Relating physico-chemical properties of frozen green peas (*Pisum sativum* L.) with sensory quality.

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DECLARATION

I hereby declare that the dissertation submitted for the degree MSc Food Science at the University of Pretoria, has not previously been submitted by me for a degree at any other university or institution of higher education.

Kathleen Mutsa Nleya

DEDICATION

To my parents, whose endless belief in education has brought me this far.

To the Almighty God who has been with me all the way.

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ABSTRACT

Relating physico-chemical properties of frozen green peas (*Pisum sativum* L.) with sensory quality.

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Green garden peas (*Pisum sativum* L.) are a popular vegetable used in meal preparation worldwide. Green peas are commonly available in their frozen form due to their short growing season. Green peas are easily susceptible to changes in the field, immediately after harvest, during processing and storage, and therefore require careful handling to maintain good quality. The acceptability of frozen green peas is greatly dependent on the sensory quality. Descriptive sensory profiles and physico-chemical properties of frozen green peas can be investigated and used to assess and explain product quality.

Six brands of frozen green peas representing product sold for retail and caterer's markets were purchased and subjected to descriptive sensory evaluation, physico-chemical analyses and quality grading. Four batches with different best before dates were purchased for each brand. Quality grading was done using statutory standards and a selected company protocol. Dry matter content, alcohol insoluble solids content, starch content, °Brix, residual peroxidase activity, size sorting, hardness using texture analysis and colour measurements were carried out for physico-chemical analyses.

Generally, retail class peas were of superior sensory quality to caterer's peas although one caterer's brand had quality traits that were more comparable with the retail brands than the other caterer's brands. Quality grading revealed that frozen green peas can be downgraded due to poor colour, presence of extraneous vegetable matter, presence of sandy grits and soil stains, poor flavour and poor texture. Downgrading of peas can be due to one reason or due to a combination of two or more poor quality characteristics. Good quality peas were described as sweeter, smaller, greener, more moist and more tender than the poorer quality peas using descriptive sensory evaluation. Good peas also had high °Brix content, more intense green colour, low starch, alcohol insoluble solids, dry matter contents and texture hardness measured. Quality grading revealed that flavour problems were the major cause for low graded samples. Sensory evaluation and the methods used for instrumental analyses however, showed more easily the variations in texture attributes than flavour attributes of peas.

Poor flavour was probably caused by ineffective blanching, low soluble solids content which enhanced the perception of bitterness and the presence of acetone notes. Poorly coloured peas were also either underblanched or had low moisture contents. Mealiness and hardness in peas were explained by high starch, alcohol insoluble solids and dry matter contents. Instrumental texture analysis showed indications that the harder peas also had tougher skins in addition to harder cotyledons. Lower peas also displayed characteristics typical of delayed harvesting and post-processing temperature abuse such as dehydration and pale green/white colouration.

The sensory quality of frozen green peas can be predicted from the physico-chemical methods of analysis used in this study. Some of the frozen peas on sale are below the acceptable standards of quality. To achieve good frozen pea quality it is important to put emphasis on maturity at harvest and post processing storage conditions (store at -18 °C or lower and avoid fluctuating temperatures). The use of a strict quality grading scheme has been shown to result in good quality frozen peas.

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1. INTRODUCTION

Quality is one of the most defined terms in use in the food industry today but it is also perhaps one of the most confusing because it is used for several distinct purposes. The most widely used concept is the fitness for purpose sense which relates to the ability of a product to satisfy a given need (Civille, 1991). The pea crop (*Pisum sativum* L.), is a common legume which plays an important role in the human diet. Green garden peas are sometimes referred to as "green gold" in some vegetable processing circles because of their short growing and processing season. In their quick frozen form they may be used as a very convenient vegetable. Green peas add colour and make a meal look attractive and thus their sensory quality may greatly influence their acceptance.

Vegetable processors pack frozen vegetables for different markets including retail stores, restaurants and institutional facilities such as prisons, schools and hospitals (Glaser and Thompson, 1999). Many companies have Quality Assurance (QA) and Quality Control (QC) programmes which use chemical and instrumental methods of analysis to pursue and maintain product quality (Munoz, 2002). Frozen peas available on the South African market are categorised into two classes; one manufactured for retail sale and the other for catering purposes. A grading system applied by a designated company specifies frozen peas into grades A, B, C and Substandard (SS) in decreasing order of quality to help define which class the products fall. The company standards are expected to be within statutory requirements (South Africa Department of Agriculture, 1998). Vegetable processing inplant QC measures include analytical or instrumental methods. It has been recommended that product quality standards should not depend entirely on instrumental methods but that reference should also be made to sensory analysis of appearance, flavour and texture (Atherton and Gaze, 1983). Instrumental measurements have been considered to be useful and reliable if they have been validated against sensory measures, through sensory-instrumental data relationship studies (Munoz, 2002). In this light descriptive sensory evaluation offers the manufacturer an opportunity to learn about how human assessors grade their food products. Sensory attributes of vegetables are a function of their physico-chemical composition (Lyon and Churchill, 1991) and for frozen peas may be dependent on the sugar content, starch content, alcohol insoluble solids content, green colour intensity, size, dry matter content and objective texture measurements.

Food manufacturing companies obtain larger market share by producing preferred products. Manufacturers offer their own judgement and skills as a guarantee of product quality (Ilbery and Kneafsey, 2000). While the expertise of a frozen vegetable company in the fundamentals of the manufacture of frozen green peas is undisputed, the underlying question is "What defines green pea quality and are the quality control systems in place ensuring the delivery of products of the expected quality?" Knowledge of frozen green pea sensory profiles and the link of these to physico-chemical properties and grading schemes may provide relevant information on what defines green pea quality and possibly how to improve the product. It was in the interest of a frozen pea manufacturing company to obtain information on how their product performs. It was thus seen fit to compare their product with other competing brands of frozen peas available on the market. This was done to give a view of its position in terms of product quality and to identify the most important quality determining sensory attributes.

The physico-chemical properties, sensory properties and quality grades of six locally available frozen green pea brands were investigated to define the characteristics of the retail and caterer's classes. Physico-chemical properties of frozen peas were related to the sensory quality.

2. LITERATURE REVIEW

2.1 The rise in popularity of green peas as frozen vegetables

Grain legumes are crops of the family Leguminosae (Fabacae) and are mainly grown for their edible seeds (Iqbal *et al*., 2006). The grain legumes are collectively ranked fifth in terms of annual world grain production (Ratnayake *et al.*, 2001). In developing third world countries, legumes are the major protein source in the diet especially for the poor. Pea (*Pisum sativum* L.), which fall under this group appears to have been first cultivated in western Asia, from where it spread to Europe, China and India. By 1800 peas were an important food crop in Rwanda and South Western Uganda (Messiaen *et al*., 2004). Peas are one of the four important legumes cultivated worldwide; soy beans, groundnuts and beans make up the rest. Pea is a predominant export crop in world trade and represents about 35–40% of the total trade in pulses (Ratnayake *et al*., 2001). The three main uses of pea cultivars have been distinguished into field pea grown for their dry seeds, garden pea grown for their immature green seeds and sugar pea grown for the immature pods (Messiaen *et al*., 2004). However, it is in their dry mature state in which they are commonly used (Alonso *et al*., 2000). This could most likely be due to easier storage, more practical usage as a food particularly in poor economies, and less stern measures and harvesting time frames required to be adhered to. Hence much documented studies on pea physiological properties are on the dry form.

Peas, which are a typical green vegetable, were the first vegetable to be available in a frozen form in the 1950s and the first to have its consumption, in a "fresh" form, detached from its seasonality (Green and Foster, 2005). Peas have also been found to be an important vegetable crop for the canning industry (Jokanovic *et al*., 2006). The popularity of fresh garden peas has decreased markedly in developed countries primarily due to harvest expense and the readily available frozen peas throughout the year (Deshpande and Adsule, 1998). Frozen peas rank third behind processed potato products and corn in their importance amongst frozen vegetables and have virtually replaced fresh peas in the American diet (Deshpande and Adsule, 1998; Luh and Lorenzo, 1988). The South Africa Department of Agriculture, Forestry and Fisheries (2011) statistics report a reduction in green peas produced from 24000 tonnes between July 1998 and June 1999 to 15 000 tonnes between July 2008 and June 2009.The reduction in green peas produced could result in more green peas imported to ensure sufficient product in the market. The gross value of fresh green peas is observably increasing with reduced availability. Gross value rose from R25 269 000 between July 1998 and June 1999 to R57 100 000 between July 2008 and June 2009. The South Africa Department of Agriculture, Forestry and Fisheries (2011) also reveals a greater than half decline in the peas sold as fresh produce, from 700 tonnes in 1999 to 300 tonnes in 2009. This could mean that South African consumers are increasingly using green peas in forms other than the fresh state such as canned, frozen or dried.

The development of convenience foods is one of the major factors that have shaped the modern food industry. These foods are defined as those that "transfer the time and activities of preparation from the household manager to the food processor" and have been classified into three categories: basic, complex and manufactured convenience (Capps, Tedford and Havlicek, 1985). Frozen vegetables such as peas which can be prepared in a very short period of time, fall under the basic convenience category according to Capps *et al*. (1985). This category is defined to constitute a group of foods where processing is more related to a preservation method than to ease of preparation; foods with a single or limited number of ingredients as well as foods with time and energy inputs and not culinary expertise built in. Freezing preserves vegetables and makes them available throughout the year out of their growing season and hence increasing convenience. The frozen vegetable industry has seen remarkable improvements such as the development of steam-in-bag technology where frozen vegetables are packed in a custom-designed film bag that becomes the steaming vessel and are prepared rapidly in the microwave (Reed Business information, 2006). Senauer and Mangaraj (2001) reported that convenience is an attribute of food products for which demand is strong. As the demand for convenience foods becomes greater, the

quality of such food products hence becomes more important (Buckley, Cowan, McCarthy and O'Sullivan, 2005). Research by McEwan and Clayton (1998) revealed that consumers preferred green peas in the frozen state as they were far more convenient in terms of both speed and ease of preparation. The study's participants also stated that frozen peas were probably "fresher" than fresh peas as they are frozen straight after picking; before fresh peas can get to the stores.

Fresh vegetables available to the consumer have typically spent a period of 3-7 days in retail distribution and storage before consumption. Increasingly this transportation and storage is carried out at lower temperatures (i.e. refrigerated), but the traditional greengrocer, market trader and many consumers continue to transport and store vegetables at ambient temperatures (Favell, 1998). Fresh vegetables have a short shelf life and their superior quality may easily be altered. Fresh vegetables can thus be exposed to a variety of conditions which offer the potential for changes in quality characteristics before in-home cooking and consumption. However, green peas for commercial freezing should be processed within hours of harvesting (Siddiq and Pascall, 2010).

Bourne (2004) refers to post-harvest technologies as the stabilisation and storage of unprocessed or minimally processed foods from the time of harvest until final preparation for human consumption. The aim of post-harvest technologies is to combine shelf life extension with maintenance of sensory and nutrient characteristics. There is a special emphasis on seasonal crops such as green peas which only grow in a very short period of the year. Freezing of foods, retards the growth of microorganisms, the metabolic activity of intact plant tissue, moisture loss, and deteriorative damage such as oxidative browning, lipid oxidation and colour degradation (Adsule *et al.*, 1989), and thus retains product sensory quality. Frozen peas can be stored at -18 °C for over a year without any significant loss in quality (Deshpande and Adsule, 1998). The main factors that have been found to contribute to the final quality of frozen vegetables are the raw materials used, processing (including blanching treatment and method of freezing) and post-processing distribution, storage and home-handling (Giannakourou and Taoukis, 2003; Bourne, 2004). Some changes to sensory quality may occur; particularly during blanching necessary to inactivate natural enzymes prior to freezing, but little further change can be expected thereafter during deep frozen storage (Favell, 1998). Thus freezing, if properly conducted, is generally regarded as the best method of preservation for selected foods when judged on the basis of retention of sensory attributes (Adsule *et al.*, 1989).

2.2 Freezing kinetics and frozen green peas processing

The objectives of freezing preservation are optimally achieved by lowering the temperature below the point where nucleation (formation of crystal embryos which serve as the nucleus for growth of crystals) occurs. This is followed by lowering the temperature further to promote crystallisation of a sufficient fraction of water to achieve a high concentration of solutes in the non-frozen part of food and storing the food at low temperatures preferably below the glass transition temperature (T_g) of the non-frozen concentrated solution (Karel and Lund, 2003). The glass transition temperature is the point at which no more water in the amorphous concentrated solution can freeze (Pardo and Niranjan, 2006). Glassy materials are brittle and highly viscous. The glassy state is characterised by molecular immobility (Blanshard, 1995) which renders frozen food stable. Figure 2.1 outlines the general steps taken in frozen green pea production. The choice of the most appropriate cultivar is essential (Knight, 1991). The growth of the frozen vegetable industry has seen many industries, research institutions and universities devoting major time to developing cultivars that show improved frozen vegetable quality. Desirable quality improvements include more productive, easy to harvest by machine plants, vegetables that remain stable for longer periods after harvesting and during frozen storage (Luh and Lorenzo, 1988).
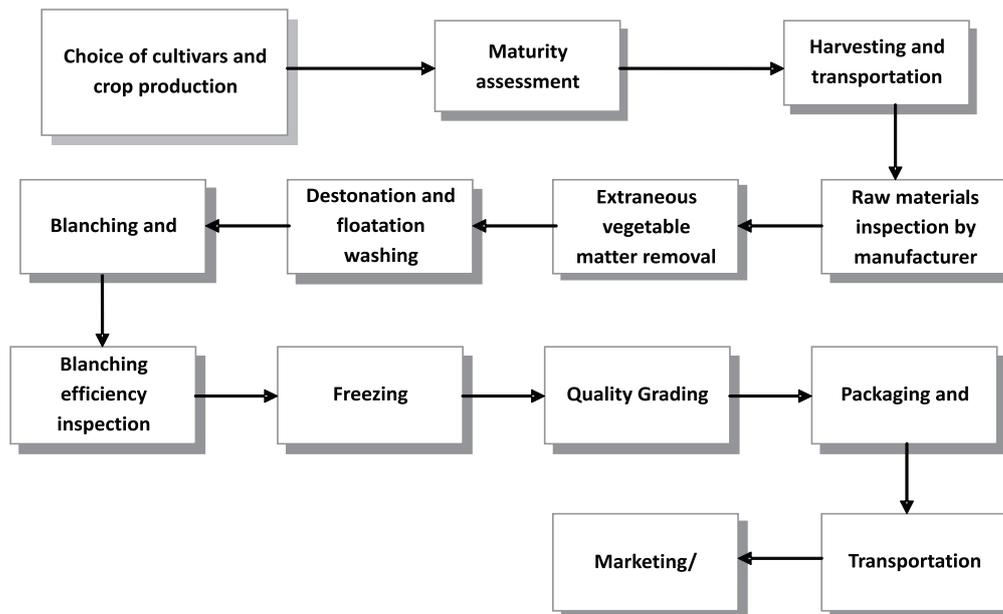
Figure 2.1: General flow-chart for frozen peas production (Adapted from Arthey, 1993)

Maturity is assessed on the pea seeds to determine time of harvest using a tenderometer. Optimum tenderometer readings for freezing stage are between TR 115 and TR 120 (Arthey, 1993). Normally contracts between the manufacturer and farmers include the required factory standards. Upon reaching the factory the peas are inspected for adherence to the set quality specifications (Rutledge, 1993).

Peas are prepared by removal of extraneous vegetable matter, destonation and washing. Blanching and subsequent cooling follow these steps. Blanching done using water or steam is mainly carried out to inactivate enzymes which may otherwise lead to quality reduction in the processed product (Grandison, 2006). Peas are blanched for a minimum time of 1.5 min at 100 °C (Luh and Lorenzo, 1988). Green peas are quick frozen and the most common freezers are fluidised or fixed bed freezers. Freezing rates in a fluidised bed are so rapid that green peas are brought down to an internal temperature of -18 °C in 4 min.

Freezing times and temperatures used have an impact on the quality of frozen peas. If temperatures are low and freezing is slow, the ice crystals grow very large and water is withdrawn from within the cells to add to the crystals. Fast freezing however prevents the water from moving before it is frozen and therefore gives smaller crystals both inside and outside the cells resulting in less damage to the plant tissue (Edwards, 1995). Green peas are quality graded after freezing and packaged accordingly. The processed product is placed in cold storage and transported for marketing.

2.3 Nature and composition of green peas

In development of leguminous fruits (pods), hull expansion begins at ovule fertilisation and proceeds by differential growth of inner and outer layers of cells to form a hollow envelope in which the seed may develop and enlarge (Bryant, 1979). As hull growth slows, seed growth rapidly increases. Bain and Mercer in 1966 according to Basterrechea and Hicks (1991) identified four phases of green pea cotyledon development. (1) cell formation which is characterised by rapid cell division and differentiation; (2) cell expansion marked by the enlargement of parenchyma cells when the cotyledon expands into space occupied by the liquid endosperm and absorbs sucrose, amino acids, ammonia salts and organic acids; (3) synthesis of storage reserves marked by rapid synthesis of starch, reserve proteins, and lipids and the attainment of maximum fresh weight

by the seed; and (4) maturation and dormancy where starch content and dry weight continue to increase while there is a marked fall in fresh weight, sucrose and respiration as the seed approaches dormancy.

Moisture (i.e. water) is a major component of fresh green peas and at processing maturity ranges from 74-81% (Lynch *et al*., 1959; Adsule, Lawande and Kadam, 1989). The water content in peas has been related to maturity as water content is seen to decrease with maturity. Green garden peas contain starch with a low glycaemic index (Nilsson *et al.,* 2004). Low glycaemic index (GI) starch from foods such as legumes and sour bread doughs, release glucose to the blood at a much slower rate than high GI starch containing foods such as potatoes and common bread (Björck *et al*., 2000). Legumes are high sources of protein; however, the nutritive value of pea proteins is low in comparison to animal proteins (Alonso *et al*., 2000). This has been attributed to poor digestibility, a deficiency of sulphur containing amino acids and the presence of anti-nutritional factors, such as phytates, polyphenols, enzyme inhibitors (trypsin, chymotrypsin, and R-amylase) and hemagglutinins (Gwiadza *et al*., 1980; Evans and Boulter, 1980; Periago *et al*., 1996). Table 2.1 presents the proximate composition of raw green peas (*Pisum sativum*) in different areas as reported by different authors.

Table 2.1 Proximate composition of raw immature green peas

Nutrient (g/100 g)	FAO (1968) For use in Africa	Chin and Dudek (1988) United States	Langenhoven *et al*. (1998) South Africa	Lukmanji *et al.* (2008) Tanzania
Protein	6.7	5.4	5.5	5.4
Available Carbohydrates	14.7	12.3	8.3	10.1
Fat	0.5	0.4	0.8	0.2
Fibre	2.5	2.2	6.3	5.5
Moisture	74.9	78.9	78.2	Not Determined
Energy (Kcal)	82	81	89	84

In terms of carbohydrate content, a study carried out by Turner and Turner (1957) shows that an increase in starch content in a pea seed with maturation is countered by a decrease in sucrose (sugar) content. The increase in starch content in maturity has also been observed to cause a decrease in moisture content. In a study by de Almeida *et al*. (2006) that included pea (*Pisum sativum* L.), common bean (*Phaseolus vulgaris* L.), chickpea (*Cicer aretinum* L.) and lentil (*Lens culinaris* Med.) it was verified that insoluble dietary fibre (IDF) contents represented the greatest part of the total dietary fibre of the legumes, soluble dietary fibre (SDF) being only a small part of the total.

2.4 Why investigate quality?

The concept of food quality has received a lot of attention in recent years. While many attempts have been made to clarify and define the concept (Bremner, 2000), there is still no general agreement on what the term food quality covers, and how it can be measured (Acebrón & Dopico, 2000; Lawless, 1995). The selection and consumption of food has always been a matter subject to a complex network of cultural and individual factors. Grunert (2006) further states that in the present day, consumer food choice is more complex than ever before as consumers have developed more dynamic, complex and differentiated demands. According to Grunert (2005) consumers' food quality perceptions can be distinguished into four groups of quality attributes and these include sensory, health, process, and as previously stated convenience attributes. Consistent product quality is therefore definitely a key focus in the food industry. Ensuring superior quality, however it is defined, is clearly required in the production and distribution of food products (Pecore and Kellen, 2002). Product quality directly relates to customer satisfaction and ultimately to

repeat sales. With increased understanding of the sensory characteristics that drive acceptance of products and focus on sensory quality, significant cost savings have been realised (Pecore and Kellen, 2002). Cardello (1995) specifies three critical aspects of food quality: (1) it uses the consumer as the referent, (2) it focuses on acceptability as the key measurement construct, and (3) it connotes the relativity of judgment reflected in the qualifying concepts of 'product category' and 'target market.' It is the manufacturer's task therefore to optimally satisfy the third category by making a product that is of the right form of quality to suit the intended consumer. Quality has thus been established to be a positional characteristic which gives a product or service a cutting edge over its rivals (Ilbery and Kneafsey, 2000).

Quality is said to be a fuzzy and relative term that is always in constant motion (Fisken, 1990). It is with this in mind that any specification method or group of methods designed to control the quality of a certain product may be applicable in a particular situation but they are subject to a constant evolution (Costell, 2002). The changes come, on the one hand as a function of methodological advances in each area (chemical analysis, microbiology, toxicology, etc.) and on the other, of changes undergone by market requirements and degree of commercial competition for the particular food product (Costell, 2002). Food quality control and assurance is evidently a top subject both in industry and in public control institutions (Juran, 1974; Herschdoerfer, 1986; Stauffer, 1988). A basic requirement of any sensory quality control (QC) system is the definition of standards or tolerance limits on a sensory basis for the product (Hough, Garitta and Sánchez, 2004).

Sensory science, a multidisciplinary field comprising measurement, interpretation and understanding of human responses to product properties as perceived by the senses such as sight, smell, taste, touch and hearing (Martens, 1999), may be used towards quality assessment ratings of a product during processing. Descriptive sensory panel (DSP) evaluation makes use of trained and calibrated human beings as tools in describing profiles of foods. This is very useful when coupled with instrumental measurements in industry as the DSP gives a more realistic interpretation of what the consumer would experience. Martens (1999) states that sensory science has been successful when used in quality assurance of food and beverage industries. The potential of using sensory evaluation to link product development to marketing has been recognized, and is receiving a lot more attention (Martens, 1999).

Munoz *et al*. (1992) classified eight test methods that can be used in sensory quality control of food products. These include overall difference tests; difference from control; attribute or descriptive tests; in/out of specifications; preference and other consumer tests; typicality measurements; qualitative description of typical production and quality grading. Most companies make use of quality grading which allows for rapid qualification of the product and for the detection of the possible causes of rejection. Grading refers to the categorisation of products with substantial variation in quality into distinct classes more homogenous in quality (Hollander *et al*., 1999). Governing bodies often have regulations regarding food processing and standards for quality. Thus, grading systems adopted by companies are expected to be within these specifications. Grades and standards improve marketing efficiency by reducing the risk of miscommunication between sellers and buyers (Shewfelt and Brückner, 2000). Costell (2002) identifies a problem in quality grading to arise from deviation in results by judges that are required to correctly interpret descriptions corresponding to each of the quality grades for selected attributes. Judges therefore should be well trained for this exercise.

Brunsø, Fjord and Grunert (2002) grouped food quality into product-oriented, process-oriented, user-oriented types and the identified quality control measures applied (Figure 2.2). The model has been adapted in this research to summarise quality as applied to frozen green peas. Product-oriented quality covers all aspects of the physical product that together give a precise description of the specific food product. Process-oriented quality covers the way the food product has been produced. Brunsø *et al*. (2002) define quality control as the standards a product has to meet in order to be approved for a specific quality class. Quality control therefore deals with the adherence of

product and process aspects to specific standards irrespective of at which level these have been defined (Lawless, 1995; Brunsø *et al*., 2002). It has been said that product oriented quality and process oriented quality is concerned with the level of quality whereas quality control considers the dispersion of quality around a predetermined level.
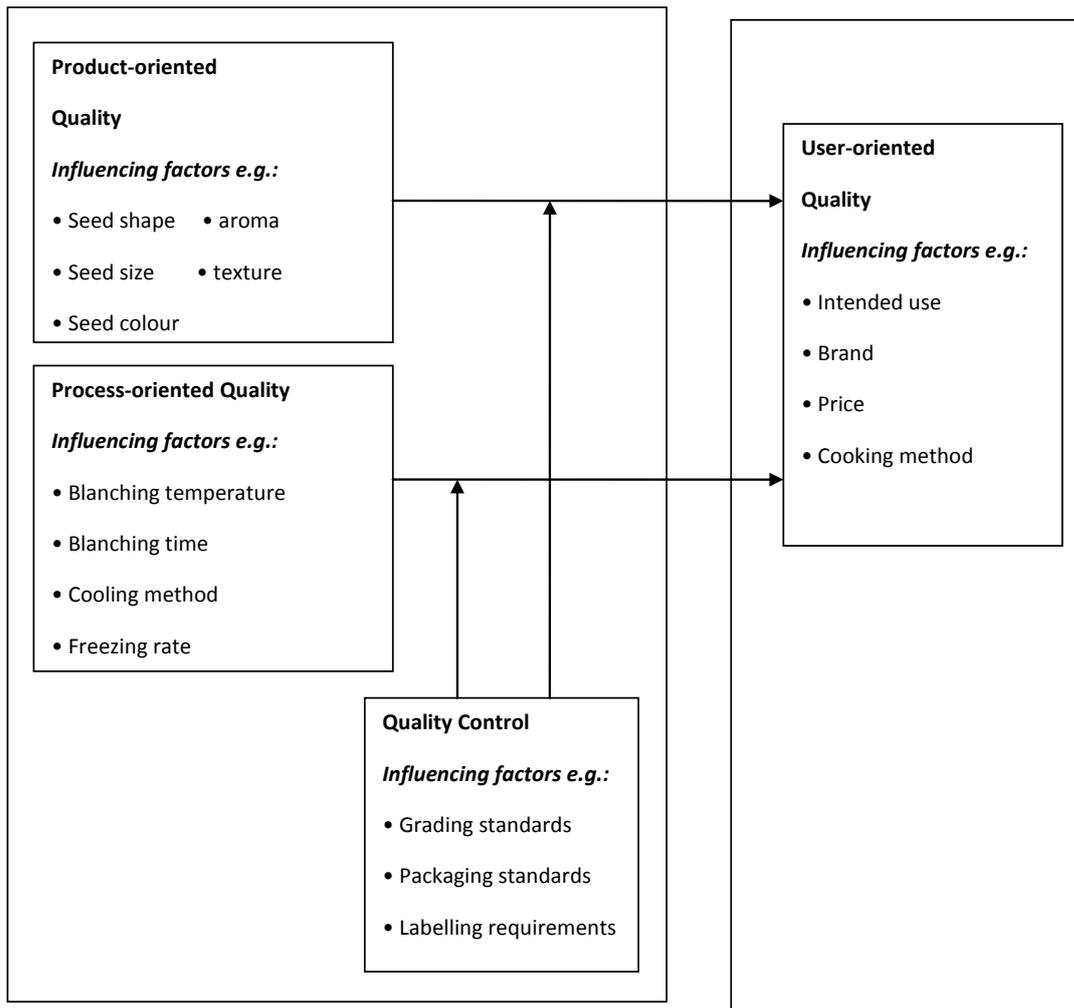
Figure 2.2: Four types of food quality proposed by Brunsø, Fjord and Grunert (2002) as applied to frozen green peas

Process-oriented, product-oriented quality and quality control can be summarised as producer's quality. Producer's quality criteria are objective (Brunsø *et al*., 2000; Hansen 2001) and can be described in terms of technical specifications (Bergman and Klefsjö, 1994). The more the product meets these specifications, the better the quality and any deviations from these would indicate depreciation in quality (Dean, 1991; Hansen, 2001). User-oriented quality is subjective perception from a user point of view and is thus individually determined (Brunsø *et al*., 2000; Hansen 2001; Ilbery and Kneafsey, 2000). A user can however be an intermediate-user in the food chain (e.g. retailer) or the end-user consumer in the home (Brunsø *et al*., 2000).

