted; and the rest are Midlea. Both cultivars were selected to be resilient to powdery pea mildew and asochyta blight and to bleaching, provided they are harvested early (Crop and Food Research, 2001; White et al., 1987).

2.3 SOAKING AND COOKING

Peas are dried after harvest to prolong storage life. Soaking and cooking are used to process dried peas for human consumption. Soaking peas before cooking decreases the cooking time as the endosperm is hydrated before heating to gelatinise starch and denature proteins (Fabbri & Crosby, 2016).

Prior to cooking, the dried peas should be hydrated to a moisture content of 57%, during which the peas expand to approximately twice their original volume ("Fried Pulses," 2016). The hydration of seeds is crucial to the frying of peas since vapour pressure is one of the factors which ensures a good texture in the fried peas (Fowler, Turner, & Siddique, 2006). Hard seeds are considered undesirable by the food processing industry as it causes non-uniform hydration.

2.4 FRYING

Frying is considered as one of the quickest, oldest and simplest processes of cooking food. This involves edible heating oil and basically cooking the food by immersion in the hot oil (mostly temperature greater than the boiling point of water). Frying has been used to cook different kinds of food like vegetables, meat and fish.

During frying, heat is transferred from the oil to the food, water is evaporated from the food, and the oil is then absorbed (Rossell, 2001). The oil is absorbed when it enters the damaged surface areas of the fried product after moisture is evaporated as steam. Throughout the deep frying of food, evaporation of water cools the product and prevents the burning of food and maintains the product temperature at or below 100°C. When all water is lost, the food burns. Although the frying of food is considered an easy way of cooking, the principle of frying is complex with oxidation and hydrolysis happening simultaneously (Erickson, 2007). Protein denaturation and starch gelatinisation are other important processes associated with frying. Starch gelatinisation is an important consequence of frying as it improves digestibility and is essential in the formation of a porous structure in the finished product. Protein undergoes in Maillard reactions with sugars present to form brown pigments and pleasant flavours (Rossell, 2001), and denaturation also may contribute to the crispness of the fried product.

2.4.1 Effects of frying

Texture or rheological properties are the behaviours of materials under an applied force. The acceptability of a food product is always connected to the texture quality. The viscoelasticity of food is strongly related to the quality attribute perceived by consumers as mouth feel. It has been documented by Sothornvit that during frying, hard texture changes are encountered because of the moisture loss (Zhu et al., 2015). As discussed by Rossel (2001), the boiling of water during frying results in a porous structure to the pea cotyledons making them softer thus improving texture (Fellows, 2009; Pedreschi & Moyano, 2005; Rossell, 2001; Sosa-Morales & Vélez-Ruiz, 2009).

The increase in the hardness of food during frying is due to the loss of moisture (Oyedeji et al., 2017). The frying temperature must be carefully controlled to optimise internal structure, prevent burning of the product, remove sufficient water to form a crisp, crunchy product, while too high and the product has high internal moisture and a burnt outer surface. If it is too low, the steam will escape too slowly to form a porous structure, and the peas will be too hard to eat (Rossell, 2001).

In frying of peas, most researchers and food manufacturers processes the dried peas by soaking it overnight or around 12 – 18 hours. After soaking, peas are fried 160-180°C for 10 to 20 mins (Barrios, Mora, & Cárdenas, 2016; Zhu et al., 2015). Some frying suggestions available are from the technical manual of the USA Dry Pea and Lentil Council, who suggest that peas are fried to reduce the moisture below 2.5%.

Frying temperatures and time varied depending on the product's size type of fryer used and desired texture (Fabbri & Crosby, 2016; Oyedeji et al., 2017; Pedreschi & Moyano, 2005; Rossell, 2001). Frying the peas at high temperatures (>180°C) causes the pericarp to detach, and a small proportion of peas split and is therefore undesirable ("Fried Pulses," 2016; Oyedeji et al., 2017). According to the study by Barrios Barrios, Osorio Mora, and Cerón Cárdenas (2016), the moisture content and oil absorption during frying are dependent on the temperature used. At the same cooking time, the higher the frying temperature, the greater the loss in moisture and minor oil absorption was observed. Frying peas at a lower temperature (<160°C) will lengthen the frying time and increase the oil absorption ("Fried Pulses," 2016). The oil absorbed from the fried peas declines as the frying temperatures increased 160, 180 and 200°C 34, 21, 28% (dry basis) respectively (Barrios et al., 2016).

The surface area-to-volume ratio of the product must also be considered because the oil transfers the heat initially by surface contact and capillary action into the product (Rossell, 2001). The ratio of product to oil volume must be adjusted to prevent unacceptable reductions

in temperature when the products are added to the oil (Rossell, 2001). Erickson (2007) suggests that the frying system should replace the heat at a faster rate than what is lost. The higher the surface area, moisture loss is fast therefore the higher rate of recovery is required for small pieces of fried products. Increasing the temperature of the fryer does not compensate for the fryer capacity limitations, as higher oil temperature can overcook the surface of the product while making the interior of the product undercook (Erickson, 2007).

In batch frying, the frying oil temperature declines from the set temperature as frying is commenced. This is mainly in response to batch size, temperature and moisture content of the product. The drop in frying oil temperature usually ranges from 16-22°C (30-40°F). However, if the temperature drops greater than 28°C (50°F) this should prompt a review as it would result in a longer recovery time (Erickson, 2007).

Peas have limited research studies relating hydration to frying which are made available to the public. Most likely, private food manufacturers have studied the problem, but there are few documents available to the public.

CHAPTER 3: MATERIALS AND METHODS

The experiments were conducted at the Institute of Food, Nutrition and Human Health at Massey University, New Zealand.

3.1 MATERIALS

All marrowfat pea samples were supplied by Midland Seeds Ltd. The peas received were from the 2014 (1 bag, MF1401) and 2015 (5 bags, MF1500, MF1508, MF1522, MF1534, and MF1552) crops, with each bag containing approximately 1-2 kilos of peas while the marrowfat peas from the 2016 harvest were packaged in a 10-kg plastic sack.

Table 7. Marrowfat peas from the 2014-2017 seasons line number and location

Line Number	LOCATION*
MF1401	Timaru Area
MF1500	Timaru Area
MF1508	Otaio (St. Andrews Area)
MF1522	Mayfield, Valetta
MF1534	Chertsey / Pendarves
MF1552	Barhill / Methven area
MF1600	Timaru Area
MF1614	Ashburton Town boundary
MF1636	Otaio (St. Andrews Area)
MF1638A	Pleasant point / Washdyke
MF1647	Wakanui
MF1655	Rangitata
MF1660	Rakaia
MF1644A – Singapore Line	Rangiora way
MF1722	Ashburton River, Hinds area (Eiffelton)
MF1746	Ashburton River, Hinds area (Costal Farm)

* The location column is where the peas were grown and harvested.

The 2017 crops were from line numbers MF1722 and MF1746 with each bag containing 1-2 kilos of peas that were taken from eight dressing processes. The information that describes the process where the pea samples were taken is presented in Table 8.

Table 8. Sample of Marrowfat Pea from different dressing processes

Batch	Description
1	Undressed –sample from farm after harvest
2	Peas passing through the 5.15mm x 19mm slot (A13 or 13/64”) and 7.144mm round screen upon dressing (small size peas (approximately < 5.15 mm) are separated here)
3	Second screening same as process 2
4	Large peas removed during de-stoning machine (approximately > 8 mm in diameter and > 0.4 - 0.5 gram)
5	Peas removed from the gravity table (< 0.3 grams average weight)
6	Peas from Colour Sorter (stained, diseased and bleached)
7	Dressed peas - Final Product Free of diseased and damaged grain, dirt and other impurities, > 5.15 mm and < 9 mm diameter and with uniform colour (specifications vary depending on customer need)

All pea accessions supplied were stored in a dry laboratory space, room temperature 22˚C in the Product Development Laboratory at Massey University.

Figure 9. Dried marrowfat peas

3.2 GENERAL METHODS

3.2.1 PHYSICAL TEST METHODS

3.2.1.1 Seed Weight

Seed weight was recorded by randomly selecting 100 peas and weighing. The analysis was done in triplicate.

3.2.1.2 Seed Volume

Fifty (50) seeds were placed in a measuring cylinder, and 50 millilitres of poppy seeds were added ensuring that there were no voids between the peas. The volume was recorded and the analysis was done in triplicate.

3.2.1.3 Density

The density was recorded as g/ml calculated from weight and volume above. See 3.2.1.1 and 3.2.1.2.

3.2.2 MOISTURE CONTENT

Ten to twenty (10 – 20) grams sample of peas were pulverised using a Breville coffee grinder for 15 – 20 seconds or until the samples were finely ground. Samples of ground peas weighing 2 – 3-grams were placed in the pre-weighed aluminium dish container. Samples were placed into a Contherm Oven set to 108°C and dried overnight or until a constant weight was achieved. The analysis was done in triplicate (Ravindran, 2016).

3.2.3 TEXTURE

Texture was assessed from the widely used compression test using a SMS TAXT2+ Texture Analyser (Stable Microsystems, UK) fitted with a 25mm diameter probe (Figure 10). A test speed of 1.00 mm/sec and target mode distance of 5.0mm for whole and 2.5 mm for half peas were used. One pea was tested at each cycle, and was placed in the texture analyser

with the division between the two cotyledons placed parallel to the platform. A 25 mm flat cylinder attachment was used (Figure 10). Ten peas were used as replicates for each sample.

The test measures the maximum applied force (stress) fractures and the corresponding strain at this point. The maximum force required to fracture the pea is correlated with hardness or firmness of the material, while the ratio of maximum stress to maximum strain is correlated with crispiness. The product is considered crisp when the product is firm and easily snaps when deformed, emitting a crunchy sound (Krokida, Oreopoulou, Maroulis, & Marinos-Kouris, 2001)

Figure 10. Texture Analyzer - 25 mm flat cylinder attachment

3.2.4 DATA ANALYSIS

Data analyses were conducted using Minitab version 17 Statistical Software (Minitab Inc., State College, PA, USA) and Microsoft® Excel® version 14.0.7181.5000 (Santa Rosa, California, USA). Tests were applied to determine the normality of the data. The data was analysed by using analysis of variance (ANOVA) and General Linear Model (GLM) procedures. Descriptive statistical analyses and graphical representations were generated using Minitab and Microsoft Excel to calculate mean values, and standard deviations for each of the experiments. Significant differences ($p < 0.05$) between means were analysed using the Fisher LSD method.

CHAPTER 4: HYDRATION AND HARD-SEEDED PEAS

4.1 INTRODUCTION

When frying peas, texture inconsistencies, in particular, with hard texture have been noticed by some Midlands Seed clients. Midlands Seed Ltd requested assistance from Massey University to investigate if hard-seeded (peas that will not absorb water (hydrate) during soaking) resulted in hard textured peas following frying. In this section, peas were evaluated using hydration, and texture analysis and the resuslts correlated with the physical properties of peas following frying.

4.2 MATERIALS AND METHODOLOGY

4.2.1 Sizing of peas

Marrowfat peas harvested from different fields during 2016 were sieved using a set comprising Endecott square hole < 6.7 mm, Tyler square hole 7.1 mm, and Endecott square hole 8.0 mm seives. On this basis the peas were categorised in four sizes; A – very small (passed through <6.7mm), B – small (retained on the 6.7 mm sieve but passed through the 7.1 mm sieve), C – medium (retained on the 7.1 mm sieve but passed through 8.0 mm sieve) and D – large (retained on the 8.0 mm sieve). One thousand grams (1000g) samples of each line was sieved in batches of 100 to 150 grams each sample being shaken manually for 30 to 60 seconds. The various size fractions were weighed for the computation of percentages by weight.

4.2.2 Hydration capacity

Pea samples of between 50 to 100 grams of the fractions described in 4.2.1 were placed in a container with water at a ratio of 1:4 seed to water and steeped for 24 hours at room temperature (20°C). The proportion of water used ensured the peas were fully submerged when the peas were fully hydrated. Following hydration, the peas are drained and dried at intervals 12, 18 and 24 hours of soaking) using paper towels to remove surface water. The hydration capacity calculated as (weight after soaking - weight before soaking) / # of peas (Tiwari & Singh, 2012).

Peas that did not hydrate were counted as hard-seeded peas (Cerón, Osorio, & Garcés, 2016; Ning Wang, Hatcher, Warkentin, & Toews, 2010). Analysis was done in triplicate.

A similar test was carried out on peas samples resulting from the dressing methods used for the 2017 lines and reference samples from the 2014 and 2015 batches of peas. These batches were analysed to confirm if the small-sized peas, immature peas, long-storage peas, and peas with a heavier weight affect the incidence of hard-seeded peas.

Figure 11. Soaking marrowfat peas in water

4.3 RESULTS AND DISCUSSION

Each of the Midichi and Midlea pea lines was sized using sieves. The majority of the peas (73 – 98%) in each sample were in the 7.1 - 8.0mm and > 8.0 mm size classes except for MF1638A,the only Midlea sample for which 66% were in the size class > 8.0 mm Figure 12.

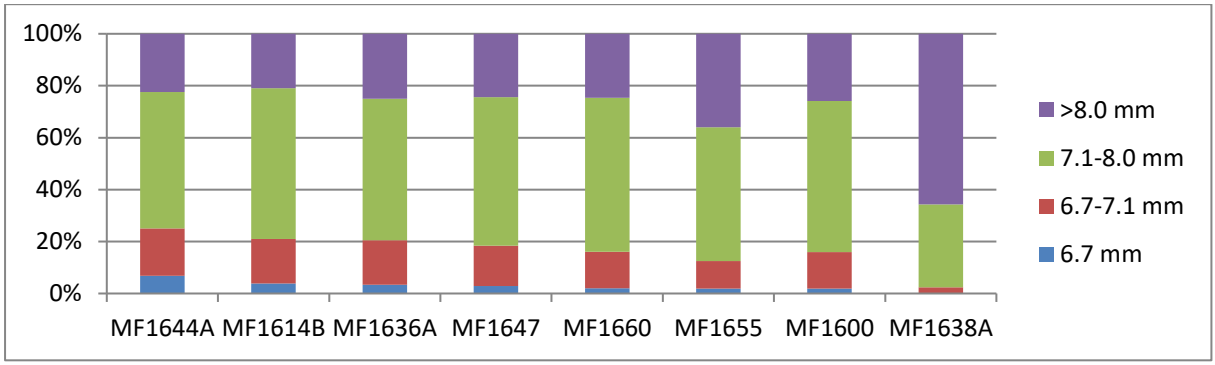

Figure 12. Size distribution of marrowfat peas

The various size classes were hydrated to determine the frequency of hard-seeded peas and their rates of water uptake. Table 9, Hard-seeded peas were associated with the small proportion of small sized peas (< 6.7 mm) in each sample. Moreover, peas with a size class of less than 7.1 mm absorb significantly more water in proportion (number) than the > 8.0 mm size class (number) on a dry weight basis. The reason behind the higher percentage of water absorbed by the smaller-sized peas seems to be the proportion of water moisture absorbed in the void space between the seed coat and the cotyledon tissue (Calzetta Resio, Aguerre, and Suárez (2003).

Table 9. Water absorption of peas of various size classes.

Size	Hard-seeded/sample (%)	Water Absorbed (%, Dry Weight Basis)	Mean weight of dried peas (g/100 seeds)
<6.7	5.17 ± 4.47^{a}	121 ± 9.94 ^{a}	27.59 ± 0.79^{a}
6.7 - 7.1	2.10 ± 2.52 ^{b}	121 ± 7.84^{a}	31.10 ± 0.71^{b}
7.1 - 8.0	1.00 ± 1.70^{c}	120 ± 8.11^{ab}	36.13 ± 2.24^{c}
> 8.0	0.23 ± 0.52^{c}	118 ± 5.46^{b}	41.90 ± 2.33^{d}

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.

Figure 13. Hydrated marrowfat peas (MF1644)

The samples of peas hydrated for 12, 18 and 24 hours are shown in Table 10. The hard-seeded peas found at the 12th hour (3.92%) soaking displays that it has significantly greater proportion of hard-seeded peas are present at 12 hrs (1.58%) compared with 18 and 24 hours (0.58%). A proportion of the hard-seeded peas identified at 12 hours are in fact simply slower to hydrate and fully hydrate after 24 hours of soaking. The delay in water absorption in cow peas was attributed in to the differences of the thickness of the seed coat (Sefa-Dedeh, Stanley, & Voisey, 1979). Since the frequency of hard-seeded peas is highest in the 12-hour soaking period, soaking time should be set to 18 or 24 hours to reduce the occurrence of hard-seeded products.

Table 10. Hard-seeded peas (%) reported at different soaking times of marrowfat peas harvested in 2016.

Soaking Time (H)	Hard-seeded Peas (%)	Water Absorbed (%, Dry Weight Basis)
12	3.92 ± 4.26 ^{a}	112 ± 5.22^{a}
18	1.58 ± 2.30^{b}	121 ± 5.13^{b}
24	0.58 ± 1.22^{c}	127 ± 5.28^{c}

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.

The hard-seeded peas with respect to the harvesting locations of the marrowfat peas are tabulated in Table 11. The proportion of hard seeds in the MF1644, MF1655 samples from the Rangiora and Rangitata areas respectively were highest and mostly found in the smaller-sized peas (< 7.1 mm). The samples MF1647 and MF1614B grown in the Wakanui and Ashburton regions had the lowest frequency of hard-seeded peas (Table 11). Comparison of the agronomic practices, harvesting and environmental conditions, along with soil types at the locations where the two groups were grown may provide clues regarding the development of hard-seeded peas.

Table 11. Percentage of hard-seeded peas from different harvesting locations.

Line Number	Hard-seeded peas (%)
MF1644A	3.75[a]
MF1655	3.67[a]
MF1600	2.62[ab]
MF1660	2.25[abc]
MF1636A	1.58[bc]
MF1647	1.08[c]
MF1614B	0.71[c]

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.

Of the supplied seed lines, MF1644A and MF1655 had the highest proportion of hard-seeded peas with 3.75% and 3.67% respectively (Table 11), which was significantly greater than the lines MF1636A, MF1647 and MF1614B. The batches of peas MF1614B, MF1636A and MF1647 have high percentage of peas categorised to size classes less than 6.7 mm and 6.7 – 7.1 mm or small sized peas, have low incidence of hard-seeded peas 0.71 – 1.58%.

Peas from the 2014 and 2015 harvests that have been stored for in excess of 3 years were tested for the proportion of hard-seeded peas. There were no significant differences in the proportion of hard-seeded peas at any soaking time ($p < 0.5$) in the lines MF1401, MF1500, MF1508, MF1522, and MF1534 which came from different locations and harvest seasons. Since there were no hard-seeded peas found in lines stored in excess of 3 years, it was clear that the peas were not stored in unfavourable growing and storage conditions such as kept at >25°C and >60% RH or that are known to result in hard-seededness.

The effect of water absorption after soaking times of 12, 18, or 24 hours was similar to the 2016 marrowfat pea lines (Table 12).

Table 12. Water absorption of marrowfat peas harvested in 2017 reported at different soaking times.

Soaking Time	Water Absorbed (%, Dry Weight Basis)
12	108 ± 4.12[c]
18	117 ± 4.20[b]
24	121 ± 4.21[a]

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.

In Table 13, the water absorbed from the different dressing processes is presented. The marrowfat peas from processes 2, 3, and 5 had the highest water absorbed in terms of the percentage (%) dry basis. Similar to earlier discussion, small-sized peas have a higher water absorbed ratio than the larger peas (4 and 7).

Table 13. Water absorbed in marrowfat peas harvested in 2017 from the seven dressing processes.

Process / Size		Water Absorbed (%, Dry Weight Basis)	Mean weight of dried peas (grams/100 pieces)
1	As harvested	114 ± 5.77[c]	36.47 ± 0.23[d]
2	Small	121 ± 6.60[a]	28.41 ± 3.45[a]
3	Small	120 ± 5.70[b]	31.32 ± 0.21[b]
4	Large	111 ± 6.17[e]	39.07 ± 0.65[e]
5	Small	119 ± 4.73[b]	33.52 ± 0.82[c]
6	Medium	114 ± 5.10[cd]	36.43 ± 0.76[d]
7	Final dressed	112 ± 5.35[de]	38.27 ± 0.88[e]

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.

Midlands Seed Ltd suggests that the final dressed product or the sample 7 is the best size for a snack product. The USA Dry Pea and Lentil Council suggests that prior to frying, peas would require re-hydration to approximately 57% moisture (wet weight basis).

Peas collected from processes 2 and 3, were of smaller size and only contained a negligible proportion (about 1%) hard-seed peas after 12 hrs soaking compared peas harvested in 2016 peas of < 6.7 mm which had 9.4 % hard-seeded peas. Peas from the 2017 harvest soaked for 18 hours or more contained no hard seeded peas.

4.4 CONCLUSION

As hard seeded peas were only detected from some sites, it can be concluded that this fault was due to the growing conditions rather than the storage conditions. In most cases, the seed hardness found in this work does not occur upon soaking for 18 hours or more. No hard seeds were found in peas harvested from the 2014 & 2015 seasons suggesting that provided storage conditions are good, hard-seeded peas does not increase with storage time.

Secondly, the frequency of hard-seeded peas increases only with decreasing seed size below 7.1 mm. Therefore, marrowfat peas processed by Midlands Seeds Ltd are of good quality for the production of fried pea snacks.

CHAPTER 5: FRYING OF PEAS

5.1 INTRODUCTION

In this chapter, marrowfat peas were subjected to laboratory scale frying to achieve the appropriate frying parameters of fried peas. All the marrowfat pea crops were examined to ascertain if hard-seeded peas was the cause of texture inconsistencies in fried marrowfat peas. Furthermore, additional processes such as soaking in salt solutions and experimenting on frying parameters such as adjustment of frying time, temperature and frying load size was conducted to find out what parameters would provide consistent or improved texture compared to the benchmark samples.

5.2 MATERIALS AND METHODOLOGY

5.2.1 Analysis of benchmark samples

The first part of this chapter was the analysis of six baseline samples of peas. These samples were subjected to moisture content, volume and break force (N, texture) to provide comparison and reference for the laboratory fried peas.

