UNIVERSITY OF KWAZULU-NATAL

EFFECT OF MATURITY AND POSTHARVEST HANDLING OF *PRUNUS PERSICA* ‘LANDRACE’ PRODUCED IN KWAZULU-NATAL: CASE STUDY OF PHYSICOCHEMICAL PROPERTIES, TUNNEL SOLAR DRYING AND QUALITY OF PROCESSED PRODUCTS

Khangelani Maxwell Mkhathini

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I, Khangelani Maxwell Mkhathini declare that:

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DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this dissertation (include publications in preparation, submitted, *in press* and published and give details of the contributions of each author to the experimental work and writing of each publication).

Author contributions: For all manuscripts KM Mkhathini reviewed the relevant literature and drafted the manuscript. TS Workneh, G Mwithiga and LS Magwaza provided guidance and edited the manuscript.

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ABSTRACT

Farmers in KwaZulu-Natal produce peach fruit. However, they are faced with overwhelming losses of the fruit due to lack of proper handling techniques, skills and facility during postharvest. In addition, these farmers have limited formal markets where they could sell fresh fruit immediately after harvesting. Thus, they are forced to consume the least they can and leave the rest of the fruit hanging on the tree. As a result, they lose close to 45% of their fruit.

The literature review congruently pointed out such challenges of food losses in less developed countries and South Africa is not an exception. With a limited understanding of peach properties, it becomes increasingly difficult for farmers to handle the fruit. The cost of storage and processing facilities (such as sophisticated refrigeration) is very high and a decision table was used to determine which affordable method can be employed to process the peach fruit.

The study is significantly important for the reduction of massive losses of fresh produce in the small-scale household farming sector as whole in South Africa. This study had three main aims to address. Firstly, it aimed to understand the physiological maturity and ripening of the peach fruit by determining physicochemical properties such as days to maturity, mass, volume, shape, moisture, pH, total soluble solids, colour (CIELab) and firmness. Secondly, the study aimed to install and test a tunnel solar dryer according to a decision table criteria that used to decide on a fruit processing method. Thirdly, the study aimed to process the fruit into dried peach slice with pre-treatments of lemon juice (LJ), ascorbic acid (AA) and a control, using a tunnel solar dryer. In addition, the study also aimed to process the peach into dried peach leather also using a tunnel solar dryer.

This study included both objective and subjective methods to test the quality of the peach slice and leather products processed. Fruits reached maturity 129 days after full bloom (DAFB) and this coincided with fruit mass, volume and moisture content at respective averages of 80.00 g, 66.10 cm^3, and 83%. Fruit firmness decreased significantly from 79.00 N to 24.70 N with increasing ripeness. Total soluble solids increased significantly from 13.50 to 19.00 °Brix during ripening. The pH value significantly increased from 3.40 to 4.00 indicating that acidity decreased with ripening. The TSS: TA ratio increased from 21.11 to 35.84. Moreover, it has been statistically verified that due the colour, yellow peach fruit produced the best products (as seen by the receipt of the highest sensory evaluation overall acceptability scores and based on

the texture profile analysis results provided by Texture Analyser instrument). The utilisation of treatment such as AA or LJ did not have a significant effect in the overall drying between the yellow and white landraces. Ascorbic acid had a tendency to perform better than LJ which was also better than the untreated slices (control) in terms of the taste and overall acceptabilty. The experiment revealed that white leather moisture was approximately 7% and received the lowest overall acceptability scores from panellists. Less quality results were also received according to the texture profile analysis, in contrast to the yellow peach leather, which had 13% of moisture content. Yellow leather received the highest overall acceptability scores by both texture profile analysis and sensory evaluation tests.

Thus, this study suggests that drying is possible in the KwaZulu-Natal Midlands. Overall, the results developed from the current study demonstrate that the fruit produced in small-scale farming sector is of good quality regardless of low yields because fertilizers and pesticides are not used. More importantly, this study reveals the significant potential of solar drying to be used by small-scale farmers to develop on-farm interventions aiming to add value to their produce and thus be able to preserve, use and sell later. It was concluded that DAFB, firmness, mass, TSS, volume, TTS: TA ratio are potential parameters to be used for maturity indexing of white peach 'landrace'. Regardless of the misty conditions that prevail during the period of harvesting fruits, it was concluded by a statistical significant difference that the tunnel solar drying is a possibility in the KwaZulu-Natal Midlands. Days after full bloom, firmness, TSS, pH and mass have a critical role to play since they significantly differ between different ripeness degrees.

These can be used to monitor peach growth stages and estimate yield for the small-scale peach grower in the area. The DAFB are a good tool that farmers can stick to without the use of advance technologies other than monitoring the number of days. Firmness is also a very important parameter for farmers in the area as the fruit hardly changes colour but can be soft showing signs of ripeness. The study has also devised a step-by-step process, which can be followed by small-scale processors in order to reduce losses using solar dryer to process fruit into leather and slice.

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ACRONYMS AND ABBREVIATIONS

a*	redness – greenness
β	beta
AA	ascorbic acid
ANOVA	analysis of variance
AOAC	Association of Official Analytical Chemists
ARC	Agricultural Research Council
b*	yellowness – blueness
B	breadth
CFU	colony forming units
ClO_2	chloride dioxide
CU	chilling units
D	diameter
DAFB	days after full bloom
DAFF	Department of Agriculture and Forestry Affairs
FAO	Food & Agriculture Organization
H_2O_2	hydrogen peroxide
HDPE	high-density polyethylene
HIS	hyperspectral imaging
HPLC	high performance liquid chromatography
IACD	Index of Absolute Colour Difference
KZN	KwaZulu-Natal
L*	lightness
L	length
LJ	lemon juice
MF	melting flesh
MPP	metalized polypropylene
N	nitrogen
NaOH	sodium hydroxide
NIR	near infrared
NMF	non-melting flesh
OECD	organisation for economic co-operation and development
PP	polypropylene

r	correlation coefficient
RH	relative humidity
SDG	sustainable development goals
SSA	Sub-Saharan African
TA	titratable acidity
TPA	texture profile analysis
TSS	total soluble solids
UN	United Nations
UV	ultraviolet
V	volume

LIST OF UNITS

t	tonne
ha	hectare
°C	degrees Celsius
°Brix	degree Brix
%	percent
$	dollar
m	metre
mm	millimetre
cm	centimetre
cm^3	volume
nm	nanometre
L	litre
mL	millilitre
g	gram
mg	milligram
kg	kilogram
N	newton
S	second
min	minute
h	hour
ppm	parts per million
W	watt

1. INTRODUCTION

1.1 Background to the Study

South African household farmers produce large quantities of fruits such as peach, but have limited storage facilities and processing skills. This results to farmers losing close to half of their peach produce. A major challenge faced by farmers and consumers is that of postharvest losses as it directly affect food security, nutrition and household welfare through various channels (Tirivayi and Tirivayi, 2016). Postharvest losses and deterioration of quality in horticultural crops are mostly caused by microbial infection, pests, and environmental conditions (such as drought, heat, improper postharvest handling and the natural ripening process) (Humble and Reneby, 2014; Kitinoja and Kader, 2015; Kasso and Bekele, 2016; Tirivayi and Tirivayi, 2016). Losses can occur through all or at least one of the postharvest activities, which include harvesting, handling, storing, processing, packaging, transporting and marketing (Mrema and Rolle, 2002). Postharvest losses are known to cause a measurable reduction in foodstuffs, and as a result affect quality and quantity (Grolleaud, 2002).

Consequently, it is becoming a challenge for rural household, small-scale farmers to meet consumer requirements while dealing with food losses concurrently. This is compounded by hunger, meaning they are coerced into opting for survival by even using poor performing crops such as fruit and vegetables that are adapted to their environment without the use of agricultural inputs. 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 addition has the potential to create more demands for agricultural products. In fruit value chain, this can reduce the storage expenses and losses during postharvest period as well as reduce the need of using food preservatives. A study by Opiyo (2012) reported that farmers produce enough amounts of good quality horticultural crops and aim to guarantee that consumers benefit from the palatable and safe food.

Fruits play a major nutritional role for both developed and less developed countries. Countries with limited means to produce certain fruits, import the required commodities. Countries that produce excess, export extra commodities to those that are running short or unable to produce their own fruit crops. This in return stimulates trade and economic growth for large commercial markets in participating countries and provides farm, packing house, processing plant employment for household dwellers. However, household fruit growers do not participate in formal markets. Nevertheless, they are able to benefit nutritionally from local landraces they produce. They consume and give to close neighbours free. Food insecure household growers produce a variety of fruits in South Africa, and peach landraces are one of the important commodity.

Peach fruit (*Prunus persica Batsch L.*) belonging to the family *Rosaceae*, is one the most important fruits grown in South Africa (Ntombela and Moobi, 2013). 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. There was an increase of production in the seasons 2015/2016 and 2016/2017 whereby 2,213,422 and 2,004,156 cartons produces respectively, with each carton weighing 2.5 kg (Anonymous 1, 2017). South Africa is ranked the eighth largest producer of peaches worldwide after China, United States of America, Turkey and Argentina (Ntombela and Moobi, 2013). South Africa's major peach producing regions are located in the provinces of Western Cape, Northern Cape, Free State, Mpumalanga, and KwaZulu-Natal. With the exception of out-dated estimates, KwaZulu-Natal's specific production areas and hectares planted with peaches are not well documented, indicating that this fruit is underutilized in this province. The markets supplied by KwaZulu-Natal peaches are also not clearly documented. Peaches grown in this province are mainly produced by smallholder farmers in rural areas, including Kokstad, Bulwer, Underberg, Impendle, Tugela and only one commercial farm at Mulder's Drift. These rural farmers grow peaches whose varieties are still being identified and classified accordingly. The poor yields of fruit in these farms can be attributed to various factors such as no use fungicide herbicide, fertilizers, low precipitation for irrigation and mismanaged soils. The KwaZulu-Natal Department of Agriculture and Environmental Affairs is currently looking at the challenges faced by these farmers to find relevant and specific solutions.

Peaches are important for human consumption since they are rich in vitamin A and contain important compounds (malvidin, pelargonidin, peonidin, petunidin delphinidin and cyaniding) used to reduce the risk of diseases such as cataracts, blood pressure, allergies, cancer initiation, diabetes and heart diseases (Kader *et al.*, 2005). Bradshaw *et al.*, (2000) reported that stroke, malnutrition and heart diseases are in the top ten causes of death in the province of KwaZulu-Natal. Promoting proper production and consumption in this province is a step forward in trying to curb hunger and diseases. It has also been shown in many epidemiological studies that increase consumption of stone fruit lowers the risk of chronic diseases, cancer and diabetes. It is also reported that it can prevent cellular oxidative stress caused by free radicals (Saidani *et al*., 2017).

In recent decades, there is an increasing interest in consumers on food with health benefits. They have begun to look beyond the basic nutritional benefits to the potential disease preventions and health enhancing compounds contained in many foods and fruits, as they are natural sources of healthy bioactive compounds and mineral nutrients exhibiting significant health benefits (Chen and Martynenko, 2018).

1.2 Problem Statement

Kasso and Bekele (2016) reported that although human material and resources devoted for planting, irrigation, fertilizer application, 50% of the horticultural crops become waste because of postharvest losses. Postharvest food losses occur in both developed and less developed countries (Gustavsson, *et al.*, 2011; Stiling *et al.*, 2012; Kader, 2005; Lipinski *et al.*, 2013; Nellemann *et al.*, 2009; Opiyo, 2012; Parfitt *et al.*, 2010; Kasso and Bekele, 2016). An estimate of about 1.3 billion tons of palatable food worldwide is lost in the postharvest chain per year (Gustavsson *et al.*, 2011; Stiling *et al.*, 2012).

Consumers are not able to benefit fully on the food produced by farmers in the Sub-Sahara African (SSA) countries such as South Africa since large amounts of fresh produce gets 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. Food is lost during agricultural production, postharvest, processing, distribution and consumption (Gustavsson *et al.*, 2011, Stiling *et al.*, 2012). 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 SSA loses more food during production, handling and storage. These losses are also product dependant with some being classified as high perishable (e.g. horticultural products) and some as non-perishable (e.g. grain) (Parfitt *et al.*, 2010).

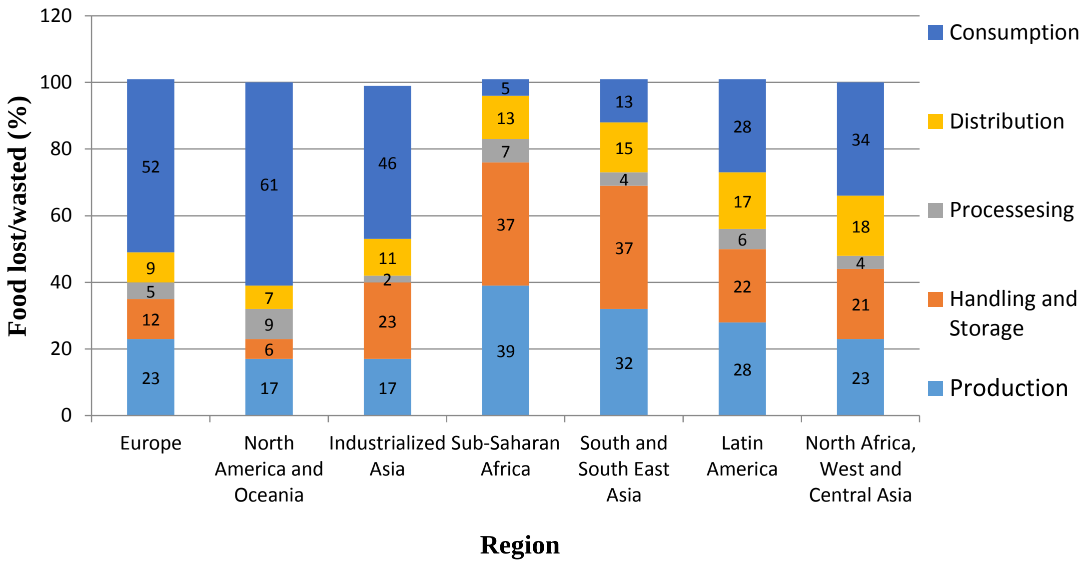

Figure 1-1 Food losses by geographical location and phase in value chain (Lipinski *et al*., 2013)

There is limit 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). Kasso and Bekele (2016) reported their study finding on major factors contributing to postharvest losses in horticulture (Figure 1-2).

