THE INFLUENCE OF PHYSIOLOGICAL MATURITY ON PHYSICOCHEMICAL QUALITY ATTRIBUTES, VALUE ADDITION AND STORAGE LIFE OF THREE PROCESSED PRODUCTS OF PEACH 'LANDARCES' PRODUCED AT IMPENDLE, SOUTH AFRICA

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LITERATURE REVIEW

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ABSTRACT

Postharvest losses have been identified as major challenges in both the developed and the less developed countries of the world. South Africa is one of the less developed countries whereby the same trend of postharvest losses has been noticed to be alarming in rural farming sector. Fruits and vegetables in particular are highly perishable and require proper postharvest handling methods in order to avoid losses. However, small-scale rural farmers lack technologies and skills required to maintain postharvest quality. Developed countries suffer most losses during postharvest and not much during production, compared to less developed countries which lose most of their food during both production and postharvest handling.

The main postharvest challenge in less developed countries is lack of food storage facilities since most poor resource farmers in these countries cannot afford expensive refrigeration. The best possible method to deal with postharvest losses in less developed countries is to create appropriate demands for available produce by applying value addition methods. This will reduce excess food which is mostly what goes into waste, especially in the rural communities of less developed countries. South African rural farmers produce a number of different fruits, such as mango, litchi, citrus, banana, avocado, macadamia, apples, peaches, plums and pears and vegetables such as cabbage, spinach, onions, carrots and tomatoes. These products are subjected to postharvest losses or at time of use most of the nutrients have vanished.

Farmers at Impendle (a Municipal District in the province of KwaZulu-Natal, KZN) produce peach fruits, yet they lack storage facilities and proper fruit processing skills. A combination of lack of markets, storage facilities and lack of fruit processing skills cause conspicuous peach losses, since the supply becomes overwhelmingly higher than the demand. To reduce the losses, most farmers delay fruit harvest, which results in both quality and quantity losses. Fruits can be stored as fresh produce or processed into many other products such drying which is the backbone of the current study, leather and juice concentrates, which are additional processing methods that will be looked at in less details compared to drying in this study. However, the peach 'landraces' in KwaZulu-Natal have not been processed into these three mentioned products, and it is not known if they can be

processed since no studies have been conducted to determine their intrinsic and extrinsic quality properties and processing ability. The aim of postharvest treatments and handling is to extend storage life and maintain postharvest quality.

The main aim of the study is to determine the effect of physiological maturity on peaches, with an aim of timely harvesting the fruit. In order to improve the marketability of fruit, determination of quality parameters at different degrees of ripeness and identification of the best degree of ripeness for processing purposes are to be attained in the study. The focus of the study is to characterise quality parameters and look at the processing ability and storability of three processed products of peach fruits.

Since electricity costs are high and refrigeration is expensive, better ways of preserving fruits need to be developed and put into practice with purposes of curbing postharvest losses in small-scale farming sector in KwaZulu-Natal. Solar energy is identified as a freely available form of energy that can be used to dry and produce leather as peach processing methods for preservation and marketability purposes. However, KwaZulu-Natal has not used the open sun solar drying because of the summer rainfall. Therefore the study aims to use a greenhouse drying method to protect the products being dried. Juice processing is an important additional conventional method of processing to the study.

In conclusion, the study will be looking at extrinsic and intrinsic quality attributes of peach fruit at five different ripeness degrees because understanding these qualities is significantly important for value adding and preservation of peach fruits. Fruit colour, juice content, density, moisture content, size, firmness, shape, mass, total soluble solids (TSS), titrable acidity (TA) and pH are some parameters the study will be looking at. All these attributes will be related to processing peaches into dried, leather and juice peach products as preservation methods. The expected outcomes of the current study are to determine the peach fruit physiological maturity for timely harvesting of peach in order reduce peach losses suffered by small scale farmers in South Africa. The study will also characterise the quality of varieties by looking at quality parameters of fruits harvested from different varieties and at different degrees of ripeness, and then processed into dried, leather and juice products at different degrees of ripeness. The review aimed to refine findings and identify needs of research by identifying a specific area of research focus to draw research questions and objectives to prepare the specific research grounds. The research grounds will be sufficient to provide originality in the work taking part to solve peach losses suffered by small-scale farmers in Impendle, South Africa by providing answers on what characteristics are expected from peach fruit landraces and their processing ability into dried, leather and juice products. All these are linked to the determination of the peach fruit physiological maturity which is the main specific objective of the study and hence the use of different degrees of ripeness aims to determine the point of physiological maturity.

DECLARATION

I Khangelani Maxwell Mkhathini declare that:

(i) The research reported in this thesis, except where otherwise indicated, is my original work.

(ii) This thesis has not been submitted for any degree or examination at any other university.

(iii) This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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1. INTRODUCTION

Peach fruit (*Prunus persica Batsch L.*) belonging to the family *Rosaceae*, is one the most important fruits grown in South Africa. Estimated production statistics provided by Ntombela and Moobi (2013) show that during 2012/2013 season, South Africa produced 1 269 829 cartons peaches, which is equivalent to 1 % of the global peach fruit production. South Africa is ranked the eighth largest producer of peaches worldwide after countries such as China, the European Union, the United States of America, Turkey and Argentina (Ntombela and Moobi, 2013). In South Africa, major peach producing regions are located in the provinces of Western Cape, Northern Cape, Free State, Mpumalanga, and KwaZulu-Natal. However, the specific production areas and hectares planted with peaches in KwaZulu-Natal are not well documented besides out-dated estimates, indicating that this fruit is underutilized in this province. The markets supplied by KwaZulu-Natal peaches are also not clearly documented. Due to quality issues, peaches produced in KwaZulu-Natal do not compete in international or export fruit market. This is mainly because most peaches in this province are grown by smallholder farmers in rural areas, including Kokstad, Bulwer, Underberg, Impendle, Tugela and only one commercial farm at Muden. These rural farmers grow peaches whose varieties are still being identified and classified accordingly. Contributing to poor fruit quality are the facts that these farmers spray no fungicides, no herbicide, trees do not get fertilizers, depend on rain for water and soils are not well managed. However, the two varieties produce fruits that are well accepted in areas where they are grown. The KwaZulu-Natal Department of Agriculture and Environmental Affairs is currently looking at the challenges faced by these farmers in trying to find relevant and specific solutions.

Peaches are important for human consumption since they are rich in vitamin A and contain phenolic compounds such as the anthocyanins: malvidin, pelargonidin, peonidin, petunidin delphinidin and cyanidin that are compounds used to reduce the risk of diseases such as cataracts, blood pressure, allergies, cancer initiation, diabetes and heart diseases (Kader *et al.*, 2005).

Peach fruit is one of the food products lost during postharvest in both developed and less developed countries (Gustavsson, *et al.*, 2011; Kader, 2005; Lipinski *et al.*, 2013; Nellemann *et al.*, 2009; Opiyo, 2012; Parfitt *et al.*, 2010). An estimate of about 1.3 billion tons of palatable food worldwide is lost in the postharvest chain per year (Gustavsson *et al.*, 2011). It is becoming a challenge to meet consumer requirements while dealing with food losses concurrently. Buyers are becoming more influential against the use of synthetic preservatives to minimise foodstuff losses. Therefore, natural methods of preservation need to be adopted (Bruhn *et al.*, 1991).

Value adding was defined by Anonymous (2014) as 'the physical segregation of an agricultural commodity or product in a manner that results in the enhancement of the value of that commodity or product'. Value adding has the potential to create more demands for agricultural products. In fruit production and value chain, this can reduce the storage expenses and losses during postharvest period. It can also reduce the need of using food preservatives. In a study by Opiyo (2012) it was reported that farmers produce enough amounts of good quality horticultural crops and aim to guarantee that consumers benefit from the palatable and safe food. However, this is impossible as large amounts of fresh produce get lost in the cold chain between producers to consumers. With respect to horticultural food loss during the postharvest period, estimates are between 5–25 % and 20–50 % in more developed and less developed countries, respectively. These losses can be classified with respect to the stage at which they occur. Peach fruit is one of the commodities lost during agricultural production, postharvest, processing, distribution and consumption (Gustavsson *et al.*, 2011). Figure 1.1 graphically displays how these estimates of food losses during pre-harvest and at the different stages of the postharvest chain differ in each regions of the world (Lipinski *et al.*, 2013). The region in the Sub-Saharan loses more food during production, handling and storage. These losses are also product dependant with some products being classified as perishable (e.g. horticultural products) and some as non-perishable (e.g. grain) (Parfitt *et al.*, 2010). There is lack of precise recent data on global food losses and it is therefore difficult to quantify these losses. Researchers have used scientific methods to estimate food loss trends (Morgan, 2009; Parfitt *et al.*, 2010; Gunders, 2012). Although many studies have been conducted on postharvest handling of fruits there are still knowledge gaps on fresh produce preservation and value adding especially because available technologies such as freezing, pickling, canning, drying and curing (Mohammed, 2004) do not favour rural smallholder producers. Therefore, in South African rural peach farming community, there is a growing need for dedicated research that will lead to production of solar dried peach products using affordable technologies for this group of producers.