The reference samples were bought from a local supermarket in Singapore; a.) Kasugai Peas & You (Japan), b.) Snapmaxx (Malaysia) c.) Kasugai Roasted Green Peas Japan) while the benchmark sample d.) Kaoshong Wasabi Peas (Thailand) was bought from local Asian store (Rangitikei St, Palmerston North). Two samples of peas were supplied by Camel Nuts (Seng Hua Hng) e.) Seng Hua Hng Green Peas and f.) Camel Nuts Wasabi Peas. All samples of peas are coated except for Seng Hua Hng green peas (sample “e”). The marrowfat peas were supplied by Midland Seeds Ltd. to Seng Hua Hng (samples e and f) and Kasugai (sample a and c).

5.2.2 Effect of frying temperature and time

The second part of the experiment was frying the soaked peas (MF1638A) using 160°C and different frying times 6, 8, 10 and 12 minutes. The sample that would render the best texture and have close physicochemical attributes to the benchmark samples would be chosen as the control process. Furthermore, frying the peas (MF1638A) using a different cooking time and temperature was carried out to explore the possibility of frying the peas at a higher

temperature (170°C and 180°C) and for a shorter time. Marrowfat peas from MF1638A were used because these have the least occurrence of hard-seeded peas and the majority of these pea sizes are greater than the 8mm range to avoid texture inconsistencies that would have an effect on setting the frying time and temperature. The basis of the frying time and temperature was from the Camel Nuts (Sheng Hua Hng.) frying process which was 160°C for 17 minutes. The cooking time was reduced to 12 minutes since the extended time of cooking caused the peas to burn. The use of 50 – 150 grams frying load and 4 litres of frying oil was based on the laboratory trials done by Zhu et al. (2015).

Peas were soaked overnight for 12, 18 and 24 hours and drained using a colander. 50 – 150 grams of the hydrated peas were deep-fried using the Hayman deep fryer at 160 - 180°C for 6 – 12 minutes. The Hayman deep-fryer used was modified with proportional–integral–derivative (PID) controller, a control loop feedback mechanism that regulates the temperature of the deep fryer to maintain the oil temperature to the set temperature. The oil used for frying was a vegetable oil (canola, 4 litres) and it was ensured that the thermal sensor was submerged and could measure the temperature accurately. The oil temperature of the fryer was calibrated using a different temperature probe to confirm the temperature of the fryer was correct. Samples were drained and placed on a paper towel to remove excess oil. Reference samples were taken for analysis of moisture content, volume, break force (N, texture) and sensory evaluation.

5.2.3 Frying peas at different frying loads

Samples of marrowfat peas from MF1614 were used in frying peas at different frying loads (100, 200, 500, 750 and 1000g). Preparations on soaking peas and the frying method used, was similar to the method in 5.2.2. Adjustments were made in the different frying time and were computed theoretically for the frying loads 500, 750 and 1000grams based on the cooking parameters of 100 grams of peas, 160°C for 12 minutes. Samples were taken for analysis of moisture content, break force (N, texture) and sensory evaluation. The fried peas were sensory evaluated on their taste (cooked pea without raw or burnt taste) and texture similar to the benchmark samples.

5.2.4 Frying of different batches (line number) of marrowfat peas

The samples of marrowfat peas were fried from the different line numbers (2014 – 2017). The preparation of soaking peas and the particular frying method were similar to the method in 5.2.2. After frying, the yield of the peas and defects per line number were measured by counting the whole peas, hard-seeded peas, split peas and loss of pericarp. The percent yield was computed as the number of whole peas divided by a total number of peas x 100 (excluding the count for loss of pericarp). Samples were taken for analysis of moisture content, break force (N, texture), and sensory evaluation.

5.2.5 Frying of peas soaked in different salt solutions

The dry MF1638A peas were soaked for 24 hours using different solutions (0.1% sodium bicarbonate, 0.1%, 1% and 2% sodium citrate). The treated peas were deep-fried at 160°C for 12 minutes. The samples were taken for moisture content, volume and break force (N, texture) to determine which treatments would produce peas with uniform texture.

5.3 RESULTS AND DISCUSSION

5.3.1 Analysis of benchmark samples

The benchmark samples of marrowfat peas are presented in Table 14 for comparison of moisture content, volume and break force (N, texture). The roasted pea sample (C) had the driest product with 1.23% while sample A and D (Kasugai and Kaoshong)had moisture less than 2.5%.The moisture of fried peas less than 2.5% was suggested by the US Dry Pea and Lentil Council in frying pulses ("Fried Pulses," 2016). The samples from Seng Hua Hng, which was sample E (fried green peas) and F (wasabi pea coated green peas) and sample B from Snapmaxx, had moisture content of 2.87%. Furthermore, samples E and F had the highest break force, being greater than 50 N, and had the lowest volume (0.70 and 0.54 ml/piece). The volume data indicates that products produced by SHH did not expand when compared to other benchmark samples (samples A, B, C and D). It is also suggested that the samples E and F had suffered case hardening. As the samples E and F had a tough texture characterised by a higher break force and moisture content compared to the rest of the samples. The benchmark samples Kaoshong, Kasugai and Snapmaxx were deemed to have a better and more acceptable texture than the SHH Products upon sensory evaluation.

Table 14. Moisture content, volume and break force of different benchmark samples.

Item	Moisture Content, % Wet Basis	Volume, mL per piece	Break Force, (N)
F- Camel Nuts Wasabi Peas [m]	4.97 ± 0.09[a]	0.70 ± 0.00[c]	53.66 ± 17.67[ab]
E - SHH Green Peas [m]	3.28 ± 0.10[b]	0.54 ± 0.02[d]	56.83 ± 12.23[a]
A - Kasugai Peas & You Japan[m]	2.62 ± 0.15[d]	0.85 ± 0.03[a]	36.03 ± 8.34[c]
C - Kasugai Roasted Green Peas Japan[m]	1.23 ± 0.13[e]	0.86 ± 0.03[a]	39.18 ± 9.69[c]
B - Snapmaxx Malaysia	2.87 ± 0.09[c]	0.81 ± 0.01[b]	42.67 ± 12.23[b]
D - Kaoshong Wasabi Peas	2.48 ± 0.10[d]	0.81 ± 0.01[b]	33.60 ± 10.23[c]

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.
[m] – superscript means that Midlands Seeds Ltd marrowfat peas may be used in these batches.

Samples A and D had the best texture among the benchmark samples analysed. The data from these samples was used as the target moisture, volume and texture of the laboratory fried peas.

5.3.2 Effect of frying temperature and time

Shown in Table 15, the 100 g soaked marrowfat peas were fried at the same temperature (160°C) but in different frying times to assess which frying time best suits the process. The chosen parameters should obtain the similar break force texture and volume of the reference samples that had an acceptable texture of approximately 33-39 N. The data indicates that the longer frying time had a minimal effect on volume as peas had no significant difference on the 8, 10 and 12 minute frying time. Additionally, on the moisture content, the longer the frying time, the dryer the peas became as more water evaporated from the peas. The p –value of the break force of peas was greater than the 0.05 (0.379). Thus, these suggest that there is no definite indication that a significant difference exists for the peas fried at different cooking times. The limitation behind the measurement of break force is that the measurement was on the surface only (first peak upon breaking). If the peas fried for a shorter time (6 minutes) had a hard surface, but were uncooked and moist inside, break force cannot be measured for these peas.

Table 15. Moisture content, volume and break force of fried peas (MF1638A) 160°C.

Frying Time	Moisture Content	Volume	Break Force (N)**
6	7.3 ± 0.10^{a}	0.89^{a}	39.13 ± 6.46
8	3.9 ± 0.02^{b}	0.86^{c}	32.09 ± 7.23
10	3.5 ± 0.13^{c}	0.85^{c}	37.19 ± 12.59
12	2.6 ± 0.08^{d}	0.86^{c}	34.62 ± 10.10

*** -** *a, b* Means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.
** - p-value is greater than 0.05

In comparison with the benchmark samples shown in Table 16, it can be inferred that all the fried laboratory samples (MF1638, 6, 10, and 12 minutes) are not significantly different, in terms of break force texture, from the preferred benchmark samples Kaoshong and Kasugai products. On the other hand, the Seng Hua Hng products Camel Nuts Wasabi peas and SHH Green peas are significantly different in break force texture from all other benchmark samples and laboratory fried peas. The volume of peas have significant differences from each other, but the importance was the volume of Seng Hua Hng products compared to all other samples, since both were less than 0.81 mL per piece. This would mean that the fried laboratory samples expanded well. Lastly, the moisture content of MF1638-12 minutes had no significant difference from the preferred samples Kaoshong and Kasugai peas.

Table 16. Comparison of moisture, volume and break force of benchmark samples and laboratory fried peas.

Item	Moisture Content, % Wet Basis	Volume, mL per piece	Break Force, (N)
F - Camel Nuts Wasabi Peas [m]	4.97 ± 0.09[b]	0.70 ± 0.00[e]	53.66 ± 17.67[a]
E - SHH Green Peas [m]	3.28 ± 0.10[e]	0.54 ± 0.02[f]	56.83 ± 12.23[a]
A - Kasugai Peas & You Japan[m]	2.62 ± 0.15[g]	0.85 ± 0.03[b]	36.03 ± 8.34[bc]
C - Kasugai Roasted Green Peas Japan[m]	1.23 ± 0.13[h]	0.86 ± 0.03[b]	39.18 ± 9.69[bc]
B - Snapmaxx Malaysia	2.87 ± 0.09[f]	0.81 ± 0.01[cd]	42.67 ± 12.23[b]
D - Kaoshong Wasabi Peas	2.48 ± 0.10[g]	0.81 ± 0.01[d]	33.60 ± 10.23[bc]
MF1638 – 6 minutes	7.3 ± 0.10[a]	0.89 ± 0.00[a]	39.13 ± 6.46[bc]
MF1638 – 8 minutes	3.9 ± 0.02[c]	0.86 ± 0.00[bc]	32.09 ± 7.23[c]
MF1638 – 10 minutes	3.5 ± 0.13[d]	0.85 ± 0.01[b]	37.19 ± 12.59[bc]
MF1638 – 12 minutes	2.6 ± 0.08[g]	0.86 ± 0.01[ab]	34.62 ± 10.10[bc]

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.
[m] – superscript means that Midlands Seeds Ltd marrowfat peas may be used in these batches.

Shown in Table 17, the volume and break force (texture) of peas fried in different temperature shows that there is no convincing evidence that a significant difference exists between the peas fried at 160, 170 and 180°C. However, a significant difference exists between the moisture content of the control (160°C) to samples fried at 170 and 180 °C. The peas that were fried in temperatures 170 and 180°C have higher moisture content than the control. The increase in moisture content of the higher temperatures would suggest that some peas experienced case hardening and the inner side of the peas did not dehydrate. As discussed earlier, higher temperatures, in general, would shorten the frying time, but it is possible that it would experience case hardening as it dehydrates the surface of the food product and give up moisture faster than the cells inside the product. The surface would become hard, thus preventing the evaporation of moisture inside the product.

Table 17. Moisture Content and Texture of Marrowfat Peas fried at different temperatures and time.

Line Number	**Fryer Load,** g	**Frying Temperature,** °C	**Frying Time,** min	**Moisture Content,** % Wet Basis	**Volume,** mL per piece**	**Break Force,** (N)**
MF1638A	100	160	12	2.59% ± 0.08[a]	0.86	34.62
MF1638A	100	170	7	3.04% ± 0.08	0.82	34.33
MF1638A	100	180	6	3.01% ± 0.08	0.84	32.69

- superscript letters mean within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence. ** - category with ** means that p > 0.05

The frying parameters chosen were used in frying 100 gram soaked peas from different line numbers at 160°C for 12 minutes. The marrowfat peas that were affected by hard-seededness phenomenon were not encountered in all the batches of fried marrowfat peas. This suggests that the percentage of hard-seeded peas found was not the cause of inconsistent texture of the fried peas. Furthermore, the yields of fried peas from different accessions obtained are 92 – 99% of whole peas as shown in Table 16. This suggests that peas that were fried at 160°C for 12 minutes recorded a yield of 92% or higher. There was no study found that could show the yield differences of fried peas. The quality issues split, and loss of pericarp may be due to the mechanical damage to the peas prior to soaking. Additionally, the frying process aggravates the damage due to the high rates of evaporation and the peas' volume expansion thus, splitting and removal of pericarp or seed coat was encountered.

Table 18. Fried peas' yield and quality defects after frying (160°C, 12 min).

Pea Name	Whole Peas	Splits	Loss of Pericarp
MF1401	93	7	4
MF1508	98	2	1
MF1522	97	3	4
MF1534	99	1	3
MF1552	97	3	3
MF1600	98	2	4
MF1614	96	4	6
MF1636A	98	2	1
MF1638A	97	3	7
MF1644A	96	4	5
MF1647	96	4	2
MF1655	97	3	1
MF1660	95	5	3
MF1722	92	8	7
MF1746	92	8	5

There were significant differences in the moisture content of fried peas (1.4% - 2.95%) and soaked peas (54.2% - 57.7%) from the different line numbers or batches. The possible reason behind the differences in moisture content for both the soaked and fried peas are because of the differences in the weight and sizes of peas per 100-gram sample. The entire batches pea to oil ratio was 1kg of peas to 40kg of frying oil, but the number of peas differ per 100 grams. As shown in the last column of Table 2, peas to oil ratio differ between different line number/batches of peas. Despite the significant differences in moisture content, the evaluation of sensory properties of the fried peas, especially the texture of the product was acceptable. This was supported by the measurement of breaking force (31.05 – 41.15 N) presented in Table 15, wherein the peas from different line number / batches that were fried at the same cooking and frying parameters (160°C, 12 minutes, 100 gram frying load) suggests that no conclusive evidence that a significant difference exists for this experiment (p-value >.05).

Table 19. Different pea batches fried at 160°C for 12 minutes

Line Number	Moisture Content, % (Wet Basis)		Break Force (N)**	Pea to Oil Ratio
	Before Frying	After Frying		Piece /mL
MF1401	57.3 ± 1.1^{ab}	1.80 ± 0.2^{cd}	41.15 ± 18.01	1/31
MF1500	56.3 ± 0.6^{abcd}	2.57 ± 0.3^{b}	33.95 ± 5.30	1/30
MF1508	55.5 ± 0.4^{cde}	2.46 ± 0.3^{b}	34.98 ± 10.82	1/26
MF1522	56.8 ± 1.7^{abcd}	2.95 ± 0.2^{a}	33.07 ± 7.08	1/25
MF1534	56.8 ± 0.3^{abc}	2.60 ± 0.2^{b}	31.43 ± 8.09	1/29
MF1552	55.2 ± 1.0^{cde}	2.66 ± 0.2^{ab}	31.05 ± 9.43	1/29
MF1600	54.2 ± 0.9^{e}	1.40 ± 0.0^{ef}	39.31 ± 8.87	1/31
MF1614	55.6 ± 0.1^{bcde}	1.60 ± 0.1^{cde}	36.52 ± 10.35	1/29
MF1636A	55.4 ± 0.8^{cde}	1.50 ± 0.1^{def}	33.07 ± 6.51	1/27
MF1638A	56.3 ± 0.5^{abcd}	1.90 ± 0.1^{c}	34.62 ± 10.10	1/34
MF1644A	55.3 ± 1.9^{cde}	1.30 ± 0.1^{f}	40.32 ± 9.81	1/28
MF1647	55.7 ± 0.9^{bcde}	2.40 ± 0.1^{b}	31.47 ± 9.23	1/34
MF1655	54.5 ± 0.8^{e}	1.30 ± 0.1^{ef}	40.09 ± 10.57	1/28
MF1660	55.5 ± 1.6^{cde}	1.50 ± 0.2^{def}	33.48 ± 12.93	1/29
MF1722	55.1 ± 0.7^{de}	2.50 ± 0.3^{b}	35.45 ± 11.00	1/29
MF1746	57.7 ± 0.9^{a}	2.65 ± 0.3^{ab}	33.47 ± 7.13	1/27

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.
** - p-value is greater than 0.05 (p =0.331)

5.3.3 Frying peas at different frying loads

Shown in Table 1, peas fried with a higher frying load needed longer time to cook the peas and reach the target moisture. The time necessary for the peas to cook, took longer due to the drop in frying temperature upon placing of the peas as the temperature took a longer time to recover (as shown in Figure 14). Rossell (2001) discusses that the frying time is valuable as the desired moisture should be achieved. If the frying time is not enough, the moisture content will still be high hence the product fails to be crispy and is susceptible to microbial growth. Low moisture content usually would render the appropriate texture (Rossell, 2001).

Table 20. Peas fried at different frying loads

Frying Load, g	Frying Time, min	Ratio of Peas to Oil (peas in kg/oil in L)	Moisture Content, % Wet Weight Basis	Break Force, (N)	Average Frying Oil Temperature per minute (°C/min)
100	12	1/40	2.1[a]	33.36 ± 3.74[a]	160
200	12	1/20	2.5[b]	35.65 ± 9.72[a]	158
500	14	1/8	2.3[b]	47.69 ± 10.23[b]	150
750	15	1/5.3	2.9[c]	59.79 ± 18.85[c]	146
1000	16	1/4	3.7[d]	49.10 ± 12.18[bc]	134

*** -** superscript letters means within a column, for each constituent with the same letter are not significantly different (P<0.05) as determined using Fisher LSD method at 95% confidence.

The range of moisture content (%, in wet weight basis) of the previously tested benchmark samples was 1.23 – 4.97% although most peas that have acceptable break force approximately 33-39 N texture have a moisture content that ranges from 1.23 to 2.87 % wet basis. In this scenario, the frying time was sufficient as the peas were evaluated by taste as a cooked pea without a raw or burnt taste is similar to the benchmark samples. The target range of moisture content was achieved as well. However, the crispiness of the product (break force) became hard as the frying load was set to 500, 750 and 1000 grams. This experiment suggests that as the frying load increases, the breaking force of pea increases. The increase in break force indicates that volume expansion on some peas was not met due to insufficient heat for the starch to gelatinise, thus creating uneven textures of fried peas. Additionally, starch gelatinisation is important in frying as starch helps in the water holding capacity and volume expansion (Rossell, 2001).

Shown in Figure 14, the frying loads, the frying oil temperature of 500, 750 and 1000 grams significantly dropped to 130°C or less as more thermal energy was needed to increase the temperature of the peas. The huge decline (> 29°C) in temperature caused less volume expansion in the latter three batches resulting in a tougher texture. Erickson (2007) discussed that if the oil temperature in deep frying drops greater than 28°C (50°F), a review should be promoted as it would result in a longer recovery time and, in this case, cause uneven expansion of peas resulting in hard texture on some peas. The break force of the peas with the frying load 500, 750 and 1000g are similar to the break force measurements of Seng Hua Hng products (uncoated peas 56.83 N ±12.23, wasabi peas 53.66 N ±17.67) which suggests that it is possible that the frying load used by the client was greater than the thermal energy

the oil can provide to the peas, as a consequence oil temperature decreased, frying time increased and the fried product was too hard.

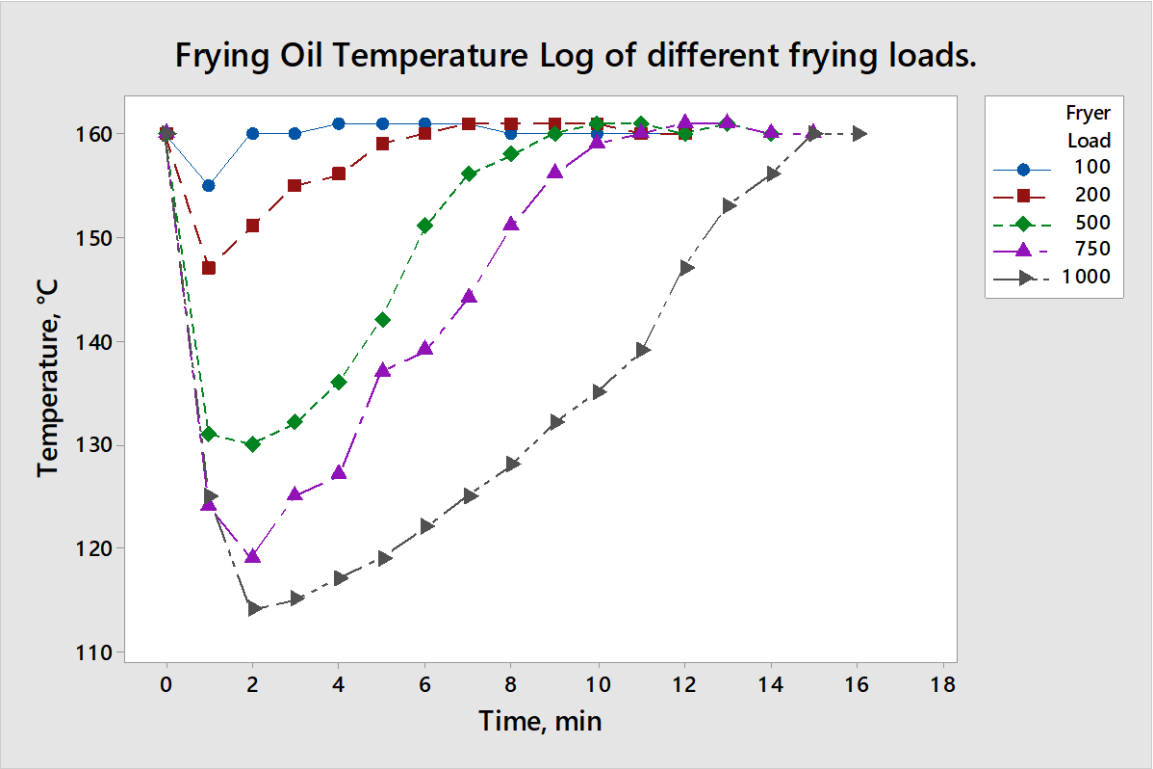

Figure 14. Frying Oil Temperature log for different frying loads.