Harvesting, handling, climate, packaging and marketing are clearly the major contributors that are significantly higher than the impact of pests and diseases. In South Africa, a mythical belief persists that small-scale farmers lose their horticultural produce mainly because of pests and diseases. This may not be the case and thus studies need to be conducted to clarify the main contributor. There are still knowledge gaps on fresh produce preservation and value addition for the household fruit handling in South Africa. This is especially pertinent since available technologies such as freezing, pickling, canning, drying and curing Mohammed (2004) do not favour rural smallholder producers. Therefore, there is a growing need for dedicated research that will lead to suitable and affordable technologies for this group of producers. Kiaya (2014) stated in a report that the main strategic areas for reducing postharvest losses by overcoming perishability of crops, improving marketing, enhancing nutritional value and economic value are through processing. Mohamed (2004) and Kiaya (2014) found and reported their studies that value addition is one the methods that can be used to reduce losses. Prior to processing, it is very important to understand the properties of the fruit that are linked to the processed product quality. Diverse physicochemical properties essential for health benefits vary greatly depending on cultivars. Those include total soluble solids, titratable acidity, pH, free sugar content, phenolic compounds, 1.1-diphenyl-2-picrylhydrazyl (DPPH), radical scavenging activity, amygdalin content, amino acid content, colour, firmness (Cano-Salazar *et al*., 2013; Kim *et al*., 2014).

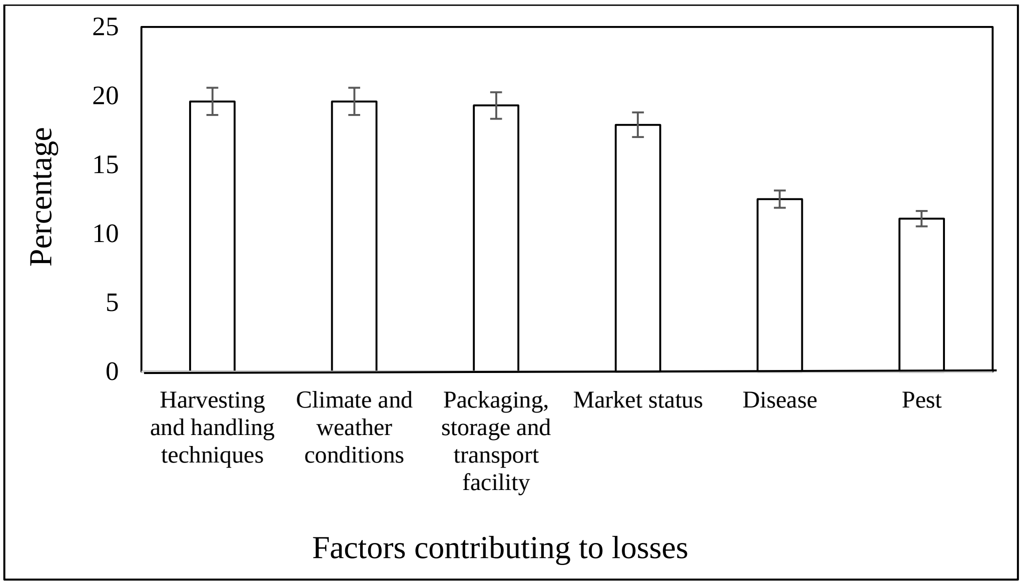

Figure 1-2 Major factors contributing to postharvest losses Horticultural Sector (Kasso and Bekele, 2016)

Due to high water content and perishability rates, numerous ways to utilize and process the fruit (such as processing into juice, jams, concentrates, pulp, dehydrated products, jellies) have been applied in the processing industry (Offia-Olua and Ekwunife, 2015). Drying is the oldest and wildly used method of postharvest food preservation. It improves postharvest handling, packaging and improves the ease of transporting products (Onwude *et al*., 2017).

1.3 Motivation of the Study

It is clearly important to understand the physico-chemical properties of the peach grown under constricted conditions with limitation of input resources like irrigation, fertilizers and pesticides. The understanding of fruit behaviour is very important. Such behaviour will provide guidelines on how this fruit needs to be graded, handled, treated and processed for value addition. The yellow and white peach landraces are produced in KwaZulu-Natal are lost by farmers due to their limited storage facilities and lack of formal markets to supply. Such losses in the SSA, of which South Africa is not an exception, create a research gap on rural dwellers' fruit industry. Using a peach, which is the one of the fruits that strives in drier areas compared, a Case Study is necessary in order to improve the livelihood and ensure enough fruit is consumed in rural communities of South Africa. The questions raised regarding the peach fruit are:

(a) What are physical and chemical differences between the yellow and the white peach landraces produced in the rural farming sector?

(b) What are the three affordable value addition methods that can be employed to peach fruits?

(c) How the quality of products processed using peach fruits grown under limited conditions is?

The study was therefore divided into two main parts; Experiment I and Experiment II. Experiment I focussed on the physical and chemical quality properties of the fruit and Experiment II focussed on value addition to peach fruit by using solar to dry the fruit into dehydrated leather and slice. The determination of quality attributes was also measured through the use objective and subjective methods.

1.4 Aims and Objectives of the Study

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

1. To study the compositional and physical aspects of peach fruits in relation to quality of fresh fruit,
2. to evaluate the performance of a solar tunnel dryer in adding value to peach fruit and,
3. to study the quality of finished products with respect to processing conditions and fruit properties.

1.5 Hypothesis

Null: Peach landraces grown in the small-scale farming sector do not have the processing ability.

Alternative: Peach landraces grown in the small-scale farming sector have the processing ability.

1.6 Significance of the Study

The study is significantly important for the reduction of massive losses of fresh produce in the small-scale household farming sector as whole in South Africa. Other significances of the study include:

- The differentiation between white and yellow peach landraces based on their processing ability and quality of processed product.
- To construct and test the tunnel solar dryer under misty conditions in the KwaZulu-Natal Midlands, where open sun food drying is not a possibility.
- To create awareness about other agricultural products dried using freely available environmental friendly method of drying using solar energy.
- To create an awareness of the household fruit growers that value addition is important for food preservation in the small-scale fruit sector.
- To create awareness of the value of other neglected food crops in the small-scale farming sector.
- To create awareness of fruit maturity indices in the small-scale fruit production sector.
- To create awareness of postharvest handling in the small-scale fruit production sector.
- To stimulate further research products towards improving production methods in the rural small-scale farming sector.
- To stimulate research for improvement of varieties of crops produced in South Africa by selecting and incorporating small-scale farmer's tree genetics when improving inbred lines so it can allow small-scale farming sector to grow slightly improved varieties.
- To demonstrate to rural farmers the importance agricultural research and the benefits of adopting research output.

The current study is a stepping-stone towards the sustainable development of the rural farming sector in South Africa. This will ensure food secure communities that have a wide variety of options in handling and processing their products and thus create employment and wealth.

1.7 Scope of Work

1.7.1 Determination of maturity indices for the peach fruit grown in the small-scale household sector using simple available knowledge to enable farmers to know when their fruit formation begins and when the end of shelf life is.

1.7.2 To construct and test a tunnel solar dryer in the Midlands of KwaZulu-Natal.

1.7.3 To dry peach slice using the solar tunnel dryer.

1.7.4 To dry peach leather using solar tunnel dryer.

1.7.5 To conduct objective and subjective tests of quality on processed products.

1.8 Layout of the Dissertation

- Chapter 1: The introduction provides the background of the study and the importance of peach fruit in South Africa. It also states the problem statement, motivation and significance of the study as well as the scope of work, study aims and objectives.
- Chapter 2: The literature review reviews previous and relevant work pertaining to the study; the challenges of postharvest losses each fruit description. Decision table to decide on a better method of value addition, methods of determining physicochemical properties of fruits.
- Chapter 3: Aims to evaluate the fruit quality parameters such as mass, pH, titratable acidity, volume, total soluble solids, colour (*CIELab*) etc. with the main objective to link such parameters to fruit maturity and ripening for the small scale's fruit.
- Chapter 4: Focusses on constructing and testing tunnel solar dryer. Internal and ambient drying conditions (such as radiation, temperature, and relative humidity) were monitored and RH, T, solar radiation, air speed, data collected accordingly.
- Chapter 5: Addresses processing and testing peach leather product quality attributes using sensory and texture profile analysis. The objective was to test the processing ability of the fruit, link the quality analysis methods, and evaluate whether or not the two methods have any trends and consistence.
- Chapter 6: Aims to provide a general discussion, conclusions and recommendations of the study. It also elucidates what the problem of the study was. Also, specify key points regarding what the literature review states about food losses, processing methods, study key findings and recommends on how to mitigate the challenge of food losses. Guidelines and step-by-step methods to tunnel specifications and processing of fruits and lastly, gaps for future research the study could not cover due to resource limits.

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2. LITERATURE REVIEW: POSTHARVEST MANAGEMENT AND PROCESSING OF PEACH FRUIT

2.1 Background Information

More than 70% of the Sub Saharan Africa (SSA) population depends on agriculture as primary source of income and food. Therefore growth in production and productivity are critical for eradicating hunger and poverty (Abass *et al*., 2014). Food losses remains one of the persistent challenges that researchers, farmers and consumers are constantly facing. The limitation of adequate fresh produce storage and preservation facilities is the main challenge in both the developing and less developed countries (Mohammed, 2004; Kasso and Bekele, 2016, Delgado *et al*., 2017). Therefore, a decrease in food loss during the postharvest period through appropriate postharvest processing techniques would have substantial economic effects in those countries (Jairaj *et al.*, 2009; Banout *et al.*, 2011). Most fruits with a high potential health benefit, such as peach fruits, are highly perishable. To compound the issue, finding appropriate postharvest food preservation methods that retain the bioactive compounds at a relatively low cost is challenging (Pavan, 2010). Some of the preservation approaches include cold storage, canning and drying. Drying is one of the oldest, most effective ways and has been widely used in the preservation of food and many reports that investigated solar drying have stated that it is an economical and green process (Mennouche *et al*., 2017; Rajkumar *et al*., 2017). Drying decreases the content of water in the product, which in turn restrains development of microorganisms and lessens degrading processes ensuring stability of product (Pavan, 2010; Mennouche *et al*., 2017; Onwude *et al*., 2017). The focus of the current study is on peach fruit value addition. Peaches belong to a group of fruits known as the stone fruits.

2.2 The Stone Fruit

Stone fruits are named because of the hard outer shell of the fruit's core. Stone fruits (*Prunus* genus) are also known as drupes; fleshy fruit that has thin edible outer skin (epicarp) and an edible flesh beneath the skin (mesocarp) (Carrasco *et al.*, 2012). 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 *et al*., 2012). Generally, stone fruits such as plums, peaches, cherries and nectarines contain 87% of water and equipped with 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.

2.3 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 as well as 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, which can escalate to cause a substantial distinction at harvest (Lurie *et al.*, 2013). However, water and nitrogen monitoring is required in order to harvest high yields of good quality fruit (Falguera *et al.*, 2012). The nutritional value of fruits depends on the quality and quantity of nutritive substances (Offia-Olua and Ekwunife, 2015). This document is focussing at reviewing literature based on peach fruit aspects of postharvest handling and processing.

2.4 Determination of Harvesting Date for Physiologically Mature Fruits

The entire postharvest cold chain begins in the farm whereby the correct fruit must be picked at the right stage of maturity. Harvest date plays an important role to the shelf life of the fruit. Whether 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 developing the correct stage of horticultural maturity for these fruit. The physiological maturity is the development stage when a fruit/plant part continues ontogeny even if picked from the tree. The horticultural maturity is defined as, a stage of growth when a fruit/plant part possesses the primary attribute for utilisation by consumers or processors for special purposes (Kader, 1999).

Peach fruit has different stages of harvesting 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 factors as well as 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). Unfortunately, the physiological maturity has not played a prominent role in determining when peaches should be harvested.

2.5 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 then packed in bags. Then kept in bins that are 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 as rapidly as possible with minimum damage, loss and minimum costs involved (Kader and Mitchell, 1989b). Failure to use a certain scheme 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 being 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 the climacteric state of the fruit is critical and must be kept minimal since respiration cannot be reversed.

2.6 The Respiration and Climacteric State of the 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 shelf life of 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 increases during the last weeks of maturation, before harvesting (Crisosto and Valero, 2008). There are four stages of respiration and ethylene gas production as illustrated in Figure 2-1 (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 rate 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.

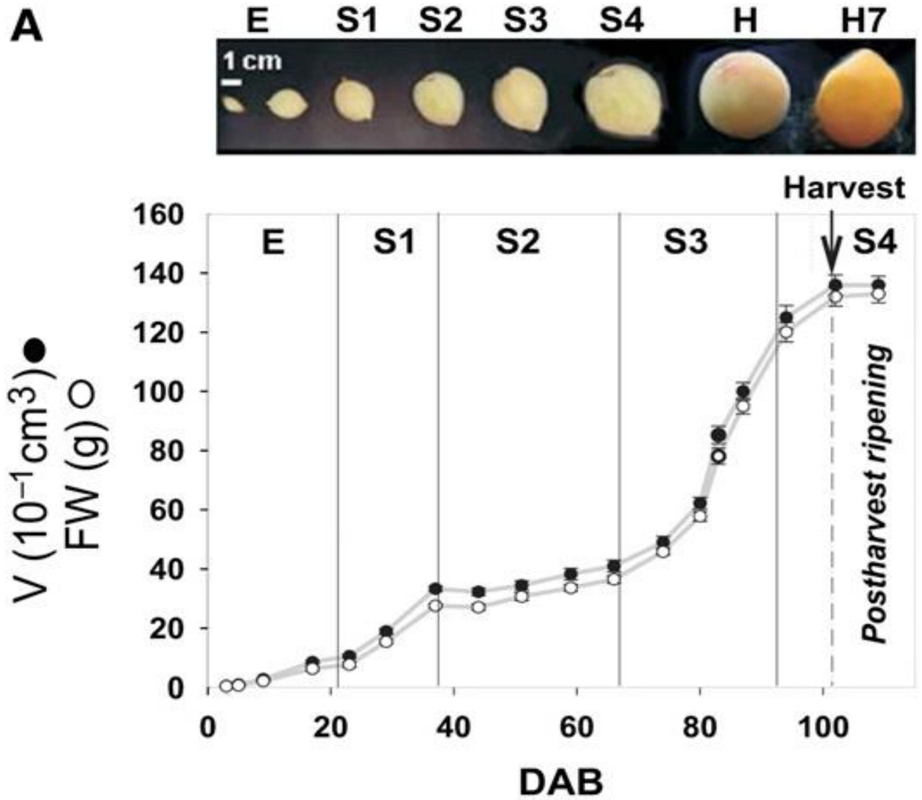

Figure 2-1 Double sigmoid curve showing peach fruits climacteric status occurrence during ripening process (Lombardo *et al.*, 2011)

If the fruit is left 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 understanding 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.