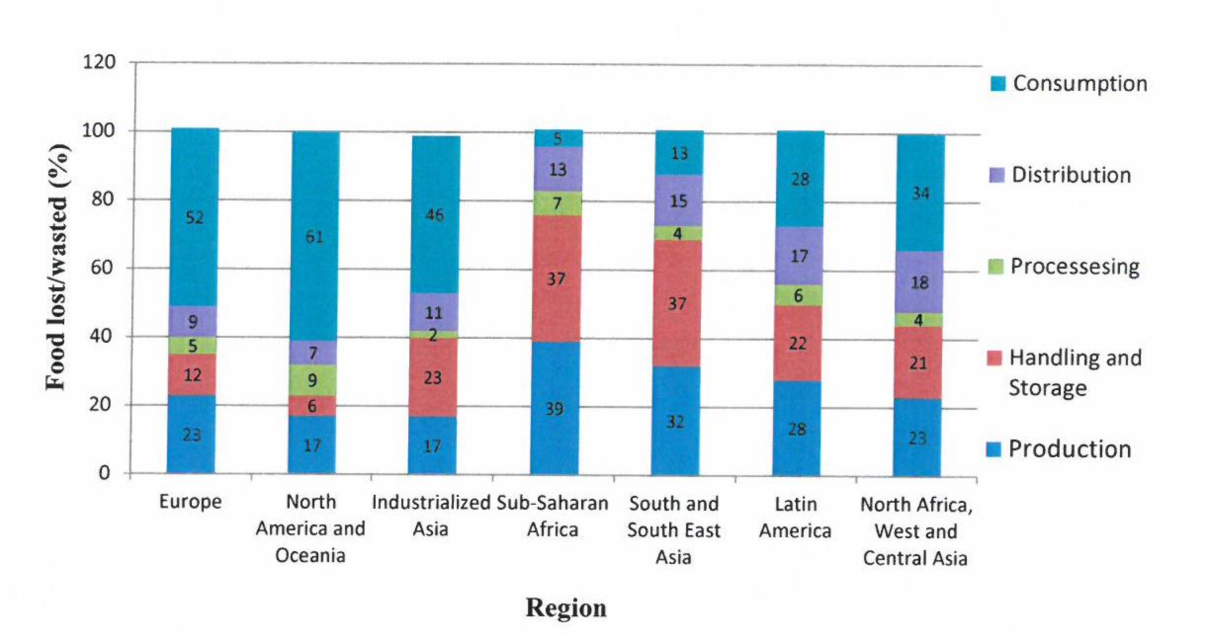

Figure 1.1 Food losses by geographical location and phase in value chain (Gunders, 2012).

The objectives of this review are to critically evaluate literature on peach fruit quality attributes and processing ability with an aim to characterise peach fruit varieties grown at Impendle, South Africa. The focus of the review is provide a rationale focus related to determination and characterisation of peach fruit quality attributes such as juice content, fruit colour, firmness, TSS, titrable acidity, pH, mass, density, size, shape and moisture content at different degrees of ripeness and also the processing of peach at variable degree of ripeness into dried product using solar dryer. The review will look at solar drying conditions with focus on equipment to measure ambient and solar dryer internal conditions such as temperature and relative humidity. The review will also look at dried peach product development and evaluation by identifying sanitising, processing methods, and packaging and storability conditions of dried peach.

2. BACKGROUND

Food losses remain one of the old challenges that researchers, farmers and consumers are still faced with. The lack of adequate fresh produce storage and preservation facilities is the main challenge in both the developing and less developed countries (Mohammed, 2004). Therefore, a decrease in food loss during the postharvest period through appropriate postharvest processing techniques should have substantial economic effects in those countries (Jairaj *et al.*, 2009; Banout *et al.*, 2011). Most fruits with high potential health benefits such as peach fruits are highly perishable and to find appropriate postharvest food preservation methods that retain the bioactive compounds at relatively low cost is challenging (Pavan, 2010). Some of the preservation approaches include cold storage, canning and drying. Drying is one of the most effective ways and has been widely used in the preservation of food. Drying decreases the content of water in the product, which in turn restrain development of micro-organisms and lessens degrading processes ensuring stability of product (Pavan, 2010). The focus of the current study is on peach fruit value adding. Peaches belong to a group of fruits known as the stone fruits.

3. THE STONE FRUIT

Stone fruits are so named because the core of the fruit comprises a seed known as stone because of its hard outer shell. Stone fruits (*Prunus* genus) are also known as drupes (Carrasco, 2012). A drupe is a fleshy fruit that has thin edible outer skin (epicarp) and an edible flesh beneath the skin (mesocarp).The core (endocarp) is made up of hard ovary wall with high lignin content, which encloses a seed (Crisosto and Valero (2008). The stone fruit species that are important in agricultural food production include *P. persica* (peaches and nectarines), *P. salicina* (Japanese plums), *P.domestica* (prune plums), *P. cerasus* (sour cherries), *P. armeniaca* (apricots), *P. avium* (sweet cherries), and *P. amygdalus* (almonds) (Carasco, 2012). Generally, stone fruits such as plums, peaches, cherries and nectarines contain 87 % of water and give 43 calories for every 100 g of fruit (Crisosto and Valero, 2008). The composition of a fruit largely depends on the management of the tree bearing that particular fruit. The quality of the fruits harvested from any tree depends on tree management techniques.

3.1 Stone Fruit Tree Management

Tree management is the key contributing factor to the pre-harvest quality of the fruit. Stone fruit trees produce excessive number of flowers and therefore a thinning practice is required in order to set yields intended for the production of large fruit (Kumar *et al.*, 2013). Thinning practices conducted during fruit development are necessary to optimise fruit size and quality and also to balance cropping and tree growth (Byers, 1989; Kumar *et al.*, 2013). Fruit development on tree is affected by many factors and this has an impact on the date at which the fruit matures (Lurie *et al.*, 2013). These factors include genetic and environmental conditions and when these build up, they cause a substantial distinction at harvest (Lurie *et al.*, 2013). However, water and nitrogen (N) monitoring is required in order to harvest high yields of good quality fruit (Falguera *et al.*, 2012). This document is focussing at reviewing literature based on peach fruit aspects of postharvest handling and processing.

4. THE PEACH FRUIT

Peach fruit belongs to the same family with cherries, plums, nectarines (Crisosto and Valero, 2008) and originated from China (Crisosto and Valero, 2008; Crisosto and Kader, 2000). The peach (*Prunus persica*, L. Batsch; *Rosacea* family) fruit is botanically, a mature ovary (Carasco, 2012). Crisosto and Valero (2008) defined peach as a soft perishable fruit with a short postharvest life. Kumar *et al.* (2013) described peach as a fruit commercially cultivated in warm temperate regions of Europe, North America, South Africa, Asia and Australia between 10° and 49°N and between 18° and 45°S latitudes. Peach fruits are generally used for fresh consumption or processed many products including juice, canned and dried food. Peaches belong to the climacteric group of fruits which means that they have a specified ripening period (Crisosto and Kader, 2000). The following section explains the climacteric state of peach fruit, in relation to postharvest handling.

4.1 Determination of Harvesting Date for Physiologically Mature Fruits

The entire postharvest cold chain begins in the farm whereby a fruit must be picked at the right stage of maturity. Harvest date plays an important role to the shelf life of the fruit. Either for fresh consumption or processing markets, a physiologically mature fruit must be harvested at the correct time. Determining the correct harvest date is always a challenge for farmers. Identifying physico-chemical changes associated with physiological maturity of peaches constitute the principal framework of research towards understanding and determine the correct stage of horticultural maturity for these fruit. The physiological maturity is the development stage when a plant continues ontogenty even if picked from the tree, while the horticultural maturity is defined as a stage of growth when a plant possesses the primary attribute for utilisation by consumers or processors for special purposes (Kader, 1999).

Peach fruit can be harvested at different stages depending on its use (Teakey and Shoemaker, 1972). There is hard (suitable for long distance export markets), firm (suitable for long distance export and domestic markets), firm-ripe (suitable for short distance export market), tree-ripe (suitable for short distance local market) and soft-ripe (suitable for ready consumption and processing purposes) (Teakey and Shoemaker, 1972). The harvesting standards vary according to variety and also the environmental conditions (Badiyala and Awasthi, 1990). Harvesting indices are determined by sensory methods (flavour, colour, aroma and texture); adequate postharvest shelf life; scheduled picking and packing operations and proper marketing (Dhatt and Mahajan, 2007). It is unfortunate that the physiological maturity has not played a prominent role in determining when peaches should be harvested. The following section focused on fruit picking process as one of the most important processes that play a role in postharvest cold chain.

4.2 Fruit Picking Process

Fruit picking is an important process since the machine or a hand picker must determine which fruit is correct for picking, in order to avoid waste. Crisosto and Kader (2000) determined that fruits are picked and packed in baskets or bags and then kept in bins that are put on trailers. The trailers themselves are parked in the orchards between tree rows until the fruits are sent to the packinghouse. The goal of harvesting is to collect a commodity from the field at the correct level of ripening with a minimum damage and loss, as rapidly as possible with minimum costs involved (Kader and Mitchell, 1989b). Failure to use a certain criteria in determining harvest dates results in the fruits being harvested too early or too late and thus affecting the quality of the batch. Bruhn (1991) and Herrero-Langreo *et al.* (2012) found that the highest number of complaints by consumers about peach varieties include the hardness of fruit and lack of flavour. Herrero-Langreo *et al.* (2012) attributes these problems to fruits picked early before reaching their maturity. Some producers do this in order to avoid fruit waste while processing and to give time for distribution. When the fruit is picked the respiration rate increases and this climacteric state of the fruit is critical and must be kept minimal since respiration cannot be reversed. The following section is focussed on respiration rate of fruits.

4.3 The Respiration and Climacteric State of the Peach Fruit

It is essential to understand physiological, chemical and physical changes occurring in the fruit during the ripening stages in order to develop measures of reducing postharvest losses. Respiration rate is one of the processes that partly determine the end of the shelf life of a product. Understanding the physico-chemical properties allows us to plan the fruit handling activities without damaging the fruit. The respiration and ethylene gas production of peaches characteristically increase during the last weeks of maturation and before harvesting (Crisosto and Valero, 2008).