The physicochemical properties of raw peas were correlated with the fried peas to check if there were factors that affect the frying texture and moisture from the peas' raw state. In Table 21, there is a significant negative correlation between the ratios of small size/large-sized peas to the weight of peas. This suggests that greater proportion of small peas would render a lighter 100-piece weight. There is a positive correlation between 100-piece weight and hydration capacity (0.316) since the heavier the peas are, the greater amount of water they can absorb. The fried peas' moisture content was positively correlated with the density of the peas. The denser peas had a higher moisture content after frying which can be correlated to its water-holding capacity. Lastly, the break force of the peas negatively correlated to moisture content. As a higher moisture content of fried peas, the fried product would fail to be crispy as low moisture content would render a crispy texture.

Table 21. Correlation between physicochemical properties of dried and fried marrowfat peas

	Dried / Raw Peas				Fried Peas	
	Size Ratio[1]	**Density[2]**	**100-piece Weight[3]**	**Hydration Capacity[4]**	**Moisture Content[5]**	**Break Force[6]**
Size Ratio[1]	1	0.030	-0.788**	0.279	0.215	-0.135
Density[2]		1	0.034	-0.161	0.527**	-0.115
100-piece Weight[3]			1	0.315*	-0.142	0.113
Hydration Capacity[4]				1	-0.206	0.061
Moisture Content[5]					1	-0.573**
Break Force[6]						1

Pearson Product-Moment Correlation (PPMC) Coefficient:
*- indicate significance at $p < 0.05$; $r(46) = 0.288$
** - indicate significance at $p < 0.01$; $r(46) = 0.372$
1 – Ratio of small size peas (<7.1mm) to big sized peas (>7.1mm), 2 – Density of dried peas(g/mL), 3 – Weight of dried peas in grams, 4- Hydration capacity of peas, 5- Moisture content of fried peas in % wet weight basis , 6- Break Force (N) of fried peas

5.3.4 Soaking solutions

The peas treated in soaking solutions of sodium bicarbonate and sodium citrate had effects on the fried peas at 160°C for 12 minutes. The moisture content of peas soaked at 0.1% sodium bicarbonate and 0.1% sodium citrate was significantly higher than the control sample. However, most treated samples had less than 2.5% moisture which was the acceptable moisture content. The use of 0.1% – 1% sodium citrate and 0.1% sodium bicarbonate does not have a significant difference with the control in terms of the break force texture while the 2% sodium citrate significantly affected the texture making it significantly softer. The increase in percentage use of sodium citrate (1 and 2%) decreases the standard deviation $12.76 < 4.52 < 3.53$ compared to the control (10.10). Since the use of 1% sodium citrate in soaking solution is not significantly different from the control in terms of texture, this soaking solution can be explored for use in hard-seeded peas' samples if it can reduce the soaking time. However, at the present time, the use of salt solutions is not practical since there was a low incidence of hard seeded peas, and the uniformity of texture can be obtained by adjusting the cooking parameters at no additional cost.

Table 22. Moisture Content and Texture of fried (160°C, 12 min) marrowfat peas with treatment in soaking solutions

Treatment	Moisture Content, % Wet Basis	Break Force (N)
No treatment, (control)	1.93 ± 0.16[a]	34.62 ± 10.10[a]
0.1% sodium bicarbonate	2.48 ± 0.06	31.58 ± 15.44[a]
0.1% sodium citrate	2.79 ± 0.05	28.71 ± 12.76[a]
1% sodium citrate	1.98 ± 0.22[a]	27.17 ± 4.52[a]
2% sodium citrate	2.00 ± 0.08[a]	19.29 ± 3.53

*** -** Means not labelled with the letter subscript "a" are significantly different from the control level mean ($P<0.05$) as determined using Fisher LSD method at 95% confidence.

5.4 CONCLUSION

Peas that were affected by the seed hardness phenomenon were not encountered in all the batches of fried marrowfat peas. This suggests that hard-seeded peas determined by the soaking test were not the cause of inconsistent and hard textures of the fried peas. Consistent break force (30-40 N), similar to the reference samples, was obtained with frying the 100-200 grams marrowfat peas at 160°C for 12 minutes in a laboratory fryer. The possible problem in texture inconsistencies of fried marrowfat peas can be attributed to the high ratio or amount of peas being fried in the oil. It is recommended that the peas are fried in a pea to oil ratio of 1/20 to 1/40.

CHAPTER 6: STARCH AND PROTEIN

6.1 INTRODUCTION

The starch properties and protein content of normal peas and peas affected with seed hardness were compared. Based on the literature discussed earlier, protein and starch properties have the water holding capability. Furthermore, the difference in starch gelatinisation or pasting properties would confirm if the starch structures of the peas have changed due to the effect of storage conditions.

6.2 MATERIALS AND METHODS

Samples of normal peas and hard-seeded peas were tested for their protein content. The marrowfat peas came from line numbers MF1655, MF1600, MF1644A, and these lines had the highest occurrence of hard-seeded peas. The normal peas and hard-seeded peas were separated by hydration of peas in 1:4 ratio of water to 12 hours. The peas that did not absorb water were the hard-seeded peas. The samples of normal peas and hard-seeded peas were ground using a Breville Coffee grinder for 10-20 seconds or until the peas were well-ground. Peas were also analysed for moisture content in order to compare the protein and starch content of peas via dry basis.

6.2.1 Protein Content

The modified Kjeldahl method was used based on the laboratory manual used by Massey University for the Food Chemistry laboratory course (Ravindran, 2016).

Digestion

Ground peas were accurately weighed (0.5 gram) in a weighing boat and were transferred to the digestion tube. The weighing boat was re-weighed to calculate the sample weight added. Two Kjeltabs (containing 3.5g K_2SO_4 and 0.0035 Se) were added followed by the 17 mL concentrated H_2SO_4. Samples were digested at 420°C for 20 minutes or more until the samples were transparent. The tubes were removed from the digester unit and were cooled in the fume hood until the tubes were cooled to ambient temperature. Seventy millilitres of RO (reversed osmosis) water was added, and the tubes were shaken gently.

Distillation and Titration

In a 250 mL labelled conical flask, 25 mL of 4% boric acid solution were added. After the distilling unit was prepared, the sample was connected to the digestion tube, and the conical flask with boric acid was placed in the receiver platform. The automatic button was pressed to add NaOH (80 mL) and start the distillation process (four minutes). After the distillation was complete, the conical flask was titrated with 0.01M HCl to a grey-mauve endpoint. The protein content analysis was done in triplicate.

6.2.2 Starch Isolation

The method of starch isolation in pulses was initially recorded by Kawamura (1955) while adding three methods was recommended by Schoch and Maywald (1968). The base method by Kawamura was done by treating the peas with 0.2% NaOH, washing with water and dehydration with the use of ethanol and water. The method suggested by Scoch and Maywald will help to prevent fermentation and enhance the technique for the hard to process samples like beans and a method for wrinkled seeds that needed additional steeping (Boye et al., 2010; Huang et al., 2007). The starch isolation used was based on the method of Schoch and Maywald (1968) modified to the availability of materials present at Massey University Institute of Food, Nutrition and Human Health.

Dried marrowfat peas weighing 300 g were ground using a Breville Coffee grinder. The sample was mixed 1L 0.3% NaOH solution (pH ranging 7-8) using a Silverson Mixer or a Warring Blender for 3-5 minutes. 100 mL 0.05% sodium azide solution was added to prevent fermentation of the solution and microbiological contamination. Ground peas were steeped overnight (12 hours) at room temperature (20°C). After the steeping process, samples were screened using a 0.5mm and 0.25mm terylene cloth. The filtered pulp was washed until most starch (white precipitate) was screened out. In a red pail, the liquid was allowed to stand for 2-3 hours to settle the starch at the bottom of the container. The supernatant liquid was decanted and was re-suspended in RO water. The liquid sample was then flowed in an inclined table (slope 0.5 inch/12.77mm) and washed twice to separate the starch from the fibrous pulp. Starch was dried in the table for five hours or until samples were powdery. The starch was scrapped off the table and placed in a clean container.

6.2.3 Pasting Properties of Pea Starch

The pasting properties of pea starch were determined using a Rapid Visco Analyser (RVA) model 4500 (Perten Instruments, Australia). Distilled water (25 ± 0.01 g) was added to the isolated pea starch (3 ± 0.01 g, dry basis) in an aluminium RVA canister to obtain a total constant sample weight of 28 ± 0.01 g. The masses of the water and pea starch were adjusted (±0.01 g) to compensate for the differences in moisture content of each sample. In all the tests, the moisture level of 12% was maintained, resulting in a relatively high solid percentage. Clumping was prevented by stirring with a plastic paddle after which pre-programmed profiles were initiated. All the RVA tests were done in triplicate.

6.3 RESULTS AND DISCUSSION

The protein content of normal peas and hard-seeded peas presented in Table 5 shows that no significant difference exists among them (p-value >0.05). The result obtained suggests that protein content of the marrowfat peas were not a factor contributing to the development of hard-seeded peas or influencing water absorption, since water absorption for both peas were almost similar (25.5% and 25.85% respectively).

Table 23. Protein of normal peas and hard-seeded peas

	Control Peas	Hard-seeded Peas
%Protein, (dry basis)*	25.46	25.53
Standard Deviation	1.46	1.18
Minimum	23.83	24.18
Maximum	27.1	28.21

*p = 0.121; p > 0.05

Similar to the results of the protein content, the starch pasting properties of hard-seeded peas and the control peas shown in Table 24 suggests that there is no conclusive evidence that a significant difference exists. The pasting properties peak, breakdown, final, setback viscosity have p values greater than 0.05. Similarly, no convincing proof that the gelatinisation temperature onset (pasting temperature) and peak viscosity of hard-seeded peas and control peas are altered, therefore, the hard-seeded peas may not have been established in the storage of peas.

The results of protein and starch properties of marrowfat peas affected by seed hardness would confirm that there are no changes in the protein content and starch structure due to storage condition.

Table 24. Pasting Properties of Marrowfat Peas Starch.

Viscosity*	State	Mean	Standard Deviation	Minimum	Maximum
Peak, cP	control peas	6684	30	6659	6728
	hard-seeded peas	6786	121	6712	6967
Trough, cP	control peas	3940	30	3905	3978
	hard-seeded peas	4002	114	3893	4159
Breakdown, cP	control peas	2745	42	2700	2792
	hard-seeded peas	2784	56	2705	2835
Final, cP	control peas	8248	81	8178	8337
	hard-seeded peas	8340	324	8065	8810
Setback, cP	control peas	4309	105	4203	4432
	hard-seeded peas	4338	401	4058	4917
Time*	**State**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Peak Time, min	control peas	4.3	0.0	4.3	4.3
	hard-seeded peas	4.2	0.1	4.1	4.3
Temperature*	**State**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Pasting, °C	control peas	70.1	0.4	69.5	70.3
	hard-seeded peas	70.1	0.4	69.5	70.3
Peak, °C	control peas	89.8	0.0	89.8	89.8
	hard-seeded peas	89.5	1.0	88.1	90.6
Hold, °C	control peas	89.2	0.5	88.8	89.7
	hard-seeded peas	89.7	1.1	88.1	90.6

*All pasting properties p value is > 0.05.

Peak Viscosity (0.154), Trough Viscosity (0.329), Breakdown Viscosity (0.309), Final Viscosity (0.604), Setback Viscosity (0.894), Peak Time (0.237), Pasting Temperature (0.966), Peak Temperature (0.681), Hold Temperature (0.506)

6.4 CONCLUSION

The experiments show that protein content and starch pasting properties of the marrowfat peas with seed hardness and the control was not a factor in contributing to the hard-seededness. The experiments for both protein and starch pasting properties would propose that the seed hardness found in marrowfat peas was not due to storage conditions.

CHAPTER 7: OVERALL CONCLUSION

From this study, it can be confirmed that the texture inconsistencies of the fried peas were not attributed to the seed hardness but to the frying parameters. The marrowfat peas affected by seed hardness (3.92%) were less than the allowable limit of Midlands Seed Ltd of 5%. Furthermore, the seed hardness identified at 12-hour soaking continued to absorb water similar to the normal peas when it was soaked for a longer time of 18 - 24 hours.

Based on this experiment, it can be concluded that the inconsistencies of the texture of Midlands Seeds' clients can be attributed to the frying conditions and parameters. The frying parameters, particularly the ratio of weight of peas to oil volume, are significant factors in contributing to the inconsistencies of the texture of fried peas. It is recommended to fry the peas at a pea-to-oil ratio range of 1/20 to 1/40 (kg of pea per L of oil), and the temperature of the fryer should not drop to 130°C. The 100-200 grams of soaked marrowfat peas fried at 160°C for 12 minutes on a laboratory fryer was the appropriate frying conditions to render a consistent crispy texture with break force ranging 30-40 N. Therefore, marrowfat peas being supplied by Midlands Seeds Ltd. have undergone sufficient quality control which provides the best quality of peas to produce fried pea snacks.

CHAPTER 8: RECOMMENDATIONS

It is recommended that the effects of environmental factors are studied, such as temperature and humidity in the development of seed and seed coat that may possibly cause the hard-seeded peas. The different agronomic practices of different farmers and contractors should be reviewed as to which practices produce the greatest amount of hard-seeded peas in a batch.

It was suggested by Argel and Paton (1999) that hot water can be used to induce physicochemical changes, thus improving the water uptake of hard-seeded peas. In order to have an efficient re-hydration of peas, it is recommended to study the effects of soaking temperature to the soaking time of marrowfat peas. The length of soaking time and temperature can be further tested in relation to the frying parameters and break force or texture of peas.

The physical/mechanical approach, such as stabbing through the seed coat of peas could be considered as an option if the hard-seeded peas' frequency significantly increases for more than the allowable level of 5%. However, it is also worth considering that stabbing of peas could result in the removal of the pericarp during frying. It is also recommended to experiment on the severity of seed coat damage that would result in a loss of pericarp during frying. It should also reflect the practicality of stabbing through the seed coat from an industrial point of view, since manual piercing was used in this experiment.

REFERENCES

Adebowale, K. O., & Lawal, O. S. (2003). Functional properties and retrogradation behaviour of native and chemically modified starch of mucuna bean (Mucuna pruriens). *Journal of the Science of Food and Agriculture, 83*(15), 1541-1546.

Alcázar-Alay, S. C., & Meireles, M. A. A. (2015). Physicochemical properties, modifications and applications of starches from different botanical sources. *Food Science and Technology (Campinas), 35*(2), 215-236.

An, D., Arntfield, S. D., Beta, T., & Cenkowski, S. (2010). Hydration properties of different varieties of Canadian field peas (Pisum sativum) from different locations. *Food Research International, 43*, 520-525. doi:10.1016/j.foodres.2009.09.034

Argel, P., & Paton, C. (1999). Overcoming Legume 14 hardseededness. *Forage seed production: tropical and subtropical species, 2*, 247-256.

Arnaudin, M., & Pyke, N. (2013). Environmental factors affecting bleaching in Marrowfat peas. *Agronomy New Zealand*.

Arntfield, S. D., & Maskus, H. D. (2011). 9 - Peas and other legume proteins *Handbook of Food Proteins* (pp. 233-266): Woodhead Publishing.

Asif, M., Rooney, L. W., Ali, R., & Riaz, M. N. (2013). Application and opportunities of pulses in food system: a review. *Critical Reviews in Food Science and Nutrition, 53*(11), 1168-1179.

Ayaquil, F. (2016). *Hydration Rate of Marrowfat Peas*. Experiment. School of Food and Nutrition. Massey University. Palmerston North, New Zealand.

Azani, N., Babineau, M., Bailey, C. D., Banks, H., Barbosa, A. R., Pinto, R. B., . . . Bruneau, A. (2017). A new subfamily classification of the Leguminosae based on a taxonomically comprehensive phylogeny The Legume Phylogeny Working Group (LPWG). *Taxon, 66*(1), 44-77.

Barrios Barrios, L., Osorio Mora, O., & Cerón Cárdenas, A. F. (2016). Study of the kinetics loss of water and oil absorption during the frying pea (Pisum sativum L.). *Acta Agronómica, 65*(3), 226-231.

Barrios, L. B., Mora, O. O., & Cárdenas, A. F. C. (2016). Study of the kinetics loss of water and oil absorption during the frying pea (Pisum sativum L.). *Acta Agronómica, 65*(3).

Beckingham, C. (2001). Snow peas and sugar snap peas. Retrieved August 25, 2017, from NSW Agriculture http://www.agric.nsw.gov.au

Black, R. G., Brouwer, J. B., Meares, C., & Iyer, L. (1998). Variation in physico-chemical properties of field peas (Pisum sativum). *Food Research International, 31*(2), 81-86. doi:http://dx.doi.org/10.1016/S0963-9969(98)00057-X

Bogracheva, T. Y., Morris, V. J., Ring, S. G., & Hedley, C. L. (1998). The granular structure of C-type pea starch and its role in gelatinization. *Biopolymers, 45*(4), 323-332. doi:10.1002/(SICI)1097-0282(19980405)45:4<323::AID-BIP6>3.0.CO;2-N

Boye, J. I., & Ma, Z. (2015). Chapter 8 - Impact of Processing on Bioactive Compounds of Field Peas A2 - Preedy, Victor *Processing and Impact on Active Components in Food* (pp. 63-70). San Diego: Academic Press.

Boye, J. I., Zare, F., & Pletch, A. (2010). Review: Pulse proteins: Processing, characterization, functional properties and applications in food and feed. *Food Research International, 43*, 414-431. doi:10.1016/j.foodres.2009.09.003

Calzetta Resio, A. N., Aguerre, R. J., & Suárez, C. (2003). Study of some factors affecting water absorption by amaranth grain during soaking. *Journal of Food Engineering, 60*(4), 391-396. doi:http://dx.doi.org/10.1016/S0260-8774(03)00062-1

Canadian Grain Commission. (2016, July 29, 2016). Peas – Chapter 16 | Official Grain Grading Guide. Retrieved from https://www.grainscanada.gc.ca/oggg-gocg/16/oggg-gocg-16d-eng.htm

Canadian Grain Commission. (2017, July 28, 2017). Specifications for sieves - Chapter 3 | Official Grain Grading Guide. Retrieved from https://www.grainscanada.gc.ca/oggg-gocg/03/oggg-gocg-3-eng.htm

Carver, B. F. (2009). *Wheat. [electronic resource] : science and trade*: Ames, Iowa : Wiley-Blackwell, 2009

1st ed.

Cerón, A. F., Osorio, O., & Garcés, L. F. (2016). Procesamiento de Arvejas (Pisum sativum L.). Parte 2: Cinética de Absorción de Agua en Semillas de Arveja, variedad San Isidro y Sureña. *Información tecnológica, 27*, 81-90.

Chadd, S., Davies, W., & Koivisto, J. (2004). *Pratical production of protein for food animals.* Paper presented at the FAO Animal Production and Health Proceedings (FAO).

Chaudhary, D. P., Kumar, S., & Langyan, S. (2014). *Maize : nutrition dynamics and novel uses*: New Delhi : Springer, [2014].

Chitra, U., Vimala, V., Singh, U., & Geervani, P. (1995). Variability in phytic acid content and protein digestibility of grain legumes. *Plant Foods for Human Nutrition (Formerly Qualitas Plantarum), 47*(2), 163-172.

Comstock, A. M., & Lothrop, B. E. (2012). *Peas: Cultivation, Varieties and Nutritional Uses*: Nova Science Publishers.

Crop and Food Research. (2001, April 2001). Midichi. *Broad Sheet,* 2.

Dahl, W. J., Foster, L. M., & Tyler, R. T. (2012). Review of the health benefits of peas (Pisum sativum L.). *British Journal of Nutrition, 108*(SupplementS1), S3-S10. doi:doi:10.1017/S0007114512000852

Dairy NZ. (2010). Facts and figures for New Zealand dairy farmers. *Hamilton: DairyNZ*.

de Almeida Costa, G. E., da Silva Queiroz-Monici, K., Pissini Machado Reis, S. M., & de Oliveira, A. C. (2006). Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes. *Food Chemistry, 94*(3), 327-330. doi:http://dx.doi.org/10.1016/j.foodchem.2004.11.020

de Ron, A. M. (2015). *Grain legumes*: New York : Springer, [2015].

Donovan, J. W. (1979). Phase transitions of the starch–water system. *Biopolymers, 18*(2), 263-275.

Dung, N. T. (2012). *Growth and development of peas in response to different inoculation methods and sowing dates.* (Thesis), Lincoln University. Retrieved from http://ezproxy.massey.ac.nz/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edsdnz&AN=edsdnz.31814815&site=eds-live&scope=site Available from EBSCOhost edsdnz database.

Eastman, J. E. (1995). Starch hydrolysates as sequesterers: Google Patents.

El-Tabey Shehata, A. M. (1992). Hard-to-cook phenomenon in legumes. *Food Reviews International, 8*(2), 191-221. doi:10.1080/87559129209540938

Englyst, K., Liu, S., & Englyst, H. (2007). Nutritional characterization and measurement of dietary carbohydrates. *European journal of clinical nutrition, 61*(S1), S19.

Erickson, M. D. (2007). *Deep frying : chemistry, nutrition, and practical applications*: Urbana, Ill. : AOCS Press, c2007

2nd ed.

Evans, I., & Haisman, D. (1982). The effect of solutes on the gelatinization temperature range of potato starch. *Starch-Stärke, 34*(7), 224-231.

Fabbri, A. D. T., & Crosby, G. A. (2016). Review Article: A review of the impact of preparation and cooking on the nutritional quality of vegetables and legumes. *International Journal of Gastronomy and Food Science, 3*, 2-11. doi:10.1016/j.ijgfs.2015.11.001

Fellows, P. J. (2009). 19 - Frying *Food Processing Technology (Third edition)* (pp. 555-577): Woodhead Publishing.

Fernando, N., & Dimsey, R. (2009). Snow pea and Sugar snap pea. Retrieved from http://agriculture.vic.gov.au/agriculture/horticulture/vegetables/vegetables-a-z/snow-pea-and-sugar-snap-pea

Finch-Savage, W. E., & Leubner-Metzger, G. (2006). Seed dormancy and the control of germination. *New Phytologist, 171*(3), 501-523.