Hansen (2001) gives an illustration of the alternative interpretations of quality (Figure 2.3) from the consumer's (user) and producer's point of view. When the consumer's and producer's criteria are in accordance, there is a higher probability that the product nears excellence in quality (Hansen, 2001). When a consumer is faced with a product, expectations of the quality aspects within are built. Expectations play a key role in any decision making and subsequent action process and they arise either from belief alone or from a sensory stimulus (Hutchings, 2003). Expectations play a role in the final judgement of perceived quality. Hence, fulfilled expectations contribute to product excellence.

Excellence

Figure 2.3: Alternative interpretations of quality (Hansen, 2001)

The notion that the quality of a product should be determined in relation to its price and not solely by its own merits describes the concept of value (Hansen, 2001) which is more realised from the producer's view point. Value is hence placed more towards the right of the diagram.

Consumer quality expectations for various products may be influenced by their intended consumer groups (such as products for children versus adults; top class restaurants versus boarding school catering). Juhl *et al.* (1998) found that the division of consumers of frozen green peas into high and low involvement in purchase groups may be important in the planning stage of product development. The revised total food quality model (Figure 2.4) integrates the multi-attribute and the hierarchical approaches to quality perception (Brunsø, Fjord and Grunert, 2002). The pieces of information used to form quality expectations are usually called quality cues (Steenkamp, 1990). Intrinsic quality cues refer to physical characteristics of the product and extrinsic quality cues refer to everything else including the price of the product, the store in which the product is bought, advertising claims about the product, and the brand (Grunert, 2002). The relationship between quality expectation (before purchase) and quality experience (after purchase) is commonly believed to determine consumer satisfaction with the product and, hence, the probability of repeated purchases (Oliver, 1980, 1993).

Figure 2.4: Revised total food quality model (Bech *et al*., 2000)

Brands are a special quality cue, because they allow consumers to draw on their previous experience with the product. A satisfactory quality experienced after the purchase will pave the way to repurchase of the branded product. When products are unbranded, quality labels can give consumers another means of deducing experience and characteristics of food products (Grunert, 2002). However, for purposes of this research some of the aspects within the model that have not been considered include brand cost cues and extrinsic cues such as growth conditions. Quality hence encompasses a number of factors which ultimately result in the success of a product. The necessity to be responsive to the needs of various consumer markets and demands places a greater emphasis on quality assessment (Brosnan and Sun, 2004). This in turn translates to greater need for more studies to be carried out to ascertain and improve product quality.

2.5 Parameters of consideration in quality grading of green peas

Agricultural produce is manipulated at various stages from the field to the final consumer and is generally oriented towards the cleaning of the product and sorting into homogeneous categories (Blasco *et al*., 2003). Quality grading is used in industrial food quality control and attributes such as appearance, aroma, texture and flavour are frequently examined by human inspectors (Brosnan and Sun, 2004).

2.5.1 Appearance

Appearance both determines and dominates expectations. According to Hutchings (2003), although flavour or perhaps texture is normally the final arbiter of quality, food must first pass the appearance test. As in most legumes, single individual pea plant or pod produces seeds

differing in their appearance (Atak *et al.*, 2008). In grain legumes, sequential development and spatial heterogeneity of the pod position can lead to significant differences in shape, size, weight and colour among the seeds (Fenner, 2010). Visual appearance is considered a main source of information for quality grading and can be broken down by image analysis to attributes such as size, colour, shape, defects and abnormalities (Jahns, Nielsen and Wolfgang, 2001).

2.5.1.1 Colour

Gifford and Clydesdale (1986) reported that colour has been shown to be of primary importance in the initial judgement of food, ultimately influencing its acceptance or rejection. Research by Atak *et al.* (2008) revealed that seed colour tones are important for pea seed quality. The darker green coloured seeds of dry green pea had better seedling vigour and germination ability. This could be useful information to the grower of seeds for frozen pea on selection of suitable cultivar.

Although frozen storage is well known for its excellence in preserving vegetable quality, significant colour and chlorophyll losses occur to green vegetables during storage (Martins and Silva, 2002). Many of these colour changes are caused partly by enzymatic reactions and the release of organic acids from disrupted tissue. Chlorophyll, the principal pigment in all green coloured vegetables, is highly susceptible to degradation during processing (Heaton *et al.*, 1996). Colour loss during frozen storage of frozen green vegetables such as green peas is attributed to the fading of the vivid green colour of chlorophyll to an olive brown, characteristic of pheophytin which ultimately is perceived by the consumer as a loss of quality (Martins and Silva, 2002; Heaton *et al.*, 1996). This phenomena is known as pheophytisation, where the centre magnesium is replaced by hydrogen and can also occur due to thermal processing (Lau, Tang and Swanson, 2000). Another common type of deterioration is the removal of the phytol chain, leading to the formation of chlorophyllide (removal from chlorophyll) or pheophorbide (removal from pheophytin). Furthermore, reactions related with the functional side groups of chlorophyll form colourless end products, that also affect colour during frozen storage (e.g. the isocyclic ring may be oxidised to form allomerised chlorophyll (Heaton *et al.*, 1996). Lynch *et al.* (1959) suggested that it may be possible for a chlorophyll-pheophytin ratio to be used as a suitable quality index for frozen peas.

Residual enzymatic activity, due to inadequate blanching treatment, is also a probable cause of chlorophyll loss, hence colour loss. Enzymes found primarily in peas are catalase, peroxidase, ascorbic acid oxidase, chlorophyllase, lipase, lipoxydase, α-hydroxy acid dehydrogenase and pyruvic decarboxylase (Lynch *et al.*, 1959). Peroxidases are known to be the most heat stable enzymes in vegetables and their inactivation are used to determine the adequacy of blanching treatments (Günes and Baymdiri, 1993). Blanching in green vegetables, if done adequately has been reported to produce a more intense colour owing to the breakage of chloroplasts and the diffusion of chlorophyll in the tissues (Lee *et al.*, 1989).

Commission International d'Eclairage (CIE) 1976 L*, a*, b* colour space values from colorimetry have been used successfully to report on colour measurements of frozen green beans (Martinez et al., 1995; Martins and Silva, 2002) and in green peas (Kosson *et al.*, 1994; Shin and Bhowmik, 1995 and Bech *et al.*, 2000). Human colour vision has been found to be trichromatic which means a single perceived colour may be regarded as resulting from the effect of three separate stimuli on the visual cortex (Wright in 1969, according to Weatherall and Coombs, 1992). These tristimulus values can by mathematical manipulation be converted to CIELAB colour space values (Weatherall and Coombs, 1992). The tristimulus colorimeter hence measures the colour of reflected light and provides a digital output of chromaticity in CIE L*, a* and b* coordinates (Hunter in 1975, according to Madeira *et al*, 2003).

L* is a measure of lightness which is the reflectance factor given as a percentage (Weatherall and Coombs, 1992). The lightness index L* ranges from no reflection (L* = 0, black) to perfect diffuse reflection (L* = 100, white). The coordinates a* and b* can take positive and negative values: on

the horizontal axis, +a* and -a* indicate hues of, respectively, red and green; and, on the vertical axis, +b* and -b* represent hues of, respectively, yellow and blue (Figure 2.5). As a* and/or b* increases, chromaticity increases. Numerical values of a* and b* are converted into the saturation index or chroma ($C^* = (a^{*2} + b^{*2})1/2$), a measure of chromaticity, and the hue angle ($H° = arctan$ b^*/a^*; Voss 1992).
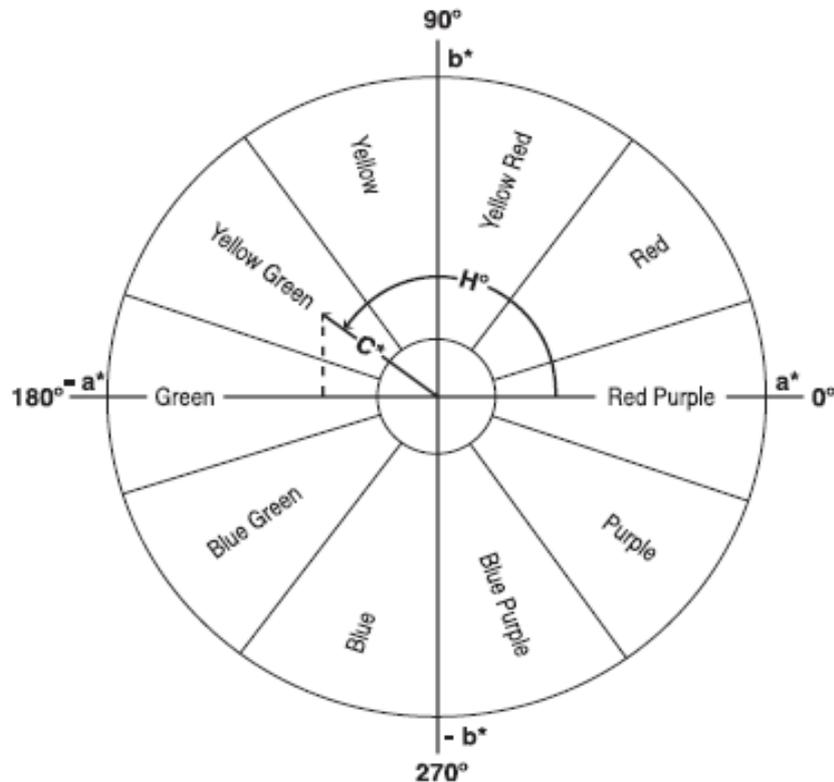
Figure 2.5: Representation of the hue angle H° and saturation index (chroma C*) on a* and b* colour space diagram (Madeira *et al*., 2003)

The hue angle H° indicates the colour of the material surface and is an angle in a colour wheel of 360°, with 0, 90, 180 and 270° representing the hues of red, yellow, green and blue, respectively. Together, L*, H° and C* give an accurate description of the colour of a sample (Madeira *et al*., 2003).

Bech *et al*. (2000) used two levels of lightness (L*) to express green colour intensity in peas when they designed a model for pea quality that incorporates both objective (instrumental) and subjective (consumer perceptual) measurements. Peas that were pale were those with L* values >42 and the dark peas had L* values <42. This two level grouping however might not give sufficient information if a large sample number is used. Edelenbos *et al*. (2001a) found the lightness values of six cultivars of green peas to fall between 41.1 and 44.5. A study by Martens (1986) revealed that descriptive sensory scores for frozen green pea colour intensity and uniformity were higher in batches of peas with lower tenderometer values (i.e. the harder peas were less green). It is assumed that the perception of colour in green peas has an indirect effect on the overall quality perception through the flavour perception (Bech *et al*., 2000). Blond peas which are yellow, pale or white in colour present a quality problem and may be as a result of uncontrollable climatic variables that influence the amount and quality of light reaching the developing pods (Duncan *et al*., 1966 and Maguire *et al*, 1973). Industrial quality grading of peas according to a specific company's criteria does not allow more than 20 units of blonds to be counted in a 500 g sample for their least superior grade C. Colour assessment for green peas ranges from bright green to pale yellow/green and are expected to be at least fairly uniformly green in colour. McEwan and

Clayton (1998) found that consumers would describe their ideal pea colour as bright, grass/ emerald green with a glossy appearance. Negative descriptions for pea colour in the same study included expressions such as acid green, dull, too light and interestingly, too dark.

2.5.1.2 Size

Green pea quality has been assessed by the sizes of seeds by passing through sieves with holes of different diameter. A number of studies on green peas has factored in size sorting of pea samples prior to analysis of sensory and physico-chemical attributes. Edelenbos *et al*. (2000a) used three size fractions 6.00 to 8.75 mm for small seeds; 8.75 to 10.20 mm for medium seeds and >10.20 mm for large seeds. Bech *et al*. (2000) and Wienberg *et al*. (2000) used four size levels in their experimental design. The pea seeds were sorted by sieve size within the range 6.0 mm to >10.2 mm. The study by Martens (1986) used four size fractions but within a narrower range. Peas used in the study were found to fall in the <7.8 mm and >9 mm range. Size has been used together with specific gravity, visual colour and seed skin character (glossy or matte) as part of the criteria of sorting frozen green grass pea (*Lathyrus sativus* L.) into maturity groups (Kmiecik *et al*., 2004). However not much has been reported on the effect of seed size on the other sensory quality attributes. Martens (1986) concluded that significant variation in colour and appearance could only weakly be related to the size of peas. In a study by Jakobsen *et al*. (1998), from a total of 31 aroma volatile compounds isolated in blanched green peas, the concentration of 17 of them were significantly influenced by seed size.

 A study by Juhl *et al*. (1998) revealed that acceptance of peas decreased with increase in size for high purchase involved customers (i.e. those customers with a more intentional brand decision), but there was no clear size effect found in customers that purchase a more casual selection of brands. Size has been linked to pea maturity with smaller sized seeds being harvested earlier than larger seeds. The smaller sized less mature seeds are expected to be more tender than their larger more mature counterparts (Sayre *et al*., 1953). Martens (1986) also reported that pea seeds became more equal sized and homogenous looking with maturity. Peas are graded by a specific company as baby peas (<8.5 mm in diameter), normal sized peas (between 8.6 mm-10.5 mm) and oversized peas (>10.5 mm). Peas are considered to be undersized if they are <5.4 mm. McEwan and Clayton (1998) reported that consumers preferred peas that are small to medium (but not too small) and fairly uniform in size. Consumer views on pea sizes in different grades (measured using Campden UK specifications) revealed that superior grade AA peas were small and uniform but had too many skins that negatively affected appearance. Grade A peas were perceived to be slightly larger with less defects and very acceptable to most consumers. The grade C peas gave inconsistent views with findings by Martens (1986) who suggested that the more mature seeds were more homogenous in appearance. The grade C peas had large seeds but was reported to be of poor appearance uniformity. However, this could have been assessed from a colour and not size perspective.

2.5.1.3 Physical defects

Pea seeds may be damaged during harvesting (Justice and Bass, 1978) or may be defective due to problems encountered in their development. The grading scheme used by the company for frozen peas includes assessment of the presence of extraneous vegetable matter (EVM), presence of insects and presence of foreign material such as stones. Seed defects considered in pea raw material assessment includes dehydrated seeds, insect damaged seeds, presence of blemishes on skin surface and split seeds. Defects are described by the company as any blemishes that detracts markedly (for major defects cover >⅓ of pea seed) or to a lesser extent (for minor defects <⅓ of pea seed) from the normal appearance, edibility and or flavour of individual units or the product in general. Major defects include khaki or sour seeds (which are seeds with

pathological damage) and units with insect damage. Damaged units include peas that are partly or wholly crushed, peas with loose skins or pieces of skin, separate whole cotyledons or peas where a whole cotyledon or large part of the cotyledon has been separated. From previous research reports on descriptive evaluation, it appears the presence of physical defects has not been identified as a sample discriminating attribute for frozen peas. The study by McEwan and Clayton (1998) however reported that the smaller peas had higher defects observed as numerous loose skins as compared to that observed in larger seeds.

2.5.2 Flavour of green peas

"Flavour can be referred to as the sensation of material or the aggregate of the characteristics of material taken into the mouth and is perceived principally by the aroma receptors in the nose and taste receptors in the mouth" (Fisher and Scott, 1997). Fisher and Scott (1997) further describe that flavour comes from the three different sensations: taste, trigeminal (mouthfeel) and aroma (odour). Both taste and trigeminal sensations occur upon contact with food in the mouth, as most substances which produce these flavours are non-volatile, polar, and water-soluble. For aroma sensations to occur, an aromatic compound must be sufficiently volatile to allow detection at the receptor sites. Belitz & Grosch (1999) state that aroma compounds reach the receptor sites when drawn in through the nose (orthonasal) or via the throat after e.g. being released by chewing (retronasal). A study by Bech *et al*. (1997) revealed that consumers rated pea flavour as the most important attribute of green pea quality. Both volatiles (e.g. aldehydes and ketones) and non-volatiles (e.g. saponins) are major components contributing to the flavour of green peas.

Carbohydrates are a major contributor to the flavour of green peas. Bech *et al*. (2000) found that the higher the amounts of sugar measured in pea samples, the closer the consumer's perception of ideal flavour. Sucrose is present in green peas in much higher amount than other sugars (Kosson *et al*., 1994; Bech *et al*., 2000; Martens, 1986; Lisiewka *et al*., 2003). Fructose and glucose are other sugars that contribute to pea sweetness. Total soluble solids (TSS) or °Brix has been used to give a measurement of sugar content of vegetable pigeon pea juice (Onyango and Silim, 2001). Unless green peas are cooled to 0 °C shortly after picking, they tend to lose part of their sugar content on which most of their flavour depends (Deshpande and Adsule, 1998). Sugars may be lost through respiration, conversion to starch during growth and development or by microbial action (Lynch *et al*., 1959). The increase in the starch content of peas has been negatively correlated to sugar content and sweetness (Martens, 1986).

In a study conducted by Wienberg *et al*. (2000), it was determined that sweetness, bitter taste, pea and pea pod flavour gave dimensions within green pea flavour quality. Earthy flavours and pea pod flavours were more apparent in cold pea samples than in warm ones and sweetness was more perceived in warm peas. Pyrazines which are volatile compounds, were measured in higher amounts in the cold peas. These could have influenced the perception of pea pod and earthy flavours. Alkylalkoxypyrazines have also been said to contribute to green flavour in peas. Hexanol has been said to contribute to the green hay-like flavour in peas (Murray *et al*., 1975). Jakobsen *et al*. (1998) found 5- or 6-methylisopropyl-2-methoxypyrazine to give off a dry grass aroma in blanched green peas. This substance has however been previously reported by Takken *et al*. (1975) to contribute to strong green and green bean-like aromas. Hexanal has been described to contribute strong green and pea pod aromas (Jakobsen *et al*., 1998; Vara-Ubol *et al*., 2004). However, hexanal has also been said to contribute to off flavour development in green peas.

Although available in minute amounts, lipids in peas may greatly influence oxidative flavour deterioration (Bengtson *et al*., 1967). Volatile off flavours in peas may also be developed as a result of the action of lipid degrading enzymes such as lipoxygenase (chiefly), peroxidase and catalase (Günes and Baymdirh, 1993; Quaglia *et al*., 1996; Jakobsen *et al*., 1998; as reviewed

by Baysal and Demirdöven, 2007). This often occurs in storage of frozen peas if blanching is not carried out effectively. Lipoxygenase was identified and biochemically characterised in green peas by Eriksson and Svensson (1970) and by Haydar *et al*. (1975). Lipase in peas was studied by Wagenknecht *et al*. (1958) to account for the release of fatty acids from the triglyceride fraction (the major pea lipid component). According to Henderson, Kanhai and Eskin (1984), phospholipase D was identified in peas by Quarles and Dawson (1969) and Bengtson and Bosund (1966) provided evidence for phospholipid hydrolysis, with concurrent free fatty acid (FFA) production, in unblanched peas placed into frozen storage. From results obtained in the study by Henderson, Kanhai and Eskin (1984) and other studies on lipid-degrading enzymes in peas, a sequential hydrolytic and oxidative enzymic pathway was proposed (Figure 2.6) for the degradation of endogenous lipids in fresh or unblanched frozen ungerminated peas during post-harvest storage, leading to flavour deterioration.
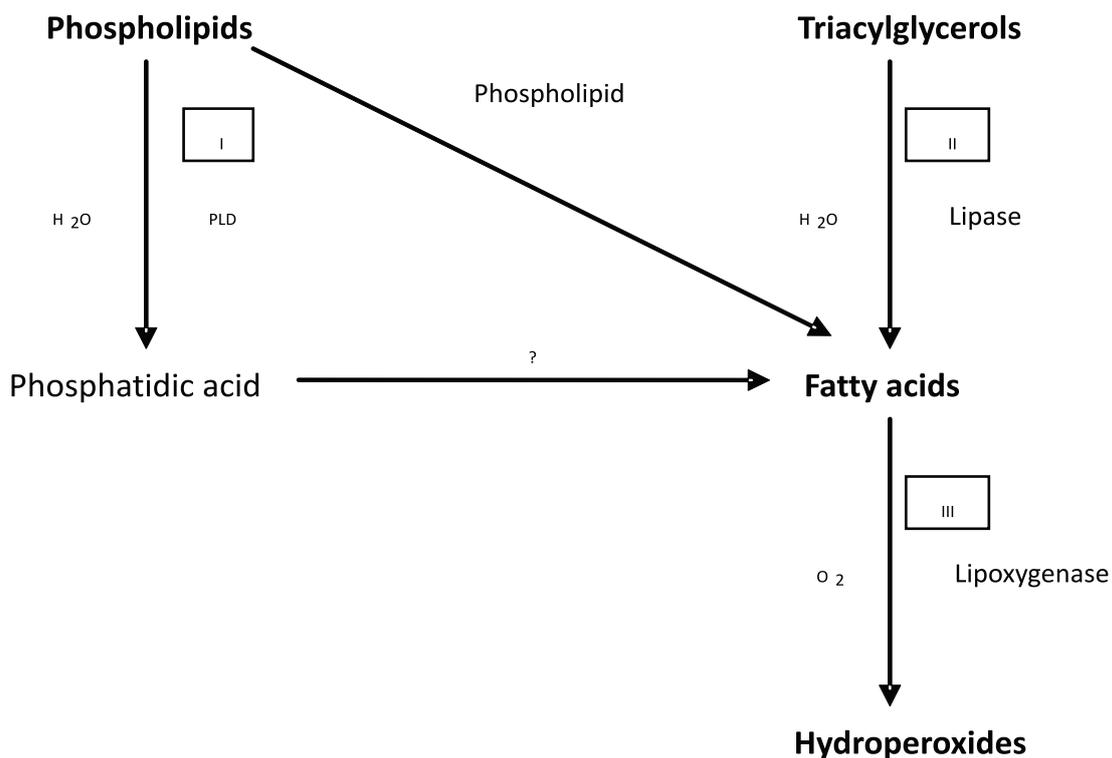
Figure 2.6: Pathway for the enzymatic degradation of endogenous lipids of *Pisum sativum* during post-harvest storage as proposed by Henderson, Kanhai and Eskin (1984). PLD =phospholipase D
*Path (I) identified by Quarles & Dawson, 1969
*Path (II) studied by Wagenknecht *et a*l., 1958
*Path (III) identified by Haydar *et al*., 1975

Off flavours in green peas could not be conclusively said to be caused by a single compound and it has hence been suggested to be caused by a number of unsaturated carbonyls (Murray *et al.*, 1975). Bitter flavours in green peas identified in the study by Wienberg *et al*. (2000) may be attributed to the presence of the non-volatile saponins. Saponins, which are surface-active triterpene glycosides, can either be sweet (Kennelley *et al*., 1995) or bitter (Price and Fenwick, 1984). Peas have been identified to contain high quantities of saponins in a review by Oakenfull (1981) and these are of importance in flavour studies because they may contribute to undesirable bitterness and astringency (Price and Fenwick, 1984; Curl *et al*., 1985 and Price *et al*., 1985). Fruity flavour was identified in the study by Martens (1986) as a relevant sensory attribute and this flavour came out as the opposite of earthy flavour. Fruity flavour was related positively to sweetness. Fruity flavour may have been attributed to the presence of hexyl acetate which gives a sweet and perfume-like aroma and octanal which gives an orange sweet flavour (Jakobsen *et al*., 1998).

Industrial quality grading of the flavour of frozen peas is done by human inspectors who physically taste the peas and allocate a grade according to their judgement. Peas are expected in the least to be fairly good flavoured and free from objectionable odours. The consumer perception of frozen peas study carried out by McEwan and Clayton (1998) found that sweetness was clearly a main positive taste attribute for peas and was associated with young fresh peas.

2.5.3 Texture

Textural properties of a food are the group of physical characteristics that arise from the structural elements of the food, are sensed by feeling or touch, are related to the deformation, disintegration and flow of food under force and are measured objectively as functions of time, mass and distance (Smith and Waldron, 2003). Texture is a major determinant of frozen green pea quality, and untrained consumers readily distinguish textural characteristics (Sandford *et al*., 1988). Numerous research and literature point out that the texture of frozen peas is greatly influenced by the maturity of seeds at harvest (Martens, 1986; Basterrechea and Hicks, 1991; Kmiecik *et al*., 2004; Edelenbos *et al.*, 2000b; Nilsson *et al*., 2004 and Jokanovic *et al*., 2006). Peas are said to harden with maturity due to respiration changes and dehydration. Juiciness, mealiness and skin toughness are texture descriptors that have been commonly used in sensory judgement of frozen peas in studies by Juhl *et al*. (1996), Martens (1986) and Wienberg *et al*. (2000). Crispness and hardness have also been used to describe green pea texture. Martens (1986) suggests that hardness described the same variation as skin toughness and thus only one of the two variables was probably required. Physico-chemical measurements including starch content, dry matter content and alcohol insoluble solids (AIS) content have been investigated to explain these descriptors and have been seen to increase with maturity (Kmiecik *et al*. 2004 and Martens, 1986). This increase is said to be due to the build up of more reserve stores by conversion of sugars to starch and by loss of moisture. Samples found to be mealy by Wienberg *et al*. (2000) also had high levels of skin toughness with a gritty starch-like sensation. The AIS in peas which consist mainly of insoluble carbohydrates and protein has been used as a guide to maturity (WHO/FAO, 2004).