2.7 The Postharvest Handling of Peach Fruits

In the last decade, the fruit industry has changed in many ways, such as increased interest in quality traits that include the nutritional value (Mestre *et al*., 2017). Thus, postharvest handling plays an important role in maintaining the fruit shelf life and quality attributes. A harvested fruit that does not receive attention at postharvest is likely to lose its state and shelf life quicker and therefore causing loss in profit. Bonora (2013) explained that the customary means used to find out harvesting times are skewed and not consistent when the fruit is left to ripen on the tree. The ground colour fading, increase in blush colour and attainment of maximum size are some of the customary characteristics used to determine harvesting times in peaches. The existence of new landraces/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 (IACD) are some of the effective 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 packinghouse since the event of mishandling accelerates the end of the fruit.

2.8 The Fruit Packing House Operations

Peach are regarded as fruits with a short shelf life potential arising from fast softening and overall ripening (Cano-Salazar, 2017). Therefore it very important that the fruit is properly managed at the pack-house in order to shorten the period and avoid fast ripening at the unintended stage of the value chain. Controlled atmosphere is one of the practices employed by pack-houses to mitigate fast ripening process (Lurie and Crisosto, 2005; Cano-Salazar, 2017). After harvesting fruits, the respiration rate increases and so does the ripening process therefore these must be controlled and suppressed immediately after picking the fruit. When the peaches reach the packinghouse, they must 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, sizing/grading, bunching/wrapping, postharvest treatments, packing and cooling.

Mechanical damage to the produce during these operations must 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. Soft brushes fitted on the sloped ramp or moving conveyor belts perform the dry dumping. They are 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 saves energy and money because culls will not be handled, cooled, packed or transported. Removing decaying fruit is important, especially 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, 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 an important step because if 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 packinghouse.

2.9 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 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), refractometer (for sugar content measurement), and NIR (for colour measurement) (McGlone *et al.*, 2002). Research has shown that 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) (Kader and Mitchel, 1989b; Rood, 1957). When the fruit is ripening, various 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.

2.10 Peach Ripeness and Determination of Fruit Properties

After harvesting, the fruit is transported to the packinghouse where a number of procedures are followed to ensure it is maintained at its required fresh state. The packinghouse operations are linked to the conditions in the field such as the maturity of fruit and 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 starch degradation, pigments development and volatile compound biosynthesis, accumulation of sugars and reduction of acids as well as the modification of structures and composition of polysaccharides (Giovannoni, 2001; 2004; Gulao and Oliveira, 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 landraces that have contrasting flesh colour, flavours, SSC and TA from conventional landraces. 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 may be internal or external and require simple or complicated methods of determination. The determination methods normally fall into destructive or non-destructive techniques. Peach fruit quality can be determined with 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).

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 postharvest systems. The physical properties 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). Postharvest parameters are carefully measured and used when peach fruit quality is to be determined during 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 determined by 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) ultimately determines whether 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 while 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. 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, 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 are limits to juicy products.

When food is not in use it is very important to keep it in good condition until time comes when it is needed. Fruit size is used by consumers to estimate the quality. Day and DeJong (1998) reported that large fruit size is essential to satisfy consumers. Growers use size as one of the important commercial criteria 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 2-1 (Sharma and Attri, 2011). However, the values measured always vary depending on the peach variety, time after harvesting and the fruit's environmental conditions. In order to determine fruit properties, non-destructive and destructive methods are used.

Table 2-1 Peach fruit quality parameters

Fruit length, mm	54.78+0.012
Fruit width, mm	56.70+0.029
Weight, g	125.00+0.464
Colour	Greenish yellow
Specific gravity	1.05+0.012
Firmness, (N)	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/100 g	3.57+0.017

2.10.1 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; Kim *et al*., 2014). The peach fruit (*Prunus persica*, L. Batsch; *Rosacea* family) 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 cool temperate regions of Europe, North America, South Africa, Asia and Australia between 10° and 49°N and between 18° and 45°S latitudes. Peaches belong to climacteric group of fruits meaning that they have a specified ripening period (Crisosto and Kader, 2000). Cultivars and soil types determine the quality parameters of peach fruits (Mestre *et al*., 2017).

2.11 Non-destructive Methods of Determining 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).

2.11.1 Determination of fruit size

Fruit size determination is one of critically important properties to determine especially in fresh produce markets, as consumers are attracted to large fruits. Barrett *et al.* (2010) and Kader (2002) reported that size may be determined by either dimensions, weight, or volume and 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 micrometre. 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 thus be used as guidelines to identify produce acceptability.

2.11.2 Determination of fruit colour

Alfatni *et al.* (2008) reported that colour provides 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 is quite often subjective and can differ from one person to the next and from day to day. The use of a colour chart for a specific landrace may take out the subjectivity on the judgment. Computer vision, use of visible light or X-ray can sort more readily but lacks adaptability. Visual inspection for attributes such as colour has been used on broccoli by Wang (1979), on cauliflower by Lipton and Harris (1976) and on cucumbers by Kader *et al.* (1973). Colour was determined using Minolta 200A calorimeter (Crisosto and Crisosto, 2005). Sing and Reddy (2006) have measured colour using Lab-Scan-XE spectro-colorimeter (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 critical studies.

2.11.3 Determination of fruit mass and shape

It is important to determine fruit mass for different grades 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. While the shape was determined by relation between the average diameter, length, size and mass (Goyal *et al.*, 2007). Various studies on avocado, apples, peaches, oranges etc. mass and shape determination have shown that these properties are critical in reference to fruit acceptance. Further studies on peaches will help determine the specific properties that allow for this fruit acceptance. Some of the properties cannot be measured only by non-destructive methods, but require destructive methods.

2.12 Destructive Methods of Determining Fruit Properties

Destructive methods that are used to determine properties require that the fruit be cut. This alters the state of the fruit. This section investigates fruit firmness, TSS, flesh colour, Brix, juice content, TA, and pH as some of the most important destructive measurements of fruit properties.

2.12.1 Determination of 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- or gamma- rays (von Mollendorff, 1996).

2.12.1.1 Firmness measurement

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

2.12.1.2 TSS measurement

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

2.12.1.3 Fruit flesh colour measurement

Fruit flesh colour was measured using a Chroma Meter CR-400 tristimulus colorimeter (Konica, Minolta Sensing, Inc., Tokyo, Japan) in the CIElab colour space. Parameters L*, a* and b* were determined.

2.12.1.4 Titratable acidity determination

Lastly, the titratable acidity was measured 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 recently introduced destructive parameter is the soluble solid content/titratable acidity ratio (Crisosto and Crisosto, 2005). Acidity is determined 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 on peaches by Crisosto and Crisosto (2005) who use an Atago N-1E (0-32%) refractometer 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). Although these methods used to determine fruit properties have become popular, newer methods have been developed recently.

2.13 Alternative methods to determine fruit and vegetable properties

Popular methods to determine fruit and vegetable properties can be out-dated due to many 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 part 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 making them 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 infrared HSI in the spectral range 650-1000 nm.

Noh and Lu (2007) predicted firmness and soluble solid contents of apples using fluorescence images. While 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 for supplying with desired fruit to the right market at the correct timing.

2.14 Marketing of Peach Fruit

Produce marketing is a critical stage as insufficient marketing channels lead to fruits not being sold. Falguera *et al.* (2012) argued that markets for fresh and processed peach fruit have increased lately. Derivatives of processed peach have also become highly useful and are in great demands for not only low grades or damaged fruits but the whole production from the industry is 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 addition 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 an opening gap 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 increased 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.

2.15 Minimally Processed 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 i.e. without freezing or thermally induced preservation, 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, which in turn disrupts tissues during processing or storage. It has been identified by Gorny and Kader (1996) that cutting with a freshly sharpened knife extends the product storage shelf life. Spoilage cannot be ignored but needs attentions as it can increase the total amount of food lost.

2.15.1 Fresh cut peaches

The ripeness sufficient 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 landrace 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, AA has been combined with organic acids and calcium salts.

2.15.2 Dried peach leathe

Raab and Oehler (2000); Garden-Robinson (2012) found and explained that fruit leather is a nutritious, high-energy snack for the young as well as adults. These are easy to make at home, portable, good for schoolchildren and hiking or camping groups. Peaches are amongst the group of fruits, which are suitable for making leather; this group includes apples, apricots, cherries, plums, strawberries, tangerines, oranges, pears, grapes, pineapples, and tomatoes (Raab and Oehler, 2000). Moreover, 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). LJ or AA, honey, syrup or sugar can be used to enhance safety and quality of the dried leather products.

2.15.3 Canned peach fruits

Fruit and vegetable canning is one of the old methods used for storing perishable products during limited 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 usually regarded as less nutritious than fresh or frozen products, past research reveals this is not always the case. There is a huge variation due to effects of cooking, canning or freezing and these depend on commodity. Canning fruits cannot be separated from other processing methods. Fruit canning also has important quality parameters that may be better than other processing methods, such as freezing, drying and cooking.

2.16 Drying as a Food Processing Method

Value addition and preservation of fruit and vegetables can be performed using a number of ways. Pavan (2010) mentioned that drying decreases the content of water in the food product, which in turn restrains development of microorganisms and lessens degrading processes ensuring stability of product. It is one of the oldest methods of food preservations that has been used for centuries. Some perishable agricultural products have their shelf life extended when dried to desired moisture content and packed in sealed packaging. For this reason, developing countries need to further exploit this method.

2.16.1 Definition of Food Drying

Food drying is one of the cheapest value addition and preservation methods. Drying food 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. Moisture movement follows this 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 and shortest phase involves drying rate increasing with time and corresponding to the rising temperature of the product being dried, until equilibrium is reached at to which 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 is the slowing down phase and it corresponds to the evaporation of bond water.

2.17 Effects of Drying on Food

When food 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 is 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 leads 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.

As a preservation and value addition 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 addition apart from freezing and canning. It is convention 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 conduction of this study. When food is being dried, the composition and its properties are altered in related steps.

May and Perre (2002); Nassiri and Heydari (2012) conducted a study on the relationship between drying time, shrinkage, moisture content and temperature 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. 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. May and Perre (2002) found that during the drying process, air pockets partition into a porous medium and sugar content held in solution (Figure 2-2).

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 explore a number of drying techniques and one solar drying method will be selected based on its operational simplicity and used for the current study.

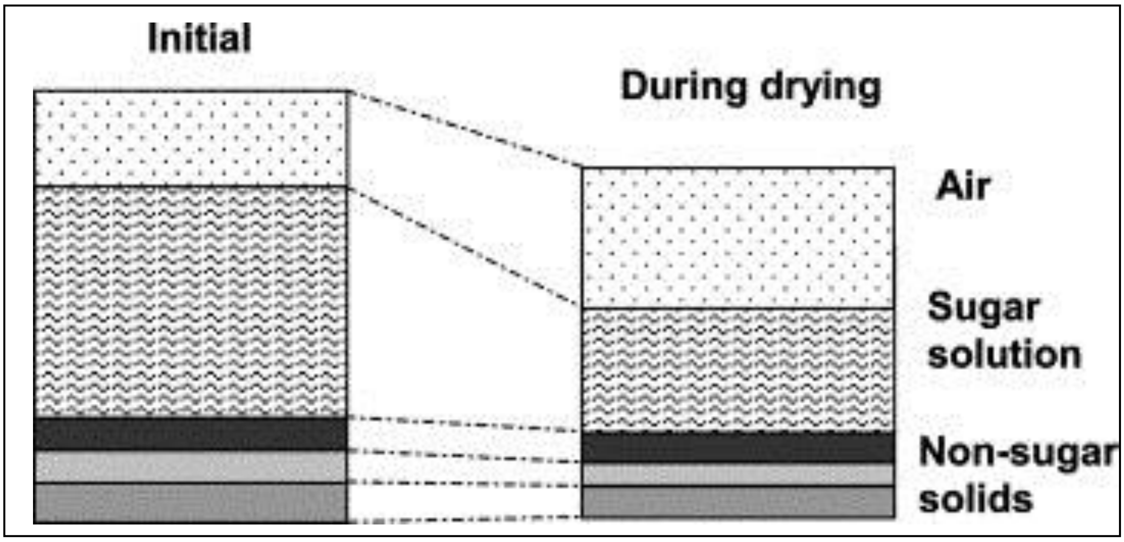

Figure 2-2 Diagram showing in a porous medium with sugar molecules held in solution at different volumes

2.18 Solar Drying Technology

A number of drying techniques are available and include the use of electricity and solar energy. 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 volatile 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 researchers (Karla and Bhuradwaj, 1981; Singh and Alam, 1982; Luz *et al.*, 1987, Das *et al.*, 2001). Figure 2-3 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).

It saves energy and time and it occupies less space compared to open-sun drying (Sharma *et al.*, 2009). The food bed is comprised of a double layer of chicken wire mesh with an open structure that allows dry air to pass through the food sample but prevents 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.