There are four stages of respiration and ethylene gas production as illustrated in Figure 4.1 (Lombardo *et al.*, 2011). The respiration is at a high rate in stage I (S1) of fruit development because the fruit growth is characterised by rapid cell division. The respiration decreases in stage II (S2) when the seed is hardening and rises steadily again from the end of stage III (S3) (2nd exponential growth, due to cell size increment) and the climacteric peak is reached at stage VI (S4). The respiration rate and ethylene production in peach fruit also increases with increasing temperature. If the fruit is allowed to start ripening on the tree the degree of ripeness at the stage of picking affects the quality of the fruit as early picked fruits have a longer shelf life compared to fruits picked very late. Postharvest handling is an important aspect that requires a clear understand of the climacteric status of the fruit since this can determine the required control of handling in order to reduce the rate of ripening process.

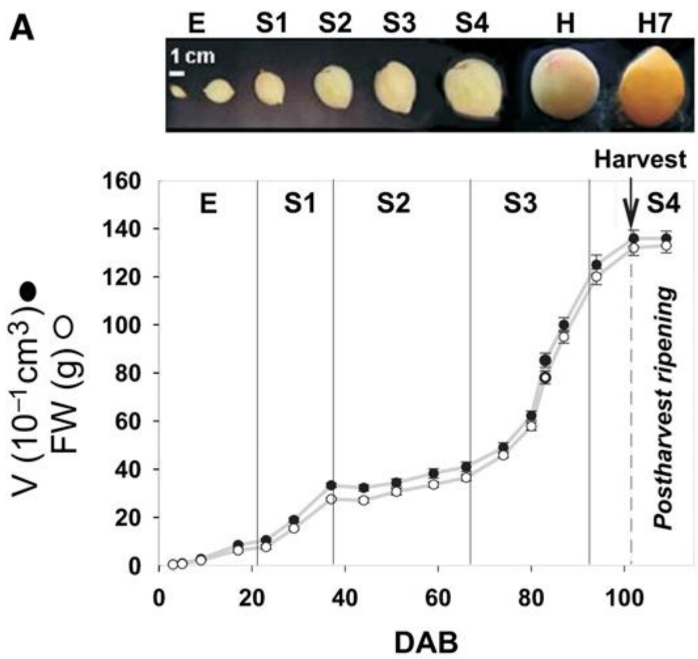

Figure 4.1 Illustration of a double sigmoid curve that occurs in peach fruits climacteric status during ripening process (Lombardo *et al.*, 2011)

4.4 The Postharvest Handling of Peach Fruits

Postharvest handling plays an important role in maintain the fruit shelf life. A harvested fruit that does not receive attention at postharvest is likely to lose its state and shelf life quicker resulting in profit losses. Bonora (2013) explained that the customary means used to find out harvesting times are skewed and not consistent when the fruit is allowed to ripen on the tree. The ground colour fading, blush colour increasing and attainment of maximum size are some of the customary characteristics used to determine harvesting times in peaches. The existence of new cultivars that reach early full development of colour make it difficult to effectively use colour as an instrument to determine the correct picking time. Near infrared (NIR) and Index of Absolute Colour Difference are some of the correct means used currently coupled with destructive methods such as TSS determination in order to forecast the maturity of peaches. Fruit handling is important and must be clarified before the fresh produce reaches the packing house since if the packing house operations are not properly handled, the fruit reaches its end quicker.

4.5 The Fruit Packing House Operations

After harvesting fruits, the respiration rate increases and so does the ripening process and these must be controlled and suppressed immediately after picking the fruit. When the peaches reach the packinghouse, they have to be graded according to different quality parameters based on the intended fruit use or market orientation (Crisosto and Kader, 2000). There are many important lines of operations where value addition can take place during postharvest handling, however, the packing house operations is one of the critical steps in determining methods to handle fresh produce.

Crisosto and Kader (2000); Dhatt and Mahajan (2007) found that the packing house operations include the dumping/collection, pre-sorting, washing/cleaning, sizing/grading, bunching/wrapping, postharvest treatments, packing and cooling. Mechanical damage to the produce during these operations must be minimised at all stages (Crisosto and Kader, 2000; Dhatt and Mahajan, 2007). Factories do follow these steps in a specific manner that could be slightly different from the steps below even when the operations serve a similar purpose.

The first step of handling is known as dumping. It should be done gently using either water or soft brushes. Wet dumping can be done by immersing the produce in water. It reduces mechanical injuries such as bruises and abrasions on the fruits since water is gentler on produce. The dry dumping is performed by soft brushes fitted on the sloped ramp or moving conveyor belts and used to remove dust and dirt from the fruit surface.

Pre-sorting is the second step and performed to remove injured, decayed and misshapen fruits. It will save energy and money because culls will not be handled, cooled, packed or transported. Removing decaying fruit is especially important because it will limit the spread of infection to other healthy fruits during other handling processes.

- Washing and Cleaning: A chlorine treated solution (100-150 ppm) is used to wash fruits. For best results, the pH of the washing solution should be within a range of 6.5 - 7.5.
- Sizing / Grading: Grading can be manual or automated. Several mechanical size graders are available for small scale operations. One of them is made up of a long slanted tray with a series of openings (largest at the top, smallest at the bottom). This

type of sizes works best with commodities such as peach fruits. Minimum requirements for good quality fruits are that fruits should be:

a) spotless, round and free from any observable dirt,
b) fresh in appearance,
c) free from pests damages or diseases, and
d) free of any bad smell and/or taste (Dhatt and Mahajan, 2007).

Grading good quality fruits from those that are not of good quality is always a very important step because if it is not followed properly, good fruit can be lost or bad quality fruit can be packed / processed for consumption. Fruit grading plays an important role in value addition. Large size fruit tend to be of better quality than small size fruit and separating the fruit into small, medium and large by grading is crucial in the packing house. The following section is looking at fruit grading.

4.6 Fruit Grading

Delays in postharvest grading and sorting of fruit can result in huge losses. Grading is a repetitive, time consuming and labour intensive process when it is done manually using visual appearance (Al Ohali, 2011). Njoroge *et al.* (2002) emphasised the need for good quality food in a limited amount of time and that machinery is crucial for the grading of fruits and vegetables. To farmers, grading is getting exceptional interest due to reduced labour costs and economic downturns. Fruit grading parameters that have been used to classify fruit include colour, size, weight, texture, firmness, flavour, shape and density (McGlone *et al.*, 2002). The equipment that have been used for the classification of fruit included conveyor belts or fruit handling systems, cameras or computer vision systems (for colour measurement) refractometry for sugar content measurement and NIR (for colour measurement) (McGlone *et al.*, 2002). Two of the most important criteria of quality assessment for harvesting peaches are the colour of fruit skin and flesh for distinguishing mature from immature fruit and the firmness for distinguishing mature from over mature fruit since research has shown these are good indicators of maturity in peaches (Kader and Mitchel, 1989b; Rood, 1957). When the fruit is ripening, there are a number of changes that take place in its properties and these must be determined and controlled properly if fruit cold chain is to be handled properly during postharvest. The following section looks at ripening.

4.7 Peach Ripeness and Determination of Fruit Properties

After harvesting, the fruit is transported to the packing house where a number of procedures are followed to ensure that fruit is maintained at a required fresh state. The packing house operations are linked to the conditions in the field such as the maturity of fruit and the maturity is linked back to the bloom date. The degree of peach ripeness largely impacts on consumer acceptance of fresh produce and is regarded as one of the most important quality aspects that consumers look for (Crisosto, 2000; Crisosto *et al.*, 2001; Crisosto *et al.*, 2003). If the fruit is allowed to ripen on the tree then ripeness depends on bloom date and fruit development period (Ferguson *et al.*, 2008). The ripening process in peaches involves many biochemical processes such chlorophyll degradation and starches degradation, pigments development and volatile compound biosynthesis, accumulation of sugars and acids as well as the modification of structures and composition of polysaccharides (Giovannoni, 2001; Gulao and Olivera, 2008; Borsani *et al.*, 2009 and Prinsi *et al.*, 2011).

The industry has relied heavily on fruit colour as an indicator of the degree of ripeness and therefore the development of a minimum quality index for peach is critical and especially for new cultivars that have different flesh colour, flavours, SSC and TA from conventional cultivars. All these aspects can be determined but the most important matter is to relate the measured value to the desired acceptance level for each use during the postharvest period. These factors can be internal or external and may require simple or very complicated methods of determination. The determination methods normally fall into destructive or non-destructive techniques. Peach fruit quality can be related to chemical and physical properties. Each of the three layers (exocarp, mesocarp and endocarp) of a peach fruit comprises of some different, important chemical and physical properties (Bonazzi and Dumoulin, 2011). These methods are briefly discussed in the next section of this report.

Tabatabaeefar and Rajabipour, (2005), Karimi *et al.*, (2009), Emadi *et al.*, (2011) and Zohrabi *et al.* (2013) stated that some of the characteristics of agricultural products are used as the most important parameters to determine designs of grading, processing, conveying and packing systems. The physical properties of horticultural fruits include fruit mass/weight, dry matter, water content, ash, fruit volume, fruit length, fruit width and fruit flesh firmness (Abd El-Razek and Salem, 2012; Zohrabi *et al.*, 2013). These parameters are carefully measured and used when peach fruit quality is determined during postharvest handling. Colaric *et al.*, (2005) found that peach fruits are composed of chemical properties such as sucrose, citric acid and malic acid compounds, as well as carotenoids, lactones, polyphenol and pectic substances. The peach fruit chemical properties are reflected by the TSS, TA, pH, TSS:TA ratio and, nutritional and vitamin contents (Abd El-Razek and Salem, 2012; Zohrabi *et al.*, 2013). The relationship between these chemical and physical properties in peach fruit is that, their modification; in turn manage the sensory modification like flavour, odour, colour and texture which ultimately, determine whether or not the peach is accepted by consumers (Biale and Young, 1981; Leshem *et al.*, 1986; Cascales *et al.*, 2005). The relationship between TSS and TA is very critical in determining fruit quality as it brings important information on the sugar/acid balance in fresh produce (Voca *et al.*, 2008). Crisosto and Crisosto (2005) reported that the level of fruit acceptance by consumer was significantly related to TSS, however, the maximum acceptance was attained at diverse TSS levels.