More rapid instrumental methods used to determine texture of green peas have made use of equipment such as tenderometers which measure the toughness of the seed coat and the firmness of the pulp (Deshpande and Adsule, 1998). The higher the reading attained from compression of the seeds, the tougher and more mature the peas. The tenderometer reading (TR) values are used to determine grade classes for peas by a specific company and should be between 116 and 140. Research by Martens (1986) obtained peas of TR values between 95 and 164. TR values were observed to increase with maturity. The use of a texture analyser fitted with multiple pea rig probe which allows individual penetration of 18 pea seeds simultaneously (puncture test) gives a measurement of the force required to do so (Figure 2.7). The area under the curve obtained from time 0 and the second major peak obtained (initial application of force and final penetration through the peas) multiplied by the speed (mm s^{-1}) the rods are travelling at for the measured mass (g) of the sample, can be used to report the work done to penetrate through the seeds as a measurement of hardness (Figure 2.8).
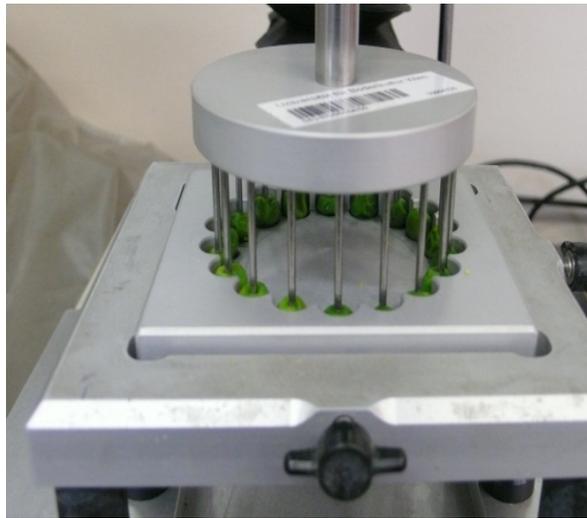
Figure 2.7: Texture analyser with multiple pea probe

Results from a study by Bech *et al*. (2000) reported that texture measurements are better predictors of perceived texture than do measurements for colour give an indication of the perceived latter attribute. This could mean that variability in texture attributes are more easily detected than colour or that the instrumental methods used to measure texture are more sensitive than those used to determine colour. McEwan and Clayton (1998) revealed that consumers prefer firm peas that have soft, but not mushy insides. The peas were also required not to have chewy skins. Upon a discussion with the consumers used in their study on the different grades of peas used (Campden specifications: i.e. grades AA, A, B, Cand D in decreasing order of quality), grades AA and A peas were considered acceptable in quality. Quality grading using the statutory and by the selected frozen pea company requires peas to be fairly tender at the least expected level of quality, which is rather vague.
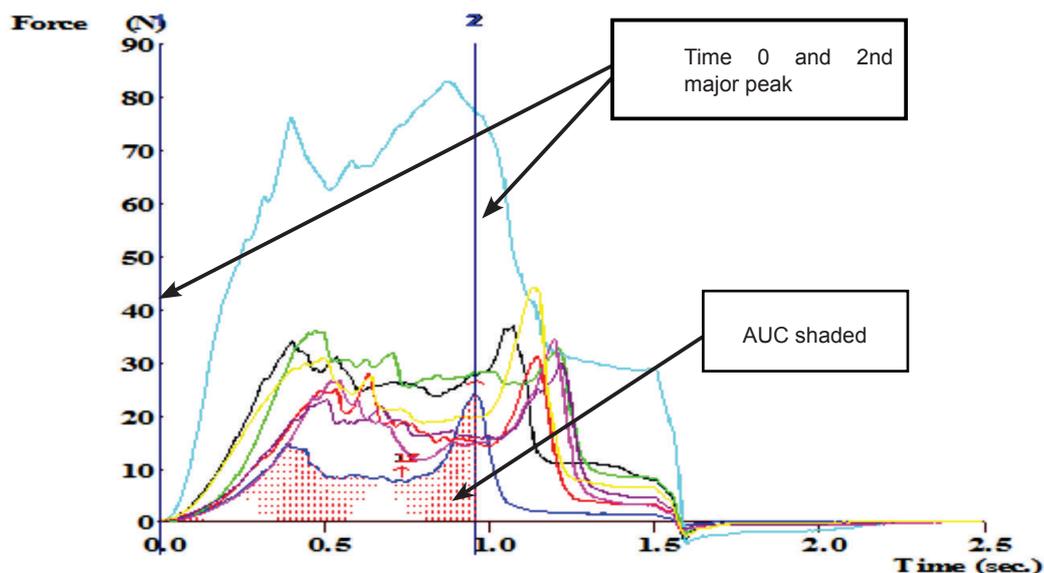
Figure 2.8: Area under curve used to quantify work done (N.mm/ g) to penetrate through different samples (denoted by different colours) of cooked pea seeds in the study.
AUC- Area Under Curve

2.6 Extrinsic factors that may influence green pea quality

For best quality, green peas are harvested before physiological maturity is achieved. Both high quality and good yields can be obtained for only a limited time (Basterrechea and Hicks, 1991). Good quality is influenced by good raw materials. Thus cultivar selection and pre-treatments before freezing are essential (Masterly, 2000). Manufacturing process design may also have a great impact on the quality of a product. An analysis of a production process could result in the identification of areas in which quality loss may occur and precautionary measures may thus be developed and applied. Such areas in the process may include the critical blanching process, which if excessive, may cause sugar leaching out and hence affect the flavour of the peas. Quality changes in frozen foods are mainly due to the rate of freezing, temperature abuse and storage conditions and the length of storage (Mallikarjunan and Hung, 1997). Post-processing factors such as cooking also have an impact on the final quality judgement.

2.6.1 Temperature abuse and storage

A key aspect of the freezing of immature peas is the time that elapses between picking and freezing. This is portrayed as being a critical factor in determining the taste of the finished product (Green and Foster, 2005). Peas should be frozen in the shortest time possible after picking to reduce quality loss from respiration. High temperatures may cause losses in sugar content. It was found that peas held for six hours at 25 ºC lost about one third of their sugar content (Lynch *et al.*, 1959) due to respiration changes. The frozen food industry has for many years used selective breeding to develop cultivars that show the best resistance to freeze-thaw damage (Kennedy, 2000). Freezing causes texture loss amongst other quality attributes of tissue-based systems such as fruits and vegetables. Vegetable texture is mainly dependent on the turgidity which is the ability to retain water inside cells (Torreggiani *et al.*, 2000). Slow freezing results in larger ice crystal formation which contribute to cell structural damage as compared to rapid freezing which results in small crystal formation (Reid, 1993; Kennedy, 2000). Freezing damage is attributed to mechanisms such as solute concentration damage (causing many biological molecules to be affected including protein denaturation, aggregation and precipitation); dehydration (from osmotic transfer of water from cell interior to the exterior environment resulting in interior cell wall dehydration and volume reduction. The cell walls may tear and membranes rupture due to pulling away from cell walls) and mechanical damage from ice crystals, as they are hard and may stress the more flexible cell components resulting in structural damage (Reid, 1993). As a result food surfaces become dry and colour tarnishes (Torreggiani *et al.*, 2000).

Various methods have been investigated by food scientists in a bid to improve the sensory quality of frozen foods including the use of high-pressure shift freezing (Van Buggenhout, Messagie, Van Loey and Hendrickx, 2005) to improve texture; incorporation of anti-freeze proteins (Kennedy, 2000) and the use of chemical agents such as zinc solution (Canjura, Watkins and Schwartz, 1999) and ammonium compounds (Eheart and Odland, 1973) for chlorophyll retention in frozen green vegetables.

Storage of most frozen foods is usually set at -18 °C and even at this temperature a fraction of the food constituent water remains liquid and free for freeze damage reactions (Torreggiani *et al.*, 2000). Lower temperatures would thus encourage better quality retention. Frozen peas should be stored at temperatures lower than the Tg. The glass transition temperature of frozen green peas was investigated by Lim *et al.* (2006) and found to be -20 °C for old peas (with a TR of 141) and -26 °C for younger peas (with a TR of 99). The older peas most likely have a higher Tg than the younger peas because they have less juice quantity and are hence more stable at higher freeze temperatures. A study by Jokanovic *et al.* (2006) however reports that storage of both blanched, defrosted (raw) and blanched, cooked frozen green peas for three months at -18 °C did not affect the important sensory characteristics (including taste, appearance, colour, odour and texture). This is most likely due to the nature of the vegetable. Green peas are small in nature and therefore likely

to be frozen effectively. It is important to ensure that peas are subjected to the right temperature conditions after processing. A study by Redmond, Gormley and Butler (2004) revealed that green beans subjected to freeze-chilling by blast freezing at -30 °C for 2.5 h, stored at -25 °C for 7 days and finally thawed and kept at 4 °C for 7 days before testing were paler in colour and firmer in texture when measured instrumentally than green beans frozen at -30 °C for 2.5 h, stored at -25 °C for 14 days and thawed at 4 °C before evaluation. This proves that freeze-thaw damage may compromise quality in even short periods of time. It was however revealed in the same experiment that there were no significant differences in sensory acceptability noted for the two treatments. Fluctuations in the temperature during storage can lead to massive losses in quality. Table 2.2 shows the minimum time required to bring about perceptible change in some frozen vegetables. Methods used to thaw peas and cook up prior to product assessment may also be considered as a potential avenue of sensory defect occurring and hence quality assessment bias.

Table 2.2 Minimum time (in days) in storage at various temperatures required to bring about a perceptible change in quality of selected frozen vegetables (Karlsson, 1988)

Temperature (°C)	Beans		Peas		Cauliflower		Spinach	
	Colour	Flavour	Colour	Flavour	Colour	Flavour	Colour	Flavour
-18	101	296	202	305	58	291	350	150
-12	28	94	48	90	18	61	70	60
-9.5	15	53	23	49	10	28	35	30
-7	8	30	11	27	6	13	20	20
-4	4	17	5	14	3	6	7	8

2.6.2 Packaging

A food package must provide the optimum protective properties to keep the product it encloses in good condition for its anticipated shelf life (Paine and Paine, 1992). Food damage can occur during the freezing process, during stacking, in retail freezers and as a result of consumer handling (Harrison and Croucher, 1993). To provide this protection the packaging must form an effective functional barrier to contamination and have sufficient impact and compressive strength to withstand the stress it is likely to meet. A good frozen vegetable package will prevent oxidation of product promoted by enzymes which may not have been eliminated by blanching and should just prevent air from entering; should prevent light entering as this accelerates oxidation; should prevent foreign odour and flavour absorption and should not be affected by physical damage caused by compression during storage and transportation (Paine and Paine, 1992). Appropriate materials that have been used for frozen vegetable packaging include cartons coated with wax or polyethylene, plastic films such as deep freeze grades of polyethylene or thermoformed high-impact polystyrene (Paine and Paine, 1992). Most frozen peas are distributed in polyethylene bags. Variations in thickness of bags and print/colour can influence the resulting quality of the product due to gaseous transfer, possibility of physical damage and tear and effects from light penetration. It is important that packaging machinery carries out the sealing of vegetable packs efficiently to prevent oxidative damage and dehydration (Paine and Paine, 1992).

2.6.3 Cooking method

Experienced quality is influenced by a number of factors. The product itself is obviously one determinant, but many others play a role as well. These include the way the product has been prepared and integrated into the meal preparation process, situational factors like time of day and type of meal and the consumer's mood (Grunert, 2002). Thus experienced quality, with the product, are only partly under the control of the producer. The importance of applying a suitable cooking method that is standardised when carrying out product quality analysis is hence realised.

Deviations from quality should not be influenced by conditions that can easily be controlled such as the temperature at which food is evaluated, and cooking times. Thermodynamics and heat transfer principles on the resulting homogeneity of cooked product should be considered. Cooking measures such as seasoning application and excess water drainage could be other contributory factors to final quality judgement.

The need to apply principles such as General Good Sensory Evaluation Practices (Lawless and Heyman, 1998) is hence considered essential in the designing and implementation of a standardised method of sample preparation that does not compromise the quality of the product being evaluated and introduce bias to results from differentiation in samples. As part of the grading protocol used by a frozen vegetable company, 250 g of peas are cooked in a microwave on 100% power for 3 min before product assessment. Methods of preparation of frozen green peas for descriptive sensory evaluation that have been used previously include steam heating on a boiling water bath (Martens, 1986); heating on a 70 °C water bath for 12 min following the thawing of peas (previously stored at -24 °C) at room temperature for 30 min (Wienberg *et al*., 2000); and even assessment of cold peas thawed at room temperature for 30 min and incubated at 18 °C for 135 min before evaluation (Wienberg *et al*., 2000). The consumer study by McEwan and Clayton (1998) used microwave cooking to prepare pea samples.

2.7 Gaps in knowledge

The South African Department of Agriculture, Forestry and Fisheries provide standards for use in the manufacture of frozen peas to regulate product safety and quality (Agricultural Standards Act, 1990). The sensory quality of the frozen green peas measured by quality grading is important in determining the food group the product is classified into according to how they will be used by the end user. According to Moskowitz (1995), "Manufacturers always search for ways to improve product quality in order to ensure ongoing consumer acceptance, and therefore to remain in business". However a manufacturer's standards used should always be in accordance with statutory regulations on quality.

The grading systems used for frozen peas distinguish products in terms of quality by their differences in colour, size and uniformity of the two attributes, texture, flavour and the presence and magnitude of physical defects. Research has been carried out on how quality grading reflects on consumer perceptions of frozen peas in the United Kingdom (McEwan and Clayton, 1998). At present no literature is available on quality studies on frozen green peas in South Africa. It would be very beneficial to the South African frozen pea industry if they acquired knowledge of the condition of the product available on the market, and deducing which specific aspects attribute to good pea quality through descriptive sensory evaluation. An indication of the efficiency of grading systems in place may be revealed. Previous studies have indicated that the most important physico-chemical attributes that are useful in understanding sensory aspects of frozen green peas include sugar content, starch content, AIS content, green colour intensity, DMC and TR values (Martens, 1986; Kmeicik *et al*., 2004). Most of this data was collected on samples that were obtained immediately after harvest and thus post-harvest handling was stipulated by the researchers. This study focuses on material obtained directly from the market to give information on the quality of product that is actually available to the consumer.

3. HYPOTHESES AND OBJECTIVES

The retail and caterer's classes of frozen peas represent different quality grades.

- The sensory quality of retail peas will be superior to caterer's peas. Quality grading of frozen peas is based on appearance, flavour and texture (South Africa Department of Agriculture, 1998; frozen vegetable manufacturing company QC staff personal communication). Retail class peas will be more intensely green, sweeter, juicier, more tender and of higher quality grades when compared with caterer's class peas.

- Caterer's class peas are often more mature than retail class peas. The caterer's peas will be characterised by seeds with higher DMC, AIS, starch content and instrumental measured hardness than retail peas as these physico-chemical attributes increase with green pea growth resulting in a reduction in quality (Edelenbos *et al*., 2000b). The caterer's grade peas will also have lower sugar content than retail peas due to higher respiration losses and increased conversion to starch (Jokanović *et al*., 2006) and hence will be of lower quality grades.

The objectives of the research were:

- To determine the sensory profiles of selected commercially available retail and caterer's brands of frozen peas in South Africa.

- To determine the physico-chemical properties of selected commercially available retail and caterer's brands of frozen peas in South Africa.

- To investigate the relationship between sensory and physico-chemical properties for frozen peas.

4. RESEARCH

This chapter is divided into two sections:

4.1   Frozen green pea (*Pisum sativum* L.) quality described by visual sensory and physical attributes.

4.2   Frozen green pea (*Pisum sativum* L.) quality described by flavour and texture sensory attributes and related physico-chemical properties.

Figure 4 shows the project summary
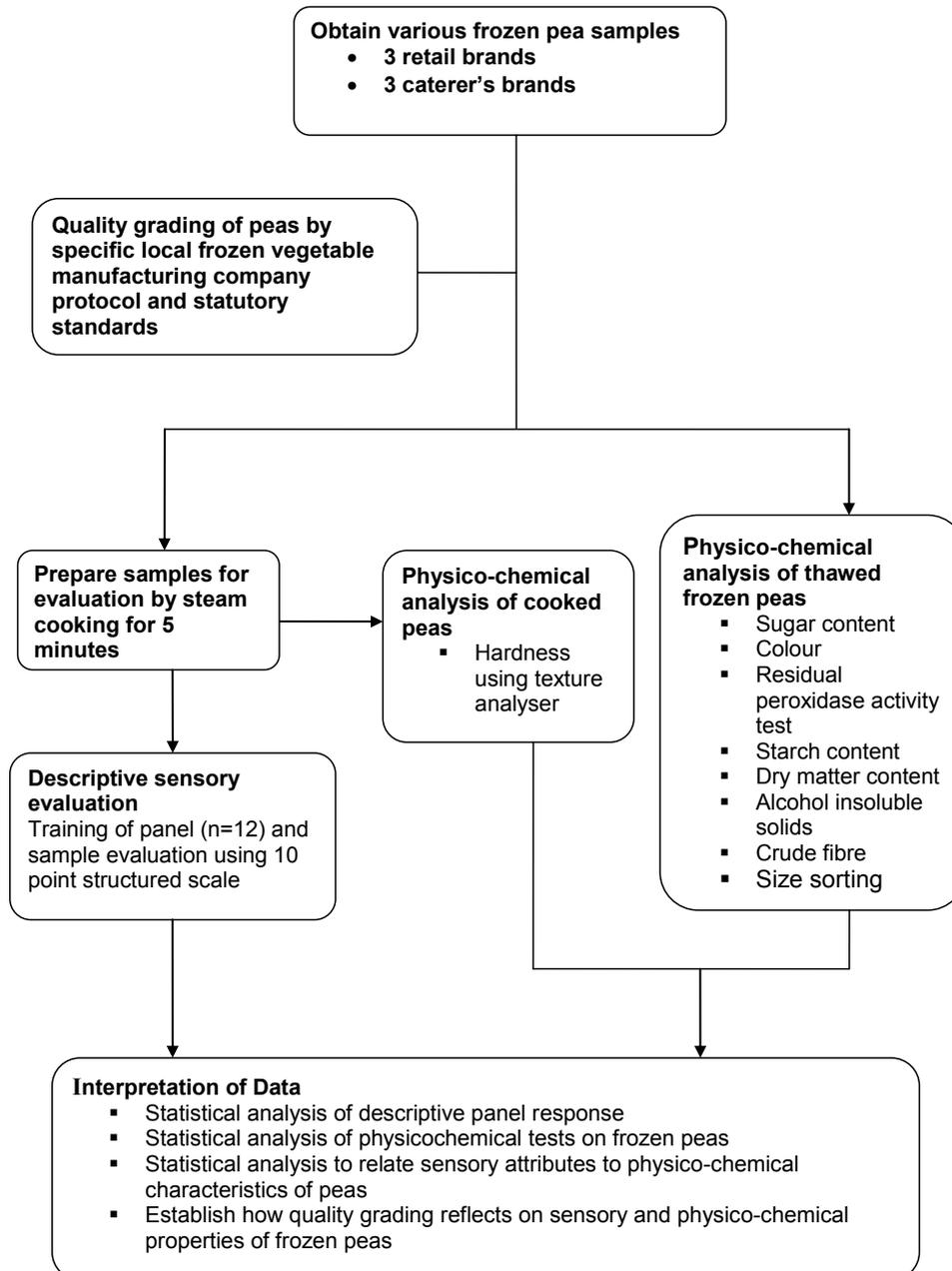
Figure 4: Project summary used for relating the physico-chemical properties of frozen green peas (*Pisum sativum* L.) with sensory quality

4.1 FROZEN GREEN PEA (*Pisum sativum* L.) QUALITY DESCRIBED BY VISUAL SENSORY AND PHYSICAL ATTRIBUTES

ABSTRACT

The first quality judgement for frozen green peas is performed by the eyes. Frozen green peas acceptability is therefore significantly dependent on appearance attributes including colour, shape, and size. Six brands of frozen green peas representing retail and caterer's classes (3 brands selected for each class) were purchased from stores around South Africa. The frozen pea samples were subjected to quality grading using a selected company scheme and statutory specifications, descriptive sensory evaluation, colour measurements and size sorting as methods for assessment of visual quality. Size and colour were found to significantly define frozen green pea quality. The smaller and more intense green coloured seeds were of superior quality than the larger, less green samples. Seed shape was a less important attribute for discriminating peas. The peas that were of superior visual quality were found to belong to the retail sales class rather than the caterer's class. The visual quality of the different brands of frozen peas varies. One brand belonging to the caterer's class was more intensely green, smaller and more uniform in size than two of the retail class brands.

4.1.1 Introduction

Green garden peas (*Pisum sativum* L.) are an important vegetable crop whose use is highly attributed to their relatively simple manufacture, pleasant taste and high nutritional value (Jovicevic *et al*., 2002). Imram (1999) convincingly suggests that the "first taste of food is almost always with the eye''. In support of this statement Cheng *et al*. (2004) state that the appearance of green peas is the most important index of perceived quality in the domestic and international markets. Appearance encompasses several basic sensory attributes that include colour, opacity, gloss, visual structure, visual texture and perceived flavour (Imram, 1999). Of all these visual aspects, the effect of colour is the most obvious and well-studied. It has been well established that colour and appearance can have a halo effect which modifies subsequent flavour perceptions and thus food acceptability (Hutchings, 1999). Colour has also been seen as an important predictor of non-sensory quality attributes like moisture content, over processing and pigment content (Clydesdale, 1991).

The heterogeneous nature and the short seasonality of foods such as vegetables often make colour measurement in industry using instruments sophisticated and uneconomic (Hutchings, 1999). Hence human vision is the most common means of assessing attributes of appearance within the food industry. Quality assessment of peas during processing normally includes visual evaluation of colour and the presence and magnitude of physical defects on the seed surface. The appearance of pea seeds may be affected by physical damage during harvesting (Justice and Bass, 1978) or may be defective due to problems encountered in their development such as bleaching from rainfall and subsequent sunny conditions before harvest (Cheng *et al*., 2004). Edelenbos *et al*. (2001a) identified 3 classes of compounds that contributed to the pigmentation of green peas and these included xanthophylls, hydrocarbon carotenoids and chlorophylls and their derivatives. Of the 17 pigments identified within these three classes, the chlorophylls were extracted at the highest concentrations and therefore contributed the most towards pigmentation. Chlorophyll is highly susceptible to degradation during processing (Heaton *et.al*, 1996). Changes in colour also occur during the maturation, harvesting and storage of peas. Colour loss during frozen storage is attributed to residual enzyme activity due to inadequate blanching (Henderson, Kanhai and Eskin, 1984) and pheophytisation where the centre magnesium in chlorophyll is replaced by hydrogen (Martins and Silver, 2002) which ultimately is perceived as a loss of quality.

Visible colours observed in nature occur between 400 and 700 nm wavelengths on the electromagnetic spectrum and depend primarily on the reflectance properties of the particular object or body (Madeira *et al*., 2003). Portable tristimulus colorimeters which give the colour of reflected light and provides a digital output of chromaticity in CIE (Commission Internationale d'Eclairage; 1976) L*, a* and b* coordinates have been used to measure the colour of vegetables and fruits quantitatively (Madeira *et al*., 2003 and Bech *et al*. 2000). Chroma defined as the visually perceived colour attribute of saturation and the hue angle described as the psychometric correlate of the visually perceived attribute of hue (Weatherall and Coombs, 1992), have in addition been used to communicate colour informatively. Size and uniformity which are also appearance attributes, are assessed on frozen pea samples as a measure of quality. Screen sieves with holes of different diameter are used for size grading (Shahin and Symons, 2005) prior to packaging. Grain size profiles and size distribution have been said to attribute to product value (Shahin and Symons, 2005). However, Shahin *et al*. (2006) in their study on soya bean seed size highlighted that determining seed size uniformity through quantitative measurements is a poorly researched area.

Frozen green pea processing involves grading practices to sort products by quality superiority and uses. The brands of frozen peas manufactured for retail and catering use available on the South African market may vary in appearance possibly due to differences in company grading and process specifications, storage time and/temperature, source materials amongst other factors. The study aims to establish descriptive sensory profiles of visual appearance attributes and physical measurements of colour and seed size of different commercial brands of frozen peas in South Africa, and the extent to which these influence the product quality.

4.1.2 Materials and Methods

Samples

Six brands of frozen green peas (*Pisum sativum* L.) from four different manufacturers were purchased in wholesale and retail shops in South Africa. The six pea brands included three types distributed for retail sale; brands RA, RB and RC (Figures 4.1.1-4.1.3) and three types distributed for catering sale; brands CA, CB and CC (Figures 4.1.4-4.1.6). Four batches per brand were purchased to obtain a total of twenty four batches. Each batch purchased within a brand was required to have a different production date (Appendix A).

Sample pooling

Sample preparation involved pooling of peas from each batch to make up 10 kg portions. All of the brands were sold in 1kg packs except for brand CC where 2 kg packs were also available. Peas that were clumped were separated by beating each sealed pack with a wooden spoon. Each pack was then subjected to shaking for ten seconds to achieve mixing and poured out into a plastic container. The 10 kg packs of frozen peas in the container were further mixed using a wooden spoon for 60 s. The pooled sample was transferred into a 650 x 1200 x 0.7 mm polyethylene bag, sealed and stored in clearly labelled, opaque 25 L plastic buckets with lids at -18 °C. The sample pooling was done at 3-5 °C and special care was taken not to exceed a time period of 60 min of exposure of the peas to this temperature condition. The frozen pea samples were stored at -18 °C until required for use

Quality grading

The 24 frozen pea batches were graded by personnel working in the quality control department of a frozen vegetable manufacturing company. The frozen pea batches were graded with respect to colour, magnitude of physical defects, flavour and texture attributes following the company's quality grading system questionnaire (Appendix B). The samples were categorised either as grade A, B, C or Substandard (SS) in descending order of quality. According to this company, retail class peas consists of grade A and B; caterer's class of grade C peas. SS (also referred to as export grade) peas are not marketed by the company. Samples were also graded following South African statutory specifications (Appendix C) and could have fallen into choice grade, standard grade, substandard (SS grade) and undergrade (UG).

(a)

RA1

Comments: Green coloured seeds. Perfectly round but small seeds. No ice in packs.

(b)

RA2
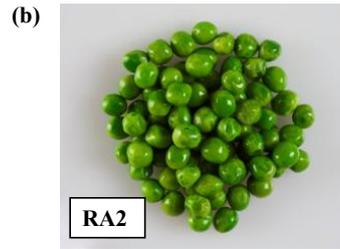
Comments: A bit pale green seeds. Lots of ice in packs. A few shrivelled seeds.

(c)

RA3

Comments: Even green coloured seeds. Good round shape. Little ice in packs.

(d)

RA4

Comments: Dark green coloured small seeds. Little ice in packs.

Figure 4.1.1: Photographs of the four batches of thawed uncooked RA brand green peas and brief descriptions of their frozen state

(a)

RB1

Comments: Green coloured seeds. Visibly different sized seeds. No ice in packs.

(b)

RB2

Comments: Green coloured seeds. Little ice in packs.

(c)

RB3

Comments: Even green coloured seeds. Good round shape. Little ice in packs.

(d)

RB4

Comments: Olive green-brown coloured seeds. Slight unidentified chemical aroma. Little ice in packs.

Figure 4.1.2: Photographs of the four batches of thawed uncooked RB brand green peas and brief descriptions of their frozen state

(a)

RC1

Comments: Even green coloured seeds. Visibly different sized seeds. Little ice in packs.

(b)

RC2

Comments: Green coloured seeds. Visibly different sized seeds. Little ice in packs. Pack s poorly sealed.

(c)

RC3

Comments: Even green coloured seeds. Good round shape. Not much ice in packs.

(d)

RC4

Comments: Poorly shaped seeds that were hard to separate. Dark olive green in colour. Lots of ice in packs.