Food and Agriculture Organization. (1994). Definition and classification of commodities: pulses and derived products. Retrieved from http://www.fao.org/es/faodef/fdef04e.htm
Food and Agriculture Organization. (2016). International Year of Pulses 2016. Retrieved from http://www.fao.org/pulses-2016/communications-toolkit/fact-sheets/en/
Fowler, C., Turner, D., & Siddique, K. (2006). Selection of field pea (Pisum sativum L.) cultivar and growing site improves germination and uniformity for sprout production. *Crop and Pasture Science, 57*(12), 1249-1257.
Fried Pulses. (2016). Retrieved from http://www.usapulses.com/ch-5-frying-pulses.html
Garcia-Vela, L. A., & Stanley, D. W. (1989). Protein Denaturation and Starch Gelatinization in Hard-To-Cook Beans. *Journal of Food Science, 54*(5), 1284-1286. doi:10.1111/j.1365-2621.1989.tb05974.x
Greenwood, R., Aves, C., & Catherwood, D. (2008). Making Peas Pay. *Pea Industry Development Group, Foundation for Arable Research. Lincoln, Canterbury: 68pp*.
Haladjian, N., Fayad, R., Toufeili, I., Shadarevian, S., Sidahmed, M., Baydoun, E., & Karwe, M. (2003). pH, TEMPERATURE AND HYDRATION KINETICS OF FABA BEANS (VICIA FABA L.). *Journal of Food Processing and Preservation, 27*(1), 9-20. doi:10.1111/j.1745-4549.2003.tb00497.x
Hashemi, Z., Yang, K., Yang, H., Jin, A., Ozga, J., & Chan, C. B. (2015). Cooking enhances beneficial effects of pea seed coat consumption on glucose tolerance, incretin, and pancreatic hormones in high-fat-diet-fed rats. *Applied Physiology, Nutrition, and Metabolism*(4), 323. doi:10.1139/apnm-2014-0380
Hohlberg, A. I., & Stanley, D. W. (1987). Hard-to-cook defect in black beans. Protein and starch considerations. *Journal of Agricultural and Food Chemistry, 35*(4), 571-576.
Hoover, R., & Sosulski, F. W. (1991). Composition, structure, functionality, and chemical modification of legume starches: a review. *Canadian Journal of Physiology and Pharmacology, 69*(1), 79-92. doi:10.1139/y91-012
Huang, J., Schols, H. A., van Soest, J. J. G., Jin, Z., Sulmann, E., & Voragen, A. G. J. (2007). Physicochemical properties and amylopectin chain profiles of cowpea, chickpea and yellow pea starches. *Food Chemistry, 101*(4), 1338-1345. doi:http://dx.doi.org/10.1016/j.foodchem.2006.03.039
Jackson, G. M., & Varriano-Marston, E. (1981). Hard-to-Cook Phenomenon in Beans: Effects of Accelerated Storage on Water Absorption and Cooking Time. *Journal of Food Science, 46*(3), 799-803. doi:10.1111/j.1365-2621.1981.tb15351.x
James, K. A. C., Butts, C. A., Morrison, S. C., Koolaard, J. P., Scott, M. F., Scott, R. E., . . . Bang, L. M. (2005). The effects of cultivar and heat treatment on protein quality and trypsin inhibitor content of New Zealand field peas. *New Zealand Journal of Agricultural Research, 48*(1), 117-124. doi:10.1080/00288233.2005.9513639
Jermyn, W. A. (1984). *Pea management and cultivar guide*: Christchurch [N.Z.] : Crop Research Division, DSIR, 1984.
Jermyn, W. A., & Batey, M. (1982). *Management strategies for less risk in pea cropping.* Paper presented at the Proceedings Twelfth Annual Conference Agronomy Society of New Zealand.
Khan, S. T. A., & Zimmer, R. C. (1989). *Production of field peas in Canada*: Ottawa : Communications Branch, Agriculture Canada, 1989

Rev. ed.
Khattak, M., & Ali, K. (2002). Physiological effects of dietary complex carbohydrates and its metabolites role in certain diseases. *Pakistan Journal of Nutrition, 1*(4), 161-168.
Khvostova, V. V. (1983). *Genetics and breeding of peas*: New Delhi : Oxonian Press, c1983.
Kigel, J., Rosental, L., & Fait, A. (2015). Seed Physiology and Germination of Grain Legumes *Grain Legumes* (pp. 327-363): Springer.
Kinyanjui, P. K., Njoroge, D. M., Makokha, A. O., Christiaens, S., Ndaka, D. S., & Hendrickx, M. (2015). Hydration properties and texture fingerprints of easy- and hard-to-cook bean varieties. *Food Science & Nutrition, 3*(1), 39-47. doi:10.1002/fsn3.188

Krokida, M., Oreopoulou, V., Maroulis, Z., & Marinos-Kouris, D. (2001). Deep fat frying of potato strips—quality issues. *Drying Technology, 19*(5), 879-935.
Kruger, J., Minnis-Ndimba, R., Mtshali, C., & Minnaar, A. (2015). Novel in situ evaluation of the role minerals play in the development of the hard-to-cook (HTC) defect of cowpeas and its effect on the in vitro mineral bioaccessibility. *Food Chemistry, 174*, 365-371. doi:http://dx.doi.org/10.1016/j.foodchem.2014.10.134
Leubner, G. (May 12, 2017). Seed Structure and Anatomy. Retrieved from http://www.seedbiology.de/structure.asp
Liu, C., Wang, S., Copeland, L., & Wang, S. (2015). Physicochemical properties and in vitro digestibility of starches from field peas grown in China. *LWT - Food Science and Technology, 64*(2), 829-836. doi:http://dx.doi.org/10.1016/j.lwt.2015.06.060
Logan, L. A., & Jermyn, W. A. (1985). *Production and utilization of New Zealand peas : an overview*: Christchurch [N.Z.] : Crop Research Division, DSIR, 1985.
Ma, F., Cholewa, E. W. A., Mohamed, T., Peterson, C. A., & Gijzen, M. (2004). Cracks in the Palisade Cuticle of Soybean Seed Coats Correlate with their Permeability to Water. *Annals of Botany, 94*(2), 213-228. doi:10.1093/aob/mch133
Ma, Y., Main, D., Coyne, C. J., Grusak, M. A., Mazourek, M., Cheng, P., & McGee, R. J. (2017). Genome-wide SNP identification, linkage map construction and QTL mapping for seed mineral concentrations and contents in pea (Pisum sativum L.). *BMC Plant Biology, 17*(1). doi:10.1186/s12870-016-0956-4
Makasheva, R. K. (1983). *The pea*: New Delhi : Oxonian, 1983.
Malcolmson, L., Frohlich, P., Boux, G., Bellido, A. S., Boye, J. I., & Warkentin, T. D. (2014). Aroma and flavour properties of Saskatchewan grown field peas (Pisum sativum L.). *Canadian Journal of Plant Science, 94*(8), 1419-1426. doi:10.4141/CJPS-2014-120
Martin, R., Wilson, D., Butler, R., Riddle, M., Russell, A., Catherwood, D., . . . Tregurtha, C. (2008). *Improving field pea yields on farm in Canterbury.* Paper presented at the Proceedings of the Agronomy Society of New Zealand New Zealand.
Mayer, A., & Poljakoff-Mayber, A. (1989). The Germination of Seeds. 4? ed: Londres: Pergamon Press.
McCrory, M. A., Hamaker, B. R., Lovejoy, J. C., & Eichelsdoerfer, P. E. (2010). Pulse consumption, satiety, and weight management. *Advances in Nutrition: An International Review Journal, 1*(1), 17-30.
Nikolopoulou, D., Grigorakis, K., Stasini, M., Alexis, M. N., & Iliadis, K. (2007). Differences in chemical composition of field pea (Pisum sativum) cultivars: Effects of cultivation area and year. *Food Chemistry, 103*(3), 847-852. doi:http://dx.doi.org/10.1016/j.foodchem.2006.09.035
Nleya, K. M., Minnaar, A., & de Kock, H. L. (2014). Relating physico-chemical properties of frozen green peas (Pisum sativum L.) to sensory quality. *Journal of the Science of Food and Agriculture, 94*(5), 857-865.
Oyedeji, A., Sobukola, O., Henshaw, F., Adegunwa, M., Ijabadeniyi, A., Sanni, L., & Tomlins, K. (2017). Effect of Frying Treatments on Texture and Colour Parameters of Deep Fat Fried Yellow Fleshed Cassava Chips. *Journal of Food Quality, 2017*.
Pedreschi, F., & Moyano, P. (2005). Oil uptake and texture development in fried potato slices. *Journal of Food Engineering, 70*(4), 557-563. doi:https://doi.org/10.1016/j.jfoodeng.2004.10.010
Pirhayati, M., Soltanizadeh, N., & Kadivar, M. (2011). Chemical and microstructural evaluation of 'hard-to-cook' phenomenon in legumes (pinto bean and small-type lentil). *International Journal of Food Science & Technology, 46*(9), 1884-1890. doi:10.1111/j.1365-2621.2011.02697.x
Plant and Food Research NZ Ltd. (2010). Plant Breeding - Field Peas. Retrieved from http://www.plantresearch.co.nz/field_peas.php
Powell, A. A., & Matthews, S. (1977). Deteriorative Changes in Pea Seeds (Pisum sativum L.) Stored in Humid or Dry Conditions. *Journal of Experimental Botany, 28*(1), 225-234. doi:10.1093/jxb/28.1.225

Pulse Canada. (2012). What is a Pulse. Retrieved from http://www.pulsecanada.com/food-health/what-is-a-pulse
Rachoñ, L., Palys, E., & Szumilo, G. (2012). Comparison of the chemical composition of spring durum wheat grain (Triticum durum) and common wheat grain (Triticum aestivum ssp. vulgare). *Journal of Elementology, 17*(1).
Ratnayake, W. S., Hoover, R., Shahidi, F., Perera, C., & Jane, J. (2001). Composition, molecular structure, and physicochemical properties of starches from four field pea (Pisum sativum L.) cultivars. *Food Chemistry, 74*(2), 189-202. doi:http://dx.doi.org/10.1016/S0308-8146(01)00124-8
Ratnayake, W. S., Hoover, R., & Warkentin, T. (2002). Pea starch: Composition, structure and properties - A review. *Starch/Staerke, 54*(6), 217-234. doi:10.1002/1521-379X(200206)54:6<217::AID-STAR217>3.0.CO;2-R
Ravindran, G. (2016). *Food Chemistry Laboratory Manual*. Palmerston North: Massey University.
Rebello, C. J., Greenway, F. L., & Finley, J. W. (2014). Whole Grains and Pulses: A Comparison of the Nutritional and Health Benefits. *Journal of Agricultural and Food Chemistry, 62*(29), 7029-7049. doi:10.1021/jf500932z
Ross, K., Arntfield, S., Beta, T., Cenkowski, S., & Fulcher, R. (2008). Understanding and modifying water uptake of seed coats through characterizing the glass transition. *International journal of food properties, 11*(3), 544-560.
Rossell, J. B. (2001). *Frying : improving quality*: Boca Raton, FL : CRC Press ; Cambridge, England : Woodhead Pub., 2001.
Schatz, B., & Endres, G. (2009). Field pea production. *NDSU extension service A-1166 (revised)*, 1-8.
Schoch, T. J., & Maywald, E. C. (1968). Preparation and properties of various legume starches. *Cereal Chem, 45*(6), 564-573.
Sefa-Dedeh, S., Stanley, D. W., & Voisey, P. W. (1979). EFFECT OF STORAGE TIME AND CONDITIONS ON THE HARD-TO-COOK DEFECT IN COWPEAS (Vigna unguiculata). *Journal of Food Science, 44*(3), 790-795. doi:10.1111/j.1365-2621.1979.tb08503.x
Shen, S., Hou, H., Ding, C., Bing, D.-J., Lu, Z.-X., & Navabi, A. (2016). Protein content correlates with starch morphology, composition and physicochemical properties in field peas. *Canadian Journal of Plant Science, 96*(3), 404.
Singh, A., Meena, M., Kumar, D., Dubey, A. K., & Hassan, M. I. (2015). Structural and Functional Analysis of Various Globulin Proteins from Soy Seed. *Critical Reviews in Food Science and Nutrition, 55*(11), 1491-1502. doi:10.1080/10408398.2012.700340
Singh, B. K., Hotti, A. H., Singh, P., & Mandal, N. (2016). Analysis of seed storage protein diversity among twelve different cultivars of Pea (Pissum sativum L.) using SDS-PAGE. *Electronic Journal of Plant Breeding, 7*(2), 378-385.
Singh, N., Kaur, N., Rana, J. C., & Sharma, S. K. (2010). Diversity in seed and flour properties in field pea (Pisum sativum) germplasm. *Food Chemistry, 122*(3), 518-525. doi:http://dx.doi.org/10.1016/j.foodchem.2010.02.064
Sinha, S. K. (1977). *Food legumes : distribution, adaptability and biology of yield*: Rome : Food and Agriculture Organization of the United Nations, 1977.
Smýkal, P., Coyne, C. J., Ambrose, M. J., Maxted, N., Schaefer, H., Blair, M. W., . . . Besharat, N. (2015). Legume crops phylogeny and genetic diversity for science and breeding. *Critical Reviews in Plant Sciences, 34*(1-3), 43-104.
Sopade, P. A., Ajisegiri, E. S., & Badau, M. H. (1992). The use of Peleg's equation to model water absorption in some cereal grains during soaking. *Journal of Food Engineering, 15*(4), 269-283. doi:http://dx.doi.org/10.1016/0260-8774(92)90010-4
Sosa-Morales, M. E., & Vélez-Ruiz, J. F. (2009). *Food Processing and Engineering Topics*. New York: Nova Science Publishers, Inc.
Spurný, M. (1964). Changes in the permeability of the seed coat in connection with the development of suberin adcrustations of the macrosclereids from the seed coat of the pea (Pisum sativum L.). *Flora oder Allgemeine Botanische Zeitung, 154*(4), 547-567.

ŠtěrbovÃ¡, L., BradovÃ¡, J., DvořÃ¡ček, V., SedlÃ¡ček, T., HolasovÃ¡, M., FiedlerovÃ¡, V., & SmrčkovÃ¡, P. (2016). Influence of technological processing of wheat grain on starch digestibility and resistant starch content. *Starch/Staerke, 68*(7-8), 593-602. doi:10.1002/star.201500162

Stevens, D., & Elton, G. (1971). Thermal properties of the starch/water system Part I. measurement of heat of gelatinisation by differential scanning calorimetry. *Starch-Stärke, 23*(1), 8-11.

Stevenson, D. G., Doorenbos, R. K., Jane, J. l., & Inglett, G. E. (2006). Structures and functional properties of starch from seeds of three soybean (Glycine max (L.) Merr.) varieties. *Starch-Stärke, 58*(10), 509-519.

Tavano, O. L., Neves, V. A., & da Silva Júnior, S. I. (2016). In vitro versus in vivo protein digestibility techniques for calculating PDCAAS (protein digestibility-corrected amino acid score) applied to chickpea fractions. *Food Research International, 89*, 756-763.

Thomas, J. (2013, Ocotber 2, 2013). Seed structure and germination. Retrieved from http://cheppila.com/?p=311

Tiedemann, J., Neubohn, B., & Müntz, K. (2000). Different functions of vicilin and legumin are reflected in the histopattern of globulin mobilization during germination of vetch (Vicia sativa L.). *Planta, 211*(1), 1-12. doi:10.1007/s004250000259

Tiwari, B., Gowen, A., & McKenna, B. (2011). *Pulse foods: Processing, quality and nutraceutical applications*: Academic Press.

Tiwari, B., & Singh, N. (2012). *Pulse chemistry and technology*: Royal Society of Chemistry.

Tiwari, B., Valdramidis, V., O'Donnell, C., Muthukumarappan, K., Bourke, P., & Cullen, P. J. (2009). Application of natural antimicrobials for food preservation. *Journal of Agricultural and Food Chemistry, 57*(14), 5987-6000. doi:10.1021/jf900668n

Tosh, S. M., & Yada, S. (2010). Review: Dietary fibres in pulse seeds and fractions: Characterization, functional attributes, and applications. *Food Research International, 43*, 450-460. doi:10.1016/j.foodres.2009.09.005

Troy, D., Ojha, K. S., Kerry, J., & Tiwari, B. Sustainable and consumer-friendly emerging technologies for application within the meat industry: An overview. *Meat Science*. doi:http://dx.doi.org/10.1016/j.meatsci.2016.04.002

Wang, N., & Castonguay, G. (2013). Effect of maturity on physicochemical and cooking characteristics in yellow peas (Pisum sativum). *Canadian Journal of Plant Science, 94*(3), 565-571. doi:10.4141/cjps2012-331

Wang, N., Hatcher, D. W., Warkentin, T. D., & Toews, R. (2010). Effect of cultivar and environment on physicochemical and cooking characteristics of field pea (Pisum sativum). *Food Chemistry, 118*(1), 109-115. doi:http://dx.doi.org/10.1016/j.foodchem.2009.04.082

White, J., Jermyn, W. A., & Wratt, G. (1987). The importance of pea in New Zealand arable agriculture. *Peas: management for quality. Agronomy Society of New Zealand special publication, 6*, 7-11.

Woodstock, L. (1988). Seed imbibition: a critical period for successful germination. *Journal of Seed Technology*, 1-15.

Yi, J., Njoroge, D. M., Sila, D. N., Kinyanjui, P. K., Christiaens, S., Bi, J., & Hendrickx, M. E. (2016). Detailed analysis of seed coat and cotyledon reveals molecular understanding of the hard-to-cook defect of common beans (Phaseolus vulgaris L.). *Food Chemistry, 210*, 481-490. doi:http://dx.doi.org/10.1016/j.foodchem.2016.05.018

Yousif, A., Batey, I. L., Larroque, O. R., Curtin, B., Bekes, F., & Deeth, H. C. (2003). Effect of storage of adzuki bean (Vigna angularis) on starch and protein properties. *LWT-Food Science and Technology, 36*(6), 601-607.

Yousif, A., Kato, J., & Deeth, H. C. (2007). Effect of Storage on the Biochemical Structure and Processing Quality of Adzuki Bean (Vigna angularis). *Food Reviews International, 23*(1), 1-33. doi:10.1080/87559120600865172

Zhu, Y.-y., Zhang, M., & Wang, Y.-q. (2015). Vacuum frying of peas: effect of coating and pre-drying. *Journal of food science and technology, 52*(5), 3105-3110. doi:10.1007/s13197-014-1314-x

APPENDIX A

Marrowfat Peas Documents

MIDLANDS Seed

Midlands Seed Limited
393-405 West Street,
Ashburton 7700, New Zealand,
PO Box 65, Ashburton 7740

p +64 3 308 1265
f +64 3 308 1266
e office@midlands.co.nz
www.midlands.co.nz

21 February 2017

Institute of Food Science and Technology
Massey University
C/- Allan Hardacre
SH 57
PH 06-356-9099 xn 83018
021-173-5373
Palmerston North

Attention: **Froilan Ayaquil**

Dear Froilan,

We have much pleasure in handing you the under-mentioned samples of Marrowfat Peas for testing.

No. ***MSL2731 (2015 Crop)***

Line Number	Variety	Boil Test 1-5	Stone Peas	Crop Harvest Year
MF1500	Marrowfat Peas	5	0	2015
MF1508	Marrowfat Peas	2	0	2015
MF1522	Marrowfat Peas	5	0	2015
MF1534	Marrowfat Peas	5	0	2015
MF1552	Marrowfat Peas	2	1	2015

Cook Test: 0-5 0 is poor with 5 being good

Yours Faithfully,

Brett Colgan
Midlands Seed Ltd

MIDLANDS Seed

Midlands Seed Limited
393-405 West Street,
Ashburton 7700, New Zealand,
PO Box 65, Ashburton 7740

p +64 3 308 1265
f +64 3 308 1266
e office@midlands.co.nz
www.midlands.co.nz

21 February 2017

Institute of Food Science and Technology
Massey University
C/- Allan Hardacre
SH 57
PH 06-356-9099 xn 83018
021-173-5373
Palmerston North

Attention: **Froilan Ayaquil**

Dear Froilan,

We have much pleasure in handing you the under-mentioned samples of Marrowfat Peas for testing.

No. MSL2731 (2014 Crop)

Line Number	Variety	Boil Test 1-5	Stone Peas	Crop Harvest Year
MF1401	Marrowfat Peas	NA	NA	2014

Cook Test: 0-5 0 is poor with 5 being good

Yours Faithfully,

Brett Colgan
Midlands Seed Ltd

MIDLANDS SEED LIMITED
393-405 WEST ST.
ASHBURTON 7700
NEW ZEALAND
PO BOX 65
ASHBURTON 7740
NEW ZEALAND
Phone (03) 308 1265
Fax (03) 308 1266
International: +64 3 308 1265
E: office@midlands.co.nz
W: www.midlands-seed.co.nz

27 September 2016

Institute of Food Science and Technology
Massey University
C/- Allan Hardacre
SH 57
PH 06-356-9099 xn 83018
021-173-5373
Palmerston North

Attention: **Allan Hardacre**

Dear Allan,

We have much pleasure in handing you the under-mentioned samples of Marrowfat Peas for testing.

No. ***MSL2694***

Line Number	Variety	Boil Test 1-5	Stone Peas	Sample Weight
MF1600	Marrowfat Peas	5	0	10 Kg
MF1614B	Marrowfat Peas	2	1	10 Kg
MF1636A	Marrowfat Peas	2.5	1	10 Kg
MF1638A	Marrowfat Peas	4.5	0	10 Kg
MF1647	Marrowfat Peas	5	4	10 Kg
MF1655	Marrowfat Peas	5	0	10 Kg
MF1660	Marrowfat Peas	3	5	10 Kg

Cook Test: 0-5 0 is poor with 5 being good

Yours Faithfully,

Brett Colgan
Midlands Seed Ltd

MIDLANDS Seed

Midlands Seed Limited
393-405 West Street,
Ashburton 7700, New Zealand,
PO Box 65, Ashburton 7740

p +64 3 308 1265
f +64 3 308 1266
e office@midlands.co.nz
www.midlands.co.nz

23 February 2017

Institute of Food Science and Technology
Massey University
C/- Allan Hardacre
SH 57
PH 06-356-9099 xn 83018
021-173-5373
Palmerston North

Attention: **Froilan Ayaquil**

Dear Froilan,

We have much pleasure in handing you the under-mentioned samples of Marrowfat Peas for testing.