Peaches are classified into melting flesh (MF) and non-melting flesh (NMF) (Peace *et al.*, 2005). When they reach full ripening stage, the flesh of MF fruit is soft, juicy and highly susceptible to postharvest handling and physical or chemical injuries. Whereas NMF is different as it remains firm when fully ripe. NMF softens slowly and never melt and thus reducing the risk of physical injuries and are not susceptible to handling disorders such as bruising (Bassi and Monet, 2008 and Prinsi *et al.* 2011). Crisosto and Kader (2000) studied how flesh firmness of intact peaches affects quality of sliced fruit. These authors reported that when flesh firmness of peaches reaches 13-27 N when measured with 8 mm probe, they are considered to have reached optimal ripeness for preparing fresh-cut slices with good eating quality for two to eight days at 5 °C and 90-95 % relative humidity. When flesh firmness reaches 9-13.5 N peaches are considered ready to eat fresh (Crisosto and Kader, 2000). However, Gorny *et al.* (1998) classified fruit ripeness as overripe at 0-13 N and can be processed further into juice; ripe at >13-27 N; partially ripe at 27-40 N and mature green at > 40-53 N. It is a clear indication that the harder the fruit the better are the chances of being able to process it into specific products. However, the softer the fruit is does not imply it cannot be processed but there a limits to juicy products. When food is not in use, it is very important to keep it in good conditions until time comes when it is needed. Fruit size is used by consumers to estimate the quality of the fruit. Day and DeJong (1998) reported that large fruit size is essential to satisfy consumers. Growers use size as one of the important commercial criterions to determine peach fruit quality (Lescourret and Genard, 2005). Crisosto *et al.* (1996) noted that fruit size affects storage and market life of peach fruit as larger fruits are in demand in fresh produce market and are known to have a longer shelf life compared to small size fruit. Peach fruit size is important as from the farm where the farmer uses size to determine the quality of fruit and of marketing level. Size is important in the entire chain in the peach industry. Physicochemical characteristics of peach fruit are measured as in Table 4.1 (Sharma *et al*., 2011). However, the values measured always vary depending on the peach variety, time after harvesting and the fruit's environmental conditions.

Table 4.1 Peach fruit quality parameters (Sharma *et al.*, 2011)

Fruit length, mm	54.78+0.012
Fruit width, mm	56.70+0.029
Weight, g	125.00+0.464
Colour (L*, a* and b*)	Greenish yellow
Specific gravity	1.05+0.012
Firmness, lbs/in2 ($N.cm^{-2}$)	10.50+0.006 (0.7392+0.004) x 9.81
Edible portion, %	91.60+0.017
Moisture, %	89.20+0.006
Total soluble solids, %	8.10+0.058
Titratable acidity, %	0.71+0.023
Reducing sugars, %	1.65+0.006
Total sugars, %	6.31+0.023
Ascorbic acid, $mg.100g^{-1}$	3.57+0.017

In order to determine fruit properties, non-destructive and destructive methods are used.

4.8 Non-destructive Methods of Determining Fresh Fruit Properties

Non-destructive methods of determining fruit properties do not cause damage or harm to the fruit, or any possible harm is minimal. The state of the fruit remains the same. Non-destructive measurements have been developed in recent years and they allow quick, efficient systematic fruit quality determination (Abbot *et al.*, 1976; De Ketelaere *et al.*, 2006; Garcia-Ramos *et al.*, 2005 and Herrero-Langreo *et al.*, 2012). Additionally, non-destructive techniques involve performance of on-line measurements and those are able to separate the undesirable or best individual fruit instead of relying on sampling of biological products with large variability (Herrero-Langrero *et al.*, 2012). The following section of the document looks at fruit colour, mass and shape determination using non-destructive methods of measurements.

4.8.1 Determination of fruit size

Fruit size determination is one of critically important properties to determine especially in fresh produce markets where consumers are attracted to large fruits. Barrett *et al.* (2010) and Kader (2002) reported that size may be determined either by dimensions, weight, or volume and further stated that there is a good correlation between size and weight. Fruit size has been measured by Goyal *et al.* (2007) as an average diameter of individual fruit, with a micrometer. Singh and Reddy (2006) measured fruit size using vernier callipers. Arthey (1995) found that characteristics such as size, shape, external skin damage/blemishes are easily identifiable and can be used as guidelines to identify produce acceptability. Chrisosto and Labavitch (2001) conducted a study to evaluate peach fruit mealiness by identifying free and extractable juice. These authors concluded that free juice is more related to force used to squeeze the juice. However the authors also concluded that different cultivars produced different amounts amount of juice. This implies that the availability of juice depends on the force used to squeeze the juice and also the variety plays an important role, probably because of variable sizes and characteristics.

4.8.2 Determination of fruit colour

Alfatni *et al.* (2008) reported that colour offers helpful information during the estimation of fruit maturity and examination of freshness. However, von Mollendorff (1996) reported that colour and blemishes can be difficult as judgement can be subjective and can differ from one person to the next and from day to day. The use of colour chart for a specific cultivar may take out the subjectivity from the judgment. Computer vision, use of visible light or X-ray can sort more readily but lack adaptability. Visual inspection for attributes such as colour has been used on broccoli by Wang (1979), on cauliflower by Lipton and Harris (1976), on cucumbers (Kader *et al.,* 1973). Colour has also been determined using Minolta 200 A calorimeter (Crisosto and Crisosto, 2005). Sing and Reddy (2006) has measured colour using LabScanXE spectrocolorimeter (Model No. LX16244, Hunter Associate Laboratory, Virginia) taking into consideration CIE lightness (L*), redness and greenness (a*) and yellowness and blueness (b*). Goyal *et al.* (2007) used a hand held calorimeter (Nippon Denshoku, NR-3000) to determine fruit colour. However, the development of colour in peaches is one area that has not had had critical studies.

4.8.3 Determination of fruit mass and shape

It is important to determine fruit mass for different grades characterizations as one of the value addition methods in fruit industry. Fruit mass of aonla fruit has been determined by Singh and Reddy (2006); Goyal *et al.* (2007) using an electronic balance. The shape of the aonla fruit was determined by relation between the average diameter, length, size and mass (Goyal *et al.*, 2007). Various studies conducted on avocado, apples, peaches, oranges mass and shape determination have shown that these properties are critical when it comes to fruit acceptance. Further studies on peaches will help determine the exact properties that allow for this fruit acceptance. Some of the properties cannot be measured only by non-destructive methods, but require destructive methods, and thus the following section is looking at destructive methods of determining fruit properties.

4.9 Destructive Methods of Determining Fruit Properties

Destructive methods used to determine fruit properties require that the fruit is cut. This changes the state of the fruit. The following section focussed on fruit firmness, TSS, flesh colour, Brix, juice content, TA, and pH as some of the most important destructive measurements of fruit properties.

4.9.1 Determination of fresh fruit firmness, TSS, flesh colour, Brix, TA, juice content and pH of fruits

Impact forces have been used to measure firmness of peaches and pears (Delwiche *et al.*, 1987). Numerous properties of such physical, chemical, electrical, optical and vibration characteristics can be used to measure fruit properties with techniques such as force deformation, nuclear magnetic resonance and X-rays or gamma rays (von Mollendorff, 1996).

4.9.1.1 Firmness measurement

Abbott *et al.* (1976) measured fruit firmness using Magness-Taylor, Effe-gi and Instron pressure testers. Herrero-Langrero *et al.* (2012) reported that destructive techniques include Magness-Taylor penetrometry, developed by Magness and Taylor in 1925 as an instrument to measure fruit flesh firmness.

4.9.1.2 TSS and °Brix measurement

Falguera *et al.* (2012) conducted a study to measure TSS and °Brix using destructive techniques to measure peach fruit ripeness and quality using five fruits in each plot. Soluble solid contents can be measured using total soluble solids concentration and °Brix can be measured with a thermo-compensated refractometry method (Atago Bussan Co., Tokyo, Japan).

4.9.1.3 Fruit flesh colour measurement

Colour is one of the important parameters used as peach fruit characteristics. Fruit skin and flesh colour is measured using a Chroma Meter CR-400 tristimulus colorimeter (Konica, Minolta Sensing, Inc., Japan) in the CIElab colour space. Parameters L*, a* and b* were determined.

4.9.1.4 Titrable acidity determination

Lastly, the titrable acidity was measured by titrating NaOH with acidity obtained from juice sample. A sample of 10 ml juice was mixed with 10 ml of distilled water and titrated with 0.1M NaOH. Results were expressed as a percentage of malic acid, however, OECD (2006) standards use tartaric acid percentage in peaches.

Shewfelt and Prussia (1993) used a destructive chemical analysis to determine sugar and acid content. The use of high resolution liquid chromatography (HPLC) to determine pigments and anthocyanins has replaced the traditional spectrophotometric methods found by Fuleki and Francis in 1968. The change in pigments is important in understanding the physiology of ripening and senescence (Shewfelt and Prussia, 1993). In peaches, another destructive parameter recently introduced by Crisosto and Crisosto (2005) is the soluble solid content/titrable acidity ratio. Acidity has been determined by Crisosto and Crisosto (2005) by titrating with a 0.1 N alkaline sodium hydroxide solution up to pH 8.1 measured using a potentiometer and results expressed as a percentage of malic acid in fresh material. Soluble solid content expressed as °Brix has also been determined by Crisosto and Crisosto (2005) on peaches using an Atago N-1E (0-32 %) refractometry at 20 °C. Sucrose, glucose, fructose, malic and citric acid contents were determined using HPLC in a Hewlett Packard Series 1100 chromatograph. Moisture content has been determined using a method by AOAC (1990). As far as other methods used to determine fruit properties have become popular, newer methods have been developed recently and the next section is looking at those new developments.