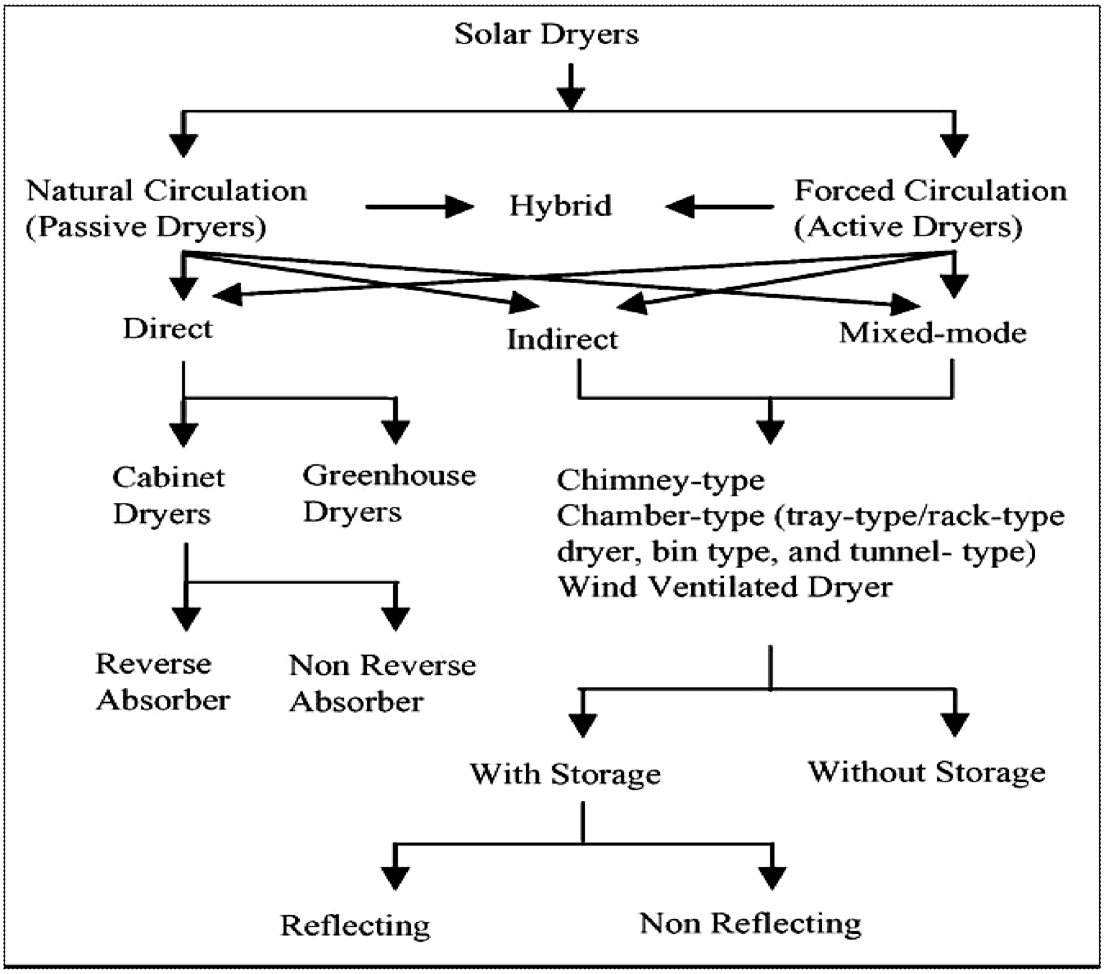

Figure 2-3 Diagram showing the classification of solar dryers

2.19 Selecting a Solar Dryer

Selecting a solar dryer relies on looking at a few simplicity aspects and availability to construct, operate and maintain. Chua and Chou (2003) elucidated that a food dryer's costs must be equitable with the value of the product being dried. The dryers that are to be used by rural farming industry should possess certain characteristics (Table 2-2) and these characteristics influenced by physical environmental parameters such as climate or weather. Similarly, these criteria were used to choose the type of a dryer to be used in the current study. Based on Table 2-2, a tunnel solar dryer with a score of 100% was selected as a suitable dryer for the study review.

Table 2-2 Table showing characteristics used for selecting a drier for rural farming

		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 (0)	✓ (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 %)	5 (95 %)	6 (100 %)

2.20 Tunnel Solar Dryer

Out of several drying techniques, a greenhouse dryer was selected as an economical dryer for the purpose of the current study review. Small-scale rural farmers can use it easily. Greenhouse solar dryers use the normal greenhouse structure, where the product is placed on trays (that receive the solar radiation through the plastic cover) while the moisture is removed by natural convection. There are passive and active as well a direct and indirect types of greenhouse tunnel solar dryers.

Figure 2-4 illustrate tunnel solar dryer. The roof of a tunnel/greenhouse dryer can be made using glass, fibreglass, 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 rainwater from 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 several conditions that affect its storability.

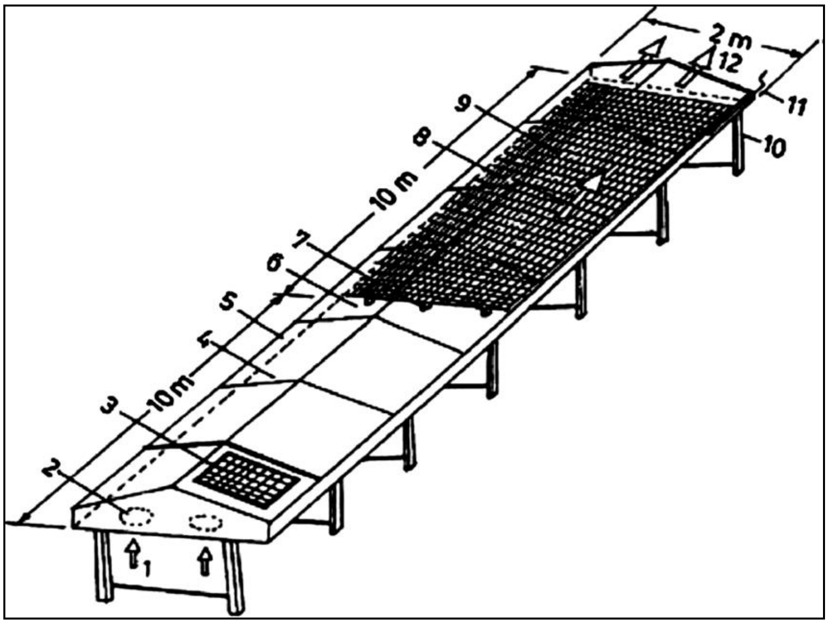

Figure 2-4 Illustration of solar tunnel drier (1) air inlet; (2) fan; (3) solar module; (4) solar collector; (5) side metal frame; (6) outlet of the collector; (7) wooden support; (8) plastic net; (9) roof structure for supporting the plastic cover; (10) base structure for supporting the tunnel drier; (11) rolling bar; (12) outlet of the drying tunnel (Kumar *et al.*, 2013)

2.21 Storability of Processed Crop Products

Once the products are minimally processed, they can be consumed immediately or they can be stored while awaiting consumption or further processing. Certain criteria is used to classify processed or fresh fruit product spoilage. This criteria includes assessment of colour, visual appearance, flavour, shape microbial load, nutrient retention, porosity, bulk density, rehydration ability, water activity texture, absence of contaminants, preservatives used, and no impurities and odours; these can be grouped into three classification groups displayed in Table 2-3 (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 does not comply with all the regulations stipulated. The spoilage of fruit is classified into two causes, those are abiotic, and biotic forces schematically represented in Figure 2-5 (Hui *et al.*, 2006).

Table 2-3 Table showing the classification of changes that occur during storage of dried food

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

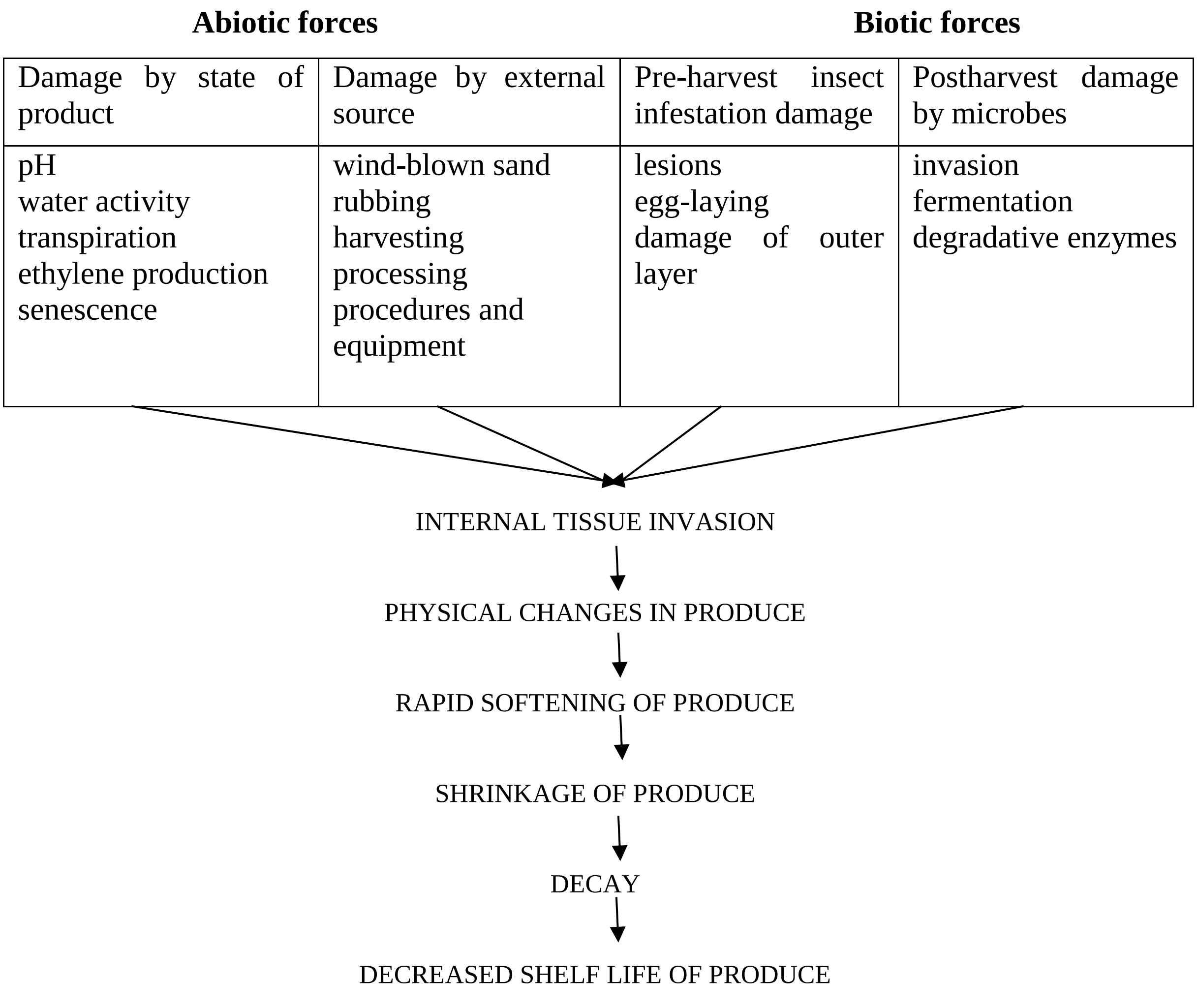

Figure 2-5 Diagram showing possible causes and factors responsible for fruit spoilage

Different products have varying shelf lives and thus require different packaging and storage conditions. Temperature, relative humidity and packaging play a significant 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 from different drying methods (tunnel, sun, freeze and vacuum). 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 titratable acidity increased significantly on freeze-dried powder, whereas there were no significant differences on the 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 a 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 3 months of storage, the AA 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 with the rubbery state 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. 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 essential 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 if 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 titratable acidity and highest in microwave. Maturity of product during harvest plays an important role to the future and shelf life of a processed product.

2.22 Impact of Maturity at Harvest on Product Storability

Maturity is a growth stage between a product that is ready to harvest and a product that is not yet ready to be harvested. The challenge is determining 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 where 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 and the liking scores dropped when the fruit was below a range between 10 N or above 45 N.

2.23 Alternative Sanitizing Products

Newer sanitizing methods have been developed that 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 (2012) reported that salicylic acid application, whether pre-harvest or postharvest, reduced fungal decay in sweet cherry, strawberry (Babalar *et al.*,2007); and peach fruit (Wang *et al.*, 2006). 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 was thus 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.

2.24 The Use of Chlorine in Processed Products for Improved Storability

Chlorine is one of the most popular sanitation products used to kill diseases, unwanted bacteria and fungi. There has been a growing concern about the use of chlorine related solutions to sanitize processed fruits and vegetables due to possible formation of carcinogenic chlorinated compounds in the water used to clean processed products (Rico *et al.*, 2007).

2.25 Discussion and Conclusion

Food losses have been identified as one of the contributing factors to hunger in developing and developed nations. The main cause in developing nations is the limitation of food storage facilities and value addition. Peach is a significant fruit commodity grown in the KwaZulu-Natal, but it is not receiving a clear recognition in agro-industry and processing. Therefore, postharvest losses of these fruit are very high, especially, in rural farming communities. The current study aims to focus on value addition to peach fruit. The aim of this review was to identify all contributing factors that affect the peach fruit processing as a method to add value and prolong the fruit shelf life. Internal and external fruit quality parameters were discussed in this Chapter. Methods and instruments used to measure quality parameters were discussed. Fruit properties discussed include TSS, TA, weight, firmness, colour, pH, density, fruit shape and size.

The review of literature has shown of the many different quality attributes and factors and that contribute to postharvest handling of fresh produce, including peach fruit. The nutritional content of peach fruit is what makes this fruit important for human consumption as it helps reduce the occurrence of some human diseases. The chemical, physical, mechanical and nutritional components all have important roles to play in ensuring that processed fruit quality attributes are considered and maintained at every step of value addition process in order to avoid the loss of these important quality attribute. Peach fruit was described as a fruit that is grouped together with fruits like cherries, plums and nectarines and classified as being climacteric. Fruit sorting, grading, packing and processing have a crucial role to play in postharvest because if one of these processes is not conducted with due process, the fruit quality will be compromised and eventually affect financial returns to all stakeholders involved in the process from the farm to the shelf.

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3. PHYSICO-CHEMICAL PROPERTIES OF SOUTH AFRICAN WHITE PEACH 'LANDRACE' PRODUCED BY SMALL-SCALE GROWERS

3.1 Abstract

Major postharvest losses are suffered by small-scale growers of white peach 'landrace' fruit due to limited indices for determining quality and protocols for postharvest handling. This study was conducted to identify physico-chemical properties that can be used as maturity indices of the South African white peach 'landrace'. Fruit was harvested from three homesteads, each with five marked trees. Homesteads were selected using a snowball sampling method. Harvested fruit was visually sorted (based on colour and size) into five maturity or ripening stages namely green, pale-green, whitish, pale-white and white; this was replicated three times. Maturity and ripening related parameters included days after full bloom (DAFB), mass, diameter, firmness, L*, a*, b*, hue angle, chroma, moisture content, total soluble solids (TSS), pH, titratable acidity (TA) and TSS:TA ratio determined. Fruit reached maturity 129 days after full bloom (DAFB) and this coincided with fruit mass, volume and moisture content at respective averages of 80.00 g, 66.10 cm^3, and 83%. Fruit firmness decreased significantly from 79.00 N to 24.70 N with increasing ripeness. TSS increased significantly from 13.50 to 19.00 °Brix during ripening. The pH value significantly increased from 3.40 to 4.00 indicating that acidity decreases with ripening. The TSS: TA ratio increased from 21.11 to 35.84. It was concluded that DAFB, firmness, mass, TSS, volume, TTS: TA ratio have potential to be used for maturity indexing of white 'landrace' peach fruit. This study provided baseline information for understanding changes in physico-chemical properties of white peach 'landraces' during maturation and ripening which can be used to plan harvesting time and schedule marketing to avoid postharvest losses.