No. ***MSL2732***

Line Number	Sample #	Comments
MF1646	1	FD – Ex harvest from farm
MF1646	2	Small peas fallen through the screen (2nds)
MF1646	3	Small peas fallen through the screen (2nds)
MF1646	4	Peas ex De-stoner machine
MF1646	5	Peas ex Gravity Table
MF1646	6	Peas rejected by colour sorter
MF1646	7	Final Dressed product to send to customer

Yours Faithfully,

Brett Colgan
Midlands Seed Ltd

APPENDIX B

Raw data and Statistical Analyses

RAW DATA PROTEIN CONTENT

Line Number	State of Peas	Protein Content
MF1600	normal	24.13
MF1600	normal	23.53
MF1600	normal	23.38
MF1655	normal	26.56
MF1655	normal	26.76
MF1655	normal	27.10
MF1644A	normal	26.44
MF1644A	normal	26.18
MF1644A	normal	25.04

Line Number	State of Peas	Protein Content
MF1600	stone	26.40
MF1600	stone	25.46
MF1600	stone	28.21
MF1655	stone	25.05
MF1655	stone	24.56
MF1655	stone	24.18
MF1644A	stone	25.36
MF1644A	stone	25.41
MF1644A	stone	25.18

PROTEIN OF PEAS MINITAB SESSION

General Linear Model: Protein Content versus State of Peas, Line Number

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
State of Peas	Fixed	2	normal, stone
Line Number	Fixed	3	MF1600, MF1644A, MF1655

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
State of Peas	1	0.0262	0.0262	0.01	0.909
Line Number	2	0.9030	0.4515	0.23	0.796
Error	14	27.2793	1.9485		
Lack-of-Fit	2	21.3640	10.6820	21.67	0.000
Pure Error	12	5.9153	0.4929		
Total	17	28.2085			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.39589	3.29%	0.00%	0.00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	25.496	0.329	77.49	0.000	
State of Peas					
normal	-0.038	0.329	-0.12	0.909	1.00
Line Number					
MF1600	-0.311	0.465	-0.67	0.514	1.33
MF1644A	0.105	0.465	0.23	0.825	1.33

Regression Equation

Protein Content = 25.496 - 0.038 State of Peas_normal
+ 0.038 State of Peas_stone
- 0.311 Line Number_MF1600
+ 0.105 Line Number_MF1644A
+ 0.206 Line Number_MF1655

Fits and Diagnostics for Unusual Observations

Obs	Protein Content	Fit	Resid	Std Resid	
12	28.211	25.222	2.989	2.43	R

R Large residual

Descriptive Statistics: Protein Content

Variable	State of Peas	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
Protein Content	normal	9	0	25.457	0.487	1.461	23.380	23.830	26.177	26.661
	stone	9	0	25.534	0.393	1.178	24.180	24.805	25.360	25.927

Variable	State of Peas	Maximum
Protein Content	normal	27.101
	stone	28.211

Residual Plots for Protein Content

RAW DATA AND MINITAB SESSIONS OF TABLES OF CHARACTERISTICS OF PEAS

Line Number	State	Peak	Trough 1	Breakdown	Final	Setback	Peak Time	Pasting Temperature	Peak Temperature	Hold Temperature
MF1600	STONE PEAS	6737	3950	2787	8244	4294	4	70.3	91	88
MF1600	STONE PEAS	6728	3893	2835	8810	4917	4	69.5	88	91
MF1600	< 6.7	6678	3978	2700	8181	4203	4	70.3	90	90
MF1600	< 6.7	6728	3936	2792	8178	4242	4	70.3	90	89
MF1644A	STONE PEAS	6712	4007	2705	8065	4058	4	70.3	90	90
MF1644A	STONE PEAS	6967	4159	2808	8240	4081	4	70.3	90	90
MF1644A	< 6.7	6659	3939	2720	8297	4358	4	70.3	90	89
MF1644A	< 6.7	6672	3905	2767	8337	4432	4	69.5	90	90

RAW DATA AND MINITAB SESSIONS OF TABLES OF CHARACTERISTICS OF PEA STARCH PASTING PROPERTIES

General Linear Model: Peak versus State

```
Method

Factor coding  (-1, 0, +1)

Factor Information

Factor  Type   Levels  Values
State   Fixed       2  < 6.7, STONE PEAS

Analysis of Variance
Source   DF  Adj SS  Adj MS  F-Value  P-Value
  State   1   20706   20706     2.66    0.154
Error     6   46743    7790
Total     7   67449

Model Summary
      S    R-sq  R-sq(adj)  R-sq(pred)
88.2636  30.70%     19.15%       0.00%

Coefficients
Term        Coef  SE Coef  T-Value  P-Value   VIF
Constant  6735.1     31.2   215.83    0.000
State
  < 6.7    -50.9     31.2    -1.63    0.154  1.00

Regression Equation

Peak = 6735.1 - 50.9 State_< 6.7 + 50.9 State_STONE PEAS

Fits and Diagnostics for Unusual Observations
                            Std
Obs    Peak     Fit  Resid  Resid
  6  6967.0  6786.0  181.0   2.37  R

R  Large residual
```

Residual Plots for Peak

General Linear Model: Trough 1 versus State

```
Method

Factor coding  (-1, 0, +1)

Factor Information

Factor  Type   Levels  Values
State   Fixed       2  < 6.7, STONE PEAS

Analysis of Variance
Source   DF  Adj SS  Adj MS  F-Value  P-Value
  State   1    7875    7875     1.13    0.329
Error     6   41944    6991
Total     7   49819

Model Summary
      S    R-sq  R-sq(adj)  R-sq(pred)
83.6100  15.81%      1.78%       0.00%

Coefficients
Term        Coef  SE Coef  T-Value  P-Value   VIF
Constant  3970.9     29.6   134.33    0.000
State
  < 6.7    -31.4     29.6    -1.06    0.329  1.00

Regression Equation

Trough 1 = 3970.9 - 31.4 State_< 6.7 + 31.4 State_STONE PEAS

Fits and Diagnostics for Unusual Observations
                              Std
Obs  Trough 1     Fit  Resid  Resid
  6    4159.0  4002.2  156.8   2.16  R

R  Large residual
```

Residual Plots for Trough 1

General Linear Model: Breakdown versus State

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
State	Fixed	2	< 6.7, STONE PEAS

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
State	1	3042	3042	1.24	0.309
Error	6	14769	2462		
Total	7	17811			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
49.6143	17.08%	3.26%	0.00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2764.3	17.5	157.59	0.000	
State					
< 6.7	-19.5	17.5	-1.11	0.309	1.00

Regression Equation

Breakdown = 2764.3 - 19.5 State_< 6.7 + 19.5 State_STONE PEAS

Residual Plots for Breakdown

General Linear Model: Final versus State

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
State	Fixed	2	< 6.7, STONE PEAS

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
State	1	16745	16745	0.30	0.604
Error	6	335451	55909		
Total	7	352196			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
236.450	4.75%	0.00%	0.00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	8294.0	83.6	99.21	0.000	
State					
< 6.7	-45.8	83.6	-0.55	0.604	1.00

Regression Equation

Final = 8294.0 - 45.8 State_< 6.7 + 45.8 State_STONE PEAS

Fits and Diagnostics for Unusual Observations

Obs	Final	Fit	Resid	Std Resid	
2	8810	8340	470	2.30	R

R Large residual

General Linear Model: Setback versus State

```
Method

Factor coding  (-1, 0, +1)

Factor Information

Factor  Type   Levels  Values
State   Fixed       2  < 6.7, STONE PEAS

Analysis of Variance
Source   DF  Adj SS  Adj MS  F-Value  P-Value
  State   1    1653    1653     0.02    0.894
Error     6  514880   85813
Total     7  516533

Model Summary
      S   R-sq  R-sq(adj)  R-sq(pred)
292.939  0.32%      0.00%       0.00%

Coefficients
Term      Coef  SE Coef  T-Value  P-Value   VIF
Constant  4323      104    41.74    0.000
State
  < 6.7    -14      104    -0.14    0.894  1.00

Regression Equation

Setback = 4323 - 14 State_< 6.7 + 14 State_STONE PEAS

Fits and Diagnostics for Unusual Observations

                            Std
Obs  Setback   Fit  Resid  Resid
  2     4917  4338    580   2.28  R

R  Large residual
```

Residual Plots for Final

Residual Plots for Setback

General Linear Model: Peak Time versus State

```
Method

Factor coding  (-1, 0, +1)

Factor Information

Factor  Type   Levels  Values
State   Fixed       2  < 6.7, STONE PEAS

Analysis of Variance

Source   DF    Adj SS    Adj MS  F-Value  P-Value
  State   1  0.005000  0.005000     1.72    0.237
Error     6  0.017400  0.002900
Total     7  0.022400

Model Summary
        S    R-sq  R-sq(adj)  R-sq(pred)
0.0538516  22.32%      9.38%       0.00%

Coefficients
Term        Coef  SE Coef  T-Value  P-Value   VIF
Constant  4.2600   0.0190   223.75    0.000
State
  < 6.7   0.0250   0.0190     1.31    0.237  1.00

Regression Equation

Peak Time = 4.2600 + 0.0250 State_< 6.7 - 0.0250 State_STONE
PEAS

Fits and Diagnostics for Unusual Observations

Obs  Peak Time     Fit    Resid  Std Resid
  2     4.1300  4.2350  -0.1050      -2.25  R
```

```
R  Large residual
```

General Linear Model: Pasting Temperature versus State

```
Method

Factor coding  (-1, 0, +1)

Factor Information

Factor  Type   Levels  Values
State   Fixed       2  < 6.7, STONE PEAS

Analysis of Variance

Source   DF    Adj SS    Adj MS  F-Value  P-Value
  State   1  0.000312  0.000312     0.00    0.966
Error     6  0.944375  0.157396
Total     7  0.944687

Model Summary

       S   R-sq  R-sq(adj)  R-sq(pred)
0.396731  0.03%      0.00%       0.00%


Coefficients

Term        Coef  SE Coef  T-Value  P-Value   VIF
Constant  70.069    0.140   499.54    0.000
State
  < 6.7    0.006    0.140     0.04    0.966  1.00


Regression Equation

Pasting Temperature = 70.069 + 0.006 State_< 6.7 -
 0.006 State_STONE PEAS
```

Residual Plots for Pasting Temperature

Residual Plots for Peak Time

General Linear Model: Peak Temperature versus State

```
Method

Factor coding  (-1, 0, +1)

Factor Information

Factor  Type   Levels  Values
State   Fixed       2  < 6.7, STONE PEAS

Analysis of Variance
Source   DF  Adj SS  Adj MS  F-Value  P-Value
  State   1  0.1013  0.1013     0.19    0.681
Error     6  3.2688  0.5448
Total     7  3.3700

Model Summary
       S   R-sq  R-sq(adj)  R-sq(pred)
0.738100  3.00%      0.00%       0.00%

Coefficients

Term        Coef  SE Coef  T-Value  P-Value   VIF
Constant  89.650    0.261   343.54    0.000
State
  < 6.7    0.113    0.261     0.43    0.681  1.00

Regression Equation

Peak Temperature = 89.650 + 0.113 State_< 6.7 -
 0.113 State_STONE PEAS

Fits and Diagnostics for Unusual Observations
            Peak
Obs  Temperature     Fit   Resid  Std Resid
  2       88.100  89.537  -1.438      -2.25  R
```

```
R  Large residual
```

General Linear Model: Hold Temperature versus State

```
Method

Factor coding  (-1, 0, +1)

Factor Information

Factor  Type   Levels  Values
State   Fixed       2  < 6.7, STONE PEAS

Analysis of Variance

Source   DF  Adj SS  Adj MS  F-Value  P-Value
  State   1  0.3828  0.3828     0.50    0.506
Error     6  4.6044  0.7674
Total     7  4.9872

Model Summary

       S   R-sq  R-sq(adj)  R-sq(pred)
0.876011  7.68%      0.00%       0.00%

Coefficients

Term        Coef  SE Coef  T-Value  P-Value   VIF
Constant  89.444    0.310   288.79    0.000
State
  < 6.7   -0.219    0.310    -0.71    0.506  1.00

Regression Equation

Hold Temperature = 89.444 - 0.219 State_< 6.7 + 0.219 State_STONE PEAS

Fits and Diagnostics for Unusual Observations
           Hold
Obs  Temperature     Fit   Resid  Std Resid
  1       88.100  89.663  -1.563      -2.06  R

R  Large residual
```

Residual Plots for Peak Temperature

Residual Plots for Hold Temperature

Descriptive Statistics: Peak, Trough 1, Breakdown, Final, Setback, Peak Time, ...

Variable	State	Mean	StDev	Minimum	Maximum
Peak	< 6.7	6684.3	30.2	6659.0	6728.0
	STONE PEAS	6786.0	121.1	6712.0	6967.0
Trough 1	< 6.7	3939.5	29.9	3905.0	3978.0
	STONE PEAS	4002.3	114.4	3893.0	4159.0
Breakdown	< 6.7	2744.8	42.2	2700.0	2792.0
	STONE PEAS	2783.8	56.1	2705.0	2835.0
Final	< 6.7	8248.3	81.1	8178.0	8337.0
	STONE PEAS	8340	324	8065	8810
Setback	< 6.7	4308.8	105.3	4203.0	4432.0
	STONE PEAS	4338	401	4058	4917
Peak Time	< 6.7	4.2850	0.0300	4.2700	4.3300
	STONE PEAS	4.2350	0.0700	4.1300	4.2700
Pasting Temperature	< 6.7	70.075	0.417	69.450	70.300
	STONE PEAS	70.063	0.375	69.500	70.250
Peak Temperature	< 6.7	89.763	0.0250	89.750	89.800
	STONE PEAS	89.537	1.044	88.100	90.600
Hold Temperature	< 6.7	89.225	0.548	88.750	89.700
	STONE PEAS	89.662	1.111	88.100	90.550

RAW DATA OF PEA BATCHES, SIZE, SOAKING TIME, WATER ABSORBED AND STONE PEAS

Line Number	Size	Soaking Time	Water Absorbed	Stone Peas 100pcs.
MF1600	< 6.7	12	101.67	11
MF1600	< 6.7	12	103.54	11
MF1600	< 6.7	18	113.96	8
MF1600	< 6.7	18	119.47	6
MF1600	< 6.7	24	126.26	2
MF1600	< 6.7	24	123.45	2
MF1600	6.7 - 7.1	12	111.46	2
MF1600	6.7 - 7.1	12	105.40	8
MF1600	6.7 - 7.1	18	115.00	0
MF1600	6.7 - 7.1	18	116.08	3
MF1600	6.7 - 7.1	24	122.09	0
MF1600	6.7 - 7.1	24	119.64	0
MF1600	7.1 - 8.0	12	110.43	4
MF1600	7.1 - 8.0	12	105.96	4
MF1600	7.1 - 8.0	18	116.70	2
MF1600	7.1 - 8.0	18	112.19	0
MF1600	7.1 - 8.0	24	122.96	0
MF1600	7.1 - 8.0	24	121.52	0
MF1600	> 8	12	111.00	0
MF1600	> 8	12	111.62	0
MF1600	> 8	18	116.51	0
MF1600	> 8	18	117.00	0
MF1600	> 8	24	122.01	0
MF1600	> 8	24	122.39	0
MF1614B	< 6.7	12	115.14	2
MF1614B	< 6.7	12	110.93	5
MF1614B	< 6.7	18	123.39	1
MF1614B	< 6.7	18	123.30	2
MF1614B	< 6.7	24	127.51	1
MF1614B	< 6.7	24	127.42	0
MF1614B	6.7 - 7.1	12	112.70	1
MF1614B	6.7 - 7.1	12	112.48	2
MF1614B	6.7 - 7.1	18	119.96	0
MF1614B	6.7 - 7.1	18	123.17	1
MF1614B	6.7 - 7.1	24	123.58	0
MF1614B	6.7 - 7.1	24	126.74	1
MF1614B	7.1 - 8.0	12	112.65	1
MF1614B	7.1 - 8.0	12	113.68	0
MF1614B	7.1 - 8.0	18	119.07	0

MF1614B	7.1 - 8.0	18	123.35	0
MF1614B	7.1 - 8.0	24	125.48	0
MF1614B	7.1 - 8.0	24	126.58	0
MF1614B	> 8	12	113.74	0
MF1614B	> 8	12	115.28	0
MF1614B	> 8	18	122.20	0
MF1614B	> 8	18	120.96	0
MF1614B	> 8	24	122.20	0
MF1614B	> 8	24	120.96	0
MF1636A	< 6.7	12	118.67	4
MF1636A	< 6.7	12	116.45	6
MF1636A	< 6.7	18	128.95	1
MF1636A	< 6.7	18	128.37	3
MF1636A	< 6.7	24	132.58	0
MF1636A	< 6.7	24	132.77	0
MF1636A	6.7 - 7.1	12	117.56	4
MF1636A	6.7 - 7.1	12	115.96	3
MF1636A	6.7 - 7.1	18	126.27	1
MF1636A	6.7 - 7.1	18	125.69	2
MF1636A	6.7 - 7.1	24	140.92	1
MF1636A	6.7 - 7.1	24	129.75	1
MF1636A	7.1 - 8.0	12	112.76	3
MF1636A	7.1 - 8.0	12	114.76	3
MF1636A	7.1 - 8.0	18	121.89	1
MF1636A	7.1 - 8.0	18	122.69	1
MF1636A	7.1 - 8.0	24	124.67	0
MF1636A	7.1 - 8.0	24	125.03	1
MF1636A	> 8	12	112.56	2
MF1636A	> 8	12	112.22	1
MF1636A	> 8	18	119.32	0
MF1636A	> 8	18	121.20	0
MF1636A	> 8	24	121.70	0
MF1636A	> 8	24	124.67	0
MF1638A	6.7 - 7.1	12	115.00	0
MF1638A	6.7 - 7.1	12	113.74	0
MF1638A	6.7 - 7.1	18	121.80	0
MF1638A	6.7 - 7.1	18	121.82	0
MF1638A	6.7 - 7.1	24	125.14	0
MF1638A	6.7 - 7.1	24	125.62	0
MF1638A	7.1 - 8.0	12	110.96	0
MF1638A	7.1 - 8.0	12	109.69	1
MF1638A	7.1 - 8.0	18	118.52	0
MF1638A	7.1 - 8.0	18	117.69	0
MF1638A	7.1 - 8.0	24	122.62	0
MF1638A	7.1 - 8.0	24	121.26	0

MF1638A	> 8	12	111.86	0
MF1638A	> 8	12	112.46	0
MF1638A	> 8	18	118.16	0
MF1638A	> 8	18	119.64	0
MF1638A	> 8	24	121.99	0
MF1638A	> 8	24	119.64	0
MF1647	< 6.7	12	113.74	9
MF1647	< 6.7	12	117.98	5
MF1647	< 6.7	18	126.25	2
MF1647	< 6.7	18	129.94	1
MF1647	< 6.7	24	131.61	0
MF1647	< 6.7	24	134.71	1
MF1647	6.7 - 7.1	12	116.72	2
MF1647	6.7 - 7.1	12	114.35	1
MF1647	6.7 - 7.1	18	124.81	1
MF1647	6.7 - 7.1	18	123.88	1
MF1647	6.7 - 7.1	24	129.16	0
MF1647	6.7 - 7.1	24	127.37	0
MF1647	7.1 - 8.0	12	112.49	1
MF1647	7.1 - 8.0	12	114.18	0
MF1647	7.1 - 8.0	18	120.01	0
MF1647	7.1 - 8.0	18	120.97	0
MF1647	7.1 - 8.0	24	123.88	0
MF1647	7.1 - 8.0	24	124.10	0
MF1647	> 8	12	112.73	1
MF1647	> 8	12	111.45	1
MF1647	> 8	18	118.89	0
MF1647	> 8	18	117.85	0
MF1647	> 8	24	122.05	0
MF1647	> 8	24	121.09	0
MF1655	< 6.7	12	105.92	13
MF1655	< 6.7	12	107.97	12
MF1655	< 6.7	18	122.69	8
MF1655	< 6.7	18	124.58	5
MF1655	< 6.7	24	131.07	4
MF1655	< 6.7	24	137.04	1
MF1655	6.7 - 7.1	12	110.07	8
MF1655	6.7 - 7.1	12	103.21	11
MF1655	6.7 - 7.1	18	124.63	3
MF1655	6.7 - 7.1	18	121.45	4
MF1655	6.7 - 7.1	24	128.27	1
MF1655	6.7 - 7.1	24	125.10	2
MF1655	7.1 - 8.0	12	122.44	4
MF1655	7.1 - 8.0	12	123.52	7
MF1655	7.1 - 8.0	18	135.30	0

MF1655	7.1 - 8.0	18	136.44	1
MF1655	7.1 - 8.0	24	141.72	0
MF1655	7.1 - 8.0	24	139.66	0
MF1655	> 8	12	109.06	2
MF1655	> 8	12	108.75	1
MF1655	> 8	18	116.78	1
MF1655	> 8	18	119.03	0
MF1655	> 8	24	121.92	0
MF1655	> 8	24	121.60	0
MF1660	< 6.7	12	110.09	11
MF1660	< 6.7	12	99.75	11
MF1660	< 6.7	18	118.33	5
MF1660	< 6.7	18	117.43	4
MF1660	< 6.7	24	134.81	1
MF1660	< 6.7	24	130.69	1
MF1660	6.7 - 7.1	12	107.36	7
MF1660	6.7 - 7.1	12	105.00	2
MF1660	6.7 - 7.1	18	117.81	3
MF1660	6.7 - 7.1	18	115.86	2
MF1660	6.7 - 7.1	24	128.27	0
MF1660	6.7 - 7.1	24	137.58	0
MF1660	7.1 - 8.0	12	109.52	5
MF1660	7.1 - 8.0	12	106.59	2
MF1660	7.1 - 8.0	18	115.51	0
MF1660	7.1 - 8.0	18	115.57	0
MF1660	7.1 - 8.0	24	127.49	0
MF1660	7.1 - 8.0	24	127.55	0
MF1660	> 8	12	103.82	0
MF1660	> 8	12	113.32	0
MF1660	> 8	18	116.98	0
MF1660	> 8	18	118.69	0
MF1660	> 8	24	124.88	0
MF1660	> 8	24	129.42	0
MF1644A	< 6.7	12	124.91	14
MF1644A	< 6.7	12	106.36	17
MF1644A	< 6.7	18	133.01	7
MF1644A	< 6.7	18	112.81	9
MF1644A	< 6.7	24	130.42	5
MF1644A	< 6.7	24	122.70	6
MF1644A	6.7 - 7.1	12	122.23	4
MF1644A	6.7 - 7.1	12	120.08	7
MF1644A	6.7 - 7.1	18	125.77	2
MF1644A	6.7 - 7.1	18	123.65	5
MF1644A	6.7 - 7.1	24	127.97	2
MF1644A	6.7 - 7.1	24	126.61	3