4.10 Recent Development on Fruit and Vegetable Measurements of Properties

Popular methods to determine fruit and vegetable properties can be outdated due to a number of factors and therefore new methods would be used instead. According to Liu *et al.* (2013) the problems associated with food quality and safety are frequently tackled in our daily lives and therefore there has been an increasing focus from consumers on the quality and safety of foods they consume. Fruits and vegetable are one of the main components of diet and they provide abundant nutritional element for the human body. Physical and chemical attributes such as firmness, presence of bruises, dry matter, organic acids, soluble solids content, pH and sugar content are used to determine the quality of fruits. These factors affect the taste and colour of fruit but also act as prerequisite for synthesis of fruit vitamins. Traditional analytical methods used for quality determination are destructive, laborious and time consuming and thus are prohibitive to automated quality measurements. However, rapid non-destructive and automated inspection and grading systems are essential (Lorente *et al.*, 2012).

Hyperspectral imaging (HSI) is an emerging non-contact analytical technique which has found widespread use in assessment of quality properties of various kinds of fruit and vegetables. The application involves determination of internal and external quality as well as detection of contamination. Researchers have used HSI to detect fruit firmness and soluble solid contents (Liu *et al.*, 2013). Nagata *et al.* (2005) developed models for prediction of firmness and soluble solid contents on strawberries, using near infra-red HSI in the spectral range 650-1000 nm. Noh and Lu (2007) predicted firmness and soluble solid contents of apples using fluorescence images. Liu *et al.* (2008) used hyperspectral-laser-induced fluorescence imaging in oranges. Lu and Peng (2006) used hyperspectral scattering profiles (600-1000 nm) as means to determine peach fruit firmness. Fruit marketing is important for the producers and distributors to supply with correct fruit to the right market at the correct timing, and hence the following section is looking at peach fruit marketing.

4.11 Marketing of Peach Fruit

Marketing heavily relies on specific markets and those are fresh produce or processing market. Fruit marketing is a critical stage since without proper marketing channels fruits cannot be sold. Falguera *et al.* (2012) argued that markets for fresh and processed peach fruit have increased lately. Derivatives of processed peach fruit have also become highly useful and are in great demands and not for only low grades or damaged fruits are useful, however, the whole production from the industry is also destined for the processing industry (Falguera *et al.*, 2012). KwaZulu-Natal (KZN) peach fruit production is not well documented and therefore does not appear on the statistics of peach production in South Africa. Value adding is one of the processing methods that can be used to market KZN peach products. South African Department of Agriculture, Forestry and Fisheries (DAFF, 2013) reported that there has been a decline in volumes of local peach fruit at local markets. The decline also implies a gap that is opening for the KZN peach industry to play a major role in peach production in South Africa. The export of peaches from South Africa to other African countries saw an average increase of 60 % in the period 2002 to 2010 while the actual increase in demand went up from 569 to 913 tons (DAFF, 2013). Value addition plays an important role in ensuring that products that would not be sold quicker when fresh are sold faster when processed. Some products are minimally processed compared to products that are processed and changed completely into new different products. The next section of the document looks at minimally and thermally peach processed products as some important alternative processing methods that can be adopted by small-scale farmers.

5. MINIMALLY PROCESSED PEACH PRODUCTS

Minimally processed products are value added products that can easily be consumed or further processed into other products faster than fresh and unprocessed products. Hui *et al.* (2006) described minimally processed fruits and vegetables as products that remain in a raw fresh state without freezing or thermally induced preservation or adding any preservatives or food additives and may be eaten raw or partially cooked. These products need to be cleaned in treated water, peeled or dices, trimmed and packed. The natural cuticle is removed when the fruit is peeled and this leaves the fruit vulnerable to exogenous fungal and bacterial attack and this in turn disrupts tissues during processing or storage. Spoilage cannot be ignored but needs attentions as it can increase the total amount of food lost. This section looks at fresh cut peaches, dried peach leather and canned peaches.

The ripeness good enough for fresh-cut peach fruit slices is reached when the fruit firmness is within a range of 13-26 N. The processed slices can retain the best eating quality for about eight days maximum and this largely depends on the type of cultivar and storage temperature, but 5 °C and 90–95 % relative humidity are recommended (Crisosto and Valero, 2008). Gorny *et al.*, (1999) found that fresh cut peaches are limited by browning on cut surfaces. The optimal stage of ripening at which a fruit can be processed into fresh cut is between 18 and 31 N firmness. However, low storage temperatures such as 0 °C and atmospherically modified packaging are extensively used since they prolong shelf life and reduce browning on cut surfaces. To reduce the extent of browning, ascorbic acid has been combined with organic acids and calcium salts.

5.1 Leather Processing

Raab and Oehler (2000); Garden-Robinson (2012) found and explained that fruit leather is a nutritious, high energy snack for young and adults. These are easy to make at home, portable, good for school children and hiking or camping groups. Peaches are amongst the group of fruits which are suitable to make leather, including apples, apricots, cherries, plums, strawberries, tangerines, oranges, pears, grapes, pineapples, and tomatoes (Raab and Oehler, 2000). Slightly overripe peaches are suitable to make leather (Garden-Robinson, 2012).

The methods used to prepare leather include cooking, drying, oven drying, sun drying, and the use of a dehydrator. Leather can be stored by freezing in plastic bags, tightly sealed containers in a cool dry place and refrigeration (Raab and Oehler, 2000; Garden-Robinson, 2012). Lemon juice or ascorbic acid, honey, syrup or sugar can be used to enhance safety and quality of the dried leather products.

5.2 Canning as Value Addition Method

Fruit and vegetable canning is one of the old practices that have been used for decades when the perishable products cannot be stored because of lacking cold chain and storage facilities (Richman *et al.*, 2007; Kaushal and Sharma, 2012). A number of methods have been used to preserve the fruit colour and flavour and those include sugar syrup which is known to mask the original fruit flavour, apple concentrates, apple juice, corn syrup and mango pulp (Kaushal and Sharma, 2012).

Richman *et al.* (2007) concluded that as much as canned foods are regarded as less nutritious than fresh or frozen products, past research results reveal this is not always correct. There is a huge variation due to effects of cooking, canning or freezing and these also depend on commodity. Canning fruits cannot be separated from other processing methods. Fruit canning also has important quality parameters that maybe better than other processing methods such as freezing, drying and cooking. The three processed peach products discussed above are among a number of products that can be produced using peaches. However, another processing method looked at in great details is fruit drying and is discussed in the next section of the document.

5.3 Juice Processing

Juice was describes as the extractable fluid contents of cells or tissues (Merriam-Webster, 1981). Different juices have been described to yield different concentration resulting to puree, juice or pulp. Other juices may be clear some may be turbid. Juice is produced by crushing, comminuting and pressing. The end result may be pulpy, cloudy or clearer. Safety and quality of juice play an important role in ensuring that consumers purchase a safe product. Juices can be classified into a number of different products as detailed in Table 5.1.

Table 5.1 Classification of different juice (Bates *et al*., 2001).

Term	Criteria	Remarks
Puree juice 100%	All juice	No adjustment, not from concentrate
Fresh squeezed	Not pasteurised	Held refrigerated, food safety concerns
Chilled, ready to serve	All juices	Held refrigerated concentrated and pasteurised
Not from concentrates	Single strength	Pasteurised after extraction
From concentrates	Concentrates	Reconstituted and pasteurised
Fresh frozen	Unpasteurised	Single strength and frozen
Juice blend	All juice	A mixture of pure juices
Puree	Pulp containing	More vicious than juices total fruity
Nectar base	Reconstitution	Has flavour, acid and sugar. Needs water
Juice drink	Low in juice	10-20% juice content
Juice beverage	Low in juice	10-20% juice content
Juice cocktail	Low in juice	10-20% juice content
Fruit + ade	Lemonade	>10% fruit juice, sugar and water
Juice extract	Water extract	Fruit extracted by water
Fruit punch	Token juice	~ 1% juice + natural flavours
Natural flavoured	Token juice	Usually > 1% juice

6. DRYING AS A PEACH FRUIT PROCESSING METHOD

Value addition and preservation of fruit and vegetables can be performed using a number of ways and among those methods, one of them is drying. Pavan (2010) pointed out that drying decreases the content of water in the food product, which in turn restrain development of micro-organisms and lessens degrading processes ensuring stability of product.

It is one of the oldest food preservation and value adding methods that have been used for centuries. Some perishable agricultural products have their shelf life extended when dried to desired moisture content and packed in sealed packaging. Developing countries need to further exploit this method as a method of preserving and adding value to their food. The next section of the document is defining peach drying.

6.1 Definition of Peach Drying

Peach drying is one of the cheapest value addition and preservation methods. Drying is defined as a heat and mass transfer operation that takes place simultaneously with physical and micro-structural modification. This definition includes variable factors such as material colour, texture, shape, size, porosity, density and shrinkage (Al-Muhtaseb *et al.*, 2004). It is a synchronized movement of heat towards the centre of the product being dried and moisture from the inner part of the product being dried to the surface. This is followed by moisture movement to the surrounding and eventually out of the dryer (Leon *et al.*, 2002). There are three phases in the drying process (Wakjira, 2010). The first phase is the shortest phase whereby drying rate is increasing with time and this phase corresponds to the rising temperature of the product being dried, until equilibrium is reached and then the phase ends. The second phase corresponds to the time when surface, free water evaporation off the product. The surface water is permanently renewed by moisture coming from inner part of the product and the rate of drying is constant. The last phase and the third is the slowing down phase and it corresponds to the evaporation of bond water. The following part of the document discusses the effects of drying on food and changes that occur in the food materials as a result of drying, since drying can change the state of the food being dried into another form.