3.2 Introduction

Peach (*Prunus persica* (L.) Batsch) growth, development and ripening are continuous critical processes that involve complex series of chemical and biochemical changes that occur in four categorical steps (Lombardo *et al*. 2011). The first exponential stage is characterized by rapid cell division, growth and elongation (the stage is known as S1). During the second stage, the endocarp (inner core) hardens to form the stone and during this stage size does not increase (the stage is known as S2). At the third stage, the second exponential phase takes place. It is characterized by fruit size increase and cell division (this stage is described as S3). The final stage, S4, stage is subdivided into S4-1 and S4-2 stages. S4-1 involves the fruit reaching the final size and S4-2 is when the fruit enters into a ripening process. This ripening process (also described as the climacteric stage) is ethylene dependent, and it continues to ripen when detached from the tree (Trainotti *et al*. 2003; Borsani *et al*. 2009; Dardick *et al*. 2010; Lombardo *et al*. 2011).

Peach ripening is a complex process with many concurrently occurring physiological and biochemical changes such as starch and chlorophyll degradation, biosynthesis of volatile compounds and pigments, accumulation of sugars and reduction of acids and modification of cell walls (Prinsi *et al*. 2011). This means that the ripening of peaches cannot be determined by a single parameter (Shinya *et al*. 2014). Peaches have a very short shelf-life potential because of a rapid ripening process. This results in a limited period during postharvest handling (Cano-Salazar *et al*. 2013). To harvest the peach at the correct period and handle it properly, a clearly understanding fruit maturity, ripeness and postharvest quality parameters is needed, as they are complex and interrelated. They need to be considered as inseparable mutually dependent parameters.

Fruit and vegetables can be harvested either at physiological maturity or at horticultural maturity, depending on the intended use of produce and shipping distances. Physiological maturity is the development stage when a plant continues ontogeny even if picked from the tree (Kader 1999). Consumers or processors on the other hand define horticultural maturity as a stage of growth when a plant possesses the primary attribute for utilization for special purposes (Kader 1999; Wills *et al*. 2013). Peach fruit has different stages of maturity depending on its intended use (Wills *et al*. 2013). 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 *et al*. 1972). The maturity standards vary according to variety of environmental conditions during fruit production and postharvest handling (Badiyala and Awasthi 1990).

Maturity indices are determined by sensory methods (flavour, colour, aroma, texture); adequate postharvest shelf life; scheduled picking and packing operations and proper marketing (Dhatt and Mahajan 2007). A clear understanding of maturity is critically important and interconnected to ripening process. Fruit ripening is greatly influenced by physiological maturity state of the fruit at harvest (Ferrer *et al*. 2005). Fruit harvested immature are susceptible to shrinkage, whereas fruit harvested at an over-mature stage are likely to be soft and to perish faster than usual (Ferrer *et al*. 2005). One of the challenges in the peach industry is the segregation of fruit with different ripening stages during picking because of a long period of flowering that takes place in peach (Shinya *et al*. 2013). Many different maturity indices such as flesh colour, firmness, and background colour (Crisosto and Valero, 2008; Infante, 2012; Slaughter, 2013), texture Prinsi (2011), ground skin colour (Shinya *et al*., 2013), total soluble solids (TSS), titratable acidity (TA), TSS: TA ratio and mass change (Ferrer *et al*., 2005) have been used to determine peach ripeness. These indices, however, vary with each landrace. Therefore, each landrace must be understood clearly in reference to consistently affected parameters during ripening so they can be incorporated to the maturity indices for that landrace.

Peach firmness, mass, TSS, pH, colour and volume are some of the most used indices in the determination of quality of fresh peach fruit (Kader 1999). Although, most of this information is available for many commercial peach varieties there are no records available for the Impendle peach ‘landrace’ grown by small-scale farmers of KwaZulu-Natal, South Africa. The Impendle scenario is no exception to a case reported by Sutasinee *et al*. (2005) about Vietnam, whereby local peach fruit with other temperate fruit crops are being grown.

Impendle small-scale peach growers rely heavily on their fruit for vitamin A. However, the biological productivity and postharvest quality once remained an issue, which is being addressed. The farmers at Impendle suffer major postharvest losses due to lack of practical maturity indices for determining quality, maturity and ripeness of the fruit. It is mandatory for farmers to understand Impendle ‘landrace’ peach to follow proper handling procedures. Major postharvest losses are currently experienced by these farmers because of limited understanding of protocols for postharvest handling. A clear understanding of the fruit behavior in terms of firmness, mass, pH, colour, and size would play a role during ripeness and postharvest handling. The small-scale farmers’ peach is very important and much appreciated for providing nutrition to the communities in South Africa. A better understanding of properties of the indigenous peach fruit (Impendle white clingstone ‘landrace’) with respect to its maturity and ripening processes would reduce these losses and improve health and wealth of the impoverished rural people. To address challenges of peach growers at Impendle, it is imperative to establish a clear understanding of peach landraces dynamics for growing, effective cultivation practices, harvesting and postharvest technology. The data generated from such studies can be used to develop appropriate technologies suitable for the produce final product development. Therefore, the aims of this study were to evaluate physico-chemical properties related maturity and ripening which can therefore be used as harvesting indices for indigenous white flesh clingstone peach ‘landrace’.

3.3 Materials and Methods

3.3.1 Site description

The site was located at a small-scale peach farming community in Impendle, South Africa (29°37’04.09”S; 29°51’23.8”E) Figure 3-1.

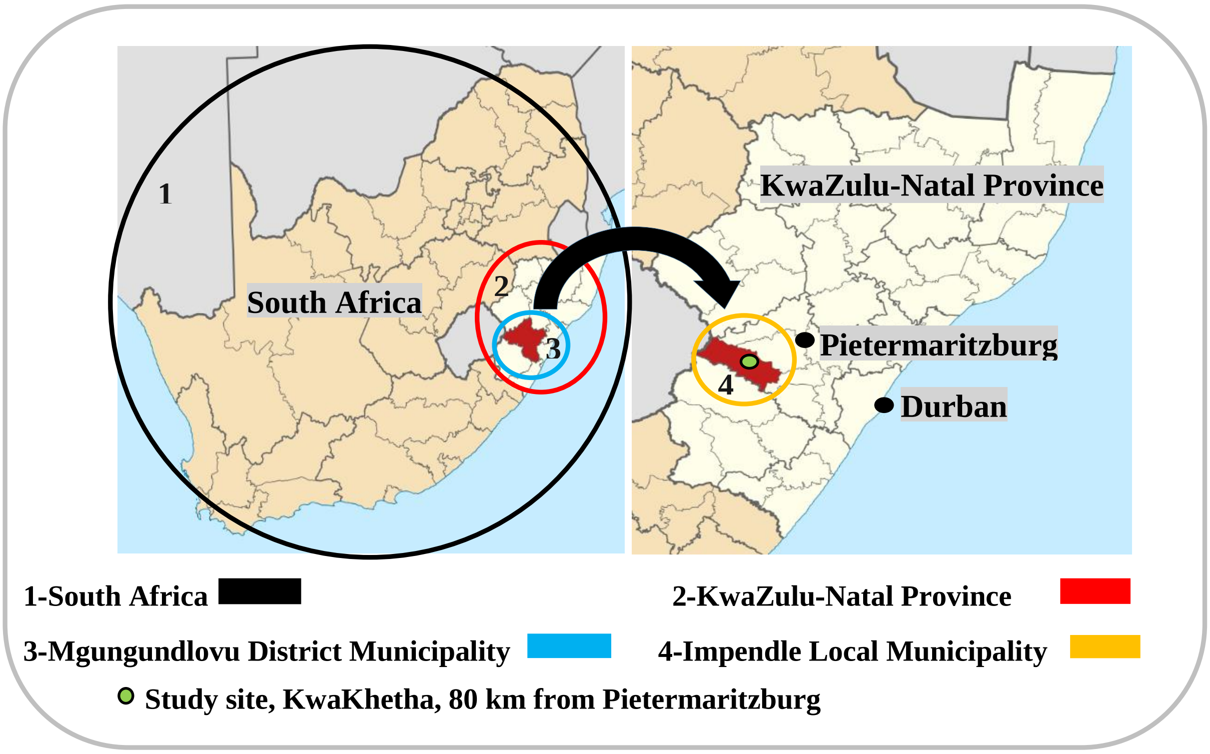

Figure 3-1 Map of Impendle Local Municipality, under UMgungundlovu District Municipality in the province of KwaZulu-Natal, South Africa (Camp, 1999)

The area is located at an elevation of 1420 m above sea level, with annual average temperature ranging between 12 and 16°C, characterized by 800 – 900 annual average chilling units (CU) (Camp, 1999). The soil type is acidic, red-yellow freely drained apedal (Camp, 1999). The peach crop used in the study depends on rainfall, which ranges between 1000 and 1100 mm per annum, no irrigation, pruning, fertilizer or pesticide treatments are used to improve tree productivity.

Farmers use cow manure only at seedling transplanting. The trees are planted in one row per homestead, with intra row spacing ranging between four and six meters. Generally, homesteads have several trees varying from one to 40, depending on the family size and period spent as residents in the area. The trees used in the study ranged between 8 and 12 years old, branches and leaves average at 1.50 m above the ground and trees grow up to 3.50 m tall.

3.3.2 Experimental plan

Experimental plan was to assess postharvest quality parameters of fruit produced under biologically controlled environment, without pest control, inorganic fertilizers or irrigation water. Three homesteads were selected using a snowball sampling method, and due to limited budget, logistics and time restrictions, five trees were marked per homestead and the fruit was harvested all around the tree to obtain samples representing the whole tree north, south, west and east facing side and from the bottom to the top.

The experiments were carried out during 2014/15 harvesting season. Fruit from homesteads that contained biologically produced fruit were harvested and these were selected by determining chilling units using a method that was used by Camp, (1999). In addition, the part of the area with the largest chill units was selected for the study. Based on that, trees were selected according to the number of trees per homestead; no homestead with trees less than 10 was selected. White flesh clingstone peach ‘landrace’ was used in the study since it is the most popular and available in the area. Three hundred fruit were tagged at full bloom and quality was being determined to tell how many days to maturity from full bloom. Fruit were harvested from three homesteads on five marked trees per homestead. Fruit that had tags for days after full bloom in the trees were used as reference for harvesting by comparing tested parameters of tagged fruits with fruits harvested for the study. The fruit were harvested manually once in a bulk randomly and packed in cooled boxes, transported to the laboratory and sorted by size using vernier calipers and colour using a calorimeter classification according to AOAC (1990) into different five colours as mature-green (1); pale-green (2); whitish (3); pale-white (4); and white (5) and three replications. Large and small fruit were discarded and only medium size fruit were used in the study in order to reduce data variation and statistical nuisance. It was graded according to blemish free, size, shape and colour. Each homestead was treated as a replication. After sorting and grading, fruit were pre-cooled to 5°C and stored at 90% relative humidity (RH) for 24 hours before conducting the experiments. Peaches were then removed from the cold room and allowed to reach a room temperature of 20°C. Five fruit from each degree of ripeness (replicated three times) were selected resulting in 15 fruit per measurement of each fruit parameter described and results recorded, grouped into three replicates and all 15 individual readings were used for statistical analysis for all parameters measured. The measured parameters were mass, colour, firmness, size, moisture content, TSS, pH and TA. Measurements were conducted in a controlled laboratory condition at 20°C.

3.3.3 Physical quality analysis

3.3.3.1 Fruit mass

Individual fruit mass was determined at each degree of ripeness by objectively and non-destructively measuring the mass using a balance scale (Model: Mettler PJ 300, Switzerland) with a ± 0.0001 g accuracy.

3.3.3.2 Fruit colour

Colour was determined using a Hunter Lab Color Flex EZ Spectrophotometer (Model: 45/0 LAV, Reston, VA, USA) that measured the CIE L*, a* and b* of the peach fruit colour attributes (Pathare *et al*. 2013). The instrument was calibrated each day using a standard white tile that had the following readings: L* = 94.0, a*=1.1, b* = 0.6.

3.3.3.3 Fruit firmness

The fruit firmness was determined destructively, using a 7.9 mm probe moving at a 60 mm/min speed and a penetrating depth of 8 mm into the flesh, after the skin was removed by scalpel (Chen and Opara 2013). The Instron Universal Testing Machine (Model: 3345, by HIS Engineering 360, USA) was used to measure peach firmness. Five fruit of each degree of ripeness were selected and measured for firmness. Two opposite sides on the equatorial face of each fruit were punctured and 10 readings were recorded per degree of ripeness. The penetration force results were expressed in Newtons (N).

3.3.3.4 Fruit volume

Fruit dimensions were measured by determining two readings with the longitudinal dimension (L) referred to as the length and the average of two readings measured perpendicular to the length as the diameter (D). A vernier calliper (Mitutoyo, Kawasaki, Japan) with a precision of ± 0.01 mm was used to measure fruit dimensions. Five fruits replicated three times were selected from each degree of ripeness and average L and D were determined for each degree of ripeness. The fruit volume could then be calculated using Equation (1) (Al-Yahyai *et al*. 2009).

$Fruit\ Volume = 4^{-3} \times \pi \times r^3$ (cm^3) Equation (1).

Where r is the average of the fruit radius of the fruit diameter and length sections (cm).

3.3.3.5 Fruit dry matter content

Dry matter content was measured from five selected fruit samples per degree of ripeness. A 10 g sample of the sliced 2 mm thick peaches was dried in the oven for six hours at 70°C. Thereafter, mass was determined every 2 hours until a constant mass was reached. Finally, dry matter was calculated as a percentage dry mass of the initial fresh weight (Chen *et al*., 2009).

3.3.4 Chemical quality analysis

3.3.4.1 Total soluble solids

The measurement of total soluble solids was carried out using a thermo-compensated refractometer (Atago, Model PR-1, Tokyo, Japan) with a precision of ± 0.1% °Brix (Magwaza *et al*. 2013). Peach juice was extracted using a household blender that was used to slice the fruit into smaller pieces. A muslin cloth was used to squeeze juice into a 50 ml glass beaker, which was then extracted for analysis using a 5 ml pipette. Two drops of the juice were placed on the refractometer prism, readings were recorded, and this was replicated three times per fruit sample while ethanol was used to clean the prism after each measurement.