Figure 4.1.3: Photographs of the four batches of thawed uncooked RB brand green peas and brief descriptions of their frozen state

(a)

CA1

Comments: Even green coloured seeds. Good round shape. No ice in packs.

(b)

CA2

Comments: Even green coloured seeds. Good round shape. No ice in packs.

(c)

CA3

Comments: Even green coloured seeds. Good round shape. Bit of ice in packs.

(d)

CA4
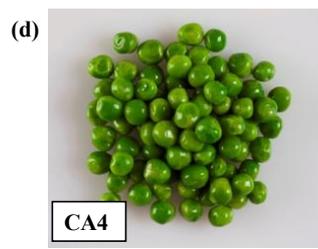
Comments: Even green coloured seeds. No ice in packs.

Figure 4.1.4: Photographs of the four batches of thawed uncooked CA brand green peas and brief descriptions of their frozen state

(a)

CB1

Comments: Even green colour. Not much ice in packs.

(b)

CB2

Comments: Even green colour. Lots of ice in packs.

(c)

CB3

Comments: Poor colour (Pale green), with yellowish and brown coloured seeds. Good shape. Lots of ice in packs.

(d)

CB4

Comments: Poor colour (Pale green) with brown coloured seeds. Good round shape. Very little ice in packs.
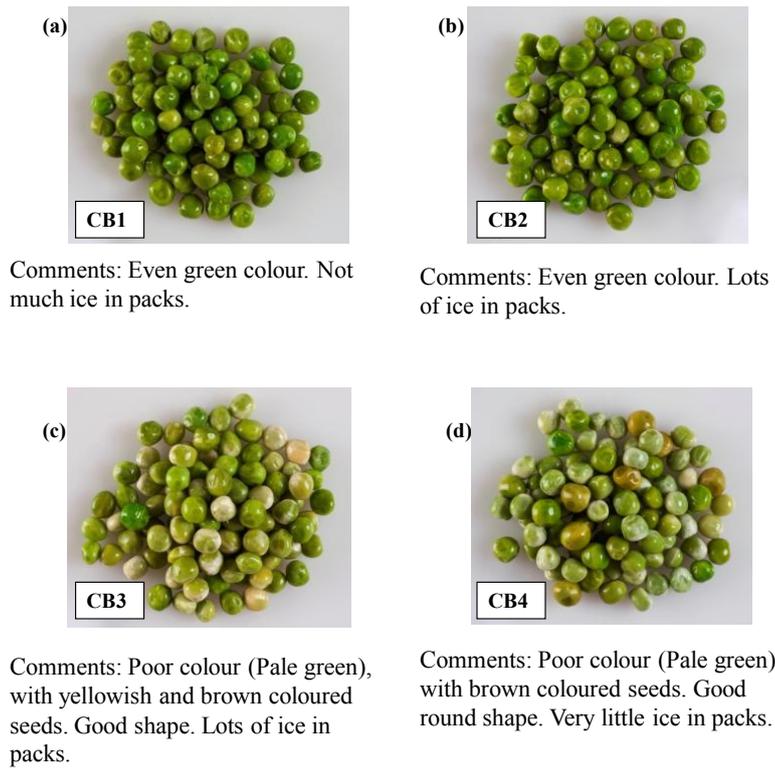
Figure 4.1.5: Photographs of the four batches of thawed uncooked CB brand green peas and brief descriptions of their frozen state

(a)

CC1

Comments: Even green coloured seeds. No ice in packs.

(b)

CC2

Comments: Even green coloured seeds. Not much ice in packs.

(c)

CC3

Comments: Even green coloured seeds. Bit of ice in packs.

(d)

CC4

Comments: Even green coloured seeds. Lots of ice in packs.
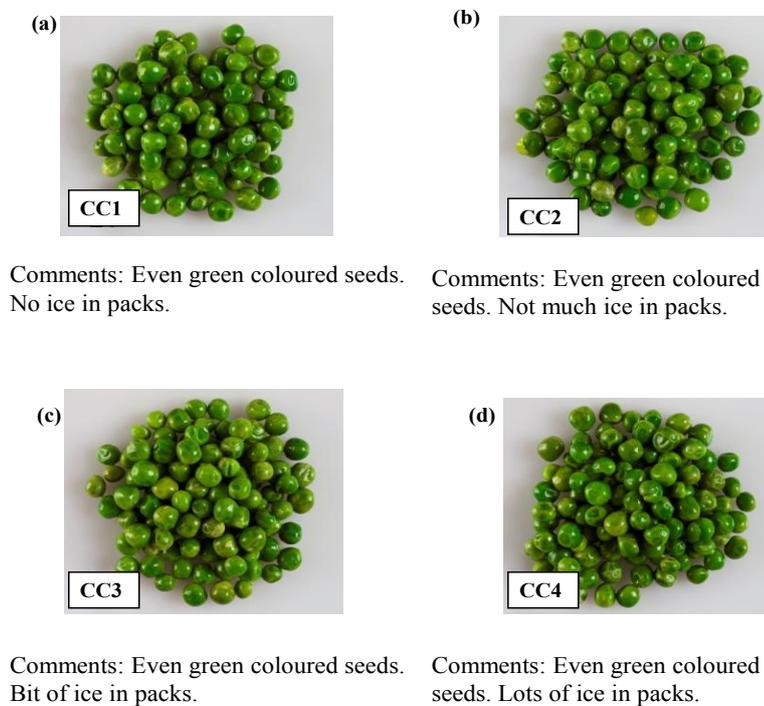
Figure 4.1.6: Photographs of the four batches of thawed uncooked CC brand green peas and brief descriptions of their frozen stateDescriptive sensory evaluation

Descriptive sensory evaluation

Panellist selection

Descriptive sensory evaluation was carried out in the University of Pretoria's sensory evaluation laboratory. A panel of twelve (10 female and 2 male) trained non-smoking, self-confessed healthy individuals were screened based on performance in the basic taste recognition tests, texture ranking and odour identification tests. Panellists were required to identify sweet, salty, bitter, sour and umami tastes on ten filter papers impregnated with the different taste solutions. One of the test papers was not treated at all and panellists were supposed to be able to identify it as blank. Taste test papers were prepared using 50% w/v sucrose solution (sweet), 7% w/v sodium chloride (salty), 4% w/v caffeine (bitter), 9% w/v tartaric acid (sour) and 20% w/v monosodium glutamate (MSG) for umami. The texture ranking test involved ranking of different types of dried fruit (mango, prunes, peaches and apples) from the least hard to the most hard. The panellists were also required to identify roast pork, fat, onion, pea and mushroom aromas on filter paper strips that had been previously dipped in the particular aroma extracts.

Training and evaluation

Pea samples were prepared for cooking by packaging ±30 g individual serving portions in labelled 100 x 110 mm zip-lock plastic bags. The sample repackaging was carried out at -18 °C. The individual pea portions were cooked for 5 min over steam in covered stainless steel dishes with 5 ml of boiling water added to each dish, and served immediately. The trained panellists assessed the 24 samples of frozen peas in duplicate over six evaluation sessions. This allowed for the evaluation of eight randomly presented samples per session. Pea samples were served monadically every 7 min allowing each panellist approximately 5 min to evaluate the sample and a 2 min break between samples. A forced 10 min break was factored in between evaluation of the first four and the last four samples. Pea samples were served at a temperature of ~70 °C in 3-digit random coded 125 ml Styrofoam cups with plastic lids. The panellists were provided with a plastic spoon for eating the peas. Peeled, sliced fresh raw carrots and filtered water was also provided for neutralising and cleansing the palate between sample tasting. Each panellist received between 25-30 g of sample in each cup. The evaluation was performed by panellists seated at individual evaluation booths under white light.

Twenty seven descriptors were developed for the appearance, flavour and texture attributes of frozen peas. These were evaluated on a ten-point structured line scale and this data was captured using Compusense Five, version 4.6 software (Compusense Inc., Guelph, Canada). Seven of the descriptors developed (Table 4.1.1) were relevant to visual sensory attributes.

Table 4.1.1 Visual descriptors developed for descriptive sensory evaluation of steam cooked frozen green peas

Descriptor	Definition	Rating scale
1.Green colour intensity	Level of greenness of peas outer surface perceived visually	0=not green 10=extremely green[a]
2. Green colour uniformity	Estimated level of homogeneity in colour of pea seeds	0=not uniform 10=extremely uniform
3. Seed size	Physical dimensions of pea seeds	0=not large 10=extremely large[a]
4. Seed size uniformity	Estimated level of homogeneity in size of pea seeds	0=not uniform 10=extremely uniform
5. Exterior seed surface texture	Degree of shrivelling of pea outer skin surface	0=not wrinkled (fresh prune) 10=extremely wrinkled (dried prune)
6. Seed shape	Characteristic surface outline/fullness of pea seeds	0=not round 10=extremely round[a]
7. Overall seed shape uniformity	Estimated level of homogeneity in shape of pea seeds	0=not uniform 10=extremely uniform

[a]Selected pea samples used as references and did not necessarily represent the optimum level for the particular descriptor.

Physical analyses

Colour measurements

100 g of peas was thawed at room temperature (±22 °C) for 3 h. Thawed peas were packed tightly into a petri dish avoiding air pockets/gaps from forming between seeds. L*, a* and b* values were measured at three points within the petri dish using a colour meter (Minolta Chroma Meter CR-400) with the lens directly touching the peas. Two petri dishes were prepared per batch and 3 readings obtained from each one to obtain a total of 6 readings per batch. Prior to the analysis the instrument was calibrated with a standard white tile supplied by the manufacturer. Averages of three calibrations obtained the values L*= 97.4; a*= 0.14 and b*= 1.85. The chroma (C = (a*² + b*²)1/2) and hue angle (H° = arctan b*/a*) were also calculated.

Size sorting

500 g of each pea batch was sieved through different square stainless steel plates (200 x 200 x 2 mm) with holes of between 6 and 14 mm in diameter. For each batch, enough seeds to cover the base of the plate were gently manually shaken for 30 s through the plates. The seeds that did not pass through the sieve were placed in ziplock bags and those that did were passed through the subsequent lower diameter sieve plate. This was done repeatedly until all seeds from the 500 g were passed through the sieve. The measurements were done using the plates with the largest holes (14 mm) down to the smallest (6 mm). The process was carried out at 3-5 °C. Special care was taken not to expose samples to these conditions for more than 40 min (samples returned to -18 °C freezer). The pea seeds collected at the different sieve sizes were weighed and the percentage mass calculated. The experiment was conducted three times per batch.

Statistical Analysis

A hierarchically nested design Analysis of Variance (ANOVA) of the General Linear Model (GLM) was used to analyse variance among pea brands for physical and sensory data. The least square means obtained were used for this evaluation. The design had three level factors (batches, brands and classes) in which the batches were considered random effects, and brands and classes were fixed effects. Four batches were nested within six brands which were nested in two classes: retail and caterer's peas. The Fisher Least Significance Difference (LSD) test was used to investigate the nature of the differences. A significance level (p-value) of <0.05 was used as the decisive criteria for significant differences. Principal Component Analysis (PCA) was used to display brand variation in sensory attributes and physical colour data computed as secondary attributes. Statistica version 7 (Statsoft, Inc., 2006) was used for the analysis.

4.1.3 Results

Quality grading

When evaluated using the company's grading protocol most pea batches intended for catering sale were classified into the substandard group (Table 4.1.2). Three of the twelve retail grade batches were also classified as SS using the company's protocol. Grading by statutory standards resulted in a lower number of SS samples and more choice graded samples. None of the twenty four samples were qualified as grade A (by the company protocol) or UG (by the statutory standards).

Descriptive sensory evaluation

Significant differences were observed between the retail and caterer's peas for all the attributes except uniformity in seed shape (Table 4.1.3).The brand F-values obtained for all the seven appearance descriptors showed significant differences at $p < 0.01$ with green colour intensity and seed size attributes obtaining the highest F-values. Follow up descriptors describing uniformity in colour, seed size and seed shape were less differentiating between batches but were all still significant. Retail brand RA did not differ significantly from catering brand CA in green colour intensity and uniformity, uniformity in shape and size and the exterior seed surface texture (i.e. presence of wrinkles on skin surface). Brand CB had the lowest green colour intensity. Brand CB however had the largest and roundest peas. Brand CC contained the most wrinkled peas.

Table 4.1.2 Quality grades allocated to different frozen pea batches by quality control personnel in industry using (a) selected company specifications and (b) statutory specifications

(a) Selected company quality grading protocol

Retail			Catering		
Batch Code	Grade allocated	Comments/Reason for grade allocation	Batch Code	Grade Allocated	Comments/Reason for grade allocation
RA1	B		CA1	C	Flavour and texture
RA2	B		CA2	B	
RA3	B		CA3	SS	Soil stain, sandy grits
RA4	B		CA4	SS	Sandy grits
RB1	B		CB1	SS	Sandy grits
RB2	B		CB2	C	Flavour and texture
RB3	SS	Flavour, EVM	CB3	SS	Dehydrated, khaki
RB4	SS	Underblanched, colour	CB4	SS	Dehydrated, khaki
RC1	B		CC1	SS	Flavour
RC2	C	EVM	CC2	SS	Flavour
RC3	B		CC3	SS	Flavour
RC4	SS	Colour	CC4	SS	Flavour

(b) Statutory quality grading standards

Retail			Catering		
Batch Code	Grade allocated	Comments/Reason for grade allocation	Batch Code	Grade Allocated	Comments/Reason for grade allocation
RA1	Choice		CA1	Choice	
RA2	Choice		CA2	Choice	
RA3	Choice		CA3	Choice	
RA4	Choice		CA4	Choice	
RB1	Choice		CB1	Choice	
RB2	Choice		CB2	Choice	
RB3	SS	High EVM	CB3	SS	Dehydrated
RB4	SS	Underblanched	CB4	SS	Dehydrated
RC1	Choice		CC1	SS	Weedy taste/flavour
RC2	Choice		CC2	SS	Weedy taste/flavour
RC3	Choice		CC3	SS	Weedy taste/flavour
RC4	Standard		CC4	SS	Weedy taste/flavour

Grades are allocated as A, B, C or SS (Substandard) in decreasing order of quality
EVM – Extraneous Vegetable Matter

Table 4.1.3 Means (± standard deviations) and F-values of visual appearance attributes for (a) the different classes (retail and caterer's) and (b) brands (RA, RB, RC, CA, CB and CC) of frozen green peas as evaluated by a descriptive sensory panel

	Green colour	Uniformity in colour	Seed size	Seed size uniformity	Exterior seed surface texture	Seed shape	Uniformity in seed shape
(a) Retail	5.8^a (±0.8)	5.7^a (±0.5)	5.3^a (±1.3)	5.1^a (±1.0)	2.9^a (±1.1)	5.2^a (±0.8)	5.0^a (±0.7)
Caterer's	4.9^b (±1.6)	4.9^b (±1.0)	5.5^b (±0.6)	5.4^b (±0.8)	3.7^b (±1.1)	5.3^a (±0.7)	5.1^a (±0.7)
(b) RA	6.2^d (±0.6)	5.7^c (±0.6)	3.9^a (±1.2)	6.1^d (±0.4)	3.7^d (±1.2)	4.9^b (±0.6)	5.1^b (±0.4)
RB	5.4^b (±1.3)	5.8^c (±0.5)	6.1^d (±0.5)	5.2^b (±0.5)	2.0^a (±0.5)	5.9^d (±0.5)	5.6^c (±0.6)
RC	5.8^c (±0.3)	5.7^c (±0.5)	5.8^c (±0.8)	4.2^a (±0.9)	3.0^c (±0.7)	4.8^{ab} (±0.7)	4.4^a (±0.7)
CA	6.1^d (±0.6)	5.9^c (±0.6)	5.3^b (±0.3)	6.2^d (±0.4)	3.7^d (±0.4)	5.5^c (±0.2)	5.4^{bc} (±0.4)
CB	2.9^a (±1.0)	4.1^a (±0.9)	6.2^d (±0.4)	5.6^c (±0.2)	2.4^b (±0.5)	6.0^d (±0.4)	5.5^{bc} (±0.3)
CC	5.7^c (±0.3)	4.6^b (±0.6)	5.1^b (±0.3)	4.4^a (±0.3)	5.0^e (±0.3)	4.5^a (±0.3)	4.4^a (±0.5)
F-value[1]	87.67***	10.65***	33.31***	15.47***	19.13***	15.98***	4.60***

[1] ***p <0.01

a,b,c,d,e When comparing classes or brands, mean values with the same letter superscripts in columns do not differ significantly at p <0.05

Descriptors rated on a 10 point scale. Refer to Table 4.1.1 for definitions of descriptors.

Colour

Table 4.1.4 displays mean values of retail versus caterer's classes and the six different brands of frozen peas for the instrumental measurements used for discerning colour. There were significant differences found between retail and catering peas for all colour parameters except lightness (represented by the L* value). At brand level however, significant differences were observed for L* values. Brand CB with the lowest b* value was significantly different from all other brands. Retail brands and catering brand CA showed no statistical differences (p <0.05) in chroma values. CB had the lowest chroma. Interestingly, retail brand RA and catering brand CA did not differ for all colour measurements (L*, a*, b*, C and °H).

Table 4.1.4 Mean (±standard deviations) colour measurement values and calculated °H and C values for (a) the two classes and (b) the six brands of frozen green peas

		L*	a*	b*	C	°H
(a)	**Retail**	43.3[a] (±2.3)	-21.2[a](±3.1)	25.9[b](±3.4)	33.6[b](±4.2)	129.3[b](±3.8)
	Catering	43.7[a](±3.2)	-18.2[b](±4.3)	24.1[a](±3.4)	30.3[a](±4.8)	126.6[a](±5.2)
(b)	**RA**	43.4[ab](±2.5)	-22.1[a](1.7)	25.5[a](±2.9.)	33.8[c](±2.9)	131.3[d] (±2.6)
	RB	44.4[bc](±1.9)	-20.0[b] (±4.5)	26.1[a](±3.8)	32.9[bc](±5.4)	127.1[b](±4.4)
	RC	45.1[cd](±2.3)	-21.6[a](±2.1)	26.2[a](±3.7)	34.0[c](±3.9)	129.7[c] (±3.0)
	CA	42.6[a](±2.3)	-21.7[a](±1.7)	25.2[a](±2.9)	33.3[c] (±2.8)	130.8[cd](±3.2)
	CB	46.1[d](±3.2)	-13.7[c](±3.4)	22.5[b](±3.9)	26.3[a](±4.9)	121.0[a] (±3.3)
	CC	42.3[a](±2.4)	-19.3[b](±2.5)	24.6[a](±3.0)	31.3[b] (±3.6)	128.1[b] (±2.9)

[a,b,c,d,e]When comparing classes or brands, mean values with the same letter superscripts in columns do not differ significantly at p <0.05
C - Chroma = $(a^{*2} + b^{*2})1/2$
°H – Hue angle = arctan b*/a*

The PCA plots of the attributes describing appearance of frozen peas and L*, a*, b*, chroma and °hue angle measurements of colour (Figure 4.1.7) showed separation of the greener pea samples that were characterised by lower lightness (L*) and more negative a* values (i.e. higher green hue). Brands RA and CA were observed to have higher green colour intensity and uniformity than the other brands. Brand CB which is located on the opposite extreme end of the plot was characterised by descriptive evaluation to have large seeds. The first factor which explained 51% of the variance separates the peas with regards to the exterior seed surface texture (presence and magnitude of wrinkles) and overall seed shape. The rounder peas were less wrinkled.

Size sorting

Figure 4.1.8 shows the seed size profiles of the different brands of frozen peas. Batches RA1 and RA4 had their largest fraction of peas (58 and 63% respectively) falling between the size range 8 to 9 mm while RA2 and RA3 had their largest fractions (57 and 64%) between 9 to 10 mm. Most of the peas in brand RB were between 10 and 11 mm. However batch RB3 had smaller peas with 67% found within the 9 to 10 mm range. All the brand CA batches had their largest fractions (from 64-71%) in the range 9 to 10 mm. Brand CC peas varied greatly in size as the seeds were generally more widely distributed across the different size fractions than the other brands.

(a)
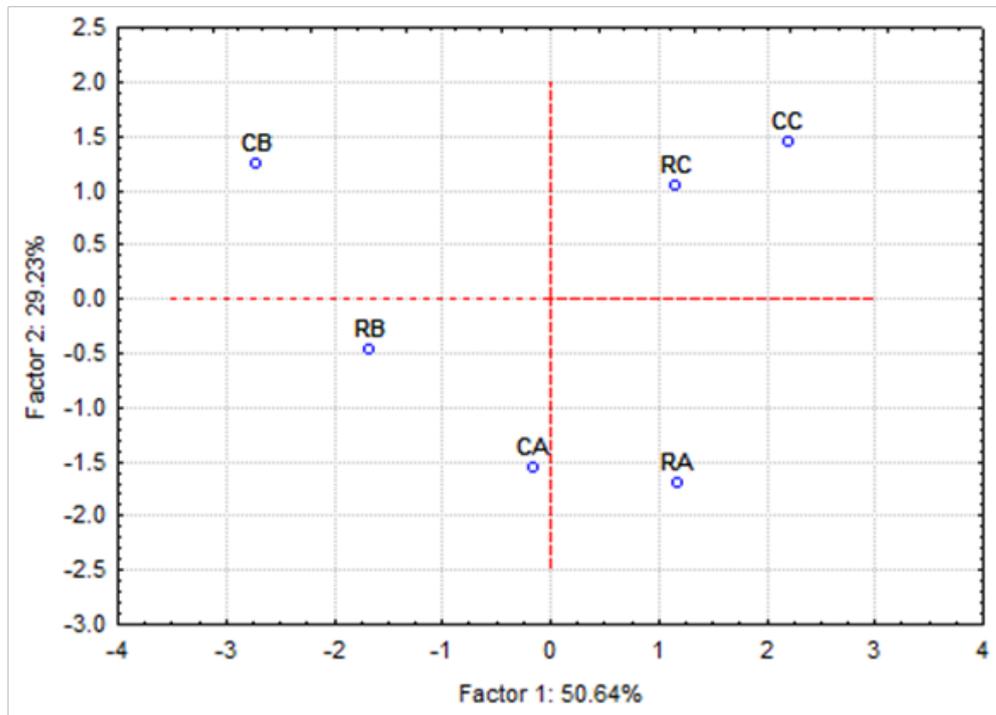
(b)
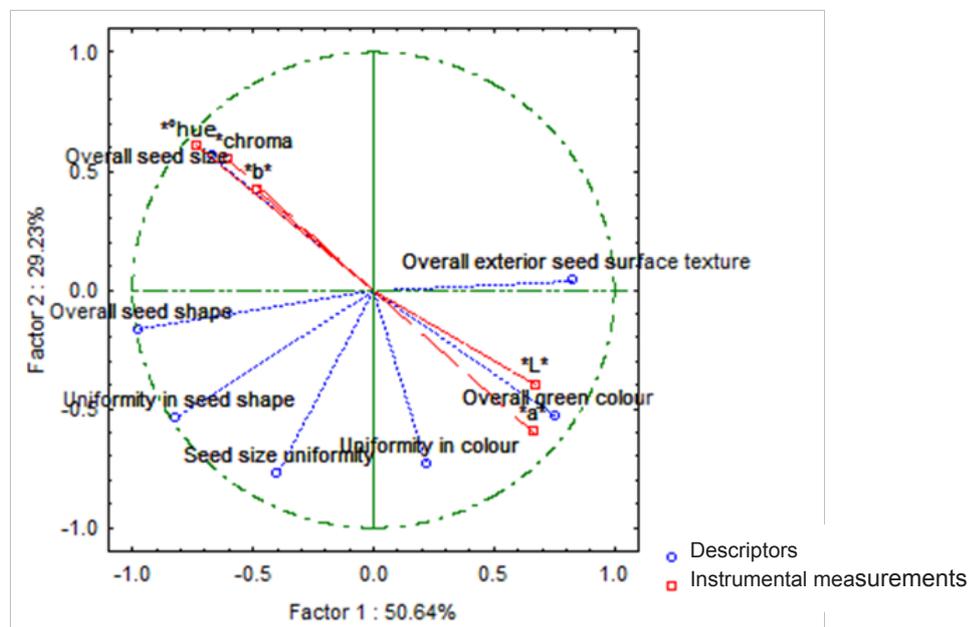
Figure 4.1.7: Principal Component Analysis (PCA) of frozen pea appearance sensory attributes and colour measurements (a) brand scores and (b) attribute loadings
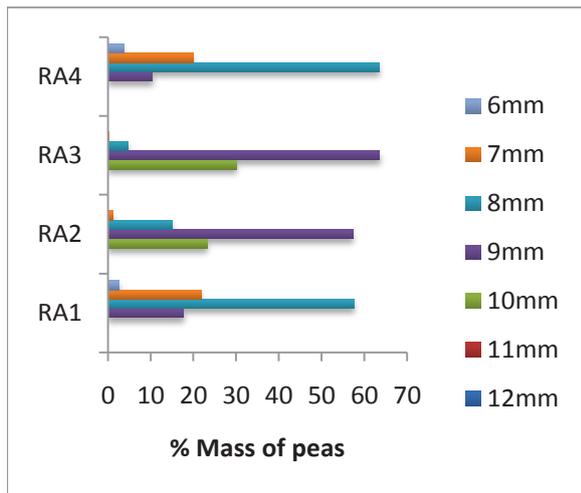
(a) Retail brand RA
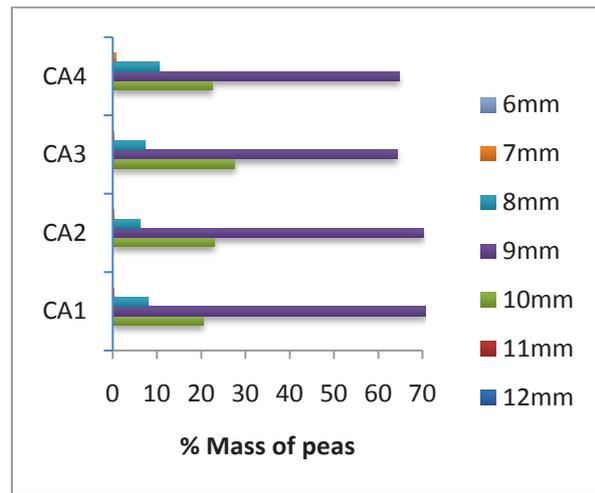
(d) Caterer's brand CA
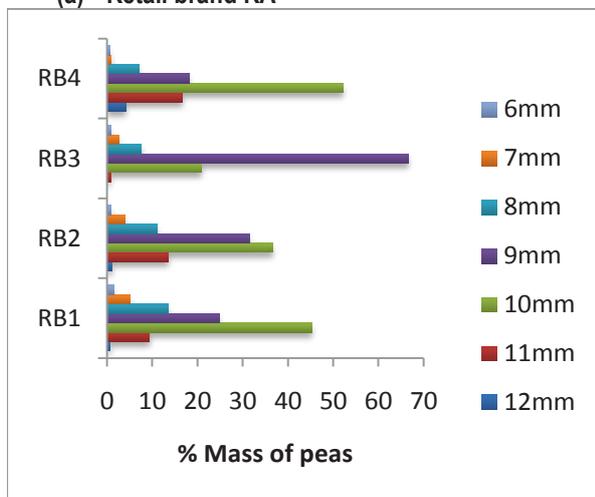
(b) Retail brand RB
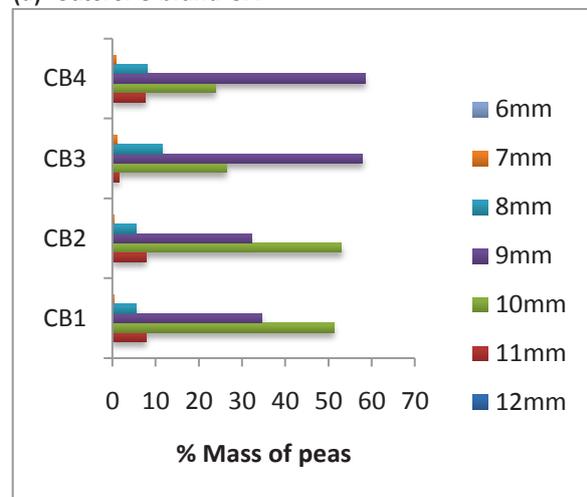
(e) Caterer's brand CB
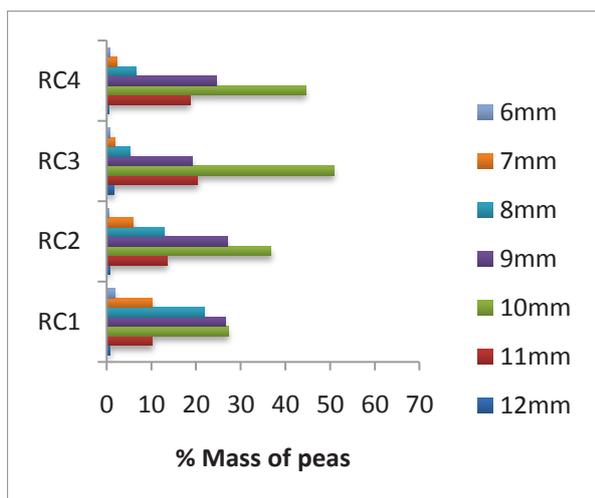
(c) Retail brand RC
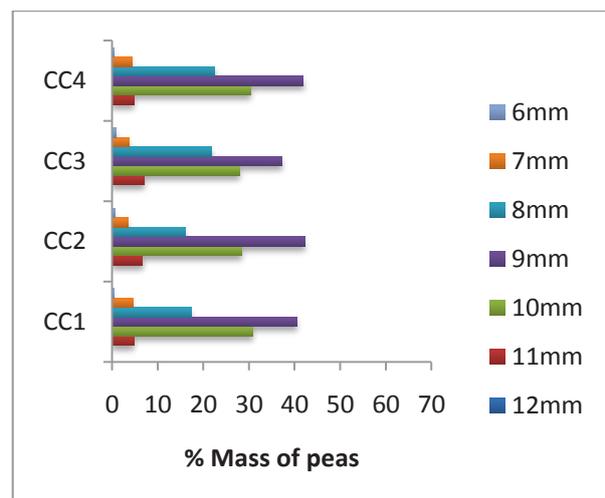
(f) Caterer's brand CC