MF1644A	7.1 - 8.0	12	112.24	5
MF1644A	7.1 - 8.0	12	112.87	0
MF1644A	7.1 - 8.0	18	115.31	2
MF1644A	7.1 - 8.0	18	115.99	0
MF1644A	7.1 - 8.0	24	127.59	0
MF1644A	7.1 - 8.0	24	125.36	0
MF1644A	> 8	12	111.26	1
MF1644A	> 8	12	120.60	1
MF1644A	> 8	18	116.58	0
MF1644A	> 8	18	126.01	0
MF1644A	> 8	24	121.46	0
MF1644A	> 8	24	129.71	0

MINITAB SESSION OF STONE PEAS AND WATER ABSORBED OF MARROWFAT PEAS

General Linear Model: Stone Peas 100pcs. versus Pea Name, Size, Soaking Time

```
Method

Factor coding  (-1, 0, +1)

Factor Information
Factor        Type   Levels  Values
Pea Name         Fixed          8   MF1600, MF1614B, MF1636A,
MF1638A, MF1644A, MF1647, MF1655,
                                MF1660
Size          Fixed       4  < 6.7, > 8, 6.7 - 7.1, 7.1 - 8.0
Soaking Time  Fixed       3  12, 18, 24

Analysis of Variance
Source           DF  Adj SS   Adj MS  F-Value  P-Value
  Pea Name        7   228.8   32.688     8.42    0.000
  Size            3   565.5  188.517    48.54    0.000
  Soaking Time    2   364.1  182.038    46.87    0.000
Error           173   671.9    3.884
  Lack-of-Fit    80   551.4    6.893     5.32    0.000
  Pure Error     93   120.5    1.296
Total           185  1884.9

Model Summary
      S    R-sq  R-sq(adj)  R-sq(pred)
1.97074  64.35%     61.88%      58.78%

Coefficients
Term            Coef  SE Coef  T-Value  P-Value   VIF
Constant       2.087    0.146    14.34    0.000
Pea Name
  MF1600       0.538    0.378     1.42    0.156  1.76
  MF1614B     -1.379    0.378    -3.65    0.000  1.76
  MF1636A     -0.504    0.378    -1.33    0.184  1.76
  MF1638A     -1.056    0.435    -2.43    0.016  2.03
  MF1644A      1.663    0.378     4.40    0.000  1.76
  MF1647      -1.004    0.378    -2.66    0.009  1.76
  MF1655       1.579    0.378     4.18    0.000  1.76
Size
  < 6.7        2.929    0.263    11.12    0.000  1.60
  > 8         -1.858    0.248    -7.48    0.000  1.52
  6.7 - 7.1    0.017    0.248     0.07    0.946  1.52
Soaking Time
  12           1.892    0.204     9.26    0.000  1.33
  18          -0.446    0.204    -2.18    0.030  1.33


Regression Equation

Stone  Peas  100pcs.  =  2.087  + 0.538 Pea Name_MF1600  -
 1.379 Pea Name_MF1614B
                       - 0.504 Pea Name_MF1636A          -
 1.056 Pea Name_MF1638A
                       + 1.663 Pea Name_MF1644A          -
 1.004 Pea Name_MF1647 + 1.579 Pea Name_MF1655
                       + 0.163 Pea Name_MF1660   + 2.929 Size_<
6.7 - 1.858 Size_> 8
                       + 0.017 Size_6.7 - 7.1 - 1.087 Size_7.1
- 8.0 + 1.892 Soaking Time_12
                       - 0.446 Soaking Time_18           -
 1.446 Soaking Time_24


Fits and Diagnostics for Unusual Observations
     Stone Peas
Obs     100pcs.     Fit   Resid  Std Resid
115      13.000   8.488   4.512       2.37  R
120       1.000   5.149  -4.149      -2.18  R
122      11.000   5.576   5.424       2.85  R
139      11.000   7.071   3.929       2.07  R
140      11.000   7.071   3.929       2.07  R
163      14.000   8.571   5.429       2.86  R
164      17.000   8.571   8.429       4.44  R
176       0.000   4.555  -4.555      -2.39  R
R  Large residual
```

Residual Plots for Stone Peas 100pcs.

General Linear Model: Water Absorbed versus Pea Name, Size, Soaking Time

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Pea Name	Fixed	8	MF1600, MF1614B, MF1636A, MF1638A, MF1644A, MF1647, MF1655, MF1660
Size	Fixed	4	< 6.7, > 8, 6.7 - 7.1, 7.1 - 8.0
Soaking Time	Fixed	3	12, 18, 24

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Pea Name	7	1058.4	151.20	7.27	0.000
Size	3	269.4	89.81	4.32	0.006
Soaking Time	2	6764.7	3382.35	162.57	0.000
Error	173	3599.4	20.81		
Lack-of-Fit	80	2622.0	32.78	3.12	0.000
Pure Error	93	977.4	10.51		
Total	185	11716.6			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
4.56134	69.28%	67.15%	64.54%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	119.984	0.337	356.11	0.000	
Pea Name					
MF1600	-4.638	0.874	-5.31	0.000	1.76
MF1614B	0.119	0.874	0.14	0.892	1.76
MF1636A	2.825	0.874	3.23	0.001	1.76
MF1638A	-1.38	1.01	-1.37	0.172	2.03
MF1644A	1.329	0.874	1.52	0.130	1.76
MF1647	1.275	0.874	1.46	0.146	1.76
MF1655	2.441	0.874	2.79	0.006	1.76
Size					
< 6.7	1.214	0.610	1.99	0.048	1.60
> 8	-1.959	0.575	-3.41	0.001	1.52
6.7 - 7.1	0.740	0.575	1.29	0.199	1.52
Soaking Time					
12	-7.846	0.473	-16.59	0.000	1.33
18	1.029	0.473	2.17	0.031	1.33

Regression Equation

Water Absorbed = 119.984 - 4.638 Pea Name_MF1600
+ 0.119 Pea Name_MF1614B
+ 2.825 Pea Name_MF1636A -
1.38 Pea Name_MF1638A + 1.329 Pea Name_MF1644A
+ 1.275 Pea Name_MF1647
+ 2.441 Pea Name_MF1655 - 1.971 Pea Name_MF1660
+ 1.214 Size_< 6.7 - 1.959 Size_> 8
+ 0.740 Size_6.7 - 7.1 + 0.004 Size_7.1
- 8.0 - 7.846 Soaking Time_12
+ 1.029 Soaking Time_18
+ 6.818 Soaking Time_24

Fits and Diagnostics for Unusual Observations

Obs	Water Absorbed	Fit	Resid	Std Resid	
59	140.92	130.37	10.55	2.40	R
115	105.92	115.79	-9.88	-2.25	R
122	103.21	115.32	-12.11	-2.75	R
128	123.52	114.58	8.94	2.03	R
129	135.30	123.46	11.84	2.69	R
130	136.44	123.46	12.98	2.95	R
131	141.72	129.25	12.48	2.83	R
132	139.66	129.25	10.42	2.37	R
140	99.75	111.38	-11.63	-2.64	R
150	137.58	125.57	12.01	2.73	R
163	124.91	114.68	10.23	2.33	R
165	133.01	123.56	9.46	2.15	R
166	112.81	123.56	-10.75	-2.44	R
182	120.60	111.51	9.10	2.07	R

R Large residual

Residual Plots for Water Absorbed

Comparisons for Stone Peas 100pcs.

Fisher Pairwise Comparisons: Response = Stone Peas 100pcs., Term = Size

Grouping Information Using Fisher LSD Method and 95% Confidence

Size	N	Mean	Grouping
< 6.7	42	5.01587	A
6.7 - 7.1	48	2.10417	B
7.1 - 8.0	48	1.00000	C
> 8	48	0.22917	C

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

Comparisons for Water Absorbed

Fisher Pairwise Comparisons: Response = Water Absorbed, Term = Size

Grouping Information Using Fisher LSD Method and 95% Confidence

Size	N	Mean	Grouping
< 6.7	42	121.198	A
6.7 - 7.1	48	120.725	A
7.1 - 8.0	48	119.988	A
> 8	48	118.026	B

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

Comparisons for Stone Peas 100pcs.

Fisher Pairwise Comparisons: Response = Stone Peas 100pcs., Term = Soaking Time

Grouping Information Using Fisher LSD Method and 95% Confidence

Soaking Time	N	Mean	Grouping
12	62	3.97977	A
18	62	1.64107	B
24	62	0.64107	C

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

Comparisons for Water Absorbed

Fisher Pairwise Comparisons: Response = Water Absorbed, Term = Soaking Time

Grouping Information Using Fisher LSD Method and 95% Confidence

Soaking Time	N	Mean	Grouping
24	62	126.802	A
18	62	121.013	B
12	62	112.138	C

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

Fisher Pairwise Comparisons: Response = Stone Peas 100pcs., Term = Pea Name

Grouping Information Using Fisher LSD Method and 95% Confidence

Pea Name	N	Mean	Grouping			
MF1644A	24	3.75000	A			
MF1655	24	3.66667	A	B		
MF1600	24	2.62500		B	C	
MF1660	24	2.25000			C	D
MF1636A	24	1.58333			C	D	E
MF1647	24	1.08333					E
MF1638A	18	1.03175				D	E
MF1614B	24	0.70833					E

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

SIZE DISTRIBUTION RAW DATA

Line Number	Size	in Grams	%
MF1600	6.7 mm	16.98	2%
MF1600	6.7 mm	18.83	2%
MF1600	6.7 mm	21.49	2%
MF1600	6.7-7.1 mm	154.29	15%
MF1600	6.7-7.1 mm	136.84	14%
MF1600	6.7-7.1 mm	130.64	13%
MF1600	7.1-8.0 mm	602	60%
MF1600	7.1-8.0 mm	554.58	55%
MF1600	7.1-8.0 mm	588.46	59%
MF1600	>8.0 mm	227.01	23%
MF1600	>8.0 mm	290.13	29%
MF1600	>8.0 mm	259.47	26%
MF1614B	6.7 mm	34.74	3%
MF1614B	6.7 mm	42.99	4%
MF1614B	6.7 mm	38.67	4%
MF1614B	6.7-7.1 mm	179.25	18%
MF1614B	6.7-7.1 mm	177.86	18%
MF1614B	6.7-7.1 mm	154.38	15%
MF1614B	7.1-8.0 mm	572.55	57%
MF1614B	7.1-8.0 mm	576.97	58%
MF1614B	7.1-8.0 mm	595.12	60%
MF1614B	>8.0 mm	213.49	21%
MF1614B	>8.0 mm	201.94	20%
MF1614B	>8.0 mm	211.32	21%
MF1636A	6.7 mm	38.73	4%
MF1636A	6.7 mm	29.63	3%
MF1636A	6.7 mm	32.2	3%
MF1636A	6.7-7.1 mm	173.82	17%
MF1636A	6.7-7.1 mm	163.32	16%
MF1636A	6.7-7.1 mm	176.18	18%
MF1636A	7.1-8.0 mm	553.85	55%
MF1636A	7.1-8.0 mm	543.56	54%
MF1636A	7.1-8.0 mm	536.87	54%
MF1636A	>8.0 mm	233.29	23%
MF1636A	>8.0 mm	263.21	26%
MF1636A	>8.0 mm	254.57	25%
MF1638A	6.7 mm	2.56	0%
MF1638A	6.7 mm	2.18	0%
MF1638A	6.7 mm	1.07	0%
MF1638A	6.7-7.1 mm	18.86	2%
MF1638A	6.7-7.1 mm	25.48	3%
MF1638A	6.7-7.1 mm	21.96	2%
MF1638A	7.1-8.0 mm	324.04	32%
MF1638A	7.1-8.0 mm	321.45	32%
MF1638A	7.1-8.0 mm	312.04	31%
MF1638A	>8.0 mm	654.6	65%
MF1638A	>8.0 mm	651.2	65%
MF1638A	>8.0 mm	664.7	66%
MF1647	6.7 mm	32.62	3%
MF1647	6.7 mm	27.19	3%
MF1647	6.7 mm	27.67	3%

MF1647	6.7-7.1 mm	151.39	15%
MF1647	6.7-7.1 mm	151.26	15%
MF1647	6.7-7.1 mm	161.66	16%
MF1647	7.1-8.0 mm	580.85	58%
MF1647	7.1-8.0 mm	553.14	55%
MF1647	7.1-8.0 mm	581.18	58%
MF1647	>8.0 mm	235.91	24%
MF1647	>8.0 mm	268.45	27%
MF1647	>8.0 mm	229.36	23%
MF1655	6.7 mm	15.86	2%
MF1655	6.7 mm	17.98	2%
MF1655	6.7 mm	24.42	2%
MF1655	6.7-7.1 mm	107.33	11%
MF1655	6.7-7.1 mm	99.11	10%
MF1655	6.7-7.1 mm	110.91	11%
MF1655	7.1-8.0 mm	521.79	52%
MF1655	7.1-8.0 mm	503.71	50%
MF1655	7.1-8.0 mm	518.79	52%
MF1655	>8.0 mm	355.09	36%
MF1655	>8.0 mm	379.32	38%
MF1655	>8.0 mm	345.41	35%
MF1660	6.7 mm	22.47	2%
MF1660	6.7 mm	28.56	3%
MF1660	6.7 mm	10.88	1%
MF1660	6.7-7.1 mm	117.84	12%
MF1660	6.7-7.1 mm	164.61	16%
MF1660	6.7-7.1 mm	138.33	14%
MF1660	7.1-8.0 mm	593.36	59%
MF1660	7.1-8.0 mm	584.58	58%
MF1660	7.1-8.0 mm	599.09	60%
MF1660	>8.0 mm	264.07	26%
MF1660	>8.0 mm	221.91	22%
MF1660	>8.0 mm	251.61	25%
MF1644A	6.7 mm	85.99	7%
MF1644A	6.7 mm	70.84	6%
MF1644A	6.7 mm	90.32	7%
MF1644A	6.7-7.1 mm	257.78	20%
MF1644A	6.7-7.1 mm	199.84	18%
MF1644A	6.7-7.1 mm	208.72	16%
MF1644A	7.1-8.0 mm	675.4	54%
MF1644A	7.1-8.0 mm	614	56%
MF1644A	7.1-8.0 mm	619	48%
MF1644A	>8.0 mm	239.33	19%
MF1644A	>8.0 mm	218.67	20%
MF1644A	>8.0 mm	362.46	28%

2017 CROPS MINITAB SESSION

General Linear Model: Water Absorbed versus Batch, Soaking Time, Pea Name

```
Method

Factor coding  (-1, 0, +1)

Factor Information
Factor        Type   Levels  Values
Batch         Fixed       8  1.0, 2.0, 3.0, 4.0, 5.0, 6.0,
6.5, 7.0
Soaking Time  Fixed       3  12, 18, 24
Pea Name      Fixed       2  MF1722, MF1746


Analysis of Variance
Source          DF   Adj SS   Adj MS  F-Value  P-Value
  Batch          7  1246.17   178.02    47.25    0.000
  Soaking Time   2  2424.05  1212.03   321.66    0.000
  Pea Name       1    55.62    55.62    14.76    0.000
Error           85   320.28     3.77
  Lack-of-Fit   37   159.31     4.31     1.28    0.206
  Pure Error    48   160.97     3.35
Total           95  4046.12


Model Summary

      S    R-sq  R-sq(adj)  R-sq(pred)
1.94113  92.08%     91.15%      89.90%


Coefficients

Term             Coef  SE Coef  T-Value  P-Value   VIF
Constant      115.625    0.198   583.62    0.000
Batch
  1.0          -1.704    0.524    -3.25    0.002  1.75
  2.0           5.839    0.524    11.14    0.000  1.75
  3.0           4.027    0.524     7.68    0.000  1.75
  4.0          -4.562    0.524    -8.70    0.000  1.75
  5.0           3.434    0.524     6.55    0.000  1.75
  6.0          -2.117    0.524    -4.04    0.000  1.75
  6.5          -1.605    0.524    -3.06    0.003  1.75
Soaking Time
  12           -6.651    0.280   -23.74    0.000  1.33
  18            1.158    0.280     4.13    0.000  1.33
Pea Name
  MF1722       -0.761    0.198    -3.84    0.000  1.00


Regression Equation

Water Absorbed = 115.625 - 1.704 Batch_1.0 + 5.839 Batch_2.0
+ 4.027 Batch_3.0
                 - 4.562 Batch_4.0 + 3.434 Batch_5.0 -
 2.117 Batch_6.0 - 1.605 Batch_6.5
                 - 3.311 Batch_7.0 - 6.651 Soaking Time_12
+ 1.158 Soaking Time_18
                 + 5.493 Soaking Time_24 -
 0.761 Pea Name_MF1722 + 0.761 Pea Name_MF1746


Fits and Diagnostics for Unusual Observations

        Water
Obs  Absorbed      Fit   Resid  Std Resid
 56   110.197  114.051  -3.854      -2.11  R
 73   116.108  111.647   4.461       2.44  R
 79   110.134  106.095   4.039       2.21  R

R  Large residual
```

Residual Plots for Water Absorbed

General Linear Model: Stone Peas 100pcs. versus Batch, Soaking Time, Pea Name

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Batch	Fixed	8	1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 6.5, 7.0
Soaking Time	Fixed	3	12, 18, 24
Pea Name	Fixed	2	MF1722, MF1746

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Batch	7	0.6667	0.09524	1.73	0.112
Soaking Time	2	0.3333	0.16667	3.04	0.053
Pea Name	1	0.1667	0.16667	3.04	0.085
Error	85	4.6667	0.05490		
Lack-of-Fit	37	3.6667	0.09910	4.76	0.000
Pure Error	48	1.0000	0.02083		
Total	95	5.8333			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.234312	20.00%	10.59%	0.00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.0417	0.0239	1.74	0.085	
Batch					
1.0	-0.0417	0.0633	-0.66	0.512	1.75
2.0	0.2083	0.0633	3.29	0.001	1.75
3.0	0.0417	0.0633	0.66	0.512	1.75
4.0	-0.0417	0.0633	-0.66	0.512	1.75
5.0	-0.0417	0.0633	-0.66	0.512	1.75
6.0	-0.0417	0.0633	-0.66	0.512	1.75
6.5	-0.0417	0.0633	-0.66	0.512	1.75
Soaking Time					
12	0.0833	0.0338	2.46	0.016	1.33
18	-0.0417	0.0338	-1.23	0.221	1.33
Pea Name					
MF1722	-0.0417	0.0239	-1.74	0.085	1.00

Regression Equation

Stone Peas 100pcs. = 0.0417 - 0.0417 Batch_1.0
+ 0.2083 Batch_2.0 + 0.0417 Batch_3.0
- 0.0417 Batch_4.0 - 0.0417 Batch_5.0 -
0.0417 Batch_6.0
- 0.0417 Batch_6.5 - 0.0417 Batch_7.0
+ 0.0833 Soaking Time_12
- 0.0417 Soaking Time_18 -
0.0417 Soaking Time_24
- 0.0417 Pea Name_MF1722
+ 0.0417 Pea Name_MF1746

Fits and Diagnostics for Unusual Observations

Obs	Stone Peas 100pcs.	Fit	Resid	Std Resid	
7	1.0000	0.3750	0.6250	2.83	R
8	2.0000	0.3750	1.6250	7.37	R
13	1.0000	0.2083	0.7917	3.59	R

R Large residual

Comparisons for Stone Peas 100pcs.

Residual Plots for Stone Peas 100pcs.