3.3.4.2 Fruit pH and titratable acidity

The measurement of peach fruit pH was carried out using a laboratory benchtop digital pH-meter (Hanna Instruments, Johannesburg, South Africa) according to the method described by (Shinya 2014). Titratable acidity of the juice was determined by titration with sodium hydroxide (NaOH) (0.10 N) to pH 8.10. The results were expressed as percentage malic acid as presented in Equation (2) (Ferrer *et al*. 2005; Chen and Opara 2013; Al-Yahyai *et al*. 2009).

$TA = titre\ (ml) \times acid\ factor\ \times$ (10 ml juice)/100, $malic\ acid$: 0.0067   Equation (2).

3.3.5 Statistical analysis

Statistical analysis was carried out using the GenStat 14th version for the analysis of variance (ANOVA) for each of the three replicated five degree of ripeness parameters measured. Significant differences were set at the 5% level ($p < 0.05$), and a multiple range Tukey's test was used to separate means.

3.4 Results and Discussion

Fruitlets marked after full bloom to determine the number of days to maturity resulted in fruit reaching maturation at 129 days with a constant mass average of 80 g and average volume averaged of 53 cm^3. This is within a range of 70 to 130 days reported by Sutasinee *et al*. (2005) for fruit development after full bloom to maturity. It was concluded that the fruit reaches maturity and starts ripening at 129 days after full bloom. This is one of the parameters that can be used by small peach growers to estimate the harvest dates for their peach crop.

3.4.1 Fruit mass

Ass seen in Figure 3-2 fruit mass varied significantly ($p < 0.001$) between the different degrees of ripeness. No major differences in mass were noted between green, pale-green, pale-white and whitish degrees of ripeness at $p < 0.05$ level of significance. However, white degree of ripeness was the most significantly different from all other degrees of ripeness and had the highest mass. These results echo those previously reported by Dejong and Goudriaan (1989) and Shinya *et al*. (2014) who reported that the riper the peach fruit, the greater the mass. Our results confirmed that mass can be used to estimate how far the fruit has grown, since mass increased with maturity. Mass can be incorporated as a maturity index for peach fruit. No major significant difference were noted during the transition from green to pale white due to reasons such as close related peach landrace, no treatments to induce differences were applied at the beginning of the season.

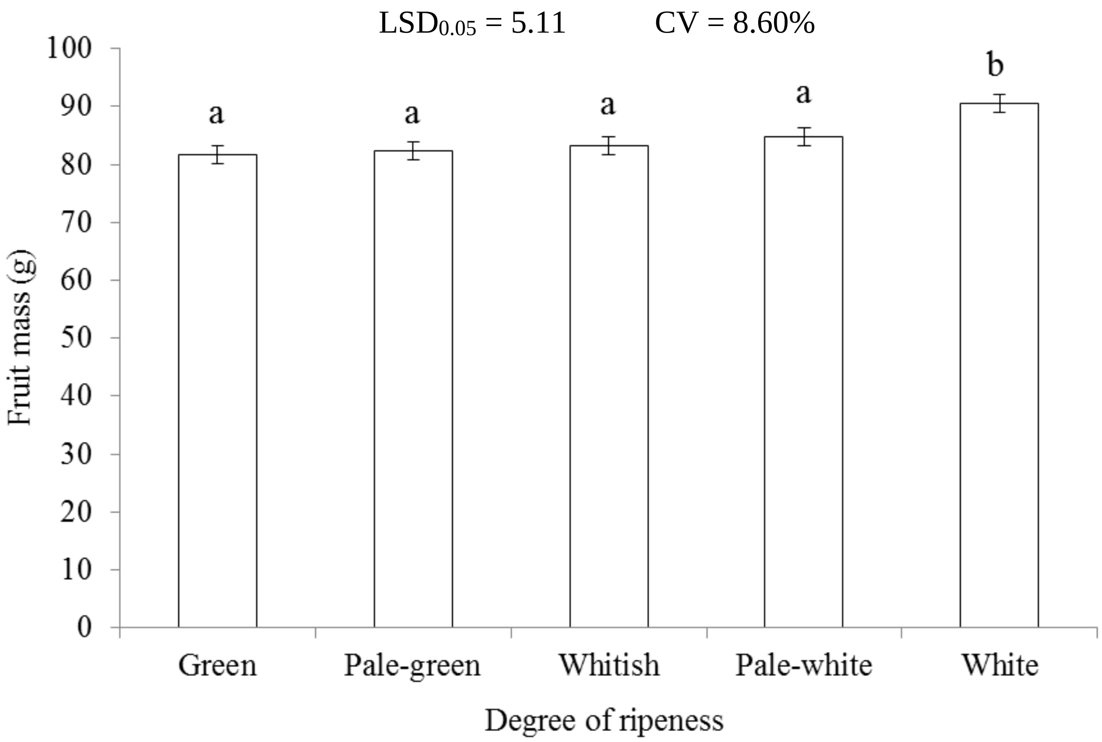

Figure 3-2 Fruit mass determined between five degrees of ripeness for the white Impendle peach 'landrace'. Error bars represent standard error of the mean, $LSD_{0.05}$ is least significant difference at 5% level of significance and CV is co-efficient of variation

3.4.2 Fruit colour

3.4.2.1 CIELab coordinate, L*

The results for fruit peel colour lightness are presented in Table 3-1. The chromatic scale lightness (L*) had no statistically significant differences ($p < 0.05$) in all five degrees of ripeness although it showed signs of increasing from green to white. It is evident that the L* values were increasing from mature green to white. Forcada *et al*. (2014) concluded after determining peach and nectarine in 90 landraces that L* ranges between a minimum of 10.6 and a maximum of 76.80 for the *Prunus persica* (L.) Batsch. The L* values of the current study averaged at 61.40 including green and white fruit colours and within the range found by Forcada *et al*. (2014). However, L* cannot be used conclusively as a parameter to determine ripeness for the white peach of a small-scale grower since slight insignificant changes take place.

3.4.2.2 **CIELab coordinate, a***

The results of greenness/redness (a*) are presented in Table 3-1. The CIELab a* coordinate showed statistically significant differences ($p \leq 0.05$) with an average of 5.54 value. The value of a* at mature green degree of ripeness was the highest and decreased from mature green to pale-green. The a* value increase from pale green to whitish, then decreased from whitish to pale white and increased from pale white to white. There was no clear stable trend between degrees of ripeness from mature green to white, as the value of a* change varied. Overall, the value decreased from mature green to white. However, the differences do not have a trend that can be followed when determining the ripeness of the peach 'landrace'. Prinsi *et al*. (2011) reported an increase in colour index 'a*' whereby it increased from -7.32 to 4.58. The current study findings were not congruent to those reported by Prinsi *et al*. (2011). Orazem *et al*. (2013) suggested that the use of a* value as a suitable maturity index, since this is the colour coordinate that changes the most during maturation. Ferrer *et al*. (2005) and Herrero-Langreo *et al*. (2011) also reported that CIELab coordinate a* changes linearly during peach maturation. Due to an unstable trend, conclusively the colour index a* parameter is not a clear parameter that can be used to determine ripeness, based on the current study results. It was used to calculate hue angle and the Chroma in the study.

3.4.2.3 **CIELab coordinate, b***

The results of blueness/yellowness (b*) are presented in Table 3-1. Chromatic scale b* showed statistically significant differences ($p \leq 0.05$). The b* values increased from green to pale green, from pale green to whitish, from whitish to pale white and lastly from pale white to white. Evidently there was an increasing trend of b* as the ripening increased.

Table 3-1 Table showing L*, a* and b* chromatic scales of five different degree of ripeness for white Impendle peach 'landrace'

Degree of ripeness	**L***	**a***	**b***
Green	60.86^{a}	9.49^{b}	34.64^{a}
Pale green	61.32^{a}	3.33^{a}	37.48^{ab}
Whitish	61.36^{a}	6.62^{ab}	39.60^{ab}
Pale white	59.41^{a}	2.92^{a}	39.99^{b}
White	63.13^{a}	5.36^{ab}	40.36^{b}
Grand mean	61.40	5.54	38.41
F Prob. (5%)	0.84	0.03	0.11
LSD (5%)	8.49	4.26	4.74
CV	10.50%	58.20%	9.40%

Different letters denote statistically significant differences in parameters by Duncan's multiple range test at $P < 0.05$ among different ripeness degrees.

Forcada *et al* (2014) found a range of b* between 8.90 and 69.10 values and the current study b* values averaged at 38.41 in the explained ranged. With such an increasing trend, it is clearly a sign that as b* increases the fruit ripening process also continues and therefore conclusively, this is one of the parameters that can be determined for the small-scale growers fruit in order to determined maturity or ripening stage of the fruit.

3.4.2.4 **Hue angle**

Table 3-2 displays the results of lightness's (hue) angle. Hue angle in white peach landrace did not show significant differences ($p > 0.05$). It started small (at 37.93) at green and increased in pale green peach (40.53) and showed significant decrease as the peach matures and changes to white. However, the trend is not smooth but has some inconsistency. This makes it uneasy to be a reliable parameter that can be used as a maturity index for the white peach landrace grown by small-scale growers in South Africa. However, the current study result averaged at 39° for the hue angle and this is comfortably within a range of 16.90 and 91.40 as described by Forcada *et al* (2014). In the current study, the challenge was that hue angle never showed conclusive results since no trend was specified for differences between different ripeness degrees.

Table 3-2 Table showing hue angle of peach fruit harvested at five different degrees of ripeness

Degree of ripeness	**Hue Angle (°)**
Green	37.93^{ab}
Pale green	40.53^{c}
Whitish	36.91^{a}
Pale-white	39.85^{bc}
White	39.78^{bc}
Grand mean	39.00
F Prob. (5%)	0.025
LSD (5%)	2.17

Different letters denote statistically significant differences in parameters by Duncan's multiple range test at $P < 0.05$ among different ripeness degrees

3.4.2.5 **Chroma**

The results on peach Chroma are presented in Table 3-3. There were no significant differences in Chroma ($p > 0.05$). The Chroma average value of 81.6 was slightly above the range of 25.3 – 80.6 described by Forcada *et al* (2014). There were no relationships between the Chroma of the different ripeness degrees. Chroma, therefore, is not a useful tool for determining ripeness stage in small-scale peach grower's crop. The lack of significant differences could be related to this crop being a white variety. Whereby, there are less activities related to ground colour changing, red and orange components that take place in yellow peaches (Brovelli *et al*. 1998).

Table 3-3 Table showing chroma of peach fruit harvested at five different degrees of ripeness

Degree of ripeness	**Chroma**
Green	79.26^{a}
Pale green	79.82^{a}
Whitish	82.14^{a}
Pale-white	83.24^{a}
White	83.69^{a}
Grand mean	81.60
F Prob. (5%)	0.025
LSD (5%)	6.80

Different letters denote statistically significant differences in parameters by Duncan's multiple range test at $P < 0.05$ among different ripeness degrees

3.4.3 Fruit volume

There were statistically significant differences in fruit volume ($p < 0.05$) in all five different degrees of ripeness (Table 3-4). The fruit volume increases from 53.30 to 66.10 cm^3 during ripening this could be linked to cell development taking place at a later stage after cell division has taken place in the early growth stages. This was a trend noticed as the fruit ripened and could be linked to the fruit mass increase.

Table 3-4 Table showing fruit volume of five different degree of ripeness for the white Impendle peach 'landrace'

Degree of ripeness	**Volume (cm^3)**
Green	53.30^{a}
Pale green	53.90^{ab}
Whitish	55.30^{a}
Pale-white	47.40^{a}
White	66.10^{ab}
Grand mean	55.20
F Prob. (5%)	0.07
LSD (5%)	12.48

Different letters denote statistically significant differences in parameters by Duncan's multiple range test at $P < 0.05$ among different ripeness degrees

Previous study results have shown that fruit volume is important to determine as it can help improve the monitoring of growth rate, set precedent for the quality standards especially for fresh produce as well as increase the market value of the produce (Khojastehnazhand *et al*., 2008). The volume of fruits is also important for the determination of possible yields, packaging planning and transportation, assessment of irrigation and fertilizer applications (Tabatabaeefar and Rajabipour, 2005; Khojastehnazhand *et al*., 2008). The current study results were congruent with results reporting the importance of fruit volume in determining growth rate and stages of growth.

3.4.4 Percentage moisture content

The moisture content percentage averaged at 83%, (Table 3-5) for five different degrees of ripeness but showed no statistically significant differences ($p > 0.05$). This parameter could not be linked to ripeness of peach fruit. However, in a research report of a study by Lopez *et al* (2011), it was reported that fruit that receive no irrigation consists of high dry matter content compared to those that received irrigation in a comparative study. The same could apply in the current scenario, Impendle peach receive no irrigation and hence they could all have high dry matter content and thus no differences regardless of different ripeness degrees.

Table 3-5 Table showing percentage moisture content of five different degree of ripeness for the white Impendle peach 'landrace'

Degree of ripeness	**Moisture content (%)**
Green	85.00[a]
Pale green	84.00[a]
Whitish	82.00[a]
Pale-white	82.00[a]
White	82.00[a]
Grand mean	83.00
F Prob. (5%)	0.72
LSD (5%)	6.56

Different letters denote statistically significant differences in parameters by Duncan's multiple range test at $P < 0.05$ among different ripeness degrees

3.4.5 Fruit firmness

Fruit firmness showed highly significant differences ($p < 0.001$) (Figure 3-3) with a clear trend being evident as the fruit firmness changed from green to whitish ripening stages and could be used as a good indicator of ripeness in white peach 'landrace'. Fruit firmness decreased during the change in ripeness from 79.00 N for the green to 24.70 N force requirements to penetrate to the depth of 8 mm for the white stage.