Figure 4.1.8: Size distribution of different brands and batches of frozen peas. Graphs (a) to (c) illustrate size fractions obtained for retail brands and graphs (d) to (f) show sizes for caterer's brands

4.1.4 Discussion

Sensory evaluation, physical size and colour measurements of peas indicated that generally the visual quality of retail class is superior to caterer's class. Quality grading however was less specific as both retail and caterer's peas were downgraded for poor appearance and the reasons given could not be concluded to belong to a specific class. Batches graded SS due to poor colour were found in both classes. Excess EVM which caused the downgrading of two retail batches when the company grading protocol was used was not observed to be a distinguishing attribute by the descriptive panel. This is most likely so because the evaluation of EVM in industry is done on a large sample size (500 g using the company protocol and 300 g using the statutory requirements) as compared to the ±30 g given to the panel. The presence of sandy grits and soil stains identified in three caterer's batches that resulted in their grading as SS using the company protocol was not identified by the panel and could also be caused by differences in the amount of sample evaluated. Samples with sandy grits and soil stains were not observed to have an impact on instrumentally measured colour findings. Only one sample was graded SS because of excess EVM when the statutory protocol was used. Therefore specifications on excess EVM and the presence of soil stains or sandy grits set by the company may be too high and probably uneconomical as these two aspects do not change in the product post processing.

Colour values and sensory evaluation revealed that retail peas were greener than caterer's peas. Retail brands had significantly higher –a* and b* values, hue angle and chroma. Retail brand RA peas was not significantly different from CA in these measurements in all the sensory descriptors except seed size and seed shape. These two brands are manufactured by the same company and may be similar due to the use the same grading scheme. The scheme may be using higher quality specifications, and does not differentiate clearly between their retail and caterer's classes in these visual quality attributes. Batch RB4 was graded as SS due to poor colour and was described as underblanched by QC in industry when both the statutory and company grading protocols were applied. The panel described RB4 to have a dull olive green colour which was not observed in any other batches from the same brand and resulted in a high standard deviation observed for RB colour intensity. Enzyme activity due to inadequate blanching has been seen to attribute to the colour instability of frozen peas (Gökmen *et al.*, 2005). Grandison (2006), states that green peas upon heating change colour from bright green to a dull olive green due to the conversion of chlorophyll to pheophytin. It is also possible that this batch had poor colour from overblanching during processing. Performance of a residual enzyme activity test would have been very meaningful to confirm these two possibilities. The other batches from brand RB (i.e. RB1, RB2 and RB3) were of high green colour intensity and hence the brand scores for instrumental measurements and sensory evaluation were not severely affected.

Although no significant differences were found in lightness (L*) values between retail and caterer's classes, high lightness (L*) values observed in CB were a result of batches CB3 and CB4 described to have khaki seeds and as dehydrated. These samples may have been low in colour due to loss of chlorophyll from delayed harvest (Cheng *et al*, 2004) or tarnishing of colour from freezer damage (Torregiani *et al.*, 2000). The L* scale ranges from 0 for a theoretical black to 100 for a perfect white (Weatherhall and Combs, 1992). A more negative a* value indicates a darker green hue (Madeira *et al.*, 2003) and brand CB had the least negative a* value which was almost double that observed in RA and CA. CB was therefore more red in colour. Hue angles closest to 180° indicate a material surface closest to green in colour and CB had the lowest value. Chroma (level of saturation) did not differentiate well between brands. The method of colour measurement could have introduced bias in the results from light deflected or shadow interference from gaps that may have occurred between individual seeds in petri dish. Effort was made however to try and press the lens of the chromameter such that it was entirely resting on the pea skin surfaces.

Unexpectedly, the greener and higher graded retail samples were described to be more wrinkled (measured as exterior surface texture) in appearance than the lower grade caterer's samples. McEwan and Clayton (1998) found that consumers associated peas with wrinkles as old and

hence of a lower quality. However in the same study consumers identified "dimpling", described as a single or few depressions on the skin surface, to indicate freshness of peas and was acceptable. Dimpling in the smaller, greener peas may have been mistaken and regarded as wrinkling in this research. The least wrinkled brands were described as rounder except CC. Panellists' ratings for wrinkling could have been greatly influenced by the shape. Dimpling may be more expected in the fresher, good quality peas that would have high moisture content and hence have a less firm shape after cooking, compared to the more mature seeds that have higher AIS, DMC and starch content (Kmiecik *et al*., 2004) and would probably be more solid; thus resulting in a more compact round shape.

The specifications for pea size given by the company grading protocol stipulate that normal size product should be within a size range of 8.6 and 10.5 mm. Baby peas are expected to be <8.5 mm and any pea size greater than 10.5 mm is considered as oversize. Screening for undersized peas (<5.4 mm) is done at raw materials assessment. The rotating screen sieve with holes of different diameter used in industry sorts peas accordingly into a few size groups. The size separation method used in the research was more specific as it gave size fractions of peas for every millimetre of seed diameter ranging from 6 mm to 12 mm of a 500 g sample aliquot. This method gave a more accurate picture of the size distribution of seeds in each sample and provided a quantifiable measurement for the size uniformity sensory descriptor. Pea seed size was observed to vary in the two classes. Patterns of similarity in size and uniformity were more noticeable at brand level. Sensory evaluation revealed that the largest peas belonged to brands CB and RB. Sieving proved that it is difficult for humans to visually detect slight differences in size because although RC had relatively the largestquantity of seeds in the 11 mm size fraction, they were of a smaller quantity than those observed in CB and RB for the 10 mm fraction, and the brand was thus perceived to be smaller by the panel.

The physical sieving done on brand RA revealed that the brand had two size patterns. Two batches had much smaller seeds than the other two. This explains the relatively high standard deviation obtained for RA in sensory evaluation of the size descriptor. Brand RA however still generally had the smallest seeds measured by both sensory evaluation and using the sieves. All of the batches in brand CA had their highest size group (9-10 mm) represented by fractions between 64 and 71%. Panellists rated CA as the brand showing the highest degree of uniformity. High size homogeneity of this brand was hence quantified by the physical sieving process. It was not expected that the human instrument (sensory panel) would be capable of accurately detecting a size difference of 1mm especially because samples were presented one at a time and could not be compared. However this was easily done by sieving. The sieving is thus a more sensitive method than descriptive sensory evaluation. However, both methods were able to relate the degree of uniformity in batches. From all the batches, a very negligible quantity of peas (4% at most) fell within the 6-7 mm range. If this sieving method is to be used in future it may be suggested that this size fraction be disregarded. Brands represented byhigher majority of smaller sized peas (RA and CA) were described by the panel to be greener and observed to have more negative a* values and low L* values. Hence it may be suggested that the results from the research show that size can indeed be related to external colour. Martens (1986) only found a weak relation between pea size and external colour and other appearance variables. It may also mentioned that the batches that were poorly graded (SS) due to reasons based on colour generally had relatively large seeds.

4.1.5 Conclusions

Generally frozen peas intended for retail sales are of better visual quality than those intended for catering applications. However some caterer's brands are of significantly superior visual quality than other retail brands. Descriptive sensory evaluation and instrumental measurements reveal that size and green colour intensity are important attributes in judgement of frozen green pea visual quality. Uniformity in seed size reflects positively on frozen green pea quality and the use of a more sensitive size sorting process may improve quality differentiation of frozen

peas. Peas graded poorly (SS) as a result of the colour parameter show traits associatedwith poor blanching and maturation (delayed harvesting/dehydration). Residual enzyme tests and dry matter content analyses are recommended to more reliably conclude on reasons for poor appearance. Colorimetry using a chromameter is a rapid and easy method that may be used in industry to give more reliable and quantitative measurements for colour of green peas and hence quality discernment. It is suggested that visual quality assessment of colour in quality grading may also be improved by comparing and scaling samples against a colour wheel or chart with predetermined grades per shade of green.

4.2 FROZEN GREEN PEA (*Pisum sativum* L.) QUALITY DESCRIBED BY FLAVOUR AND TEXTURE SENSORY ATTRIBUTES AND RELATED PHYSICO-CHEMICAL PROPERTIES.

ABSTRACT

The in-mouth quality of frozen green peas was investigated using 6 brands of peas (3 representing retail class and 3 representing caterer's class) purchased from different stores in South Africa. The frozen pea samples were quality graded in industry using a selected company scheme and statutory grading specifications; subjected to descriptive sensory evaluation; and physico-chemical measurements of texture (hardness), starch content, alcohol insoluble solids content, dry matter content, residual peroxidase activity and soluble solids content (°Brix) to assess the flavour and texture quality. Good quality peas were described as sweeter, more tender, less mealy and juicier than poorer quality peas and this was confirmed by the physico-chemical analyses tests. The less sweet peas had bitter notes. Soluble solids content was highly negatively correlated to starch content, hardness, alcohol insoluble solids content and dry matter content. The brand of peas with high °Brix (11) was less hard and required a lower force to penetrate through the seeds (2.2 N.mm/g), had lower starch (15.3%), lower alcohol insoluble solids (12.5%) and was also more juicier (dry matter content of 20.9%) when compared to the lowest °Brix (6.6) brand which had hardness of 5.1 N.mm/g, starch content of 34.6%, alcohol insoluble solids content of 26.1% and dry matter content of 31.7%. Peas with high residual peroxidase activity had an intense undesirable flavour. Generally the retail class peas were of superior sensory quality when compared to caterer's class peas.

4.2.1 Introduction

Consumers consider appearance, flavour and texture as the three main properties decisive in their selection and ingestion of a particular food. A study by Sandford *et al.* (1988) revealed that texture and flavour were rated as the most important sensory attributes with respect to acceptance of peas. Companies in the food industry apply grades and standards that are intended to control thequality of their products. The grading systems used for frozen peas include assessment of flavour and texture (South Africa Department of Agriculture, 1998). The flavour and texture quality are very important in determining whether the frozen peas are packaged for retail or catering sales.

The flavour and texture sensory characteristics may be explained by the physico-chemical properties of the frozen peas. Maturity of pea seeds at harvest plays a major role in the quality of flavour and texture of the frozen product. Shortly after harvest, loss of sensory characteristics such as sweetness, crispness as well as degreening and the development of mealiness may reduce quality (Basterrechea and Hicks, 1991). Alcohol insoluble solids (AIS) have been used as a maturity index for fresh green peas (WHO/FAO Food Standards Program, 2004) as this parameter indicates protein, fibre and starch contents. As peas mature, sugars become converted into starch and the largest pea sizes consistently exhibit higher AIS and dry matter content (DMC) and these are negatively correlated with the sensory quality of the harvested peas (Martinez *et al*., 1995; Deshpande and Adsule, 1998). Measurement of sugar content as soluble solids (°Brix) may give an indication of flavour in peas which may be expressed as sweetness in descriptive evaluation. Starch content and force of compression have been used to explain related texture attributes in a study by Martens (1986). Flavour of frozen peas is also influenced by the presence of lipoxygenase, peroxidase and catalase enzymes whose action result in the development of undesirable taints (Quaglia *et al*., 1996). Peroxidase which is considered the most heat stable has been used as a prime-index of measuring the effectiveness of blanching of peas prior to freezing. Findings of the investigation of visual quality of frozen peas (section 4.1) suggested that poor colour may possibly be due to residual enzyme activity. Performing a residual peroxidase test to explain flavours may also confirm this suggestion.

The objective of this part of the project was to determine selected physico-chemical analyses and associated profiles from descriptive sensory evaluation explaining flavour and texture of retail and caterer's classes of frozen peas available in the South African market. Partial Least Squares regression analysis was used as a multivariate data analysis tool to explain the relationships between the sensory and physico-chemical parameters.

4.2.2 Materials and Methods

Samples, quality grading and sensory analysis

The frozen pea samples used in the study were obtained, graded industrially and prepared for sensory evaluation in the same way as described in 4.1.2. Of the twenty seven sensory descriptors developed, twenty of them were relevant to flavour and texture attributes of frozen peas (Table 4.2.1).

Physico-chemical analyses

Sugar content

50 g of frozen peas were packed into 100 ml round bottom plastic dishes and covered with cheese cloth secured by rubber bands. The samples were freeze dried for 8 days in an Instruvac lyophilizer model 13KL freeze drier (Vacuum and temperature settings: -85 kPa and -40 °C). The dried seeds were ground into a powder of particle size not more than 0.5 mm using a IKA® A11 basic analytical mill (230 V, 50/60 Hz). 1 g of the freeze dried pea flour was reconstituted with 4 g distilled water in a glass beaker to an 80% moisture content paste. This reconstitution ratio was selected to imitate the typical moisture content of about 80%, calculated from dry matter content of commercially frozen peas of 20.5% as found by Stea et al. (2006). The paste was incubated in a 20 °C water bath for 5 min. The paste was squeezed through cheese cloth and °Brix of the juice measured using a Pal-1 digital pocket refractometer (Brix 0-53°, Atago, USA). The analysis was carried out three times for each batch.

Dry matter content (DMC)

DMC of thawed uncooked frozen peas was determined by drying 5 g of peas overnight to a constant weight (±20 h) in a draught oven at 70 °C following the method used by Martens (1986). The experiment was carried out three times for each batch.

Peroxidase activity test

50 g sample portions of frozen peas were thawed at room temperature (23 °C) for 2 h. Ten randomly selected thawed uncooked pea seeds were longitudinally cut and arranged with the cotyledon surface exposed and sprayed with peroxidase test solution (50:50 1% guaiacol and 2% hydrogen peroxide). Inadequately blanched batches were recorded as those showing colour change in more than 10% of the seeds within 10 s of spraying the solution. The analysis was carried out three times for each batch.

Alcohol Insoluble Solids (AIS)

The AIS contentof thawed peas was measured using the gravimetric method based on the AOAC 971.29 (2002). Twenty grams from a blend of 1:1 w/w of peas and distilled water was used for the experiment. Analysis was done in triplicate for each batch.

Table 4.2.1 Definitions and references for flavour and texture descriptors developed for descriptive sensory evaluation of steam cooked frozen green peas

Descriptor	Definition	Rating scale and references
1. Aroma intensity	The strength of odour that is released from sample upon taking the first few sniffs	0=not intense 10=extremely intense
2. Sweet aroma	Aromatic associated with high sugar content vegetables	0=not sweet (filtered water) 10=extremely sweet (freshly boiled sweet corn)
3. Earthy aroma	Aromatic characteristic of damp soil, wet foliage or undercooked potato	0=not intense 10=extremely intense (unpeeled and cut raw-undercooked potato)
4. Acetone aroma	Aromatic characteristic of ketones, specifically acetone	0=not intense 10=extremely intense (acetone)
5. Beany aroma	Aromatic characteristic of leguminous plants	0=not intense 10=extremely intense (boiled sugar beans)
6. Green aroma	Aromatic associated with freshly cut green vegetables	0=not intense 10=extremely intense (freshly cut green beans)
7. Sweet taste	Taste on tongue stimulated by sugars and high potency sweeteners	0=not sweet 10=extremely sweet (50% sucrose solution on filter paper)
8. Bitter taste	Taste on tongue stimulated by caffeine, quinine and certain other alkaloids	0=not bitter 10=extremely bitter (4% caffeine solution on filter paper)
9. Starchy flavour	Flavour associated with tubers particularly boiled potato	0=not intense 10=extremely intense (boiled potato)
10. Fresh taste	Taste associated with fresh green peas, free from any unfavourable odours	0=not fresh (boiled peas kept at room temperature for 5 days) 10=extremely fresh (fresh green peas steam cooked for 5 min)
11. Fruity flavour	Flavour associated with overripe fruit characteristic of aldehydes and ketones	0=not intense 10=extremely intense (overripe pear)
12. Flavour intensity	Degree of flavour concentration released in mouth when pea sample is chewed	0=not intense 10=extremely intense
13. Crunchiness	Level of sound produced when chewing through peas sample	0=not crunchy10=extremely crunchy (raw carrots)
14. Tenderness	Ease in which pea sample is masticated in the mouth	0=not tender 10=extremely tender (overcooked sugar beans)
15. Mealiness	Coarseness in texture experienced when chewing peas	0=not mealy 10=extremely mealy (80% moisture maize meal paste)
16. Chewiness	Amount of work required to masticate a sample with molars	0=not chewy 10=extremely chewy[a]
17. Moistness	The amount of juice released from peas upon chewing through a spoonful	0=not moist 10=extremely moist[a]
18. Uniformity in texture	Estimated level of homogeneity in texture in a spoonful of peas	0=not uniform 10=extremely uniform
19. Bitter aftertaste	Intensity of bitter taste that lingers after swallowing	0=not bitter 10=extremely bitter
20. Residue remaining after swallowing	The amount of pea pieces that remain in mouth after swallowing	0=not intense 10=extremely intense (roasted peanuts)

[a]Selected pea samples used as references and did not necessarily represent the optimum level for the particular descriptor.

Starch content

Starch content was measured on freeze dried pea flour (prepared as described for sugar analysis) using the Megazyme alpha-amylase/amyloglucosidase test kit based on the AOAC Method 996.11; AACC Method76.13 and ICC Standard Method No. 168. The analysis was performed in duplicate.

Texture Measurements (Hardness)

The texture analyser TA-XT2 (Stable Micro Systems, Godalming, UK) fitted with a multiple pea rig probe was used to measure the force of compression to pierce through 18 randomly selected cooked pea seeds of a known mass. The probe is comprised of a round based metal plate with 18 individual circular grooves in which individual pea seeds can be placed. The grooves had a hole in the centre of approximately 3 mm diameter. The probe also had a top plate fitted with 18 metal spikes (~1 mm) that fit through the holes on the base plate after piercing the seeds. The samples were prepared and cooked using the method prescribed for descriptive sensory evaluation (section 4.1.2) and cooled for 30 min in closed polystyrene cups before the analysis. The cooked seeds were transferred and spread out on a paper towel lightly patted dry and randomly picked. The 18 cooked seeds were picked, weighed and arranged in the probe base plate for penetration. The area under curve (AUC) measured between time 0 and the second highest peak (final penetration) multiplied by the test speed of 10 mm s-1 for every gram of the sample was used to report pea hardness (work done). The mass of peas was factored into the texture calculation because single pea seeds measured were selected randomly and were visibly of different sizes. The texture analyser used pre-test, test and post-test speeds set at 10.0 mm s-1; a rupture test speed of 4mm s-1, distance of 15 mm, load cell at 25 kg, temperature at 25 °C, force set at 0.98 N and time set at 5 s. This method of analysis was performed six times on every batch.

Statistical Analysis

A hierarchically nested design Analysis of Variance (ANOVA) of the General Linear Model (GLM) was used to give an indication of the variance amongst pea batches for physical and sensory data. The design had three level factors/categorical predictors (batches, brands and classes) in which the batches were considered random effects and brands and classes were fixed effects. Four batches were nested within six brands which were nested between two classes of retail and catering peas (2 x 3 x 4 nested design). The Fisher Least Significance Difference (LSD) test was used to investigate the nature of the differences and the least square means obtained were reported for this evaluation. F-statistic values were used to show levels of significance of the variation in brand sensory properties. A significance level (p-value) of <0.05 was used as the decisive criteria for significant differences between pea batches, brands and classes. Statistica version 7 (Statsoft, Inc., 2006) was used for the analysis. Partial Least Squares (PLS) Regression was used to investigate the relationship of sensory and physico-chemical data. An X-Y matrix with physico-chemical attributes as the X variables and sensory attributes as Y variables with full cross validation was computed. The Unscrambler version x10.0 data analytical software (Camo software Inc, Oslo, Norway 2009-2010) was used to carry out this analysis.

4.2.3 Results

Quality grading

Results obtained for the quality grading of peas are shown in Section 4.1 (Table 4.1.2).

Sensory evaluation

F-values for all the descriptors related to flavour and aroma attributes except for beany aroma showed significant sensory differences between brands at $p < 0.05$ (Table 4.2.2). Between retail and catering classes all the aroma and flavour attributes except beany aroma and fruity flavour showed significant differences. However, interestingly the caterer's brand CA obtained scores more comparable with the other retail brands for most descriptors. Fresh flavour and sweet taste were the attributes that separated the brands more distinctly while fruity flavour and flavour intensity were less clear brand distinguishing descriptors. Brand CB samples were characterised by significantly higher bitter, acetone and starchy notes as compared to other brands.

All the texture attributes developed were relevant in explaining the variance between retail and catering peas at a significance level of < 0.05 (Table 4.2.3). Tenderness, moistness and crunchiness attributes described the variation between frozen pea samples to a higher extent than the other attributes as seen from the higher F-values obtained. Much more residue was observed to remain in the mouth post swallowing in brand CB peas (4.4) than all the other batches. There were no significant differences in mealiness of retail brand RB (3.2) and the two catering brands CA (3.3) and CC (3.3). Brand RA was significantly more moist and tender and was observed to have the lowest mealiness, crunchiness and chewiness.

Table 4.2.2 Means (± standard deviations) and F-values of aroma and flavour attributes for (a) the two classes, retail and catering and (b) the 6 brands (RA, RB, RC, CA, CB, CC) of frozen green peas as evaluated by a descriptive sensory panel

	Aroma intensity	Sweet aroma	Earthy aroma	Acetone aroma	Beany aroma	Green aroma	Sweet taste	Bitter taste	Starchy (boiled potato) flavour	Fresh taste	Fruity flavour	Flavour intensity	Bitter aftertaste
(a) Retail	5.8a (±0.4)	3.9a (±0.6)	2.9a (±0.2)	2.0a (±0.3)	3.1a (±0.4)	3.6a (±0.7)	5.2a (±0.8)	1.0a (±0.4)	2.5a (±0.7)	5.4a (±1.0)	1.9a (±0.4)	5.5a (±0.5)	0.7a (±0.4)
Catering	6.3b (±0.6)	3.2b (±0.8)	3.3b (±0.6)	2.4b (±1.1)	3.4a (±0.5)	3.0b (±1.1)	3.3b (±1.3)	1.6b (±0.6)	3.7b (±0.4)	3.7b (±1.3)	1.8a (±0.5)	5.2b (±0.3)	1.1b (±0.5)
(b) RA	5.6a (±0.4)	4.5e (±0.5)	2.6a (±0.2)	1.7ab (±0.3)	3.1ab (±0.4)	4.1d (±0.5)	5.8e (±0.3)	0.8a (±0.2)	2.2a (±0.8)	5.9a (±0.5)	2.0b (±0.3)	5.7a (±0.3)	0.6a (±0.2)
RB	6.0b (±0.5)	3.5bc (±0.3)	3.1b (±0.4)	2.3c (±0.3)	3.0ab (±0.3)	3.3b (±0.9)	4.5c (±0.9)	1.3b (±0.7)	2.7b (±0.8)	4.7c (±1.4)	1.8b (±0.6)	5.5b (±0.9)	0.9b (±0.6)
RC	5.8a (±0.2)	3.6c (±0.6)	3.0b (±0.2)	2.0bc (±0.4)	3.2ab (±0.4)	3.5bc (±0.5)	5.3d (±0.3)	0.8a (±0.2)	2.6ab (±0.5)	5.6e (±0.3)	2.0b (±0.4)	5.4ab (±0.2)	0.6a (±0.2)
CA	5.6a (±0.3)	4.0d (±0.4)	2.8ab (±0.3)	1.6a (±0.3)	3.4b (±0.3)	3.8cd (±0.4)	4.6c (±0.3)	1.0ab (±0.4)	3.3c (±0.5)	5.0d (±0.2)	2.0b (±0.4)	5.1a (±0.2)	0.6a (±0.2)
CB	6.6c (±0.4)	2.4a (±0.7)	3.1b (±0.3)	3.7d (±0.9)	2.9a (±0.3)	1.7a (±0.6)	2.3a (±1.1)	2.2d (±0.7)	4.0d (±0.6)	2.2a (±1.0)	1.8b (±0.7)	5.3ab (±0.5)	1.5d (±0.5)
CC	6.8c (±0.2)	3.2b (±0.3)	4.1c (±0.3)	2.0bc (±0.3)	3.8c (±0.5)	3.6c (±0.3)	2.9b (±0.7)	1.6c (±0.3)	3.7cd (±0.5)	3.9b (±0.5)	1.4a (±0.4)	5.1a (±0.5)	1.2c (±0.2)
F-value[1]	8.85***	8.77***	5.37***	13.48***	1.59ns	17.45***	52.53***	11.90***	6.34***	41.05***	3.56*	3.00*	16.32***

[1] *** $p < 0.01$, * $p < 0.05$, ns - not significant

a,b,c,d,eWhen comparing classes or brands, mean values with the same letter superscripts in columns do not differ significantly at $p < 0.05$

Descriptors rated on a 10 point scale. Refer to Table 4.2.1 for definitions of descriptors.