Fisher Pairwise Comparisons: Response = Stone Peas 100pcs., Term = Soaking Time

Grouping Information Using Fisher LSD Method and 95% Confidence

Soaking Time	N	Mean	Grouping
12	32	0.125	A
18	32	0.000	B
24	32	-0.000	B

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

Comparisons for Water Absorbed

Fisher Pairwise Comparisons: Response = Water Absorbed, Term = Soaking Time

Grouping Information Using Fisher LSD Method and 95% Confidence

Soaking Time	N	Mean	Grouping
24	32	121.118	A
18	32	116.783	B
12	32	108.974	C

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

Comparisons for Water Absorbed

Fisher Pairwise Comparisons: Response = Water Absorbed, Term = Batch

Grouping Information Using Fisher LSD Method and 95% Confidence

Batch	N	Mean	Grouping			
2.0	12	121.463	A			
3.0	12	119.652		B		
5.0	12	119.059		B		
6.5	12	114.019			C	
1.0	12	113.920			C	
6.0	12	113.507			C	D
7.0	12	112.314				D	E
4.0	12	111.062					E

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

FRYING RAW DATA - MOISTURE CONTENT OF BENCHMARK SAMPLES

Item Name	Moisture Content Wet Basis	Average	STDev	Moisture Content (Dry Basis)	Average	STDev
camel nuts coated	4.88%	4.97%	0.09%	5.13%	5.23%	0.10%
camel nuts coated	5.07%			5.34%		
camel nuts coated	4.97%			5.23%		
kasugai roasted	1.09%	1.23%	0.13%	1.10%	1.25%	0.14%
kasugai roasted	1.27%			1.29%		
kasugai roasted	1.35%			1.36%		
snapmaxx	2.89%	2.87%	0.09%	2.98%	2.95%	0.10%
snapmaxx	2.77%			2.84%		
snapmaxx	2.95%			3.04%		
kasugai peas and you	2.79%	2.62%	0.15%	2.87%	2.69%	0.16%
kasugai peas and you	2.49%			2.56%		
kasugai peas and you	2.58%			2.65%		
kaoshong	2.38%	2.48%	0.11%	2.43%	2.55%	0.11%
kaoshong	2.59%			2.66%		
kaoshong	2.48%			2.55%		
shh gp	3.38%	3.28%	0.10%	3.50%	3.39%	0.11%
shh gp	3.17%			3.28%		
shh gp	3.29%			3.40%		

FRYING MINITAB SESSION MOISTURE CONTENT OF BENCHMARK SAMPLES

General Linear Model: Moisture Content Wet Basis versus Item Name

```
Method

Factor coding  (-1, 0, +1)


Factor Information

Factor     Type   Levels  Values
Item Name  Fixed       6  camel nuts coated, kaoshong,
kasugai peas and you, kasugai roasted,
                          shh gp, snapmaxx


Analysis of Variance

Source       DF    Adj SS    Adj MS  F-Value  P-Value
  Item Name   5  0.002241  0.000448   334.46    0.000
Error        12  0.000016  0.000001
Total        17  0.002258


Model Summary

        S    R-sq  R-sq(adj)  R-sq(pred)
0.0011577  99.29%     98.99%      98.40%
```

```
Coefficients

Term                          Coef   SE Coef  T-Value  P-Value
VIF
Constant                  0.029102  0.000273   106.65    0.000
Item Name
  camel nuts coated       0.020630  0.000610    33.81    0.000
1.67
  kaoshong               -0.004277  0.000610    -7.01    0.000
1.67
  kasugai peas and you   -0.002880  0.000610    -4.72    0.000
1.67
  kasugai roasted        -0.016765  0.000610   -27.47    0.000
1.67
  shh gp                  0.003709  0.000610     6.08    0.000
1.67


Regression Equation

Moisture Content Wet Basis = 0.029102
+ 0.020630 Item Name_camel nuts coated
                                - 0.004277 Item Name_kaoshong -
 0.002880 Item Name_kasugai peas
                                and you -
 0.016765 Item Name_kasugai roasted
                                + 0.003709 Item Name_shh gp -
 0.000417 Item Name_snapmaxx
```

Residual Plots for Moisture Content Wet Basis

Descriptive Statistics: Moisture Content Wet Basis

```
Variable                 Item Name                Mean      StDev
```

Moisture Content Wet Bas	camel nuts coated	0.049732	0.000918
	kaoshong	0.024825	0.001064
	kasugai peas and you	0.026222	0.001517
	kasugai roasted	0.012337	0.001340
	shh gp	0.032811	0.001045
	snapmaxx	0.028685	0.000937

Comparisons for Moisture Content Wet Basis

Fisher Pairwise Comparisons: Response = Moisture Content Wet Basis, Term = Item Name

Grouping Information Using Fisher LSD Method and 95% Confidence

Item Name	N	Mean	Grouping
camel nuts coated	3	0.0497316	A
shh gp	3	0.0328107	B
snapmaxx	3	0.0286853	C
kasugai peas and you	3	0.0262219	D
kaoshong	3	0.0248251	D
kasugai roasted	3	0.0123372	E

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

VOLUME OF BENCHMARK SAMPLES – RAW DATA

Item	Volume (mL/piece)
Camel Nuts Coated	0.70
Camel Nuts Coated	0.70
Camel Nuts Coated	0.70
SHH Green (uncoated)	0.54
SHH Green (uncoated)	0.56
SHH Green (uncoated)	0.52
Kaoshong	0.80
Kaoshong	0.80
Kaoshong	0.82
Kasugai	0.88
Kasugai	0.82
Kasugai	0.85
Snapmaxx Wasabi Peas	0.80
Snapmaxx Wasabi Peas	0.82
Snapmaxx Wasabi Peas	0.81
Kasugai Roasted Green Peas	0.82
Kasugai Roasted Green Peas	0.89
Kasugai Roasted Green Peas	0.86

VOLUME OF BENCHMARK SAMPLES – MINITAB SESSION

General Linear Model: Volume (mL/piece) versus Item

```
Method

Factor coding  (-1, 0, +1)


Factor Information

Factor  Type   Levels  Values
Item    Fixed       6  Camel Nuts, Kaoshong, Kasugai, Kasugai
Roasted Green Peas, SHH Green
                       (uncoated), Snapmaxx Wasabi Peas


Analysis of Variance

Source  DF    Adj SS    Adj MS  F-Value  P-Value
  Item   5  0.221407  0.044281    96.32    0.000
Error   12  0.005517  0.000460
Total   17  0.226924


Model Summary

        S    R-sq  R-sq(adj)  R-sq(pred)
0.0214411  97.57%     96.56%      94.53%


Coefficients

Term                              Coef  SE Coef  T-Value  P-
Value   VIF
Constant                       0.76028  0.00505   150.44
0.000
Item
  Camel Nuts                  -0.0603   0.0113    -5.33
0.000  1.67
  Kaoshong                     0.0464   0.0113     4.11
0.001  1.67
  Kasugai                      0.0897   0.0113     7.94
0.000  1.67
  Kasugai Roasted Green Peas   0.0947   0.0113     8.38
0.000  1.67
  SHH Green (uncoated)        -0.2203   0.0113   -19.49
0.000  1.67


Regression Equation

Volume (mL/piece) = 0.76028 - 0.0603 Item_Camel Nuts
+ 0.0464 Item_Kaoshong
                    + 0.0897 Item_Kasugai
+ 0.0947 Item_Kasugai Roasted Green Peas
                    - 0.2203 Item_SHH Green (uncoated)
+ 0.0497 Item_Snapmaxx Wasabi Peas
```

Residual Plots for Volume (mL/piece)

Descriptive Statistics: Volume (mL/piece)

```
Variable           Item                          Mean     StDev
```

Volume (mL/piece)	Camel Nuts	0.70000	0.000000
	Kaoshong	0.80667	0.01155
	Kasugai	0.8500	0.0300
	Kasugai Roasted Green Pe	0.8550	0.0350
	SHH Green (uncoated)	0.5400	0.0200
	Snapmaxx Wasabi Peas	0.81000	0.01000

Comparisons for Volume (mL/piece)

Fisher Pairwise Comparisons: Response = Volume (mL/piece), Term = Item

Grouping Information Using Fisher LSD Method and 95% Confidence

Item	N	Mean	Grouping
Kasugai Roasted Green Peas	3	0.855000	A
Kasugai	3	0.850000	A
Snapmaxx Wasabi Peas	3	0.810000	B
Kaoshong	3	0.806667	B
Camel Nuts	3	0.700000	C
SHH Green (uncoated)	3	0.540000	D

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

BREAK FORCE OF BENCHMARK SAMPLES – RAW DATA

Item	Break Force (N)	Item	Break Force (N)	Item	Break Force (N)
SHH Green (uncoated)	53.71	Kasugai	34.19	Kaoshong	26.71
SHH Green (uncoated)	62.79	Kasugai	37.68	Kaoshong	25.11
SHH Green (uncoated)	37.09	Kasugai	50.49	Kaoshong	31.40
SHH Green (uncoated)	65.53	Kasugai	39.15	Kaoshong	36.14
SHH Green (uncoated)	48.47	Kasugai	36.21	Kaoshong	47.33
SHH Green (uncoated)	62.23	Kasugai	31.24	Kaoshong	17.87
SHH Green (uncoated)	48.47	Kasugai	20.63	Kaoshong	34.77
SHH Green (uncoated)	71.60	Kasugai	41.48	Kaoshong	50.67
SHH Green (uncoated)	73.97	Kasugai	41.96	Kaoshong	39.33
SHH Green (uncoated)	44.41	Kasugai	27.30	Kaoshong	26.60
Camel Nuts Coated	78.27	Snapmaxx Wasabi Peas	18.10	Kasugai Roasted Green Peas	37.64
Camel Nuts Coated	69.01	Snapmaxx Wasabi Peas	43.46	Kasugai Roasted Green Peas	34.65
Camel Nuts Coated	35.35	Snapmaxx Wasabi Peas	31.80	Kasugai Roasted Green Peas	30.55
Camel Nuts Coated	54.44	Snapmaxx Wasabi Peas	41.88	Kasugai Roasted Green Peas	57.55
Camel Nuts Coated	42.25	Snapmaxx Wasabi Peas	44.83	Kasugai Roasted Green Peas	43.76
Camel Nuts Coated	68.75	Snapmaxx Wasabi Peas	65.53	Kasugai Roasted Green Peas	23.23
Camel Nuts Coated	48.66	Snapmaxx Wasabi Peas	58.44	Kasugai Roasted Green Peas	46.17
Camel Nuts Coated	46.24	Snapmaxx Wasabi Peas	36.01	Kasugai Roasted Green Peas	38.56
Camel Nuts Coated	70.31	Snapmaxx Wasabi Peas	40.40	Kasugai Roasted Green Peas	46.34
Camel Nuts Coated	23.34	Snapmaxx Wasabi Peas	46.20	Kasugai Roasted Green Peas	33.37

BREAK FORCE OF BENCHMARK SAMPLES – MINITAB SESSION

General Linear Model: texture versus item

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
item	Fixed	6	camel, kaoshong, kasugai, kasugai roasted, shh, snapmaxx

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
item	5	4539	907.8	6.03	0.000
Error	54	8130	150.6		
Total	59	12669			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
12.2701	35.83%	29.89%	20.78%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	43.66	1.58	27.56	0.000	
item					
camel	10.00	3.54	2.82	0.007	1.67
kaoshong	-10.07	3.54	-2.84	0.006	1.67
kasugai	-7.63	3.54	-2.15	0.036	1.67
kasugai roasted	-4.48	3.54	-1.26	0.211	1.67
shh	13.16	3.54	3.72	0.000	1.67

Regression Equation

texture = 43.66 + 10.00 item_camel - 10.07 item_kaoshong - 7.63 item_kasugai
- 4.48 item_kasugai roasted + 13.16 item_shh - 0.99 item_snapmaxx

Fits and Diagnostics for Unusual Observations

Obs	texture	Fit	Resid	Std Resid	
11	78.27	53.66	24.60	2.11	R
20	23.34	53.66	-30.32	-2.60	R
41	18.10	42.67	-24.57	-2.11	R

R Large residual

Residual Plots for texture

Comparisons for texture

Fisher Pairwise Comparisons: Response = texture, Term = item

Grouping Information Using Fisher LSD Method and 95% Confidence

item	N	Mean	Grouping		
shh	10	56.8257	A		
camel	10	53.6628	A	B	
snapmaxx	10	42.6669		B	C
kasugai roasted	10	39.1813			C
kasugai	10	36.0330			C
kaoshong	10	33.5951			C

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

Descriptive Statistics: texture

Variable	item	Mean	StDev
texture	camel	53.66	17.67
	kaoshong	33.60	10.23
	kasugai	36.03	8.34
	kasugai roasted	39.18	9.69
	shh	56.83	12.23
	snapmaxx	42.67	13.17

FRYING –RAW DATA FRYING 160°C in DIFFERENT COOKING TIME

Line Number	treatment	state	soaking time, H	Load Size	temperature, °C	frying time	Moisture Content Wet Basis	Average, (Wet basis)	STDev
MF1638A	no treatment	fried	12	100	160	6	7.3%	7.3%	0.1%
MF1638A	no treatment	fried	12	100	160	6	7.4%		
MF1638A	no treatment	fried	12	100	160	6	7.2%		
MF1638A	no treatment	fried	12	100	160	8	3.9%	3.9%	0.0%
MF1638A	no treatment	fried	12	100	160	8	3.9%		
MF1638A	no treatment	fried	12	100	160	8	3.9%		
MF1638A	no treatment	fried	12	100	160	10	3.4%	3.5%	0.1%
MF1638A	no treatment	fried	12	100	160	10	3.5%		
MF1638A	no treatment	fried	12	100	160	10	3.6%		
MF1638A	no treatment	fried	12	100	160	12	2.6%	2.6%	0.1%
MF1638A	no treatment	fried	12	100	160	12	2.5%		
MF1638A	no treatment	fried	12	100	160	12	2.7%		

FRYING 160°C in DIFFERENT COOKING TIME – MINITAB SESSION

General Linear Model: Moisture Content Wet Basis versus cooking time, 8m, Load Size

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
cooking time, 8m	Fixed	4	6, 8, 10, 12
Load Size	Fixed	3	50, 100, 150

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
cooking time, 8m	3	0.019015	0.006338	342.63	0.000
Load Size	2	0.000102	0.000051	2.75	0.080
Error	30	0.000555	0.000018		
Lack-of-Fit	6	0.000516	0.000086	52.91	0.000
Pure Error	24	0.000039	0.000002		
Total	35	0.019671			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0043011	97.18%	96.71%	95.94%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.043509	0.000717	60.70	0.000	
cooking time, 8m					
6	0.03749	0.00124	30.19	0.000	1.50
8	-0.00346	0.00124	-2.78	0.009	1.50
10	-0.00939	0.00124	-7.56	0.000	1.50
Load Size					
50	-0.00024	0.00101	-0.24	0.814	1.33
100	-0.00193	0.00101	-1.90	0.067	1.33

Regression Equation

Moisture Content Wet Basis = 0.043509
+ 0.03749 cooking time, 8m_6
- 0.00346 cooking time, 8m_8 -
0.00939 cooking time, 8m_10
- 0.02465 cooking time, 8m_12 -
0.00024 Load Size_50
- 0.00193 Load Size_100
+ 0.00217 Load Size_150

Fits and Diagnostics for Unusual Observations

Obs	Moisture Content Wet Basis	Fit	Resid	Std Resid	
1	0.09213	0.08316	0.00897	2.28	R

R Large residual

Residual Plots for Moisture Content Wet Basis

Descriptive Statistics: Moisture Content Wet Basis

Variable	cooking time, 8m	Mean	StDev
Moisture Content Wet Bas	6	0.08100	0.00763
	8	0.04005	0.00307
	10	0.03412	0.00355
	12	0.018863	0.001401

Comparisons for Moisture Content Wet Basis

Fisher Pairwise Comparisons: Response = Moisture Content Wet Basis, Term = cooking time, 8m

Grouping Information Using Fisher LSD Method and 95% Confidence

cooking time, 8m	N	Mean	Grouping
6	9	0.0809965	A
8	9	0.0400525	B
10	9	0.0341231	C
12	9	0.0188635	D

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

Fisher Pairwise Comparisons: Response = Moisture Content Wet Basis, Term = Load Size

Grouping Information Using Fisher LSD Method and 95% Confidence

Load Size	N	Mean	Grouping
150	12	0.0456771	A
50	12	0.0432685	A B
100	12	0.0415811	B

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

General Linear Model: Texture, (N) versus cooking time, m

```
Method

Factor coding  (-1, 0, +1)

Factor Information
Factor           Type   Levels  Values
cooking time, m  Fixed       4  6, 8, 10, 12

Analysis of Variance
9.41680  8.10%      0.44%       0.00%

Coefficients

Term              Coef  SE Coef  T-Value  P-Value   VIF
Constant         35.76     1.49    24.02    0.000
cooking time, m
  6               3.37     2.58     1.31    0.200  1.50
  8              -3.66     2.58    -1.42    0.164  1.50
  10              1.43     2.58     0.55    0.582  1.50

Regression Equation

Texture, (N) = 35.76 + 3.37 cooking time, m_6 -
 3.66 cooking time, m_8
```

Descriptive Statistics: Texture, (N)

```
             cooking
```

```
Source              DF  Adj SS  Adj MS  F-Value  P-Value
  cooking time, m    3   281.2   93.74     1.06    0.379
Error               36  3192.3   88.68
Total               39  3473.6

Model Summary

      S   R-sq  R-sq(adj)  R-sq(pred)
              + 1.43 cooking time, m_10 -
 1.14 cooking time, m_12

Fits and Diagnostics for Unusual Observations

     Texture,                   Std
Obs       (N)    Fit  Resid  Resid
 22     57.03  37.19  19.84   2.22  R
 36     56.14  34.62  21.52   2.41  R

R  Large residual
```

Residual Plots for Texture, (N)

```
Variable      time, m   Mean  StDev
Texture, (N)   6       39.13   6.46
               8       32.09   7.23
              10       37.19  12.59
              12       34.62  10.10
```

FRYING –RAW DATA FRYING DIFFERENT COOKING TIME AND TEMPERATURE

Line Number	treatment	state	soaking time, H	Load Size	temperature, °C	frying time	Moisture Content Wet Basis	Volume
MF1638A	no treatment	fried	12	100	180	6	2.9%	0.86
MF1638A	no treatment	fried	12	100	180	6	3.0%	0.82
MF1638A	no treatment	fried	12	100	180	6	3.1%	0.82
MF1638A	no treatment	fried	12	100	170	7	3.1%	0.84
MF1638A	no treatment	fried	12	100	170	7	3.0%	0.84
MF1638A	no treatment	fried	12	100	170	7	3.1%	0.80
MF1638A	no treatment	fried	12	100	160	12	2.6%	0.83
MF1638A	no treatment	fried	12	100	160	12	2.5%	0.84
MF1638A	no treatment	fried	12	100	160	12	2.7%	0.84

FRYING DIFFERENT COOKING TIME AND TEMPERATURE – MINITAB SESSION

General Linear Model: Moisture Content Wet Basis versus temperature, °C, frying time

```
Method

Factor coding  (-1, 0, +1)

Factor Information

Factor           Type   Levels  Values
temperature, °C  Fixed       3  160, 170, 180

Analysis of Variance
Source             DF    Adj SS    Adj MS  F-Value  P-Value
  temperature, °C   2  0.000038  0.000019    30.58    0.001
Error               6  0.000004  0.000001
Total               8  0.000042

Model Summary
        S    R-sq  R-sq(adj)  R-sq(pred)
0.0007896  91.07%     88.09%      79.90%

Coefficients
Term                  Coef   SE Coef  T-Value  P-Value   VIF
Constant          0.028772  0.000263   109.32    0.000
temperature, °C
  160            -0.002905  0.000372    -7.80    0.000  1.33
  170             0.001617  0.000372     4.34    0.005  1.33

Regression Equation

Moisture Content Wet Basis = 0.028772 -
 0.002905 temperature, °C_160
                            + 0.001617 temperature, °C_170
+ 0.001288 temperature, °C_180
```

Residual Plots for Moisture Content Wet Basis

Comparisons for Moisture Content Wet Basis

Fisher Multiple Comparisons with a Control: Response = Moisture Content Wet Basis, Term = tem

```
Grouping Information Using Fisher LSD Method and 95%
Confidence
temperature, °C  N       Mean  Grouping
160 (Control)    3  0.0258679  A
170              3  0.0303890
180              3  0.0300605
Means not labeled with the letter A are significantly
different from the control level mean.
```

Fisher Individual 95% CIs

Descriptive Statistics: Moisture Content Wet Basis

```
                          temperature,
Variable                  °C            N  N*      Mean    SE
Mean     StDev   Minimum
Moisture Content Wet Bas  160           3   0  0.025868
0.000469  0.000812  0.025181
                          170           3   0  0.030389
0.000465  0.000805  0.029521
                          180           3   0  0.030061
0.000433  0.000750  0.029200
                          temperature,
Variable                  °C                  Q1    Median
Q3   Maximum
Moisture Content Wet Bas  160           0.025181  0.025658
0.026764  0.026764
                          170           0.029521  0.030535
0.031112  0.031112
                          180           0.029200  0.030413
0.030569  0.030569
0.030569  0.030569
```

RAW DATA FRYING SOAKED TREATED PEAS at 160°C , 12 minutes

Treatment	Texture
na citrate and salt	68.70
na citrate and salt	79.39
na citrate and salt	69.63
na citrate and salt	57.44
na citrate and salt	86.78
na citrate and salt	38.11
na citrate and salt	38.59
na citrate and salt	87.94
na citrate and salt	79.98
na citrate and salt	36.93
na bicarb	19.57
na bicarb	66.06
na bicarb	26.39
na bicarb	23.70
na bicarb	42.03
na bicarb	19.71
na bicarb	17.07
na bicarb	36.70
na bicarb	43.11
na bicarb	21.47

na citrate 0.1	14.17
na citrate 0.1	46.33
na citrate 0.1	46.33
na citrate 0.1	35.10
na citrate 0.1	21.55
na citrate 0.1	35.35
na citrate 0.1	14.70
na citrate 0.1	13.97
na citrate 0.1	23.43
na citrate 0.1	36.23
1% NacCitrate	25.41
1% NacCitrate	28.76
1% NacCitrate	29.81
1% NacCitrate	34.27
1% NacCitrate	29.76
1% NacCitrate	18.64
1% NacCitrate	22.93
1% NacCitrate	29.24
1% NacCitrate	29.46
1% NacCitrate	23.46
2% Nacitrate	21.59

2% Nacitrate	25.03
2% Nacitrate	16.13
2% Nacitrate	17.45
2% Nacitrate	17.77
2% Nacitrate	14.83
2% Nacitrate	20.32
2% Nacitrate	24.80
2% Nacitrate	17.92
2% Nacitrate	17.04
control	34.75
control	27.90
control	37.18
control	25.92
control	29.48
control	56.14
control	32.28
control	32.53
control	22.95
control	47.09

treatment	Moisture Content Wet Basis
1% sodium citrate, 4% salt	1.5%
1% sodium citrate, 4% salt	1.5%
1% sodium citrate, 4% salt	1.8%
0.1% sodium bicarbonate	2.5%
0.1% sodium bicarbonate	2.4%
0.1% sodium bicarbonate	2.5%
0.1% sodium citrate	2.7%
0.1% sodium citrate	2.8%
0.1% sodium citrate	2.8%
1% nacitrate	2.2%
1% nacitrate	1.8%
1% nacitrate	2.0%
2% nacitrate	2.0%
2% nacitrate	1.9%
2% nacitrate	2.1%
no treatment	1.9%
no treatment	2.0%
no treatment	1.9%

FRYING SOAKED TREATED PEAS at 160°C , 12 MINUTES – MINITAB SESSION

General Linear Model: Moisture Content Wet Basis versus treatment

```
Method

Factor coding  (-1, 0, +1)


Factor Information

Factor     Type   Levels  Values
treatment  Fixed       5  0.1% sodium bicarbonate, 0.1%
sodium citrate, 1% nacitrate, 1%
                          sodium citrate, 4% salt, 2%
nacitrate


Analysis of Variance

Source       DF    Adj SS    Adj MS  F-Value  P-Value
  treatment   4  0.000261  0.000065    36.16    0.000
Error        10  0.000018  0.000002
Total        14  0.000279


Model Summary

        S    R-sq  R-sq(adj)  R-sq(pred)
0.0013434  93.53%     90.95%      85.45%


Coefficients

Term                                 Coef    SE Coef  T-Value
P-Value   VIF
Constant                         0.021680  0.000347    62.51
0.000
treatment
  0.1% sodium bicarbonate        0.003072  0.000694     4.43
0.001  1.60
  0.1% sodium citrate            0.006214  0.000694     8.96
0.000  1.60
  1% nacitrate                  -0.001872  0.000694    -2.70
0.022  1.60
  1% sodium citrate, 4% salt    -0.005703  0.000694    -8.22
0.000  1.60


Regression Equation

Moisture Content Wet Basis = 0.021680
+ 0.003072 treatment_0.1% sodium bicarbonate
                              + 0.006214 treatment_0.1% sodium
citrate - 0.001872 treatment_1%
                              nacitrate -
 0.005703 treatment_1% sodium citrate, 4% salt
                              - 0.001711 treatment_2%
nacitrate


Fits and Diagnostics for Unusual Observations

      Moisture
       Content                          Std
Obs  Wet Basis       Fit     Resid  Resid
 10   0.022111  0.019808  0.002303   2.10  R

R  Large residual
```

Descriptive Statistics: Moisture Content Wet Basis

Residual Plots for Moisture Content Wet Basis

```
Variable                 treatment                      Mean
StDev
```

Moisture Content Wet Bas	0.1% sodium bicarbonate	0.024752
0.000631		
	0.1% sodium citrate	0.027894
0.000581		
	1% nacitrate	0.01981
0.00224		
	1% sodium citrate, 4% sa	0.015978
0.001611		
	2% nacitrate	0.019970
0.000812		

Comparisons for Moisture Content Wet Basis

Fisher Pairwise Comparisons: Response = Moisture Content Wet Basis, Term = treatment

Grouping Information Using Fisher LSD Method and 95% Confidence

treatment	N	Mean	Grouping
0.1% sodium citrate	3	0.0278945	A
0.1% sodium bicarbonate	3	0.0247522	B
2% nacitrate	3	0.0199700	C
1% nacitrate	3	0.0198082	C
1% sodium citrate, 4% salt	3	0.0159776	D

Means that do not share a letter are significantly different.