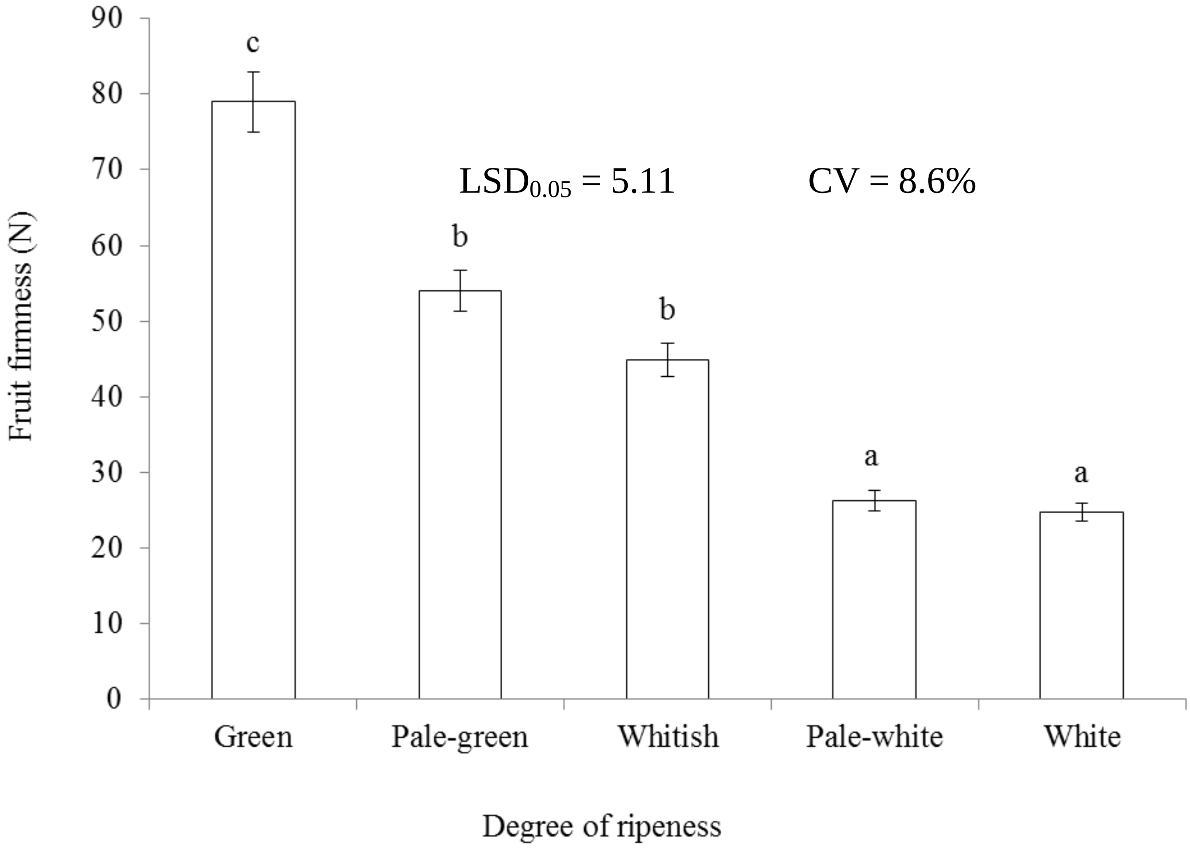

Figure 3-3 Fruit firmness at five different degrees of ripeness for the white Impendle peach 'landrace'. Error bars represent standard error of the mean, $LSD_{0.05}$ is least significant difference at 5% level of significance and CV is co-efficient of variation.

This was a clear trend, which evidently showed constant decrease in fruit firmness as the ripeness degree changed from green to white, and this may be related to abscisic acid that develops and digest cell walls of the fruit and thus making it soft. Prinsi *et al*. (2011) reported results on a study on peach firmness measured on unripe and ripe fruit, and the conclusion was that firmness decreases with ripeness from unripe to ripe stage. However, when the fruit is too soft, the needle is less sensitive (Shinya *et al*. 2014). The results obtained from this study were congruent to Prinsi *et al*. (2011) and Shinya *et al*. (2014). With such congruency with literature, current study results do confirm that the fruit firmness is an important quality attribute to use in determining the ripeness stage in peach fruit.

3.4.6 Total soluble solids

Total soluble solids were significantly different ($p < 0.05$) ranging from the green to the whitish degrees of ripeness with the pale green fruit having a lower TSS (13.5 °Brix) than white fruit (19.0 °Brix) (Figure 3-4). Cascales *et al*. (2005) reported study results whereby TSS increased from 11.5 to 13.1 °Brix. Prinsi *et al*. (2011) reported their study results of peach TSS was determined at two different ripening degrees, where there was a significant increase in TSS levels from unripe to ripe. It can be confirmed that the small-scale grower's peach confirms that TSS increases during peach ripening (Brovelli *et al*. 1998).

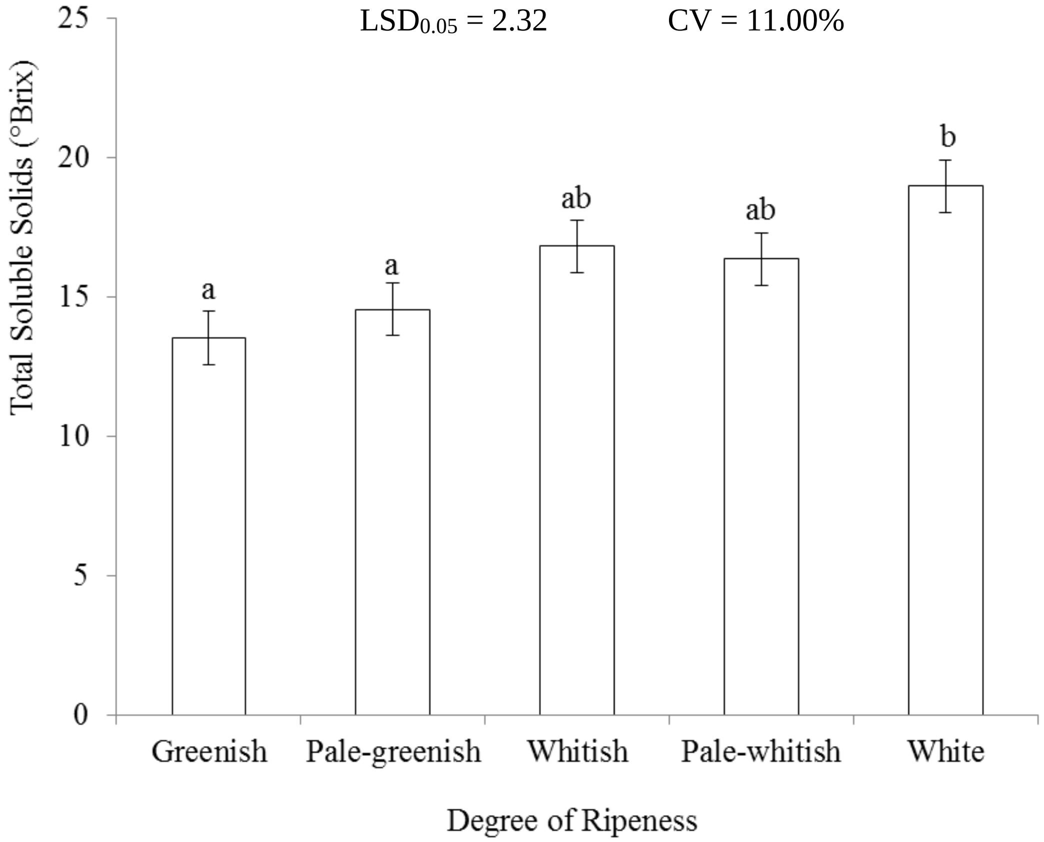

Figure 3-4 Total soluble solids of five different degrees of ripeness for the white Impendle peach 'landrace'. Error bars represent standard error of the mean, $LSD_{0.05}$ is least significant difference at 5% level of significance and CV is co-efficient of variation.

3.4.7 Fruit pH and titratable acidity

The fruit pH (Figure 3-5) showed statistically significant differences ($p < 0.05$) in pulp pH ranging from 3.4 in pale-green to 4.0 in whitish fruit. Both green and pale-green pH had statistically significant differences from whitish with an LSD = 0.36 and grand mean =3.6. There were no significant differences ($p > 0.05$) on titratable acidity and the average for different degrees of ripeness was 0.63% malic acid. Cascales *et al*. (2005) reported a decrease of malic acid from 0.68% of the unripe fruit to 0.58% to the ripe fruit, whereas, in the current study, malic acid remained constant in all five degrees of ripeness. The study on peach ripening, conducted by Prinsi *et al*. (2011) showed an increase in juice pH from unripe to ripe peaches, which the current study has also proven and congruent results have been recorded. The current study results also showed that with transition of maturity degrees from mature-green to whitish, the pH increased significantly.

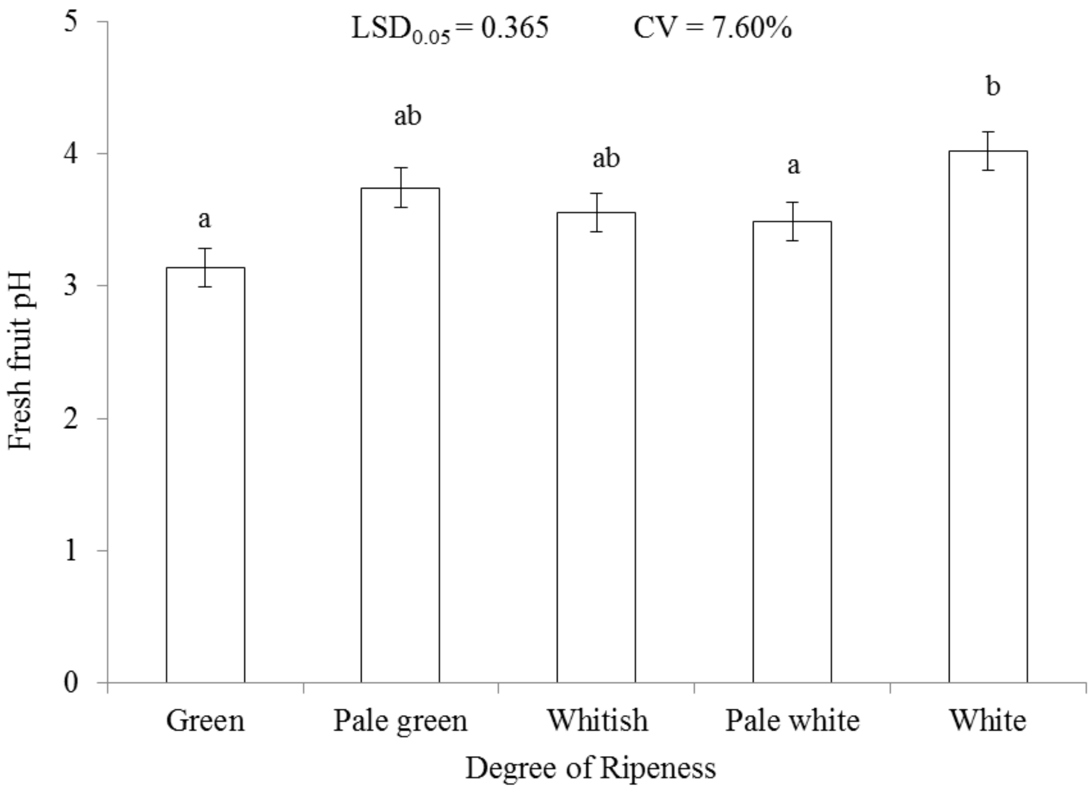

Figure 3-5 Peach fruit pH determined at five different degrees of ripeness for the white Impendle peach ‘landrace’. Error bars represent standard error of the mean, $LSD_{0.05}$ is least significant difference at 5% level of significance and CV is co-efficient of variation.

3.4.8 TSS: TA Ratio

Peach TSS: TA ratio was determined (Figure 3-6) and showed that the ratio was increasing with maturity. However between green, pale green, whitish and pale whitish, there were no statistical significantly differences, even though there was an increasing trend. White peach had the highest ratio and significantly different from all other degrees of ripeness. The increase ranged between 21.11 and 35.84 and this increase is almost related to an increase previously reported by Cascales *et al*. (2011), in which TSS: TA ratio ranged from 19.77 to 38.17. Magwaza *et al*. (2015) reported that TA, TSS and their ratios have a considerable variation during maturation thus are not reliable to give proper indexing because of non-static ratios. The current study findings showed an increasing trend when it comes to TSS: TA ratio. However, the study showed that the increase is much more dependent on increasing TSS values, which increase with increasing maturity, and values of TA that decrease with decreasing ripeness from green to white (Figure 3-6). However, with an increased ratio for the whitish mature, since there is a lack of constant trend, the ratios cannot be used reliably to index maturity in peaches. The increasing ratio of TSS: TA can be linked to a reduction of acidity and increasing °Brix and when expressed as a ration the denominator decreases while the numerator increases.

Magwaza and Tesfay (2015) and Woolf *et al*. (2003) argued that in order to establish reliable maturity indices for deciding when to harvest a fruit, some measurable quality attributes must change during fruit development and maturation. A classic example of such change observed in this study is the gradual increase in soluble solid content and TSS: TA ratio and a decline in firmness as fruit matures. This indicated that the quality parameters could be used as indices for maturity of white-flesh peach ‘landraces’. Considering that smallholder farmers usually have limited access to instruments for measuring these parameters, days after full bloom is the cheapest option for determining maturity.