Table 4.2.3 Means (± standard deviations) and F-values of texture/mouthfeel attributes for (a) the two classes retail and catering, and (b) the 6 brands of frozen green peas

		Crunchiness	Tenderness	Mealiness	Chewiness	Moistness	Texture uniformity	Residue remaining after swallowing
(a)	**Retail**	4.2[a] (±1.1)	5.8[a] (±1.3)	2.3[a] (±1.1)	4.5[a] (±0.7)	5.8[a] (±1.2)	5.8[a] (±0.5)	2.6[a] (±0.8)
	Catering	4.9[b] (±0.7)	4.5[b] (±1.2)	3.9[b] (±1.2)	5.4[b] (±0.6)	4.2[b] (±1.3)	5.4[b] (±0.4)	3.7[b] (±0.7)
(b)	**RA**	3.5[a] (±0.5)	6.7[e] (±0.7)	1.6[a] (±0.8)	3.8[a] (±0.5)	6.7[d] (±0.9)	6.3[d] (±0.6)	2.0[a] (±0.6)
	RB	5.4[e] (±1.0)	4.5[b] (±1.4)	3.2[c] (±1.3)	5.2[c] (±0.7)	4.8[b] (±1.3)	5.5[abc](±0.4)	3.3[c] (±0.9)
	RC	3.9[b] (±0.3)	6.1[d] (±0.3)	2.2[b] (±0.3)	4.4[b] (±0.3)	6.0[c] (±0.2)	5.6[bc] (±0.2)	2.5[b] (±0.2)
	CA	4.3[c] (±0.3)	5.2[c] (±0.4)	3.3[c] (±0.4)	5.0[c] (±0.3)	4.9[b] (±0.3)	5.2[a] (±0.3)	3.3[c] (±0.3)
	CB	5.5[e] (±0.8)	3.3[a] (±1.5)	5.1[d] (±1.3)	6.0[d] (±0.6)	2.9[a] (±1.4)	5.8[c] (±0.5)	4.4[d] (±0.8)
	CC	4.8[d] (±0.4)	5.0[c] (±0.4)	3.3[c] (±0.3)	5.3[c] (±0.3)	4.8[b] (±0.5)	5.3[ab] (±0.3)	3.5[c] (±0.4)
	F-value[1]	32.51***	53.96***	28.33***	13.70***	43.28***	4.23***	20.14***

[1]***$p < 0.01$, *$p < 0.05$, ns - not significant
[a,b,c,d,e]When comparing classes or brands, mean values with the same letter superscripts in columns do not differ significantly at $p < 0.05$

Descriptors rated on a 10 point scale. Refer to Table 4.2.1 for definitions of descriptors.

Physico-chemical Analyses

Table 4.2.4 displays mean values for the various physico-chemical analyses of retail versus catering classes and the six different brands of frozen peas. It was observed that there were significant differences in the two classes of peas for all the parameters except for residual peroxidase enzyme activity. The retail class peas were significantly lower in DMC, AIS, starch content and instrumentally measured hardness; and significantly higher in soluble solids (°Brix) content. High standard deviations were observed for brand CB.

Table 4.2.4 Dry matter content (DMC), alcohol insoluble solids (AIS) content, starch content, hardness, °Brix and residual peroxidase activity means and (±standard deviations) for (a) the two classes and (b) the six brands of frozen pea samples

		DMC (%)	AIS (%)	Starch (%)	Hardness (N.mm/g)	°Brix	Peroxidase positive (%)
(a)	Retail	22.1[a] (±2.9)	14.1[a] (±2.9)	17.1[a] (±3.1)	2.5[a] (±0.7)	9.9[a] (±1.3)	9[a] (±17.9)
	Catering	26.6[b] (±5.5)	20.2[b] (±5.8)	26.2[b] (±9.5)	3.5[b] (±1.8)	7.6[b] (±1.1)	7[a] (±9.6)
(b)	RA	20.9[a] (±3.5)	12.5[a] (2.2)	15.3[a](±3.0.)	2.2[a](±0.3)	11.0[f] (±1.1)	3[a](±4.5)
	RB	23.6[c](±3.0)	15.9[c] (±3.8)	19.2[b](±3.1)	3.1[c](±1.0)	9.3[d](±1.5)	19[c](±27.8)
	RC	21.8[b] (±0.9)	14.0[b] (±1.2)	16.7[a](±1.9)	2.1[a](±0.2)	9.5[e] (±0.3)	4[ab](±6.7)
	CA	23.2[c](±1.0)	17.8[e] (±0.6)	23.4[c] (±1.6)	2.7[b](±0.4)	8.3[c] (±0.2)	4[ab](±5.1)
	CB	31.7[e] (±7.0.)	26.1[f](±6.9)	34.6[d] (±12.8)	5.1[d] (±2.3)	6.6[a] (±1.2)	7[ab] (±12.3)
	CC	24.9[d](±1.3)	16.7[d] (±1.0)	20.5[b](±0.9)	2.7[b](±0.3)	8.0[b] (±0.5)	9[b](±10.0)

[a,b,c,d,e]When comparing classes or brands, mean values with the same letter superscripts in columns do not differ significantly at p <0.05

DMC for the different pea brands was between 20.9 (RA) and 31.7% (CB). There was no significant difference between retail brand RB and catering brand CA. Brand CB had markedly higher DMC when compared to the other brands.

The AIS content of the brands were significantly different (Table 4.2.4). Generally the retail brands had lower AIS than the catering brands with RA having the lowest (12.5%). Brand CB had very high AIS, notably more than double the amount found in RA.

The two retail brands, RA and RC, did not differ significantly in starch content and had the lowest values (15.3 and 16.7% respectively). RB, a retail brand, did not differ significantly from CC, a catering brand. Again brand CB was distinctly separated from all other brands and was observed to have very high starch content. This brand also recorded high standard deviations, which means that the different batches were very dissimilar.

Pea hardness (N.mm/g) calculated from the work done to pierce through a measured mass of peas, showed no significant differences between brands RA and RC. Catering brands CA and CC were also not significantly different and retail brand RB was observed to be harder than these two. Brand CB required the highest force to pierce through the seeds.

The amount of soluble solids was analysed to give a measurement of sugar content as °Brix in the different pea samples. The retail pea brands were significantly sweeter than the catering brands. Brand RA had the highest soluble solids content (11%), almost double that of brand CB (6.6%). Brands RB, RC, CA and CC had intermediate °Brix values of between 8.0 and 9.5.

Brand RB had the highest residual enzyme activity and was the only brand that exceeded the permissible tolerance level of blanching efficiency (10%). Brands CB and CC had values approaching the minimum acceptable limit (7 and 9% respectively). It was observed that these three brands with the highest scores also had the highest standard deviations. There were no significant differences in the three brands that were lowest in residual enzyme activity (RA, RC and CA).

Table 4.2.5 shows the relationships established between the different physico-chemical parameters used to measure green pea flavour and texture quality. All correlations were significant at $p < 0.05$. DMC, starch, AIS and hardness results were highly positively correlated. DMC was positively correlated with AIS, starch and texture in decreasing order. Sugar content as soluble solids (°Brix) of the pea samples was also fairly highly negatively correlated with AIS, starch, DMC and texture values. This negative relationship is highest between sugar and AIS, followed by DMC, starch content and lastly the force required to penetrate through the seeds (texture).

Table 4.2.5 Correlations of DMC, hardness, °Brix, starch and AIS content of frozen green pea samples

	DMC (%)	Hardness (N.mm/g)	°Brix	Starch (%)	AIS (%)
DMC (%)	1				
Hardness (N.mm/g)	0.93	1			
°Brix	-0.85	-0.72	1		
Starch (%)	0.97	0.94	-0.84	1	
AIS (%)	0.98	0.93	-0.90	0.98	1

All correlations are significant at $p < 0.05$

Partial least squares regression (PLS) analysis

The PLS regression variances for the 19 significant sensory attributes related to flavour and texture (Y variables) and the 6 physico-chemical attributes (X variables) are presented in Table 4.2.6. Three PLS factors were seen to be significant to report reliable correlations. It was observed that the y block texture variables explained the variance in samples more than the flavour attributes. Most texture attributes were explained by the first PLS factor and had values between 78.3 and 91.9% except crunchiness which had a value of 58.3% and overall texture uniformity which was rather negligible as it only explained 0.2%. Mealiness gave the highest explanation of variance in the pea samples. The second and third PLS factors brought out more variation in the flavour (taste and aroma attributes). Sweet taste, sweet aroma, fresh taste, starchy flavour and bitter taste differentiated the samples better than the other flavour attributes. The total variation explained by the x block was greater than what was explained by the y variables. DMC and residual peroxidase activity (1.3 and 1.8% respectively) basically did not explain any of the variation in the first factor.

The scores and loading plots (Figure 4.2.1) show how the batches and variables are projected along the model components. The variance explained by the first two factors in the x block is 79% and y block is 64%. Generally the retail sales peas were separated from the catering sales peas. The retail batches are observed to occupy the right side of the plots while the catering batches are found on the left of the plot (Fig 4.2.1a). A few exceptions include a retail batch RB3 which was situated more to the left amongst other catering samples. RB4 was clearly different from all the other samples and positioned at the top of the plot and was thus better explained by the second factor. RB4 was observed to be associated with the x-variable high residual peroxidase enzyme activity. The retail samples on the right (particularly batches RA1 and RA4) were associated with high °Brix and those on the left were more explained by texture hardness, starch and AIS content. Batches CB3 and CB4 were clearly separated from all the other samples, and were observed to be best explained by the latter three attributes.

Table 4.2.6 Partial Least Squares regression used to study relationships between the sensory (Y-block) and physico-chemical (X-block) variables of frozen green peas

		% Explained Variances		
		Factor 1	Factor 2	Factor 3
Y- variables	Aroma intensity	24.5	45.0	46.0
	Sweet aroma	61.1	64.5	64.5
	Earthy aroma	3.0	3.9	4.4
	Acetone aroma	60.3	68.8	75.2
	Green aroma	48.5	61.3	61.4
	Sweet taste	70.7	73.3	73.5
	Bitter taste	62.0	79.6	81.1
	Starchy (boiled potato) flavour	60.7	71.4	71.5
	Fresh taste	73.0	81.4	81.9
	Fruity flavour	20.2	20.3	25.7
	Flavour intensity	9.2	39.9	41.1
	Crunchiness	58.3	72.0	82.4
	Tenderness	81.7	85.3	90.5
	Mealiness	91.9	92.1	92.9
	Chewiness	78.3	78.7	85.0
	Moistness	91.2	91.2	92.6
	Uniformity in texture	0.2	25.4	56.4
	Bitter aftertaste	51.8	81.1	82.5
	Remaining of residue in mouth	85.3	85.6	88.3
Total explained variance for Y (sensory) block		**54.3**	**64.3**	**68.3**
X – variables	Starch	96.2	96.4	96.7
	Alcohol Insoluble Solids	97.7	98.5	98.9
	Dry Matter Content	1.3	29.2	94.4
	Hardness	89.7	92.9	95.2
	Peroxidase positive	1.8	65.7	100.0
	°Brix	78.6	89.1	89.2
Total explained variance for X (Physico-chemical) block		**60.9**	**78.6**	**95.7**

(a)
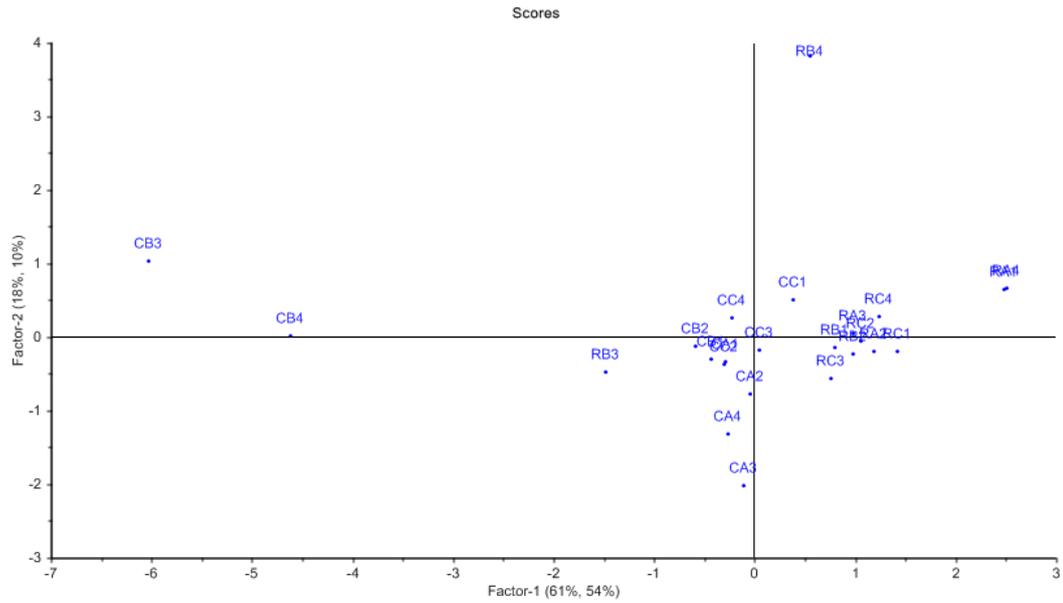
(b)
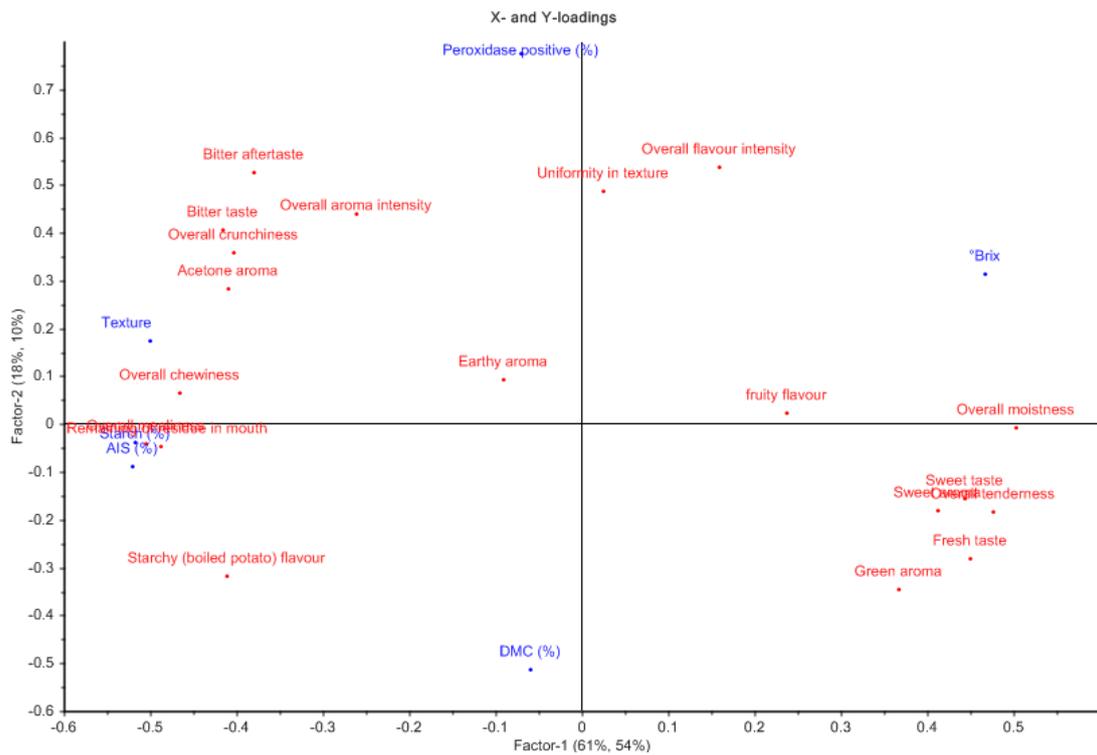
Figure 4.2.1: Partial least squares (PLS) Regression plots of factors 1 and 2 showing frozen pea texture and flavour attributes (a) sample scores and (b) X (physico-chemical) and Y (sensory loadings)

Retail class samples: RA1-4; RB1-4 and RC1-4. Caterer's class samples: CA1-4; CB1-4 and CC1-4)

DMC – Dry Matter Content   AIS – Alcohol Insoluble Solids

As PLS attempts to maximise the covariance between X and Y variables in the first calculated factors, the T vs. U plot (Figure 4.2.2) should ideally show a straight line (linear) relationship and samples that deviate noticeably are regarded potential outliers (The Unscrambler, 2010). Figure 4.2.2 shows such a plot for the frozen pea samples and it is observed that a good straight line relationship is formed with the samples being identified as potential outliers being represented by those samples that have uniquely higher scores in certain attributes than the other samples (e.g. RB4 with high residual peroxidase activity). However these samples do not deviate too much from the straight line and may thus be considered to be very influential to the model but not necessarily outlying.
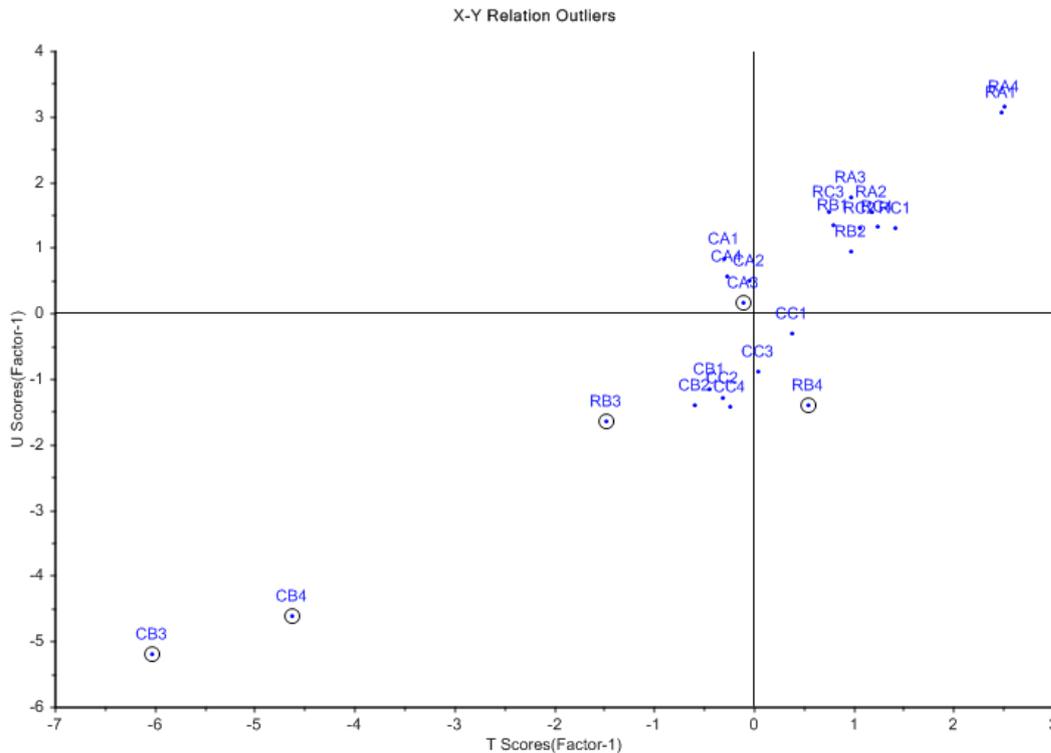
Figure 4.2.2: PLS Regression X-Y relationship outliers plot for factor 1 of the U (sensory) versus T (physico-chemical) variables for the frozen pea samples (potential outliers marked by circles)

Retail class samples: RA1-4; RB1-4 and RC1-4.

Caterer's class samples: CA1-4; CB1-4 and CC1-4.

Figure 4.2.3 displays two model prediction plots for two selected sensory attributes, earthy aroma and overall mealiness. Plot (a) of earthy aroma which had very low variance explained in the PLS regression analysis gives a poor model that may not be useful in future predictions. Plot (b) model for the mealiness attribute is interpreted as very reliable with a relatively low Root Mean Square Error of Prediction (RMSEP) of 0.38 (in relation to the data scale) and a high regression coefficient of 0.92 resulting in a very good linear relationship. It is also observed that the general trend in the reliable mealiness plot shows the retail grade samples grouped at one end and the catering samples at the other with increasing mealiness. However in plot (a) for earthy aroma there is no particular trend observed. The attributes with the highest explained variances were mostly the texture attributes (such as mealiness, chewiness, residue remaining in mouth after swallowing) than the flavour attributes except sweet taste and these could be used to make reliable predictions of green pea quality as compared to poor variance explaining attributes (such as earthy aroma and uniformity in texture).

(a)
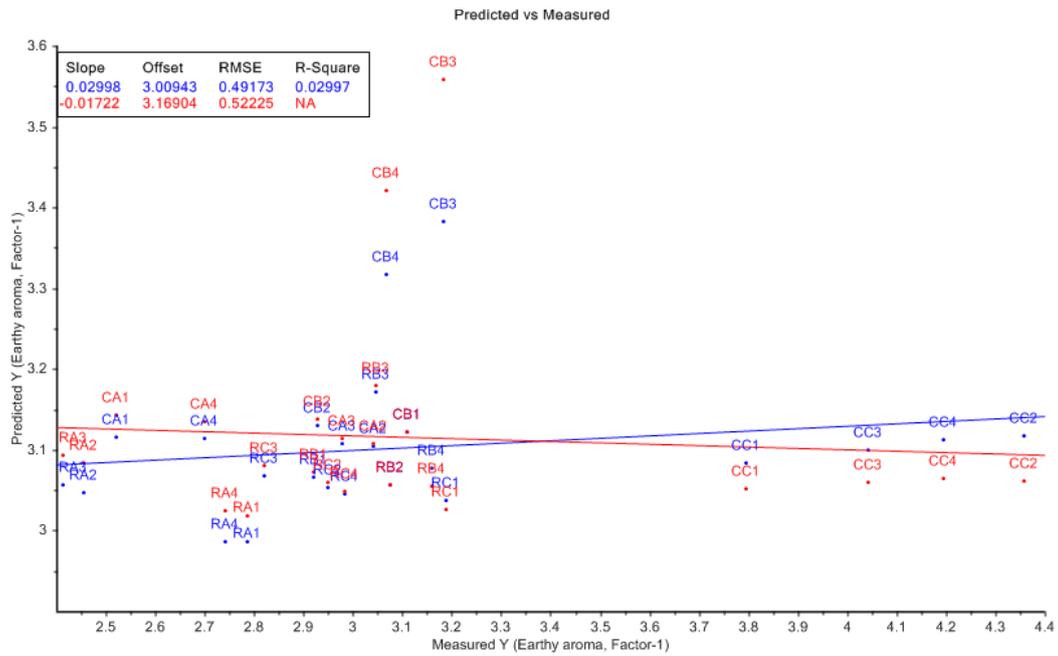
(b)
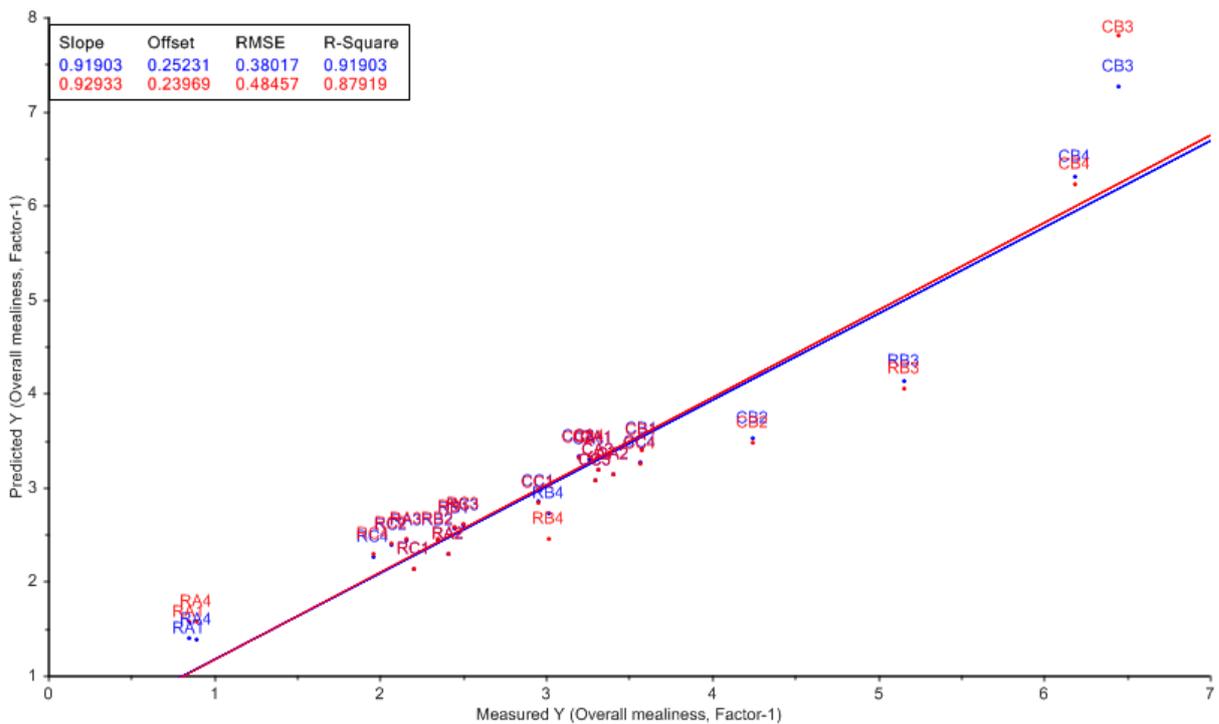
Figure 4.2.3: PLS Regression Actual versus Predicted plots for (a) earthy aroma and (b) overall mealiness of the frozen pea samples
Retail class samples: RA1-4; RB1-4 and RC1-4.
Caterer's class samples: CA1-4; CB1-4 and CC1-4

4.2.4 Discussion

The results from descriptive sensory evaluation, physico-chemical analyses and industrial quality grading showed that generally retail class peas were more superior in quality than the caterer's class with regards to flavour and texture. The retail brands showed attributes favourable for good quality frozen peas. However, one caterer's brand CA was more comparable to the retail brands.