6.2 Effects of Drying on Peach

Drying is one of the cheapest and among some other important techniques that have been used for centuries for peach preservation or value addition. However, when peach is dried, some structural, chemical, physical, nutritional or mechanical changes do occur. For instance grapes shrink when they are dried to raisins. The volume of food gets reduced by the drying process (Lang *et al.*, 1994; Krokida and Maroulis 1997; Mayor and Sereno, 2004). Water loss and heat induce stress in the structure of the material being dried leading to a change in texture, shape and dimensions. Drying can also degrade nutrients in fruits due to very high temperature and long drying times. In order to avoid the degradation of nutrients, pre-treatments have been well researched in fruit drying and are used effectively. Nassiri and Heydari (2012) determined food porosity and shrinkage on apple, avocado, carrot and pear and found that when the drying temperature was increased, there was a significant difference on the reduction of drying time. In essence, both increase in air speed and temperature have positive effect in speeding up the drying time. Negative linear relationship was observed between shrinkage and moisture content in a constant drying air speed. Moisture pockets are increased when moisture is removed from high moisture content samples. The bulk density declines with decreasing dampness of the material being dried. The conclusion of the study was that temperature has more significant effects on volumetric shrinkage of pear cubes compared to air velocity and therefore for spongy fruit, drying with higher drying air velocity and temperature was recommended.

As a preservation and value adding method, food drying has been practiced for centuries on different food types. Apples, bananas, apricots, blueberries, grapes, pears, peaches, plums and vegetables such as broccoli, carrots, cauliflower, corn, green beans, onions, sweet peas pods, peppers, potatoes, summer tomatoes and zucchini as well as mushrooms and herbs can be dried using solar drying techniques (Fodor, 2006). Drying peach fruits is one of the common methods used in fruit preservation and value adding apart from freezing and canning. It is usual that peaches are dried as cubes, slices, halves and are used as baking ingredients, fruit leather, fruit sauces and cake mixtures (Kingsly *et al.*, 2006). The perfect degree of ripeness has not been well researched in for production of dried peaches for best results, and hence this study is designed. Besides physical or microbial changes in food, also the colour changes in a process related to chemical changes. When peach is being dried, the composition and its properties are altered in related steps as discussed in the following section.

There is a strong relationship between drying time, shrinkage, moisture content and temperature. May and Perre (2002); Nassiri and Heydari (2012) conducted studies to present investigational data on food porosity and shrinkage of apple, avocado, carrot and pear; and to determine a change in bulk density and shrinkage of pear. Nassiri and Heydari (2012) found that when the drying temperature was increased, there was a significant difference on the reduction of drying time. May and Perre (2002) reported that during the drying process, air pockets partition into a porous medium and sugar content held in solution (Figure 6.1).

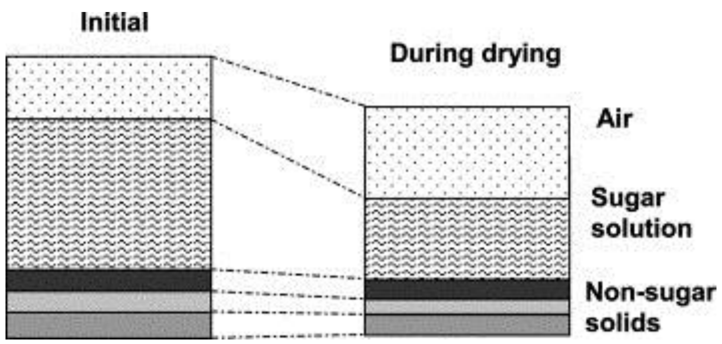

Figure 6.1 Different volumes in a porous medium with sugar molecules held in solution (May and Perre, 2002).

The reduction of exchange surface area due to shrinkage must be considered when analysis of drying process of some products is being conducted. There are many ways to dry food and thus the following section is looking at a number of drying techniques and one solar drying method will be selected based on its operational simplicity and used for the current study.

7. CLASSIFICATION OF SOLAR DRYERS

A number of drying techniques are available and include the use of electricity and solar energy. However, with high electricity costs, the solar energy dryer is selected for the current review. Solar dryers can be classified to two major groups, namely active solar energy and passive solar drying systems. The agricultural industry has seen the potential of using solar energy due to variation in the prices of fossil fuel, environmental concerns and expected reduction of conventional fossil fuels (Fudholi *et al.*, 2010). Many solar driers have been developed by different scientists (Karla and Bhuradwaj, 1981; Singh and Alam, 1982; Luz *et al.*, 1987, Das *et al.*, 2000). Figure 7.1 displays a methodical categorization of solar dryers for agricultural use (Fudholi *et al.*, 2010).

The use of solar drier must be realistic, inexpensive and the responsible approach environmentally (Sharma *et al.*, 2009). Solar drying technology offers clean, hygienic and sanitary conditions to national and international standards with zero costs (Sharma *et al.*, 2009).

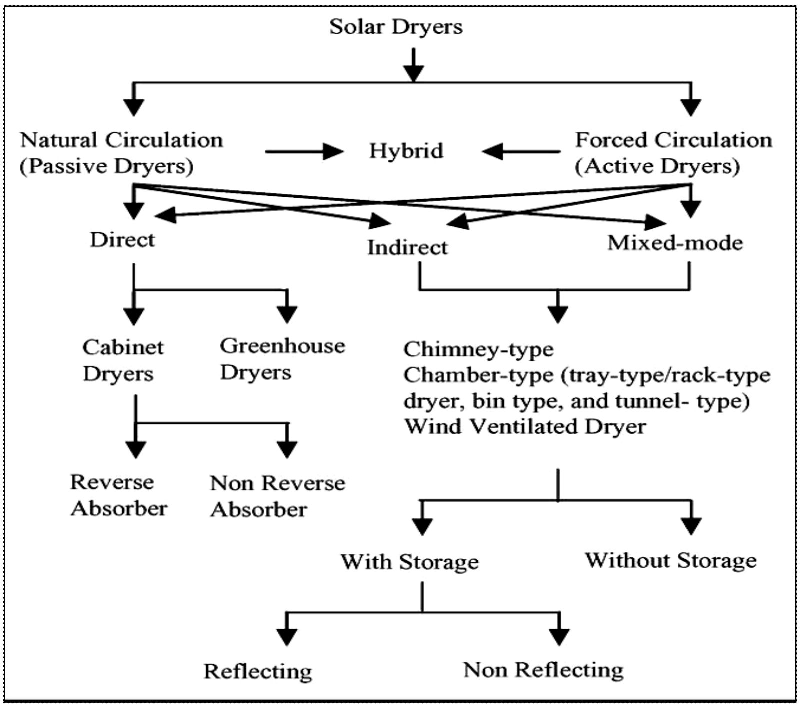

Figure 7.1 The classification of solar dryers (Fudholi *et al*., 2010).

It saves energy and time and it occupies less space compared to open-sun drying (Sharma *et al.,* 2009). The food bed is made from double layer of chicken wire mesh with a fairly open structure to allow dry air to pass through the food sample but preserve the pieces of food from falling into the plenum chamber (Ayensu, 1997; Sharma *et al.*, 2009). Different drying techniques are available based on the use of solar and electricity. A criterion was used to select a solar dryer to be used in the study as explained below.

7.1 Selecting a Solar Dryer

Selecting a solar dryer relies on looking at a number of simplicity aspects and availability to construct, operate and maintain. Chua and Chou (2013) elucidated that a food dryer costs must be equitable with the value of the product being dried. The dryers to be used by rural farming industry should possess the following characteristics and those characteristics are used to select the best solar dryer to be used by a group or individuals with the farming rural communities. The criteria illustrated on Table 7.1 were used to choose the type of a dryer to be used in the current study.

Table 7.1 Decision table with characteristics used when selecting a drier for rural farming (Chua and Chou, 2013)

		DISTRIBUTED (Indirect, passive)	MIXED MODE (passive)	INTEGRAL (Direct, Passive)	INTEGRAL (Direct, Passive)	INTEGRAL (Indirect, Passive)
	%	Cabinet Dryer (%)	Cabinet Dryer (%)	Cabinet Dryer (%)	Greenhouse Dryer (%)	Tunnel Solar Dryer (%)
Low initial capital costs	40	X (0)	X (0)	X (0)	✓ (40)	✓ (40)
Easy to construct and fabricate	20	X (0)	X (0)	✓ (20)	✓ (20)	✓ (20)
Easy-to-operate with no complicated electronic/mechanical protocol	15	✓ (15)	✓ (15)	✓ (15)	✓ (15)	✓ (15)
Effective in promoting better drying kinetics and product quality than the sun-drying method	5	✓ (5)	✓ (5)	X (0)	X (5)	✓ (5)
Easy to maintain all parts and components	10	X (0)	X (0)	✓ (10)	✓ (10)	✓ (10)
Simple replacement of parts during breakdowns	10	X (0)	X (0)	✓ (10)	✓ (10)	✓ (10)
Total score	100	2 (20 %)	2 (20 %)	4 (55 %)	6 (100 %)	6 (100 %)

Based on the table displayed above, a tunnel solar dryer with a score of 100 % was selected as a suitable dryer for review. The following section is looking at the tunnel solar dryer in more details.

7.2 Tunnel Solar Dryer

Out of several drying techniques, a greenhouse dryer was selected as an economical dryer for the purpose of the current review and can be used easily by small scale rural farmers. Greenhouse solar dryers use the normal greenhouse structure where the product is placed on trays receiving the solar radiation through the plastic cover while the moisture is removed by natural convection. There are passive and active, direct and indirect types of greenhouse, tunnel solar dryers. Figure 7.2 illustrate tunnel solar dryer. The roof of a tunnel/greenhouse dryer can be made using glass, fibre glass, UV stabilised plastic, and polycarbonated sheets. The transparent material is fixed on a steel frame support or pillars with bolts and rubber packing to prevent humid air or rain water leaking into the chamber (Kumar *et al.*, 2013). After processing food products, storage is the next step that follows. When food has been processed, there are still a number of conditions that affect its storability. The next section is looking at the storability of processed products.