Fisher Individual 95% Cis

General Linear Model: Texture versus Treatment

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Treatment	Fixed	6	1% NacCitrate, 2% Nacitrate, control, na bicarb, na citrate 0.1, na citrate and salt

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	5	12178	2435.5	15.38	0.000
Error	54	8554	158.4		
Total	59	20731			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
12.5859	58.74%	54.92%	49.06%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	34.29	1.62	21.10	0.000	
Treatment					
1% NacCitrate	-7.11	3.63	-1.96	0.055	1.67
2% Nacitrate	-15.00	3.63	-4.13	0.000	1.67
control	0.33	3.63	0.09	0.927	1.67
na bicarb	-2.71	3.63	-0.74	0.460	1.67
na citrate 0.1	-5.57	3.63	-1.53	0.131	1.67

Regression Equation

Texture = 34.29 - 7.11 Treatment_1% NacCitrate - 15.00 Treatment_2% Nacitrate
+ 0.33 Treatment_control - 2.71 Treatment_na bicarb
- 5.57 Treatment_na citrate 0.1
+ 30.06 Treatment_na citrate and salt

Fits and Diagnostics for Unusual Observations

Obs	Texture	Fit	Resid	Std Resid	
6	38.11	64.35	-26.24	-2.20	R
7	38.59	64.35	-25.76	-2.16	R
10	36.93	64.35	-27.42	-2.30	R
12	66.06	31.58	34.48	2.89	R

R Large residual

Residual Plots for Texture

Comparisons for Texture

Fisher Multiple Comparisons with a Control: Response = Texture, Term = Treatment

Grouping Information Using Fisher LSD Method and 95% Confidence

Treatment	N	Mean	Grouping
control (Control)	10	34.6212	A
na citrate and salt	10	64.3489	
na bicarb	10	31.5818	A
na citrate 0.1	10	28.7145	A
1% NacCitrate	10	27.1745	A
2% Nacitrate	10	19.2882	

Means not labeled with the letter A are significantly different from the control level mean.

Fisher Individual 95% CIs

Descriptive Statistics: Texture

Variable	Treatment	Mean	StDev
Texture	1% NacCitrate	27.17	4.52
	2% Nacitrate	19.29	3.53
	control	34.62	10.10
	na bicarb	53.14	13.86
	na citrate 0.1	28.71	12.76
	na citrate and salt	64.35	20.36

RAW DATA FRYING PEAS at 160°C, 12 MINUTES, DIFFERENT FRYING LOAD

Line Number	Frying Load, g	Break Force, (N)
MF1614	100	35.07
MF1614	100	26.77
MF1614	100	38.18
MF1614	100	34.74
MF1614	100	29.24
MF1614	100	37.36
MF1614	100	35.77
MF1614	100	34.59
MF1614	100	31.88
MF1614	100	29.97
MF1614	500	46.63
MF1614	500	46.42
MF1614	500	33.09
MF1614	500	56.36
MF1614	500	64.03
MF1614	500	58.22
MF1614	500	50.50
MF1614	500	32.68
MF1614	500	41.43
MF1614	500	47.55
MF1614	750	54.96
MF1614	750	59.28
MF1614	750	71.12
MF1614	750	31.87
MF1614	750	75.30
MF1614	750	55.70
MF1614	750	93.44
MF1614	750	71.59
MF1614	750	50.27
MF1614	750	34.37
MF1614	1000	23.03
MF1614	1000	46.46
MF1614	1000	40.93
MF1614	1000	56.06
MF1614	1000	53.60
MF1614	1000	49.09
MF1614	1000	71.30
MF1614	1000	51.44
MF1614	1000	52.21
MF1614	1000	46.85
MF1614	200	31.39
MF1614	200	35.15
MF1614	200	42.69
MF1614	200	31.60
MF1614	200	41.38
MF1614	200	23.06
MF1614	200	36.70
MF1614	200	34.52
MF1614	200	23.66
MF1614	200	56.35

Line Number	Load Size	frying time	Moisture Content Wet Basis
MF1614	100	12	2.1%
MF1614	100	12	2.1%
MF1614	100	12	2.1%
MF1614	500	14	2.2%
MF1614	500	14	2.2%
MF1614	500	14	2.5%
MF1614	750	15	2.8%
MF1614	750	15	2.9%
MF1614	750	15	2.9%
MF1614	1000	16	3.7%
MF1614	1000	16	3.7%
MF1614	1000	16	3.7%
MF1614	200	12	2.6%
MF1614	200	12	2.3%
MF1614	200	12	2.5%

FRYING PEAS at 160°C, 12 MINUTES, DIFFERENT FRYING LOAD – MINITAB SESSION

Descriptive Statistics: Break Force, (N)

Variable	Frying Load, g	Mean	StDev
Break Force, (N)	100	33.36	3.74
	200	35.65	9.72
	500	47.69	10.23
	750	59.79	18.85
	1000	49.10	12.18

General Linear Model: Break Force, (N) versus Frying Load, g

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Frying Load, g	Fixed	5	100, 200, 500, 750, 1000

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Frying Load, g	4	4656	1164.1	8.12	0.000
Error	45	6449	143.3		
Total	49	11105			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
11.9713	41.93%	36.77%	28.31%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	45.12	1.69	26.65	0.000	
Frying Load, g					
100	-11.76	3.39	-3.47	0.001	1.60
200	-9.47	3.39	-2.80	0.008	1.60
500	2.57	3.39	0.76	0.451	1.60
750	14.67	3.39	4.33	0.000	1.60

Regression Equation

Break Force, (N) = 45.12 - 11.76 Frying Load, g_100 - 9.47 Frying Load, g_200
+ 2.57 Frying Load, g_500 + 14.67 Frying Load, g_750
+ 3.98 Frying Load, g_1000

Fits and Diagnostics for Unusual Observations

Break

Obs	Force, (N)	Fit	Resid	Std Resid	
24	31.87	59.79	-27.92	-2.46	R
27	93.44	59.79	33.65	2.96	R
30	34.37	59.79	-25.42	-2.24	R
31	23.03	49.10	-26.07	-2.30	R

R Large residual

Residual Plots for Break Force, (N)

Comparisons for Break Force, (N)

Fisher Pairwise Comparisons: Response = Break Force, (N), Term = Frying Load, g

Grouping Information Using Fisher LSD Method and 95% Confidence

Frying Load, g	N	Mean	Grouping		
750	10	59.7891	A		
1000	10	49.0970	A	B	
500	10	47.6910		B	
200	10	35.6508			C
100	10	33.3571			C

Means that do not share a letter are significantly different.

Fisher Individual 95% CIs

RAW DATA DIFFERENT PEA BATCHES (LINE NUMBER) FRIED AT 160°C

Line Number	Break Force, (N)
MF1638A	34.75
MF1638A	27.90
MF1638A	37.18
MF1638A	25.92
MF1638A	29.48
MF1638A	56.14
MF1638A	32.28
MF1638A	32.53
MF1638A	22.95
MF1638A	47.09
MF1647	30.65
MF1647	26.10
MF1647	32.05
MF1647	52.06
MF1647	27.72
MF1647	41.29
MF1647	23.11
MF1647	32.50
MF1647	28.86
MF1647	20.33
MF1614	35.07
MF1614	26.77
MF1614	43.85
MF1614	45.93
MF1614	18.96
MF1614	37.36
MF1614	40.66
MF1614	54.77
MF1614	31.88
MF1614	29.97
MF1401	36.96
MF1401	28.58
MF1401	21.71
MF1401	26.33
MF1401	39.32
MF1401	25.78
MF1401	37.75
MF1401	33.47
MF1401	28.12
MF1401	28.74
MF1600	27.02
MF1600	37.36
MF1600	28.69
MF1600	44.02
MF1600	26.98
MF1600	34.01
MF1600	28.55
MF1600	24.47
MF1600	44.56
MF1600	50.54
MF1636A	47.30
MF1636A	28.92
MF1636A	61.79
MF1636A	26.42
MF1636A	38.25
MF1636A	28.22
MF1636A	22.31
MF1636A	25.05
MF1636A	22.22
MF1636A	44.99
MF1644A	31.58
MF1644A	28.16
MF1644A	34.16
MF1644A	36.58
MF1644A	38.01
MF1644A	38.03
MF1644A	63.63
MF1644A	31.09
MF1644A	33.79
MF1644A	38.16
MF1655	29.77
MF1655	62.06
MF1655	33.28
MF1655	46.45
MF1655	37.46
MF1655	35.27
MF1655	30.08
MF1655	53.19
MF1655	35.38
MF1655	37.97
MF1660	30.40
MF1660	45.45
MF1660	28.90
MF1660	28.83
MF1660	55.57
MF1660	31.86
MF1660	23.62
MF1660	24.39
MF1660	21.65
MF1660	44.08
MF1508	16.83
MF1508	73.55
MF1508	36.37
MF1508	44.21
MF1508	29.10
MF1508	42.48
MF1508	59.16
MF1508	21.60
MF1508	53.77
MF1508	34.41
MF1522	46.69
MF1522	26.65
MF1522	22.76
MF1522	37.45
MF1522	31.16
MF1522	41.07
MF1522	28.77
MF1522	34.57
MF1522	30.27
MF1522	31.32
MF1534	46.05
MF1534	24.29
MF1534	37.69
MF1534	40.88
MF1534	30.27
MF1534	21.44
MF1534	23.33
MF1534	29.82
MF1534	26.80
MF1534	33.72
MF1552	18.57
MF1552	37.87
MF1552	33.46
MF1552	47.10
MF1552	37.44
MF1552	24.41
MF1552	22.17
MF1552	24.49
MF1552	40.38
MF1552	24.59
MF1722	25.40
MF1722	34.42
MF1722	17.18
MF1722	31.08
MF1722	31.19
MF1722	33.89
MF1722	32.68
MF1722	24.77
MF1722	33.20
MF1722	19.35
MF1746	18.59
MF1746	30.26
MF1746	37.00
MF1746	22.04
MF1746	31.65
MF1746	27.01
MF1746	40.25
MF1746	32.16
MF1746	40.61
MF1746	24.24

Line Number	Moisture Content Wet Basis	Average, (Wet basis)	STDev
MF1638A	1.9%	1.9%	0.1%
MF1638A	2.0%		
MF1638A	1.9%		
MF1647	2.5%	2.4%	0.1%
MF1647	2.4%		
MF1647	2.2%		
MF1638A	2.6%	2.6%	0.1%
MF1638A	2.5%		
MF1638A	2.7%		
MF1614	1.6%	1.6%	0.1%
MF1614	1.6%		
MF1614	1.8%		
MF1614	1.8%	1.8%	0.0%
MF1614	1.8%		
MF1614	1.8%		
MF1401	1.6%	1.8%	0.2%
MF1401	1.7%		
MF1401	2.0%		
MF1600	1.4%	1.4%	0.0%
MF1600	1.3%		
MF1600	1.4%		
MF1636A	1.6%	1.5%	0.1%
MF1636A	1.5%		
MF1636A	1.3%		
MF1655	1.4%	1.3%	0.1%
MF1655	1.4%		
MF1655	1.2%		
MF1660	1.4%	1.5%	0.2%
MF1660	1.3%		
MF1660	1.7%		
MF1644A	1.4%	1.3%	0.1%
MF1644A	1.2%		
MF1644A	1.2%		
MF1508	2.3%	2.46%	0.29%
MF1508	2.3%		
MF1508	2.8%		
MF1522	2.9%	2.95%	0.17%
MF1522	3.1%		
MF1522	2.8%		
MF1534	2.5%	2.60%	0.22%
MF1534	2.9%		
MF1534	2.5%		
MF1552	2.7%	2.66%	0.17%
MF1552	2.8%		
MF1552	2.5%		
MF1722	2.6%	2.57%	0.32%
MF1722	2.3%		
MF1722	2.9%		
MF1746	2.9%	2.65%	0.26%
MF1746	2.4%		
MF1746	2.6%		

FRYING DIFFERENT PEA BATCHES (LINE NUMBER) AT 160°C ,12 MINUTES – MINITAB SESSIONS

General Linear Model: Moisture Content Wet Basis versus Line Number

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Line Number	Fixed	16	MF1401, MF1500, MF1508, MF1522, MF1534, MF1552, MF1600, MF1614, MF1636A, MF1638A, MF1644A, MF1647, MF1655, MF1660, MF1722, MF1746

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Line Number	15	0.001544	0.000103	26.17	0.000
Error	32	0.000126	0.000004		
Total	47	0.001670			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0019832	92.46%	88.93%	83.04%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.020676	0.000286	72.23	0.000	
Line Number					
MF1401	-0.00289	0.00111	-2.61	0.014	1.88
MF1500	0.00502	0.00111	4.52	0.000	1.88
MF1508	0.00389	0.00111	3.51	0.001	1.88
MF1522	0.00885	0.00111	7.98	0.000	1.88
MF1534	0.00533	0.00111	4.80	0.000	1.87
MF1552	0.00596	0.00111	5.38	0.000	1.88
MF1600	-0.00685	0.00111	-6.18	0.000	1.88
MF1614	-0.00428	0.00111	-3.86	0.001	1.88
MF1636A	-0.00597	0.00111	-5.39	0.000	1.88
MF1638A	-0.00141	0.00111	-1.27	0.213	1.88
MF1644A	-0.00800	0.00111	-7.22	0.000	1.87
MF1647	0.00289	0.00111	2.61	0.014	1.88
MF1655	-0.00747	0.00111	-6.74	0.000	1.88
MF1660	-0.00584	0.00111	-5.26	0.000	1.87
MF1722	0.00498	0.00111	4.50	0.000	1.88

Regression Equation

Moisture Content Wet Basis = 0.020676 - 0.00289 Line Number_MF1401
+ 0.00502 Line Number_MF1500
+ 0.00389 Line Number_MF1508
+ 0.00885 Line Number_MF1522
+ 0.00533 Line Number_MF1534

```
                              + 0.00596 Line Number_MF1552 -
 0.00685 Line Number_MF1600
                              - 0.00428 Line Number_MF1614 -
 0.00597 Line Number_MF1636A
                              - 0.00141 Line Number_MF1638A -
 0.00800 Line Number_MF1644A
                              + 0.00289 Line Number_MF1647 -
 0.00747 Line Number_MF1655
                              - 0.00584 Line Number_MF1660
+ 0.00498 Line Number_MF1722
                              + 0.00581 Line Number_MF1746


Fits and Diagnostics for Unusual Observations

      Moisture
       Content                          Std
Obs  Wet Basis      Fit    Resid  Resid
  6    0.02795  0.02456  0.00338   2.09  R
 47    0.02938  0.02569  0.00369   2.28  R

R  Large residual
```

Residual Plots for Moisture Content Wet Basis

Comparisons for Moisture Content Wet Basis

Fisher Pairwise Comparisons: Response = Moisture Content Wet Basis, Term = Line Number

```
Grouping Information Using Fisher LSD Method and 95% Confidence

Line Number  N       Mean      Grouping
MF1522       3  0.0295250  A
MF1552       3  0.0266357  A  B
MF1746       3  0.0264831  A  B
MF1534       3  0.0260025     B
MF1500       3  0.0256921     B
MF1722       3  0.0256595     B
MF1508       3  0.0245621     B
MF1647       3  0.0235640     B
MF1638A      3  0.0192684        C
MF1401       3  0.0177809        C  D
MF1614       3  0.0163984        C  D  E
MF1660       3  0.0148396           D  E  F
MF1636A      3  0.0147015           D  E  F
MF1600       3  0.0138215              E  F
MF1655       3  0.0132056              E  F
MF1644A      3  0.0126718                 F

Means that do not share a letter are significantly different.
```

CORRELATION RAW DATA

Pea Name	Ratio of Size	Density	Weight	Hydraction Capacity	Moisture	Texture
MF1600	0.21	1.23	35.09	0.39	1.43%	34.27
MF1600	0.19	1.20	35.53	0.38	1.34%	39.30
MF1600	0.18	1.21	35.11	0.38	1.38%	46.05
MF1614B	0.27	1.15	34.94	0.35	1.59%	37.90
MF1614B	0.28	1.15	34.77	0.35	1.58%	32.33
MF1614B	0.24	1.15	34.53	0.36	1.75%	38.87
MF1636A	0.27	1.18	34.61	0.35	1.55%	30.43
MF1636A	0.25	1.20	34.54	0.33	1.51%	32.88
MF1636A	0.26	1.19	34.41	0.34	1.34%	36.78
MF1638A	0.02	1.20	45.14	0.41	1.87%	31.44
MF1638A	0.03	1.19	44.01	0.40	1.99%	39.30
MF1638A	0.02	1.20	44.31	0.40	1.92%	34.19
MF1644A	0.23	1.16	36.73	0.35	1.41%	38.19
MF1644A	0.22	1.13	36.45	0.36	1.20%	40.64
MF1644A	0.23	1.14	36.56	0.37	1.19%	42.84
MF1647	0.14	1.15	36.39	0.35	2.45%	27.28
MF1647	0.13	1.14	36.43	0.35	2.43%	33.84
MF1647	0.16	1.14	36.10	0.35	2.19%	34.68
MF1655	0.16	1.22	36.54	0.36	1.39%	39.30
MF1655	0.22	1.18	35.84	0.36	1.35%	40.62
MF1655	0.18	1.20	36.01	0.38	1.22%	40.62
MF1660	0.38	1.15	36.18	0.34	1.41%	33.40
MF1660	0.34	1.13	35.83	0.38	1.33%	39.23
MF1660	0.30	1.15	36.88	0.36	1.71%	31.98
MF1722	0.20	1.25	37.65	0.36	2.6%	33.32
MF1722	0.21	1.27	37.33	0.35	2.3%	38.65
MF1722	0.20	1.22	38.09	0.35	2.9%	35.09
MF1401	0.08	1.27	40.01	0.34	1.6%	40.18
MF1401	0.10	1.28	40.26	0.34	1.7%	43.53
MF1401	0.09	1.29	39.45	0.34	2.0%	42.71
MF1746	0.17	1.22	36.89	0.35	2.9%	34.45
MF1746	0.16	1.22	37.06	0.34	2.4%	32.97
MF1746	0.17	1.26	37.18	0.35	2.6%	32.34
MF1508	0.29	1.25	35.10	0.41	2.3%	32.58
MF1508	0.27	1.27	35.58	0.40	2.3%	36.55
MF1508	0.26	1.27	35.72	0.40	2.8%	36.59
MF1522	0.74	1.23	30.94	0.33	2.9%	33.39
MF1522	0.58	1.18	30.21	0.33	3.1%	33.67
MF1522	0.65	1.35	31.65	0.33	2.8%	32.05
MF1534	0.22	1.23	35.88	0.38	2.5%	37.23
MF1534	0.15	1.25	37.70	0.39	2.9%	25.01
MF1534	0.20	1.24	36.26	0.38	2.5%	30.11
MF1552	0.16	1.25	35.41	0.34	2.7%	34.25

MF1552	0.14	1.27	36.09	0.39	2.8%	28.01
MF1552	0.19	1.25	36.20	0.35	2.5%	29.82
MF1500	0.26	1.27	35.43	0.27	2.3%	36.55
MF1500	0.23	1.28	36.04	0.27	2.9%	30.99
MF1500	0.20	1.26	37.23	0.27	2.5%	33.46