No significant difference was found between retail and catering samples in terms of beany aroma and fruity flavour. Wienberg *et al.* (2000) found fruity flavour relevant in describing green pea quality, especially when it was coupled with sweet taste. Brand CC that was significantly lower in fruity flavour compared to the other brands, was also graded SS due to flavour problems using both the statutory and company grading schemes. The brand was described by QC personnel as having a weedy flavour. CC possibly had low levels of hexyl acetate which has been found to contribute to fruity flavours of peas (Jakobsen *et al.*, 1998). Brand CC with the lowest fruity flavour recorded the highest earthy aroma which supports findings by Martens (1986) who found that fruity flavour was negatively correlated to earthy flavour. The presence of high levels of 5- or 6- methylisopropyl-2-methoxypyrazine may have caused weedy taste in brand CC as it has been reported to contribute to dry grass aroma in blanched green peas (Jakobsen *et al.*, 1998). 5- or 6- methylisopropyl-2-methoxypyrazine has also been reported to contribute to green bean-like aromas of green peas by Takken *et al.* (1975) which were observed to be highest in brand CC. Pyrazines that give off earthy flavours in some fresh vegetables (Buchbauer *et al.*, 2000) and were measured in cold peas (Wienberg *et al.*, 2000) could also be responsible for the weedy taste. The presence of the weedy taste probably reduced the perception of sweet taste which was relatively low as compared to the other brands except CB when measured by sensory evaluation and instrumentally (°Brix).

The acetone aroma descriptor developed by the panel has not been identified in previous work reviewed by the researcher. The attribute was very perceptible in batches CB3 and CB4, and at lower levels in batch RB4. Acetone aroma was rather negligible in the other samples. CB3 and CB4 were described as very dehydrated with a few brown and pale green coloured seeds and RB4 was described olive green in colour. Addition of lipoxygenase in homogenates of sweet corn in a study by Theerakulkait (1995) showed an increase in painty (typical of acetone) and stale/oxidised odours. Acetone aroma detected could thus have been attributed to the presence of "bad smelling" ketones and aldehydes formed as products of peroxidation reactions (Varoquaux and Wiley, 1994) by the action of enzymes. Linoleic and linolenic fatty acids present may be broken down by lipoxygenase enzymes found in abundance in grain legume seeds particularly beans and peas (Baysal and Demirdöven, 2007). Statistically only one brand, RB, exceeded the permissible tolerance level for blanching efficiency measured by the residual activity of the enzyme peroxidase. RB4 described as underblanched by industrial grading and off flavoured by the descriptive panel, was 63% residual peroxidase enzyme activity positive. These results confirmed suspicions raised in section 4.1 for the cause of poor colour of the batch. It was expected that the trained panel would have identified higher levels of acetone aroma in RB4. However CB3 and CB4 were rated higher for the attribute. The appearance of CB3 and CB4 may have overshadowed the flavour perception and influenced panellist to give higher ratings for acetone aroma (halo effect).

Sweet smelling and tasting brands had the highest levels of green aroma and fresh taste. The fresher younger peas with green aromas and fresh tastes are sweeter due to less conversion of sugars to starch during maturation (Lynch *et al.*, 1959). All the retail brands were described by the panel to be sweeter than the caterer's brands except CA which was actually described to be sweeter than brand RB. Sweetness measured instrumentally (°Brix) showed the retail brands had higher sugar content than all the caterer's brands. Brand RA generally had small sized peas and were described as the sweetest and had the highest °Brix. The two batches within brand RA found to have the smallest seeds (Section 4.1) had higher sugar content than the other two

batches within the brand. A sweetness/sugar content-size relation is hence observed with the smaller seeds being sweeter than the large seeds. Peas with lower sugar content may have also been caused by poor post harvest handling practises. Delay in cooling of peas soon after harvest results in loss of sugar through respiration (Deshpande and Adsule, 1998). Interestingly batch RB4 had the third highest °Brix content but was not described as sweet by the panel. This sample also had the highest residual peroxidase enzyme activity. The action of the enzymes still present in the pea seeds may have increased the soluble solids content of RB4 by breaking down substances such as the fatty acids into more soluble carbonyls. This thus gave high soluble solids content (°Brix) but not necessarily sugar content and hence may not have contributed to green pea sweetness supporting findings by Bajaj *et al*. (1978).

Generally, the less sweet peas had higher boiled potato flavour and were more mealy, and this was verified by physico-chemical analysis for starch content. Caterer's brand CA described by the panel as sweeter than RB, however had a higher starch content than RB. The caterer's peas may be more mature than retail peas with higher starch in the more developed storage reserves (Basterrechea and Hicks, 1991). The higher starch containing peas were mealy probably due to the high amounts of starch granules within the seeds. The more mealy samples had higher amounts of residue remaining in the mouth after swallowing. Samples CB3 and CB4 particularly stood out for starch content. Inter-laboratory evaluation results (Megazyme Total Starch Procedure, 2009) revealed that starch contents of mature green peas fall between 39 and 47%. CB3 and CB4 had starch contents of 48 and 45%, respectively, typical of mature dry peas, unlike the other samples that had starch contents between 12 and 24%. AIS which consists mainly of insoluble carbohydrates and protein (WHO/FAO, 2004) used as a standard maturity index for green peas (Basterrechea and Hicks, 1991; Bajaj and Dhillon, 1978), was highly positively correlated to starch content.

According to the FAO Codex Alimentarius (2004), AIS of sweet green garden peas must not exceed 19%. All brands were within AIS specifications except CB. The results showed that generally the catering sales batches had higher AIS content than the retail batches. However batch RB4 had very low AIS and resulted in a high brand standard deviation. It was observed when carrying out the experiment that the pea blend for this sample appeared to be separated into a frothy phase at the top and a liquid phase that settled at the bottom. Most of the pea skin pieces (that would basically make up the AIS because of polysaccharides present) were observed to be trapped on the air bubble surfaces of the frothy phase. This observation was not made in any other sample as they all formed smooth pastes when blended. When the 20 g aliquot used in the analysis for this sample was measured, the liquid phase made of the cotyledon mostly constituted the fraction even though constant mixing was done. This most certainly can explain the low values of AIS obtained. Samples CB3 and CB4 had much thicker pastes compared to the rest, probably because they were dehydrated. The two samples also had extremely high AIS and starch contents which could mean these were very mature seeds. The high starch content would result in increased viscosity from swelling of starch grains (thicker paste) as seen in canned potatoes by Reid *et al*. (2000). Samples RA1 and RA4 had significantly lower AIS content compared to the other samples. These samples were notably smaller physically as compared to the other samples. It was expected that they would have slightly higher AIS due to a high proportionate number of seeds used compared to other samples and hence have a larger skin component (surface area) in the blend. It is however possible that the size difference was not significant enough to have an effect on AIS as the skins of these peas could have been much less developed and softer, thus not necessarily contribute much to AIS.

The less sweet brands were also described to be more bitter in taste. This could have been caused by the presence of saponins which are surface-active triterpene glycosides (Price and Fenwick, 1984) found in high quantities in peas (Oakenfull, 1981). Bech *et al*. (1997) describe juicier peas to be more tender. The sweeter peas were described as more moist, more tender and less chewy than the less sweeter peas and this was confirmed by DMC and texture measurements. Retail class peas were more tender than caterer's class. The more tender and juicy peas were described

to produce a "popping" sound in the mouth at first bite and this sound was reported to be different from the sound produced when judging crunchiness. The popping sound might be similar to what is described in Weinberg *et al*. (2000) as crispness due to the pressured release of the juice from the seeds upon compression with the molars.

Samples that were chewy and had high amounts of residue remaining in the mouth after swallowing were described as having hard skins. Samples CB3 and CB4 described as dehydrated in the quality grading, were the least tender in sensory evaluation and the hardest when measured by the texture analyser. This is expected as dehydrated seeds would have less moisture content (high DMC) and hence a tougher, drier skin that is more difficult to penetrate. Skin thickness may be caused by maturation. The pea testa has four layers consisting of an outer macrosclereid layer with thickened cell walls (containing homogalacturonan in a highly methyl esterified form), a layer of osteosclereids and two parenchyma layers (McCartney and Knox, 2002). The macrosclereid layer with the pectin thickens with maturation causing the pea skins to become more tough and rubbery. A study by Kmeicik, Korus and Liesiwska (2004) on frozen green grass pea (*Lathyrus sativus* L.) showed that dry matter content of pea seeds certainly increases with maturity. Dehydration in peas could be caused by delayed harvesting or processing of fresh pea seeds. Dehydration of frozen seeds could also be attributed to osmotic transfer of water from the cell interior to the exterior environment dueto temperature abuse during frozen storage (Reid, 1993). If frozen peas are not kept at the required temperature during storage (i.e. below the glass transition temperature Tg´) the stability is compromised (Karel and Lund, 2003). An increase in temperature transforms the glassy state with reduced mobility into the amorphous state in which both molecular mobility and diffusion increase (Blanshard, 1995). It is at this point that reactions that can change colour, flavour and texture, hence affecting the quality of peas occur.

The PLS regression of the sensory variables versus the physico-chemical variables revealed a number of attributes with high regression coefficients. This means the high variability in these sensory variables can be explained by the physico-chemical parameters. The texture descriptors mealiness, moistness, tenderness, chewiness and residue remaining in mouth after swallowing were more strongly explained than most of the flavour attributes. Of all the flavour attributes, sweet taste was fairly well explained. The descriptors explained more clearly suggest that AIS, DMC and starch content and work required to penetrate seeds (hardness) are reliable for predicting descriptive profiles and quality of peas. Martens (1986) showed that AIS, starch and DMC increase with maturity. It may thus be said that the maturity of peas strongly determines the quality of product. An increase in the age of peas results in lower pea quality. Compared to the other physico-chemical parameters sugar content (°Brix) was a less reliable predictor of quality. The PLS U (sensory) versus T (physico-chemical) relationship outlier plot of the data obtained in the research gives good indication that a good representation of pea samples were used in the study. This is important in designing a good, reliable prediction model from actual samples (as shown in Figure 4.2.3) that can cater for a wider range of samples. A good model may be very useful in quality control and assurance departments of frozen peas manufacture. Such a model can be used to evaluate for example the characteristics of a new variety of seeds to be introduced in the market or the effects of climatic conditions on quality of produce. Predicted results may be used to implement improvement techniques or make more informed decisions on what to control and regulate to achieve products of good quality.

4.2.5 Conclusions

The flavour and texture quality of green peas can reliably be interpreted by the three methods of analyses namely quality grading, descriptive sensory evaluation and physico-chemical analyses. However quality grading does not give as detailed information on the nature of the pea characteristics as the other methods. Products intended for retail sale which are generally more expensive, were as expected of better quality than those intended for catering sales. Most samples that were graded poorly in industry were due to flavour problems. However, descriptive sensory

evaluation and the physico-chemical analysis methods used showed that texture attributes are easier to judge. Low quality samples exhibit characteristics typical of over mature and temperature abused peas. Lack of homogeneity within batches of the same brand was identified and affects overall brand quality. It is possible to reliably predict the most important quality defining flavour and texture sensory attributes for frozen peas which include mealiness, tenderness, moistness, crunchiness, sweet taste, fresh taste and bitter taste using starch, AIS, DMC, instrumentally measured hardness and °Brix physico-chemical parameters used in the study.

5. GENERAL DISCUSSION

The study was carried out to determine the quality of retail and caterer's brands of frozen peas. The approach used to achieve this objective was by making use of descriptive sensory profiling, quality grading and determining the physico-chemical properties of the frozen pea samples obtained. This chapter is divided into two sections. The first section reviews the strengths and weaknesses of the experimental design and methodologies used in the study. This section also presents suggestions of how the methods could be improved for future work. The second section critically evaluates the findings of the study. A scheme is proposed for the sensory, physico-chemical and extrinsic factors affecting frozen green pea quality.

5.1 Strengths and weaknesses of the experimental design and methodologies used

Green pea is an early season crop that grows well in cool weather and many cultivars are ready for harvesting 8-12 weeks after planting. The general harvesting period for frozen peas in South Africa is in spring (between September and October). Sample collection of the frozen peas used in the study started in September 2009 and was expected to be completed by the end of October of the same year. However frozen pea availability on the market was less than expected and it became impossible to entirely fulfil the requirements set for sampling. Sampling was carried out four times per brand and each batch was required to have different batch numbers and production dates. Due to the scarcity of product, samples purchased in December 2009 for brands RC and CB had identical production dates to previously obtained samples. The two brands were hence only represented by samples with three different production dates each (Appendix A). However the number of batches purchased per brand gave a good representation of frozen peas. Another challenge faced during sampling was the coding for brand CC. Samples from brand CC had batch codes of poor legibility and had no production dates. The coding of the Best Before (BB) dates on this brand (used as the sampling criteria instead of production date, together with the batch numbers) was less defined than in the other brands as it specified the month and year but gave no details of the actual date. This resulted in the purchase of four samples in the brand with poorly distinguishable batch numbers represented by the two BB dates JUL 2010 and OCT 2010. This may highlight a need to look into and improve the labelling requirements of frozen peas used by manufacturers.

Good quality of frozen peas is influenced by good raw materials. Thus good cultivar selection and pre-treatments before freezing are essential (Maestrelli, 2000). Information on cultivar type, growth conditions and location and processing protocols was only available for two brands of the frozen peas used in the study. This greatly reduced any deductions of the extrinsic factors that may have affected the quality of the samples used. Another potential source of quality changes may have been in the transportation of samples from retail to the University of Pretoria where the study was conducted. Pea samples were purchased from different areas and were transported in Styrofoam cooler boxes. Distances travelled to deliver the frozen samples from the different areas of purchase therefore varied and samples from the furthest suppliers may have been more exposed to temperature damage.

The use of statutory grading and the company grading schemes was a very good idea to show the potential strengths and possible weaknesses of each system and to determine if frozen vegetable processors were manufacturing products within legal specifications for quality. It may have also been very useful to know the quality grading criteria used for all the other brands as this would have been used to assess the magnitude of post process handling damage. The knowledge of the grading used for all the brands would also suggest which specifications resulted in products of good quality and give a more conclusive view of the important areas of consideration to prevent quality loss. It is however suggested that more than one company's QC protocol should be used for the quality grading of samples. In further research of this nature, in-process data and QC records of all the samples should be obtained. In this study statutory grading for all the samples was carried out by one selected company's QC personnel. As observed from the results of grading,

one of the statutory grades, UG, was not used to define any of the pea samples. Results from descriptive evaluation and physico-chemical analysis indicated that some of the samples may have been better classified as UG instead of SS. The unfamiliarity of grading using the statutory system by the particular company may have caused this irregularity. Statutory grading results may have hence been more meaningful if carried out by government authorities.

Storage of frozen food is usually set at -18 °C and although most foods are said to be stable at this temperature, a fraction of the food constituent water may remain liquid and free for freeze damage reactions (Torregiani *et al*., 2000). The mixing process carried out on the peas during the pooling before storage in the opaque buckets was done thoroughly. However it was difficult to remix the peas in the container each time a portion was taken at the different periods in which the various analyses were carried out. Any changes that may have occurred to samples at the top of the container due to different exposure conditions such as light and air as compared to those at the bottom during frozen storage may not have been accounted for. To prevent bias in results from changes in storage, it was ensured that each selected analysis was carried out on all the samples in the least possible time frame. The optimum protective properties to be provided by a frozen food package include the exclusion of air to prevent oxidative changes (Paine and Paine, 1992). The sealing of the plastic bags in which pooled samples were repackaged into proved to be a challenge and introduced the risk of inadequate protection of samples from exposure to air. Initially the bags were sealed using a hot press sealer. The sealer required electrical power to be used and hence resulted in exposure of samples to high temperatures for longer periods than necessary. The process was also tedious and time consuming. It was seen to be more convenient to let air out from the bag, twist the unfilled section of the plastic bag and sealing the neck with tape. This provided an easier method of reopening and resealing of the plastic bags which occurred several times throughout the course of the laboratory work.

The experimental design for the study included 6 brands of frozen peas, 3 of which represented the retail class and the other 3 represented the food service class. The six different brands were sampled four times each with the intention of obtaining four sample replicates for each brand. However, it was observed during the pooling period that some of the replicates of frozen peas of the same brand varied physically. The replicates were as a result treated as individual samples for the evaluation. This resulted in the attainment of 24 samples and this was adapted for all the analyses done in the study. An advantage of this was that a larger amount of information was attained for each brand used. However the downside was the increase in the workload and time taken to carry out each analysis. This was particularly an issue in the designing of a suitable cooking method for sensory evaluation, and the repackaging and coding of individual panellist portions which was carried out in the -18 °C freezer.

It is critical in the designing and implementation of sensory evaluation for the researcher not to introduce any variance in the state of the products presented for evaluation. Because the pea samples used in the study were purchased from shops, most of the packages included suggested cooking instructions which gave different cooking methods such as boiling and microwave cooking with different prescribed cooking times. Following the cooking instructions for each brand would have been ideal to present products in the quality defined and expected by the manufacturer. However this presented a problem in the design of a reliable and practical cooking method. In scientific research it is critical to minimise variables that could affect results and it was hence very important to develop a standardised cooking method with a selected average cooking time which could be applied and would not contribute to perceived differences in samples and cause bias in results. Standardising the cooking time however did not take into account the different cooking times that would be suitable for the different sizes of seeds.

The initial cooking method suggested for the sensory evaluation was cooking individual servings of pea samples in ramekins that would be presented to the panellists in the microwave oven. It was then discovered during preliminary trials that this method resulted in different heating in the samples located in different sections of the microwave. This was ascertained by measuring

the temperature of peas in each ramekin post cooking. The method would have also presented a problem in the number of samples that could be prepared and presented at a time. Two Anvil Bain Maries (Model BMA 0002) were used preferentially to cook the peas. Each Bain Marie had 18 individual compartments which were heated by steam produced from boiling water using a centrally positioned heating element. The efficiency of each Bain Marie was tested by measuring the temperature of water after 30 min of switching on the equipment. The temperature of the water in both cooking units was found to be 96 °C. Five millilitres of boiling water was added to each compartment before adding the sample and each serving portion of peas (±30 g) was cooked in the covered stainless steel compartments for 5 min. The timed cooking procedure was designed such that each previously prepared individual pea pack was placed in the Bain Marie after every 20 s within each serving set. This allowed sufficient time to remove sample from cooking vessel and serve a panellist without negatively affecting cooking time of other samples. Panellists therefore received samples 20 s apart from each other which were of the same serving temperature. A five minute interval was allowed between cooking of samples from different sets. The Bain Marie compartments were cleaned between cooking of different pea samples by rinsing with boiled water.

The generic descriptive analysis method (Einstein, 1991) was used in the training of the panel. During this training period visual performance monitoring as described by Tomic *et al*. (2007) was done using PanelCheck software version 1.3.2 (Nofima Mat, Norway) to test reproducibility and consistency of the sensory panel. The results were reported back to the panellists to improve their calibration. Performance monitoring was a very good way to ensure that the final evaluation was carried out by a competent panel that has been efficiently adjusted through further training where necessary. The large number of samples resulted in a rather long period of training (eleven sessions that took 1.5-2 h each) and 6 days were required for the evaluation. Eight samples were evaluated on each day of evaluation and it was extremely important to factor in a forced 10 min break between evaluation of the first four and the last four samples to avoid panellist fatigue. During the descriptive sensory evaluation it may have been very useful to provide photographs of peas and green colour fans as references for use in the scaling of the intensity in colour. Descriptive sensory evaluation is a good method to use to evaluate product quality because it uses trained humans (who are the final product consumers) as an instrument. The challenge however is that human beings can experience various forms of setbacks (such as emotional and physical conditions) that could have a negative impact on results.

The method used for the evaluation of sugar content in the different pea samples was by measuring the refractive index which was reflected on a °Brix scale. This method gives a measurement of the total soluble solids which are most likely to be sugars as a percentage. This has been done previously on pigeonpea by squeezing juice from the crushed fresh pea seed onto the lens on the refractometer and recording the °Brix reading (Onyango and Silim, 2001). When the same method was applied, it was discovered that some samples produced very little juice to work with. In addition the juice extracted from these samples also reported the highest °Brix values (average 15), which was not expected. It is suggested that the concentration of the total soluble solids in the juice extracts was higher in the samples that produced less juice than in the samples producing more juice and this could have influenced the °Brix values obtained. To fix this problem, pea flour made by freeze drying whole seeds and grinding them was reconstituted with distilled water to make an 80% moisture paste. This was done to imitate the actual pea moisture content of about 80% (Stea *et al*., 2006). High Performance Liquid Chromatography (HPLC) has been used by Martens (1986) and Bech *et al*. (2000) to give green pea sugar profiles. This method may have been a more accurate and informative method which would have described the types and quantities of sugars present in the different samples. However, HPLC is time consuming and more expensive.

The method used to measure pea size gave good feedback as it was very specific and sorted samples into size fractions for every millimetre in the range 6-14 mm. The method was however very time consuming as the frame was not very deep (30 mm) and only a small amount of peas

could be sorted at a time. A way to improve this could have been by designing a stacked frame of the different circular sieves arranged in descending order of diameter size. The efficiency of the instrument could have been enhanced by increasing the diameter of round sieve plates and increasing the depth of the frame walls. Increasing the depth of the walls would also reduce the number of pea seeds that fell out during sieving and would give a more accurate value for percentage weight of the size fractions. Other methods that have been used to measure seed size of legumes include counting the number of seeds in a 100 g sample (Liebenberg *et al.*, 2003) and using the mass of 100 seeds counted physically (Shimelis and Rakshit, 2005). These methods were not suitable as they would take longer and because the product was frozen, moisture loss from exposure and handling would provide bias in the results obtained. Results from research by Shahin and Symons (2005) revealed that scanner based image analysis can be used as an alternative method for the sizing of peas, soybeans and chickpeas with minimal effect on the accuracy in comparison with the sieving method. This method is very suitable for the more regular spherically shaped seed such as peas than the irregular shaped seeds such as kidney beans. Although it is a more expensive method, it may be suggested that it is implemented in quality control as it is much more rapid.

The method used to analyse texture used a specific probe that was especially designed for immature green peas. This method can thus be said to have been very reliable in interpreting hardness of the samples. According to the particular frozen pea company used for industrial grading, texture measurement of seeds is performed in the raw materials assessment section using the tenderometer with a shear press probe. It would however have been very informative to measure the texture of the samples using the tenderometer as done in industry and compared the results with those obtained using the multiple pea rig to give an indication of the accuracy of method. Similar methods that have been used to determine texture of peas include minimum force required to break or crush single pea seeds placed between afixed and moveable plate of a T-1200 G FTC texture test system/ tenderometer and Kramer shear press cell (Kosson *et al.*, 1994; Martens, 1986; Bech *et al.*, 2000). All of these methods are used to measure the toughness of the seed coat and the firmness of the pea pulp (Deshpande and Adsule, 1998).

It was initially proposed that tests be carried out to ascertain the crude fibre content of the peas to explain texture. A few selected representative samples were subjected to the test and the analysis method was discontinued. This was because starch content, DMC, AIS content and texture analysis were other methods of analysis also used to evaluate texture were seen to give sufficient information. Crude fibre analysis was carried out by the University of Pretoria's Nutrilab using the Fibertec method. Initially two samples, one representing the retail class and small seeds (RA4) and a sample representing the large seeds from the food service class (CB3), were selected. The results obtained for samples RA4 and CB3 for crude fibre were 10.1 and 7.1 g/100 g of freeze dried pea flour (particle size not more than 0.5 mm) respectively. It was expected that the smaller, tender "younger" retail class seeds would have lower crude fibre content than the large, hard seeds that have thicker and less easily digestible seed coats due to maturation. To verify these results samples exhibiting similar characteristics as the first samples, RA1 (representing the retail class, small seeds) and CB4 (representing food service class, large seeds) were analysed and similar results were obtained. It was then postulated that the reason for the retail samples having higher crude fibre content than the food service is that the samples had smaller seeds which would have a larger surface area:volume ratio of seed coat in a sample of the same weight as the larger seeds. The smaller moist seeds would have also more seed coat making up the flour component in the flour than the larger seeds which would have a higher amount of starch molecules contributing to the flour composition further reducing ground seed coat distribution. The final set of samples analysed for crude fibre were retail sample RC3 and food service sample CA3 which were of similar size and had relatively comparable descriptive texture characteristics. Crude fibre content for the two samples were 10.2 and 10.6 g/100 g respectively further supporting the postulated reason that seed size influences crude fibre content.

5.2 Critical evaluation of the physico-chemical properties and sensory quality of frozen green peas

As expected, most of the samples that were graded poorly in industry were generally found to be from the caterer's class than from the retail class. However, an overlap of good quality comparable to retail class was observed in one of the caterer's brands. Most retail peas were described as greener, sweeter, more moist and tender than caterer's peas. Caterer's peas were characterised by higher DMC, AIS, starch content and were harder.

Problems associated with flavour resulted in more low graded samples than visual and texture attributes. Flavour descriptors that negatively affect green pea quality include bitterness, acetone and earthy aroma. Peas graded SS with flavour given as the reason for the allocation got high scores in the descriptive evaluation for one or more of these attributes. Saponin analysis may have given an explanation for poor pea quality as a result of bitterness as Price and Fenwick (1984) stated their presence to cause bitterness in peas. The measurement of °Brix was the only method used to evaluate flavour. The use of an electronic nose or gas chromatography could have provided better explanations for the other flavours described.

The two different grading methods resulted in different grades being allocated to frozen peas. The company's protocol resulted in more SS graded samples than the statutory scheme showing that the former is stricter than the latter. SS is not a good grade but a large number of samples including some retail class peas were of this grade. According to the company's grading scheme, the peas they grade SS are channelled for export. These SS grade peas are possibly used as dried seeds or marketed under a different brand but are expected to be within government requirements, and it is ensured that the peas satisfy the specifications of the target company and/or country of export. There is no information on how the company treats frozen peas that are of poorer quality than the statutory requirements. The government grade UG defines samples that may not be presented for sale. However from results of descriptive evaluation and physico-chemical analysis there is concern that it appears there is unsuitable product in the market available to consumers.

Uniformity in seed shape is the only visually assessed descriptor developed by the panel that did not significantly differentiate the retail and food service samples. The highly coloured seeds were small; however, the larger seeds had a more round shape. Martens (1986) suggested that seeds become more homogenous in shape as they mature. CB had the highest seed size and was described to be the most round brand by the descriptive evaluation panel. The reason behind CB being very round could be that these were very mature seeds with low moisture and were thus more solid and maintained the round shape better than the less mature moist seeds.

Seed size uniformity was identified as a relevant frozen pea differentiating descriptor. Shahin *et al*. (2006) suggest that discrepancies observed from trained inspectors in the grading of size uniformity are due to the subjectivity and vagueness associated with visual assessment of the attribute. Shahin *et al*. (2006) thought it would be beneficial to breeders, producers, exporters, processors and consumers to develop a quantitative method to determine and predict size uniformity in soya beans. Histograms and size distribution parameters determined from image measurements of soya bean samples were good indicators of size uniformity and were highly correlated (>84%) to subjective visual assessment. This quantitative method may possibly be adapted to predict uniformity in size of frozen green peas. The bar charts used to display the size fractions of the different samples of frozen peas give a good picture of size uniformity of different samples, and clearly uniformity is low in all the brands except CB. All the batches of brand CC, although not very uniform in size displayed the same kind of size distribution pattern.