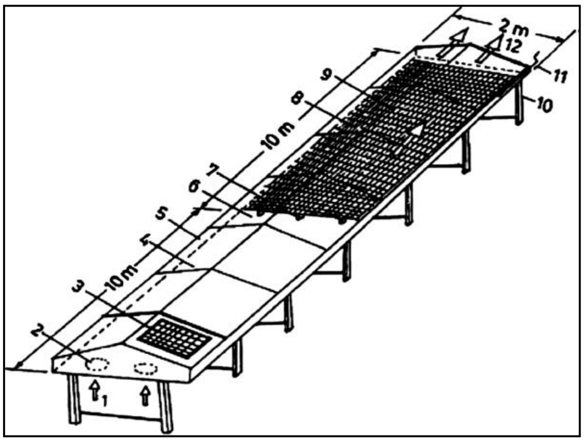

Figure 7.2 An illustration of solar tunnel drier (Kumar *et al*., 2013).

(1) air inlet; (2) fan; (3) solar module; (4) solar collector; (5) side metal frame; (6) outlet of the collector; (7) wooden support; (8) plastic net; (9) roof structure for supporting the plastic cover; (10) base structure for supporting the tunnel drier; (11) rolling bar; (12) outlet of the drying tunnel

8. STORABILITY OF PROCESSED PEACH PRODUCTS

Once the products are minimally processed, they can be consumed immediately or they can be stored while awaiting consumption or further processing. A number of conditions such as maintained postharvest quality must be met when a product is processed and stored before it can be consumed or further processed. There is a criterion used to classify processed or fresh fruit product spoilage. The classification includes assessment of colour, visual appearance, flavour, shape microbial load, nutrient retention, porosity, bulk density, rehydration ability, water activity texture, no contaminants, preservatives used, and no impurities and odours and these can be grouped into three classification groups displayed in Table 8.1 (Hui *et al.*, 2006; Kebitsamang *et al.*, 2011).

The assessments of these quality attributes in dried products are conducted according to different product types. Dried food is easily rejected when the standard do not comply with all the regulations stipulated. The spoilage of fruit is classified into two causes and those are abiotic and biotic forces schematically represented in Figure 8.1 (Hui *et al.*, 2006).

Table 8.1 Classification of changes that occur during storage of dried food (Hui *et al*., 2006).

Physical	Chemical	Microbiological
Porosity Shrinkage Changes in solubility Reduced rehydration Hardening and cracking Aroma and flavour loss	Lipid oxidation Vitamin and protein loss Browning reaction Degradation of nutriceutical compounds Enzyme reaction	Microbial survival Loss in activity

Abiotic forces		**Biotic forces**	
Damage by state of product	Damage by external source	Pre-harvest insect infestation damage	Postharvest damage by microbes
pH water activity transpiration ethylene production senescence	wind-blown sand rubbing harvesting processing procedures and equipment	lesions egg-laying damage of outer layer	invasion fermentation degradative enzymes

INTERNAL TISSUE INVASION

↓

PHYSICAL CHANGES IN PRODUCE

↓

RAPID SOFTENING OF PRODUCE

↓

SHRINKAGE OF PRODUCE

↓

DECAY

↓

DECREASED SHELF LIFE OF PRODUCE

Figure 8.1 Different causes and factors responsible for fruit spoilage (Hui *et al*., 2006; Kebitsamang *et al*., 2011)

Different products have varying shelf lives and require different packaging and storage conditions. Temperature, relative humidity and packaging play a huge role to the shelf life of a product and its storage stability. Verma *et al.* (2013) studied physicochemical attributes and nutritional properties of guava fruit powder prepared by drying using tunnel, sun, freeze and vacuum drying methods. The powder from different drying methods was stored at fixed 5-7 °C in sealed plastic bags for 0, 20, 40 and 60 days. Verma *et al.* (2013) found that the bulk density of guava was affected by the drying methods with minimum bulk density from freeze dried compared to maximum from vacuum drying. The results showed that storage had a significant effect on colour deterioration. During storage there was also an initial increase in moisture content of powder. No significant differences were noted with 60 days storage. With storage at 60 days, the titrable acidity increased significantly on freeze dried powder, whereas there were no significant differences on other drying methods. The increase in acid could be induced by inter-conversion of sugars and other chemical reactions.

Moraga *et al.* (2012) studied the effects of storage time at different relative humidity on the main bioactive compounds (such as vitamin C, major flavonoids, total phenols and major organic acids) and antioxidants capacity of freeze dried grape fruit powder. The different powders were stored at fixed temperature of 20 °C at 10-80 % relative humidity in the same hermetic chambers for 3 and 6 months. These authors found that samples stored for 3 months containing significantly higher antioxidant capacity values than samples stored for 6 months. The antioxidants of powder stored at relative humidity higher than 11.3 % caused a significant decrease of its antioxidants capacity. After 3months of storage, the ascorbic acid of freeze dried grapefruit powder was practically constant till 52 % relative humidity, but decreased sharply over the range of 52 % to that value of 68 %. These authors concluded that in order to ensure the functional quality preservation of freeze dried grapefruit powder during long term storage, the glassy state of amorphous matrix must be guaranteed and the rubbery state must be avoided.

Badii *et al.* (2012) conducted a study to investigate the effects of storage relative humidity on physical stability of dried figs. Figs were sun dried and stored at different relative humidity. It was evident that changes in water content as a function of storage condition may lead to undesirable physical properties of fig. The structural stability was also studied at different relative humidity and it was evident that water has a great plasticization effect on this fruit.

For any given product, its properties and nature must be well understood in order to have the product stored longer before it is used.
Seevaratnam *et al.* (2012) studied the storability of green leafy (Alternenthera sessilis and Amaranthus polygonoides) vegetables which are known to contain important nutritional compounds that are important for human health such as vitamin A, β carotene, ascorbic acid, folic acid, vitamin C etc. Green leafy vegetables were cleaned, dried and ground into powder and packaged in three different packages i.e. a 300 gauge metalized polypropylene bag (MPP), 300 gauge high density polyethylene (HDPE) and a 200 gauge polypropylene (PP) bags and stored at ambient temperature of 28-36 °C and relative humidity between 52-65 % for 3 months. It was concluded that moisture content increased with time in all different packaging bags. Components such as ascorbic acid, β carotene, chlorophyll significantly declined with increasing storage time until 90 days.

Pareek and Kaushik (2012) conducted a study on drying of gooseberry using direct sunlight, oven, fluidised bed and microwave. Part of the aim of the study was to evaluate whether or not different drying techniques affect the storability of dried products. The product was stored for 90 days. The fluidized bed had a significantly high reducing sugars compared to other drying methods at the beginning which became the lowest at the end of experiment. The fluidized bed was also found to have caused the lowest titrable acidity and highest in microwave. Maturity of product during harvest plays an important role to the future and shelf life of a processed product. The following section looks at the role of maturity on processed product storability.

8.1 Impact of Maturity at Harvest on Product Storability

Maturity is a growth stage between a product ready to harvest and a product not yet ready to be harvested. The challenge is determination of a point between the ready and unready fresh peaches. Stanley *et al.* (2013) found that the maturity stage during fruit harvest has an impact to the storability of apricot. The more mature the fruit is at harvest the softer it is when it goes for storage. In this study, consumers liked the apricot fruit with an intermediate firmness ranging between 20-40 N, the liking dropped when the fruit was below 10 N or above 45 N. This is an indication that in processing a similar trend may apply depending on the product being processed and intended storage period. Sanitizing and storability improving products can be used to prolong the processed products shelf life. There are a number of alternative products.

8.2 Alternative Sanitizing Products

Newer sanitizing methods have been developed and those include: chlorine dioxide (ClO_2), organic acids, and calcium based solutions such as calcium lactate, hydrogen peroxide (H_2O_2), ozone, and electrolyzed water and use natural methods. Physical methods of treatment include modified atmospheric packaging, thermal treatments such as blanching and heat-shock, irradiation, hurdle technology (combination of different preservation techniques) and ultraviolet light use.

Yao and Tian (2005); Xu and Tian, (2008); Khademi *et al*., (2012) reported that salicylic acid application either pre-harvest or postharvest reduced fungal decay in sweet cherry, strawberry Babalar *et al.* (2007). These authors reported that a defence resistance develops and stimulates antioxidant enzymes. In cold storage of peaches combined with the application of salicylic acid, TSS increased during storage, without effects in grapes and persimmon. Salicylic acid prevented weight loss, retained firmness and it was concluded that an accelerated softness simultaneously occur during the decrease in endogenous salicylic acid content. Salicylic was also able to suppress microbial development in store fruit, for the first two weeks in storage (Khademi, 2012). Chlorine based products are some of the oldest products available in the market. The following section is looking at the use of chlorine since a number of sanitation products contain it as one of the ingredients.

8.3 Packaging of Fresh and Processed Peach Products

Noomhorm and Potey (1993) explained that highly perishable commodities require special treatment to reduce any possible chance of spoilage from harvesting, handling of produce during postharvest and also during storage. A number of different techniques are used to preserve fresh produce and those methods include the refrigeration, chemical treatment, controlled atmosphere storage and hypobaric storage methods. Modified atmosphere (MA) was studied and concluded by Lurie and Crisosto (2005 to reduce chilling injury and extend shelf life. Modified atmosphere packaging (MAP) was studied by Zoffoli *et al.* (1997) and reached conclusions that this was a lesser expensive method of packaging. However, these methods are both related on cultivar characteristics when it comes to storage life of fresh produce. Both these methods have regulated carbon dioxide and oxygen contents within the package. Studies have been conducted to monitor changes of CO_2 and O_2. Regina *et al* (2005) concluded that increased CO_2 in the MAP was able to reduce fruit ripening and extended storage life peaches.

9. DISCUSSION AND CONCLUSION

Lack of postharvest handling techniques in rural farming is recognised as a huge challenge by rural farmers however, they are not capable to devise technologies that are appropriate for their farming systems. This challenge costs farmers a lot since close to half of their fresh produce is lost during postharvest. The main cause of losses in developing nations is lack of food storage facilities and value adding technologies. Peach is one of fruit commodities grown in the small-scale farming sector KwaZulu-Natal, however, not receiving a clear recognition in agro-industry and processing sector. Consequently, postharvest losses of this fruit are very high, especially, in rural farming communities. No studies have been conducted to assess the quality attributes of the peach fruit produced in rural KZN farming sector. This in return is a huge burden to these farmers. They have misconception about storing peach fruits on tree, trying to extent storage life, however, this does not work as fruit are attacked by microorganisms or drop off from the tree, losing quality and value. The harvesting season of peach fruit is very short, and therefore the supply becomes overwhelmingly higher than the demand. With no storage facilities and value addition methods, their fruit is lost in large quantities.

Fruit grading, processing and packaging have a crucial role to play in postharvest because if one of these processes is not done properly or carefully, fruit quality can diminish and eventually no financial returns to all stakeholders involved in the process from the farm to the shelf. Different degrees of ripeness were identified in the review as fundal of peach processing since each degree of ripeness comprises of different intrinsic and extrinsic attributes which is a huge contributing factor to quality of processed peach products. The subj-objective identified for the study was to use fruits at different grades in order to answer a question of whether or not different ripeness affect the quality of processed products.

A clear understanding of their peaches fruit quality attributes is critically important since this can be used to classify their peaches according to their type and possible uses, depending on the quality parameters of the fruit. The literature review has looked at fruit properties such as TSS, TA, weight, firmness, colour, pH, density, fruit shape and size and none of these parameters have been identified for the peach fruits at Impendle. This leaves a gap to study the peaches and be able to identify ranges of the quality attribute of these peaches by identifying each of the above and more parameters in order to have a clear understanding of the fruit. A clear objective about answering a question of the unknown quality parameters of Impendle peaches would be: to assess TSS, TA, weight, firmness, colour, pH, density, fruit shape and size of peach fruits in relation to quality of fresh fruit grown at Impendle. A formulated null hypothesis to achieve the answer of quality attributes question was that: Impendle fruit lack optimal quality parameters suited for processing ability.

Peaches are grouped into freestone, clingstone and melting or non-melting types. These groups determine specific uses of the peach. Fruits at Impendle have not been grouped. Probably farmers struggle to preserve their fruits because they are not able to group the fruit appropriately. This leaves a gap to study and classify Impendle peaches into clingstone or freestone and to melting or non-melting type. A relevant sub-objective was: To classify Impendle fruit to clingstone, freestone and melting or non-melting types. A suitable null hypothesis to answer this question was that: Impendle fruit cannot be classified as clingstone, freestone and melting or none-melting types.

Intrinsic and extrinsic fruit quality parameters were discussed in this write up. Methods and instruments used to measure fruit quality parameters were reviewed none of these are suitable or applicable to be used by small scale peach farmers in KZN. The review of the literature has shown a number of different factors and quality attributes that contribute to postharvest handling of peach fruits.

One of the fruit preservation methods identified in literature is processing the fruit into other storable, value added products. The chemical, physical, mechanical and nutritional factors have important roles to play in ensuring that processed peach quality attributes are considered and maintained in value adding processes in order to avoid the loss of these important quality attribute. However, peaches grown at Impendle have not been evaluated for processing ability. This leaves a gap to assess the processing ability of the Impendle peach fruits. The objective to answer this question was: To determine the effects of processing conditions and fruit properties on the quality of finished products. The formulated null hypothesis to achieve this sub objective was: Impendle fruits cannot be processed into juice, dried and leather peach products.

Peach drying as one of the processing method was related to KZN conditions whereby there is summer rainfall compared to the Cape where drying is popular and done in open sun since they do not have summer rainfall as much as KZN does. This makes open sun drying of peaches not so easy in KZN since there is high moisture content in air (Bertling, 2014). Therefore a greenhouse dryer was identified as a tool to be used in drying peaches during the current study. Conventional methods of value addition were also identified as a method to prepare juice and leather using Impendle fruits.

The current study aims to focus on adding value to peach fruit. The aim of this review was to identify all contributing peach attributes that affect the peach fruit processing using methods of adding value in order to prolong the fruit storage life.

10. PROJECT PROPOSAL

10.1 General Introduction

Postharvest losses occur in both developed and less developed countries (Gustavsson, *et al*., 2011; Kader, 2005; Lipinski *et al*., 2013; Nellemann *et al*., 2009; Opiyo, 2012; Parfitt *et al*., 2010). About 1.3 billion ton per year of the palatable food produced for humans is lost worldwide (Gustavsson *et al*., 2011). It is becoming a challenge to meet consumer requirements while dealing with food losses concurrently. Clearly something needs to be done. Value adding has the potential to create more demands for agricultural products. This can reduce the storage expenses and losses during post-harvest period. It can also reduce the needs for using food preservatives. With respect to horticultural food loss during the post-harvest period, estimates are between 5–25 % and 20–50 % in more developed and less developed countries, respectively. These losses can be classified with respect to the stage at which they occur. According to Gustavsson *et al.* (2011) food is lost during agricultural production, postharvest, processing, distribution and consumption.

The Sub-Saharan region loses more food during production, handling and storage periods. These losses are also product dependant with some products being classified as perishable (e.g. horticultural products) and some as non-perishable (e.g. grain) (Parfitt *et al*., 2010). The South African small scale farmers are suffering horticultural postharvest losses similar to those experienced by less developed countries. Adding value to their produce will improve storability. The aim of this study is firstly, to study the physical composition and other properties of peach fruit. Secondly, to study the possibilities of adding value through processing peach fruits into juice, dried and peach leather products. Lastly processed products will be studied for the storability.

10.2 Justification of Study

Although many studies have been conducted on postharvest handling of fruits, there are still knowledge gaps on fresh produce preservation and value addition. This is because the available technologies such as freezing, pickling, canning, commercial drying and curing do not favour rural smallholder producers (Mohammed, 2004). There is need for research that will lead to appropriate technologies for this group of producers. KwaZulu-Natal farmers in South Africa lose up to 50 % of the fruit produce due to lack of storage felicities and value adding skills. Processing peaches into other products is likely to add value to the peach and create a demand. There is a need to determine the properties of fruit produced under limited input resources, by rural small scale of South Africa, KwaZulu-Natal. There is also a need to determine which fruits have the best properties for various processed products including storage characteristics of processed products.

10.3 Hypothesis:

The determination of precise physiological maturity point on peach fruit is imperative for fresh and processed fruit quality attributes during postharvest handling and that a certain degree of ripeness exists where highest possible processed quality products can be attained and that another degree of ripeness exist that is critical for potentially optimal storage life of processed peach fruit products.

10.4 The Objectives

The overall aim of this study is to add value to peach fruits. To fulfil this aim, the study will have the following specific objectives:

1. To assess the compositional and physical aspects of peach fruits in relation to quality of fresh fruit,
2. To determine the effects of processing conditions and fruit properties on the quality of finished products.
3. To determine the storage life of the processed products.

10.5 Experiment One: To assess the compositional and physical aspects of peach fruits in relation to quality of fresh fruit

10.5.1 Materials and Methods

The fruit will be harvested at Impendle which is located in the province of KwaZulu-Natal, South Africa. Fruits will be harvested at different degrees of ripeness. Fruit will be transported immediately to the cold room and store at 4°C before the experiments. Fresh fruit properties will be determined before storage.

10.6 Experiment Two: To determine the effects of processing conditions and fruit properties on the quality of finished products.

10.6.1 Materials and methods

Fruit will be processed into juice, dried and leather peach products using fruit of various qualities. The product will then be evaluated using both objective and subjective tests.

10.6.2 Juice processing

Juice will be processed in laboratory using a juice extraction machine. The resulting juice will be evaluated for quality using both objective and subjective methods. Juice will be processed using a method explained by Kitinoja and Kader (2003).

10.6.3 Drying peaches

The fruit of varying quality will be prepared for drying by peeling and cutting. The resulting fruit pieces will be dried in a solar dryer. The dry products will be evaluated for quality using subjective and objective methods. Peach fruits will be drying applying methods such as that used by Togrul and Pehlivan (2004).

10.6.4 Peach leather processing

The fruit of varying quality will be prepared for peach leather. Peach leather will be processed. After processing peach leather, properties will be measured objectively and subjectively. Peach leather will be processed using methods followed by Triebe (2009).

10.7 Experiment three: To determine the storage life of the processed products.

Products of varying ripeness will be store for variable period specific to each of dried, juice leather peach products. Subjective and objective methods will be used to determine the acceptable standards of these stored products.

10.8 Project Plan

A project plan for three years is illustrated in Table 10.1.

Table 10.1 Project plan

	2013												2014												2015											
Task Name	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Registration					■																															
Lit. Review					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■															
Presentation																					■															
Equipment																					■	■	■													
Data collection																						■	■	■	■	■	■	■	■	■	■					
Data analysis																						■	■	■	■	■	■	■	■	■	■	■	■	■		
Write up	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Handing in																																				■

10.9 Expected Outcome and Outputs

It is expected that at least three conference papers and two Department of Higher Education and Training (DHET) recognized articles will be published from the research of this study.

The products of the overall aims of the study are:

- To propose or develop appropriate methods for adding value to peaches by small-holder farmers
- Knowledge of factors affecting value adding by processing of peaches will be generated

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