The small sized seeds from brand RA were the sweetest and the most tender. The brand may be said to contain peas harvested at an earlier stage of maturity than the other brands. However other factors that are unknown of the samples may have influenced the perceived flavours and sugar content (°Brix). These include the cultivar type, harvesting period and post harvest handling. The texture of RA has been suggested to have been attributed to less conversion of sugars to starch

in these samples. However because uniform cooking conditions were used to cook all the pea samples, the smaller seeds may have been more easily cooked and starch in these seeds more rapidly gelatinized because of addition of heat than the large seeded samples. The correlations between DMC, starch, AIS and hardness were very high such that one of these parameters can be measured to give an indication of green pea texture and a reliable prediction/estimation of the other parameters can be made.

None of the small sized seeds were poorly graded as SS. Martens (1986) found that pea size could weakly be linked to the colour of peas with the large seeds being paler in colour. Small seed size has been identified to result in good quality peas when visual attributes were considered, and again the smallest seeds exhibited more of the superior quality defining flavour and texture attributes. Size therefore significantly impacts on the overall quality of green peas. It is suggested that manufacturer's use the smallest pea size (8 mm) as the target size specification to improve on the product quality. This could mean shifting the harvesting times a bit earlier to obtain a larger quantity of the small sized peas.

Giovannucci and Reardon (2000) describe grades as specific systems of classifications that uniformly and consistently identify quantifiable and qualifiable attributes. Descriptive evaluation and physico-chemical methods of analysis give qualitative and quantitative measures for graded green peas, hence defining the quality. Information gathered in this study has been used to propose a scheme (Figure 5.1) for factors influencing frozen green pea quality. The scheme shows how extrinsic factors, sensory properties, physico-chemical parameters contribute to the final quality of frozen green peas.

Some process determined extrinsic factors such as inadequate blanching, slow freezing rate and poor packaging result in poor colouration, development of undesirable flavours and hard, mealy textures. The specifications used in grading greatly influences the quality of the product marketed. A good, strict system will result excellent quality of retail peas and caterer's class product of very good quality and thus possibly reduce the chances of finding unsuitable product on supermarket shelves. The scheme shows the sensory descriptors that were best explained by the physico-chemical analyses methods used in the study.

Multivariate PLS regression which integrates sensory and physico-chemical data, provides a good tool to identify the most essential descriptors that can be interpreted by selected instrumental analysis methods. PLS carried out on the flavour and texture attributes revealed that sweet aroma and taste, bitter taste, fresh taste, mealiness, tenderness, moistness, chewiness and amount of residue remaining in mouth after swallowing were important quality descriptors for frozen green peas explained by °Brix, instrumentally measured hardness, starch content, dry matter content and alcohol insoluble solids content. The evaluation of the two data sets in combination gives a better understanding of how the nature of the product determines the sensory outcome. PLS regression offers an opportunity to create models in which known physico-chemical information may be used to predict sensory attributes. Such models may hence be very beneficial to industry and may reduce costs and time required for descriptive evaluation by the use of selected simple and more rapid instrumental techniques.

Quality grading, descriptive sensory evaluation and physico-chemical analyses reported on the nature of the different frozen pea batches. Although the work done in this research was sufficient in reporting the parameters relevant in describing green pea quality, it would have been very useful to also assess consumer evaluation data collected on the peas (this was carried out by a different researcher). Integrating consumer data with information found in this research will give a full picture of quality for frozen peas from all parties involved in its discernment (i.e. the manufacturer and the consumer). This step would enable companies in industry to make decisions or changes on product and the process that would maximise profits and also satisfy consumer's demands.

QUALITY GRADES FOR PEAS (INTEGRATED)

- GRADE A (Retail class)
- GRADE B (Retail class)
- GRADE C (Caterer's class)
- SUBSTANDARD GRADE
- UNDERGRADE

PHYSICO-CHEMICAL FACTORS

↑ Green colour
Small seed size
↑ °Brix

↓ AIS
↓ Starch
↓ DMC
↓ Work done for penetration

↓ Green colour
Large seed size
↓ °Brix

↑ AIS
↑ Starch
↑ DMC
↑ Work done for penetration

SENSORY FACTORS

↑ Green colour
Small seed size
↑ Round shape
↑ Uniformity in size and colour

↑ Sweet taste
↑ Sweet aroma
↑ Fresh taste
↓ Bitter taste
↓ earthy aroma
↓ Starchy flavour

↑ Tenderness
↑ Moistness
↓ Mealiness
↓ Chewiness
↓ Crunchiness

↓ Green colour
Large seed size
↓ Round shape
↓ Uniformity in size and colour

↓ Sweet taste
↓ Sweet aroma
↓ Fresh taste
↑ Bitter taste
↑ earthy aroma
↑ Starchy flavour

↓ Tenderness
↓ Moistness
↑ Mealiness
↑ Chewiness
↑ Crunchiness

EXTRINSIC FACTORS

- Good harvest times
- Rapid cooling after harvest
- Effective blanching
- Fast freezing rate
- Good packaging
- Good post-process handling temperatures (e.g. during transportation, storage)

- Delayed harvest times
- Delayed cooling after harvest
- Inadequate blanching
- Slow freezing rate
- Poor packaging
- Post-processing temperature abuse (e.g. during transportation, storage)

Figure 5.1: Proposed factors influencing frozen green pea quality and subsequent grading

6. CONCLUSIONS AND RECOMMENDATIONS

Descriptive sensory evaluation, physico-chemical analyses and industrial quality grading were able to explain the quality of frozen green peas. Quality grades allocated to peas were further explained by the sensory descriptors developed and the physico-chemical properties exhibited by the samples. Generally the retail class peas are of superior quality when compared to caterer's class peas. However brand CA from the caterer's class was very comparable to the retail brands.

Good quality batches are sweeter, greener and more tender than poor quality batches. Small sized peas exhibit these characteristics more than the larger seeds. These preferred characteristics were observed more in the retail class peas than caterer's class peas as hypothesised. Industrial grading of frozen peas by different manufacturers is therefore effectively sorting peas based on their quality for the different intended markets. Bitterness is observed to be higher in the less sweet batches and may hence be unmasked with the loss of sweetness. Poor quality graded batches (SS) are dehydrated, less sweet, mealy and have poor colour. These are characteristics that have been identified to increase with maturity of seeds. Most sugar losses occur during respiration and due to delayed reduction of temperature of seeds soon after harvesting. It may hence be very beneficial for plant breeders and geneticists to identify and/or develop pea cultivars that may withstand longer periods of postharvest stress. Climatic conditions for growth must also be considered.

Blanching is indeed a very critical step in ascertaining green pea quality and the only batch that was severely underblanched was easily identified by quality grading, physico-chemical analysis and sensory evaluation to have poor colour and flavour. This was encouraging and revealed that the blanching of frozen peas in industry was done rather effectively. Dehydration and poor colour of samples may also be caused by temperature abuse (freeze-thaw damage and freezer burn). The state of some of the batches purchased showed signs of poor post-process handling. The quality of the bad batches could not be concluded to have been entirely caused by poor post-process handling because the quality which they were in when they were dispatched is unknown. However it is very important to note that this may have contributed to the low quality and frozen pea manufacturers and retailers should ensure good storage conditions.

Some peas available on the South African market are of unacceptable quality. The use of strict quality grading protocols results in peas of good quality. This was highlighted by the brands manufactured by a company with a grading protocol that is more strict than the statutory protocol being of better quality than the other brands. Reviewing the legal standards and specifications for frozen green peas to make them stricter could result in improved pea quality countrywide. The new standards however should be selected carefully to ensure that there are minimal economical consequences and affordability is not affected. An important area that was identified and requires attention is the legibility and labelling of some frozen pea packages. It is recommended that the results of this study and that of a consumer acceptability study on the frozen green peas be incorporated to determine consumer defined quality specifications. The results from this research thus provide useful information to manufacturer's that can be used in redefining standards for frozen peas. When reviewed in combination with the consumer response, product excellence (as described by Hansen, 2001) will be reached.

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8. APPENDICES

8.1 Appendix A

Table 8.1 Quality class, brand codes, batch numbers and best before dates for the frozen peas used in the study.

Quality class	Brand	Batch	Batch number	Best Before date
Retail	RA	1	9257 S2	14.03.2011
Retail	RA	2	9265 S2	22.03.2011
Retail	RA	3	9246 S4	03.03.2011
Retail	RA	4	9261 S3	18.03.2011
Retail	RB	1	L9315 DD	31.07.2011
Retail	RB	2	L9332 DD	11.08.2011
Retail	RB	3	L9281 DD	06.07.2011
Retail	RB	4	L9355 DD	28.08.2011
Retail	RC	1	L9333 DD	12.08.2011*
Retail	RC	2	L9333 DD	12.08.2011*
Retail	RC	3	L9321 DD	03.08.2011
Retail	RC	4	L9361 DD	31.08.2011
Caterer's	CA	1	9260 S4	17.03.2011
Caterer's	CA	2	9264 S3	21.03.2011
Caterer's	CA	3	9292 S4	19.04.2011
Caterer's	CA	4	9279 S3	06.04.2011
Caterer's	CB	1	No code[a]	07.09.2011*
Caterer's	CB	2	No code[a]	07.09.2011*
Caterer's	CB	3	No code[a]	16.08.2011
Caterer's	CB	4	No code[a]	20.09.2011
Caterer's	CC	1	L09288EEZ[b]	07.2011
Caterer's	CC	2	L09284EE[b]	07.2011
Caterer's	CC	3	L09396E[b]	10.2011
Caterer's	CC	4	L09392EZ[b]	10.2011

*Samples represented by two replicates with the same best before dates
[a] Samples had no batch number
[b] Sample batch numbers of poor legibility. Best before date has month and year only.

8.2 Appendix B

Table 8.2. Quality gradingprotocol for frozen green peas used by a particular South African company (Personal communication).

QUALITY FACTOR	MAXIMUM ALLOWABLE DEVIATIONS			
	GRADE A	GRADE B	GRADE C	SUBSTANDARD
*Maturity	TR < 116	TR 116-125	TR 126-140	TR > 140
Extraneous Vegetable Matter (EVM)[a]	2 units	3 units	4 units	4 units
Foreign Matter[a]	Nil	Nil	Nil	Nil
Major Defects[a] -Blemishes >⅓ of the Pea, -insect damage, -khaki, sour, dehydrated peas -over-blanched peas	3 units	7 units	9 units	9 units
Minor Defects[a] -Blemishes <⅓ of the pea	12 units	18 units	28 units	28 units
Total Defects[a]	12 units	18 units	28 units	28 units
Damaged Peas[a]	4%m/m	12% m/m	14% m/m	14% m/m
Colour[a]	Uniform bright green	Fairly uniform green	Fairly uniform green	Fairly uniform green
Presence of Blonds[a]	5 units	10 units	20 units	20 units
Flavour and Texture[b]	Good flavour and very tender. Free from objectionable odours	Fairly good flavour and reasonably tender. Free from objectionable odours	Fairly good flavour and fairly tender. Free from objectionable odours	Fairly good flavour and fairly tender. Free from objectionable odours

*Maturity measured on thawed peas at raw materials inspection
[a]Assessment carried out on 500 g of thawed sample
[b]Assessment carried out on 250 g sample cooked in microwave for 3 min at 100% power
[c] Substandard is also known as export grade and these products must comply with the government and or specifications of the customer/import country
TR – Tenderometer Reading

Size

Peas should be between 8.6 mm and 10.5 mm (oversize peas >10.5 mm, undersize <5.5mm). Size is assessed on frozen sample

8.3 Appendix C

DEPARTMENT OF AGRICULTURE

No. R. 727   29 May 1998

AGRICULTURAL PRODUCT STANDARDS ACT, 1990
(ACT No. 119 OF 1990)

REGULATIONS REGARDING CONTROL OVER THE SALE OF
FROZEN FRUIT AND FROZEN VEGETABLES IN THE REPUBLIC OF SOUTH AFRICA*

*   To update existing regulations relating to frozen fruit and frozen vegetables in order to accommodate the changes that have taken place in the industry locally as well as internationally.

The Deputy Minister of Agriculture, acting on behalf of the Minister of Agriculture, has under section 15 of the Agricultural Product Standards Act, 1990 (Act No. 119 of 1990) --

(a)   made the regulations in the Schedule;

(b)   determined that the said regulations shall come into operation three months after date of publication; and

(c)   read together with section 3(2) of the said Act, repealed the regulations published by Proclamation No. R. 210 of 1974 and Government Notice No. R. 1969 of 1 November 1974 with effect from the said date of commencement.

SCHEDULE

Contents

Definitions

1.   In these regulations, unless inconsistent with the text, any word or expression to which a meaning has been assigned in the Act, shall have a corresponding meaning, and --

"**blemishes**" means any external defect on the surface of the frozen fruit or frozen vegetables, which detrimentally affects the appearance of the frozen fruit or frozen vegetables;

"**consignment**" means a quantity of frozen fruit or frozen vegetables of the same kind which is delivered at any one time under cover of the same delivery note or receipt note, or which is delivered by the same vehicle, or if such a quantity is subdivided into different production groups, grades or packing sizes, each quantity of each of the different production groups, grades or packing sizes;

"**container**" means the immediate container in which frozen fruit and frozen vegetables are packed and which is the unit of sale to the ultimate consumer or user, excluding the internal plastic bags used for portions or bulk packaging;

"**diameter**" with regard to frozen fruit and frozen vegetables, means the largest diameter measured at right angles to the longitudinal axis of the frozen fruit and frozen vegetables, as the case may be, unless otherwise indicated;

"**extraneous vegetable matter**" means any harmless parts of the plant concerned not normally present in the frozen fruit or frozen vegetables concerned;

"**free moisture**" means the percentage of water present in frozen fruit and frozen vegetables calculated as prescribed in regulation 11;

"**frozen fruit and frozen vegetables**" means --

        (a)   fruit and vegetables which are frozen; or

        (b)   fruit and vegetables, presented as frozen products;

"**inspector**" means the Executive Officer or an officer under his or her control, or an Assignee or an employee of an Assignee;

"**outer container**" means a container which contains one or more containers of frozen fruit or

frozen vegetables;

"**production group**" means a quantity of frozen fruit or frozen vegetables marked with the same code mark;

"**sound**" means free from external or internal disorders which detrimentally affect the quality of the frozen fruit or frozen vegetables;

"**the Act**" means the Agricultural Product Standards Act, 1990 (Act No. 119 of 1990); and

"**trimmed**" with regard to frozen fruit and frozen vegetables, means that uneven portions or portions with blemishes have been cut away and "trimming" has a corresponding meaning.

Restrictions on the sale of frozen fruit and frozen vegetables

2.   (1)   No person shall sell frozen fruit and frozen vegetables in the Republic of South Africa

        (a)   unless such product is graded in accordance with the grades referred to in regulation 3;

        (b)   unless such product complies with the standards referred to in regulations 4
            and 5;

        (c)   unless the containers in which such product is packed, comply with the requirements referred to in regulation 6;
        (d)   unless such product is packed in accordance with the packing requirements referred to in regulation 7;
        (e)   unless such product is marked with the particulars and in the manner prescribed in regulation 8;
        (f)   if such product is marked with particulars and in a manner so prescribed as particulars with which it may not be marked; and
        (g)   unless such product is stored and transported under the temperature requirements prescribed in regulation 14.

    (2)   The Executive Officer may grant written exemption, entirely or partially, to any person on such conditions as he or she deems necessary, from the provisions of subregulation (1).

QUALITY STANDARDS

Grades of frozen fruit and frozen vegetables
3.   There are four grades of frozen fruit and frozen vegetables, namely Choice Grade, Standard Grade, Substandard Grade and Undergrade
.
Standards for grades of frozen vegetables

5.   (1)   Choice Grade, Standard Grade and Substandard Grade frozen vegetables shall --

        (a)   be prepared from sound, fresh, clean and washed vegetables;
        (b)   subject to the provision of paragraph (c), be free from any substance which does not normally form part of frozen vegetables, excluding extraneous vegetable matter;
        (c)   contain only food additives permitted under the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act No. 54 of 1972); and
        (d)   show a negative peroxidase reaction for enzyme activity, as prescribed in regulation 12.
    (2)   Subject to the provisions of subregulation (1), --
        (a)   Choice Grade and Standard Grade frozen vegetables shall comply with the specific standards and requirements for each kind of frozen vegetable as

set out in Part II;

(b)   Substandard Grade frozen vegetables shall comprise of frozen vegetables that do not comply with the specific standards and requirements for Choice Grade or Standard Grade, as set out in Part II, but which are still edible, normal in appearance and free from any foreign flavours and odours; and

(c)   Undergrade frozen vegetables, which may not be presented for sale, shall comprise of frozen vegetables that do not comply with the standards and requirements for Choice Grade, Standard Grade or Substandard Grade, as set out in paragraphs (a) and (b), and are inedible due to the presence of harmful or aesthetically objectionable foreign matter or foreign flavours and odours which indicate the start or presence of decay.

REQUIREMENTS FOR CONTAINERS

General

6.   (1)   Containers for frozen fruit and frozen vegetables shall --

(a)   be intact, new, clean, moisture resistant, suitable and strong enough for the packing and normal handling of the frozen fruit and frozen vegetables;

(b)   not pass any odour, taste, colour or other foreign characteristics on to the product during processing, where applicable, or distribution of the product; and

(c)   be closed properly and in a manner permitted by the nature thereof.

(2)   If containers containing frozen fruit or frozen vegetables are packed in outer containers, such outer containers shall be clean, neat and intact.

PACKING REQUIREMENTS

General

7.   (1)   Frozen fruit and frozen vegetables shall be packed in the free flow or frozen block form.

(2)   Except where otherwise stipulated in these regulations, frozen fruit and frozen vegetables of different kinds, grades or styles shall not be packed together in the same container.

(3)   Frozen fruit and frozen vegetables shall not be size graded if so requested in writing by the packer or buyer.

(4)   In the case of frozen fruit mixes and frozen vegetable mixes, the specific com position of each mix, in descending order, shall be submitted in writing to the Executive Officer.

(5)   In the case of unspecified frozen fruit and unspecified frozen vegetables, the proposed standards shall be submitted in writing to the Executive Officer.

MARKING REQUIREMENTS

8.   (1)   *Code marks* - The name or trade mark and physical address of the establishment which prepared the frozen fruit or frozen vegetables, together with the date of preparation thereof, shall be marked in clearly legible and indelible letters in code form on every container and outer container of frozen fruit and frozen vegetables and shall be approved in writing by the Executive Officer.

(2)   *General particulars for containers* - Each container containing frozen fruit and frozen vegetables shall be marked in clearly legible and indelible letters with the following particulars:

(a)   The name or trade mark of the manufacturer or packer.

(b)   The physical address of the manufacturer or packer.

(c)   A true description of the contents thereof which shall include the style or styles: Provided that in the case of transparent containers the style or styles do not have to be indicated.

(d)   An indication of the grade thereof: Provided that the expression "Caterer's Grade" may be used instead of the expression "Standard Grade".

(e)   The net mass of the contents thereof as required in terms of the Trade Metrology Act, 1973 (Act No. 77 of 1973).

(f)   The country of origin.

(3)   *General particulars for outer containers* - If one or more containers containing frozen fruit or frozen vegetables are packed in an outer container, such outer container shall be marked in clearly legible and indelible letters with the following particulars:

(a)   The name or trade mark of the manufacturer or packer.
(b)   The physical address of the manufacturer or packer.
(c)   A true description of the contents thereof which shall include the style or styles: Provided that in the case of transparent containers the style or styles do not have to be indicated.
(d)   An indication of the grade thereof: Provided that the expression "Caterer's Grade" may be used instead of the expression "Standard Grade".
(e)   The net mass of the contents thereof as required in terms of the Trade Metrology Act, 1973 (Act No. 77 of 1973).
(f)   The country of origin.
(g)   The number of containers packed therein.

(4)   Subject to the provisions of subregulations (1) and (2) and regulation 9, frozen fruit shall comply with the additional marking requirements, where applicable, for each kind of frozen fruit as set out in Part I.

Prohibited particulars

9.   No word, mark, illustration, depiction or any other method of expression that constitutes a misrepresentation, or directly or by implication creates or may create a misleading impression regarding the contents, quality or grade, shall appear on a container or outer container containing frozen fruit and frozen vegetables.

SAMPLING

10.   (1)   For the purpose of an inspection, an inspector shall proceed as follows:
(a)   Draw at random a representative sample by drawing the number of containers indicated in column 2 of Table 1 or Table 2, depending on the character of the product, opposite the production group in column 1 of Table 1 or Table 2, taking the net mass of each container into consideration.
(b)   Examine from each of the containers which were drawn for inspection in accordance with the standards and requirements, a working sample which is representative of the contents of the container of a size or number, as the case may be, as prescribed for every kind of frozen fruit and frozen vegetables.
(c)   Determine the number of containers of which the contents do not comply with the regulations.
(d)   If the number of containers obtained in paragraph (c) exceed the number of containers in column 3 of Table 1 or Table 2, the consignment shall be rejected.
(2)   A working sample shall, in the case of frozen fruit and frozen vegetables, be defrosted or cooked before inspection according to the instructions appearing on the label of the product concerned.

METHODS OF INSPECTION

Determination of free moisture

11.   The percentage of free moisture in a sample of block-frozen fruit or vegetables shall be determined as follows:

(a)   The whole contents of a container or at least 1 kg, whichever is the smallest, of either the frozen fruit or the frozen vegetables, as the case may be, shall be drained over a sieve with a 6 mm mesh and a diameter of 300 mm.

(b)   The mass of the sieve shall be determined before adding the sample and then the total mass thereof.

(c)   Allow to stand for a period of four hours at a temperature of 20°C, and determine the mass thereof again.

(d)   The loss in mass of free water shall be expressed as a percentage of the original frozen mass of the sample.

Peroxidase test

12.   For the determination of enzyme activity, a peroxidase test shall be carried out as follows, except in the case of all fruit, pumpkin, baby marrows, mushrooms, onions, sweet peppers, whole and baby carrots, potato products, leeks, celery, tomatoes and cabbage, in which case the test is not necessary:

(a)   Defrost a sample of frozen vegetables consisting of 10 units in the case of large units, and 20 g in the case of small units, and crush it in a mortar or cut the units longitudinally so that the cotyledons or cross-sections are exposed.

(b)   Mix, just before use, equal quantities of Guaiacol 0,5 per cent aqueous solution and hydrogen peroxide 1,5 per cent [that is one part per 100 volume hydrogen peroxide added to 19 parts of water on a (m/m) basis].

(c)   With the temperature of the sample and solution at room temperature, place the prepared sample in a suitable container and wet the sample or cotyledons or cross-sections, as the case may be, with the prepared solution: Provided that in the event of a dispute the test shall be repeated with both the sample and solution at a temperature of 20°C ±1°C.

(d)   If a red brown discolouration appears within 35 seconds, the test is positive, indicating enzyme activity and therefore inadequate blanching: Provided that --
 (i)   slight stem or skin reaction within this period shall be regarded as a negative reaction;
 (ii)   in the case of Brussels sprouts --
  (aa)   a maximum of 20 per cent by number of the prescribed sample may show a positive reaction within 45 seconds; and
  (bb)   a discolouration which is limited to the centre of the sprout, shall be regarded as a negative reaction; and
 (iii)   in the case of broccoli and cauliflower, a maximum of 10 per cent by number of the prescribed sample may show a positive reaction within 35 seconds.

Net mass

13.   For the determination of the net mass, the following procedure shall be followed:
(a)   Draw at random at least 10 containers from the production group.
(b)   Place each container on a mass meter and record the mass thereof.
(c)   Now place an empty, new, dry and clean container, identical to the containers in the representative sample, on the mass meter and record the mass thereof.
(d)   Calculate the net mass of each container by deducting the mass recorded in paragraph (c) from the mass recorded in paragraph (b).
(e)   The difference between the actual net mass and the declared net mass of each container shall be within the limits of error, as set out in Table 3: Provided that the average net mass of the 10 or more containers shall be at least equal to or more than the declared net mass.

TEMPERATURE REQUIREMENTS

14.   (1)   The average temperature of frozen fruit and frozen vegetables shall during any 5 consecutive days of storage, not exceed –18°C: Provided that the temperature shall at any time

not exceed –15°C.

(2) Frozen fruit and frozen vegetables shall be transported in suitable and effectively refrigerated or adequately insulated units, in order to maintain a product temperature of –18°C and the temperature shall at any time not exceed –15°C.

OFFENCES AND PENALTIES

15. Any person who contravenes or fails to comply with the provisions of these regulations shall be guilty of an offence and upon conviction be liable to a fine or to imprisonment for a period not exceeding 2 years.

Specific standards and requirements for FROZEN GREEN PEAS

33. The standards and requirements for frozen green peas are as follows:

Definitions

(1) Where used with regard to green peas --

(a) "**blond peas**" means peas which are yellow, cream or white and are edible, but do not include sour or rotten peas.

(b) "**damaged units**" means --
   (i) peas where a whole cotyledon or a large part thereof has been separated;

   (ii) separate whole cotyledons;
   (iii) loose skin or pieces of skin; or
   (iv) partly or wholly crushed peas.

(c) "**major defect**" means --
   (i) a unit affected by dark discolouration, either as a single blemish or as an aggregate of blemishes, with a surface area of more than 2,5 mm^2, including rust;
   (ii) units with insect damage;
   (iii) blond peas; or
   (iv) any other defect which detracts markedly from the normal appearance, edibility or flavour of the individual units or a quantity of green peas.

(d) "**minor defect**" means --
   (i) a unit affected by dark discolouration, either as a single blemish or as an aggregate of blemishes, with a surface area of less than 2,5 mm^2, including rust;
   (ii) a unit affected by light discolouration, either as a single blemish or as an aggregate of blemishes, with a surface area of more than 2,5 mm^2, including rust;
   (iii) damaged units; or
   (iv) any other defect which detracts to a lesser extent from the normal appearance, edibility or flavour of the individual units or a quantity of green peas.

Style
(2) Frozen green peas shall be presented as whole green peas.

Working sample size
(3) The working sample size shall be 300 g for the style concerned.

Quality standards

(4)   The quality standards for frozen green peas are as follows:

	Quality factor	Choice Grade	Standard Grade
(a)	Vegetable ingredient	Sound, clean and immature seeds of peas	As for Choice Grade
b)	Colour	Bright green, typical of the cultivar	Typical of the cultivar
(c)	Flavour	Typical sweet flavour	As for Choice Grade
(d)	Texture	Tender	As for Choice Grade

Permissible deviations

(5)   The maximum permissible deviations per 300 g of frozen green peas are as follows:

	Quality factor	Choice Grade	Standard Grade
(a)	Units with a colour that deviate from the predominant colour of the quantity	30 g per 300 g	60 g per 300 g
(b)	Occurrence of extraneous vegetable matter	2 units per 300 g	4 units per 300 g
(c) Occurrence in green peas of:			
	(i) Major defects	6 g per 300 g	12 g per 300 g
	(ii) Minor defects	45 g per 300 g	60 g per 300 g
	(iii) Total defects	45 g per 300 g	60 g per 300 g
(d)	Units of which the texture is not tender	15 g per 300 g	30 g per 300 g