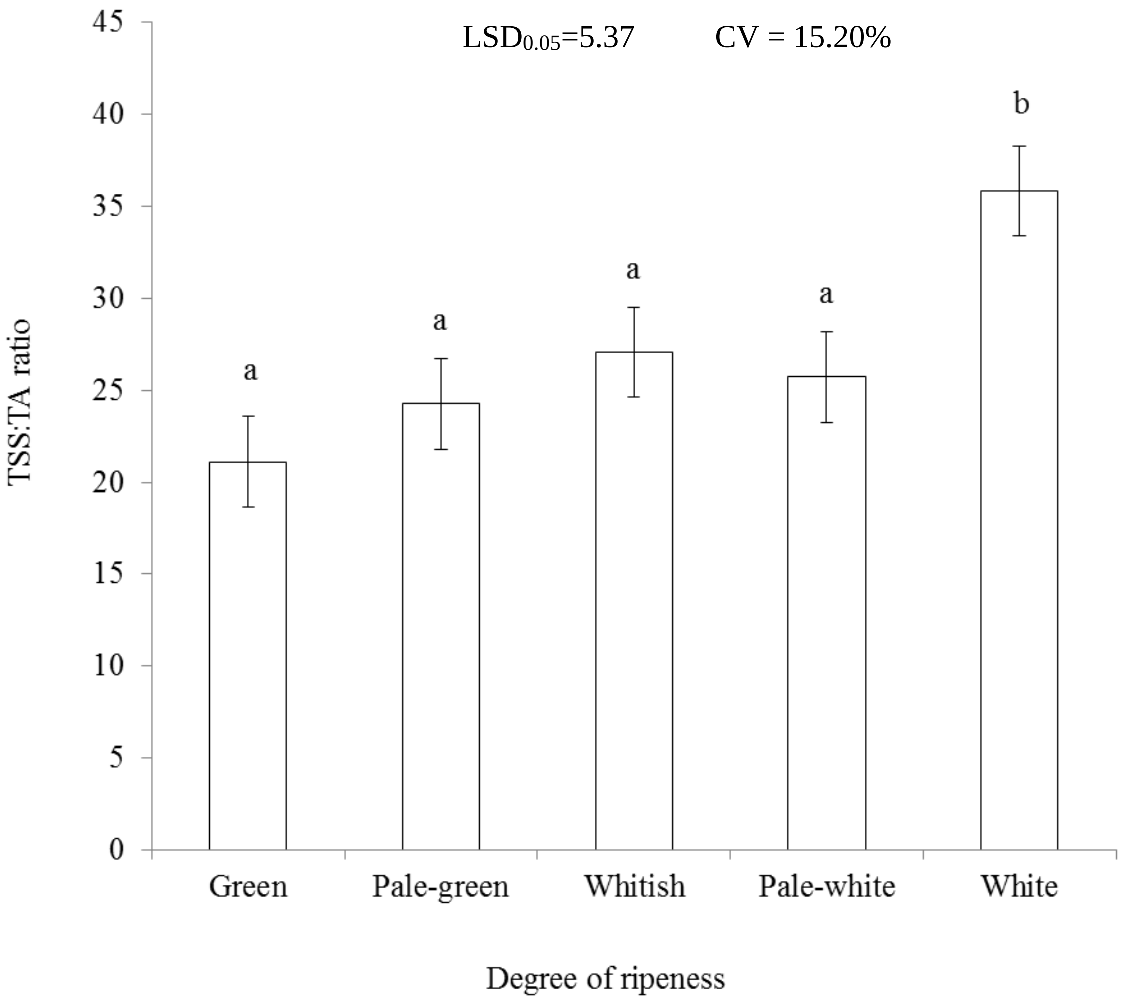

Figure 3-6 TTS: TA ratio of white clingstone peach 'landrace' at different degrees of maturity or ripeness. Error bars represent standard error of the mean, $LSD_{0.05}$ is least significant difference at 5% level of significance and CV is co-efficient of variation.

3.5 Conclusion

The determination of peach fruit mass, volume, b*, TSS, pH and TSS: TA ratio showed statistically significant differences ($p < 0.05$) during ripeness from green to white. The colour of the fruit determined hue angle and chroma did not come out clearly or with a noticeable trend that can be used in determining the fruit ripening stage, this result was not conclusive in determining peach ripeness. The fruit pH also show a significantly decreasing trend ($p > 0.05$) during fruit ripening, as was determined in all five degrees of ripeness, showing as increase during ripeness. However, the role of determining TSS is crucial, since there is a steady increase as the fruit ripens. During the determination of fruit sugar to acid ratio, there was an increase in the acid ratio, which can be used as an indication of 'landrace' ripeness. Fruit firmness showed a clear trend of a steady decrease as the fruit ripened from green to whitish degree of ripeness. The fruit starts hard at green mature stage and get very soft at white mature stage. However, the use of firmness as a quality indicator, could slightly be linked with the use of a* CIELab coordinate during ripening. Generally, the firmness decreased while the other quality attributes such as mass, TSS, 129 DAFB volume, and TTS: TA ratio increased and hence have an important role to play as parameters that can be used to indicate maturity of white 'landrace' peach fruit. Hue angle, chroma, L* and a* as well as moisture content did not evidently show any significance changes and hence seems to not play much role in the determination of maturity and ripeness of the white peach landrace. Fruit colour results showed that only b* determined individually could be used as tool to determine colour change in peach during the ripening process. However, hue and chroma were able to conclusively determine the ripeness stage in the study. During the current study, it was concluded that fruit DAFB, firmness, TSS, pH and mass have a critical role to play since they significantly differ between different ripeness degrees. These can be used to monitor peach growth rates and estimate yield for the small-scale peach grower in the area. The DAFB are a good tool that farmers can stick to not using advance technologies other than monitoring the number of days. Firmness is also very important for farmers in the area as the fruit hardly changes colour but can be soft showing the ripeness.

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4. TUNNEL SOLAR DRYING OF PEACH FRUIT SLICE IN THE MIDLANDS OF KWAZULU-NATAL

4.1 Abstract

The study aimed to investigate the performance of tunnel solar dryer. To test the effectiveness of the dryer on peach landraces produced by the small scale growers in KwaZulu-Natal Midlands. Peaches were sliced and dried. The study was split over two seasons in two years. In season one, the study aimed to investigate the relationships between tunnel and ambient temperature as well as relative humidity. This was followed by the drying of peach slices in season two. The temperature and relative humidity demonstrated an inversely proportional relationship where in case of an ambient temperature increase there would be a decrease in both the tunnel and ambient relative humidity. There is a directly proportional correlation between the ambient and tunnel temperature. The utilisation of treatments such as ascorbic acid (AA) or lemon juice (LJ) did not have a significant effect in the overall drying between the yellow and white landraces. Ascorbic acid had a tendency to perform better than LJ which was also better than the untreated slices in terms of the taste testing and overall acceptabilty. It was concluded that solar drying is possible in the Midlands region. Extension, Reseachers and Farmers have the potential to form partnerships with different communities and implement old and cheap but ignored technologies such as this one of using solar to dry food as a preservation strategy.

Keywords: Ambient temperature, ambient relative humidity, tunnel relative humidity, tunnel temperature, LJ and AA.

4.2 Introduction

Extension services and researchers working in the Impendle area of rural KwaZulu-Natal mistbelt in South Africa are well aware that peaches are grown all over the area. Whereby almost each homestead can have up to 30 trees that have long been an important source of nutrition for the mostly impoverished households in this traditional authority area (Philips, 2015). Peaches are not however exclusively grown at Impendle since areas of Tugela Region and Kokstad do produce this fruit in the small scale sector. Small-scale peach growers in the province of KwaZulu-Natal lose a significant portion of their fruit due to lack of capacity to store and also resources to process harvested fruit. They tend to use or process all this harvested fruit, which is produced within a short two and half months harvesting season (Phillips, 2015). Pests and diseases are also a consistent problem in the small scale farming sector as there is limited proper crop husbandry skills as well as sparse, expensive chemicals treatment (Phillips, 2013; Phillips, 2015). It becomes challenging for the Extensionist when farmers bring their issues; such as the lack of storage facilities or the spoiling fruit. Farmers tend to leave the fruit hanging on the tree even during ripening stages which leaves them prone to dieseases thus fruit dropping off the tree and losing its value. An estimated SSA farmers lose that about 50% of food during postharvest due to lack of storage facilities (Gunders, 2012) , a statistic that Extension is aware of. Ayua *et al*. (2016) reported that the reduction of postharvest losses in fruit and vegetable is important to ensure food security and availability now, and in the future. Kader and Rolle (2004) had earlier reported that there is less funding for research projects geared towards reducing food losses, especially in the developing countries. Mustayen *et al*., (2014) explained that the quality and quantity of many agricultural food products, (such as fruits, grains and vegetables) are often deteriorating because of poor processing techniques and lack of storage facilities.

Drying of agricultural products has always been considered to be an important technique of conserving agricultural commodities (El-Sebii *et al*., 2012). Drying is defined as the process of moisture removal due to simultaneous heat and mass transfer (El-Sebii *et al*., 2012). Open sun drying has been widely used by developing countries, due to mechanical dryers being expensive and unaffordable to operate and maintain (El-Sebii *et al*., 2012). However, food drying depends largely on a number of weather parameters. It has been reported that the most important weather parameters are relative humidity, temperature and wind speed for evapotranspiration models (Valipour, 2014). Pangavhane *et al*., (2002) explained that open sun drying food under unfavourable misty and cool climatic conditions (similar to those in the Midlands of KwaZulu-Natal) leads to severe losses in the quality and quantity of dried products.

Introduction of solar dryers especially to areas with high moisture percentage is difficult without tunnel solar dryer, therefore tunnel solar drying is one of the solutions in order improve the quality of solar dried products (Yaldiz *et al*., 2002). Artificial solar food drying has improved dried product quality as opposed to open sun drying (Banout *et al*., 2011). Jain and

Tiwari (2004) stated that air velocity, temperature, mass transfer of air, evapouration of water and a requirement of high heat energy during evaporation. are some of the drying condition requirements that play an important role in ensuring that the product is dried effectively. Tunnel solar drying is one of the methods currently used by developing nations to protect and improve the quality of their dried agricultural products. Zomorodian *et al*., (2007) described tunnel drying as the absorption of solar radiation into the chamber resulting in temperature increasing and discharging of long wave length radiation as the main working phenomena of such a solar dryer. These authors(which ones) further reported that although the temperature in the chamber may increase above that of the crop, the main limitation is the moisture condensing inside the drying chamber. There is therefore a relationship between the weather parameters and drying conditions required in a solar tunnel dryer. An imbalance between the two environments may result in the improper drying of food. During the solar drying period, maximum solar radiation, maximum efficacy and minimum ambient moisture content should always be considered. According to an explaination by Jain and Tiwari (2004) drying a product enclosed in a plastic covering produces a greenhouse effect that traps the solar energy. Howerver, the rate of drying (moisture evapouration) depends on a number of external factors. Solar radiation, ambient temperature, wind velocity and RH as explained by Valipour (2015) are some of the paramaters. Instead of sun or shade drying, solar drying provides better quality product and is classified into four categories (Table 4-1) based on the mechanism of the energy used to remove moisture transferred to the product (El-Sebaii and Shalaby, 2012). When the product being dried it is stored under shelter during the night and when it is subjected to high moisture content or rain it can be remoistened. This will result in considerable spoilage that includes enzymatic reaction, growth of micro organisms, augmentation of mycotoxin, all of which cause reduction in product quality (Mustayen *et al*., 2014). There are specific requirements that properly designed solar drying systems (such as tunnel dryers) must consider before drying specific crops (Gurlek *et al*., 2009). These include thickness of the product dried, season of drying and weather conditions. Clearly, in order for the product to be dried the ambient relative humidity, which is weather dependant, must be lower than the solar energy-dried moisture content of the product . Mustayen *et al*., (2014) described tunnel solar drying as the most effective in terms of low costs, maintenance and operation; however, these authors further explained that this type of drying is met with some limitations. Solar dryers may be limited by high rainfall or high saturation of atmosphere with moisture content and low temperatures.

Table 4-1 Description of four solar drying methods (El-Sebaii and Shalaby, 2012)

Category of dryer	**Description**
Sun or natural dryer	The material to be dried is placed directly under hostile climate conditions like solar radiation, ambient air temperature, relative humidity and wind speed to achieve drying.
Direct solar dryers	In these dryers, the material to be dried is placed in an enclosure, with transparent covers or side panels. Heat is generated by absorption of solar radiation on the product itself as well as the internal surfaces of the drying chamber. This heat evaporates the moisture from the drying product and promotes the natural circulation of drying air.
Indirect solar dryers	In these dryers, air is first heated in a solar air heater and then ducted to the drying chamber.
Mixed-type solar dryers	The combined action of the solar radiation incident directly on the material to be dried and the air pre-heated in the solar air heater furnishes the energy required for the drying process.

4.3 Problem Statement and Study Aims

Agricultural reseachers are mainly focusing on production, be it fruits or vegetables. There are significant losses losses of peach fruit and limited of processing techniques and facilities in KwaZulu-Natal Midlands, compounded by the fact that open sun drying may not always be a possibility because of unpredictable weather conditions and high moisture content. Tunnel solar drying was tested. The aim of this study was to investigate drying conditions in season one and test whether the the mistbelt of the Midlands in KwaZulu-Natal tunnel solar dryer could be used to dry peach fruit during season two of the study. It is important to know that drying has no limits to only peaches and that other food comodities such vegetables, mushroom and other fruit types available in the region and can be be dried.

4.4 Objectives of the Study

The following were the objectives of the study.

1. To evaluate the performance of tunnel drier during the 2014/2015 season.
2. To evaluate the effects of lemon juice, ascorbic acid and the non-treated control on the quality of dried peach slice.
3. To evalutate the effect of solar tunnel drying on the organoleptic assesment of dried peach slice and leather.

4.5 Hypothesis

Alternative: Solar drying can be applied succesively in KwaZulu-Natal Midlands.
Null: Solar drying cannot be applied succesively in KwaZulu-Natal Midlands.

4.6 Materials and Methods

The study was conducted over a two-year period during 2014/2015 (Season 1) and 2015/2016 (Season 2) from December to March period. The Cedara Research Station is located at 30°16'E, 29°32'S and 1130 m above sea level. In season one all data parameters were collected concurrently using local weather station (by Agricultural Research Council, ARC) to determine ambient data and hobo data loggers to determine tunnel data. Also in season two, the data collected in season one was repeated, white peach slice drying data was also collected.

4.6.1 Season one 2014/2015

A parabolic solar tunnel dryer was designed and installed at Cedara Research Station in the mistbelt of KwaZulu-Natal, South Africa with doors facing northward and the back side facing south (Figure 5-1). A transparent 200-micron plastic sheet was used to cover the tunnel. The tunnel dimensions were as follows: length (l) - 7 m; breadth (b) - 2.95 m; height (h) - 2.65 m; door size - 0.6 m (b) x 2.35 m (h); triangular ventilation two at the top of the door, base - 2.1 m and height is 0.6 m; wind speed averaged at 0.8 m/s; and the floor was covered with black plastic sheet. The wire was used to make tray supports on the sides of the tunnel, to place loaded trays on during the drying process and there was a passage in the middle from the door to the back of the tunnel. A curtain was made on top of the door so as to be opened during drying and all wet and warm air to escape the tunnel, while the back vent would allow the dry air to come into the tunnel through the 0.9 m^2 air vent opening. The total drying area of the tunnel was 20.65 m^2. Racks of 0.30 m x 0.60 m food grade nets were constructed and used to dry peach slices. Tunnel temperature and RH were determined using four HOBO Pro v2 onset data loggers installed in the tunnel and were moved around to different locations of the tunnel to determine any variation in temperature and RH (Nishizaki and Carrington, 2014). In order to determine ambient temperature and RH, a Campbell Scientific CR10 Data Logger such as the one used by Gush (2008) installed in the local weather station was used. The data was collected in every 10 min for 24 hours a day.

4.6.2 Season Two 2015/2016

The aim of Season two was to dry the fruit while monitoring all the parameters that were recorded in Season One of the study. White and yellow peach landraces were handpicked at Impendle in KwaZulu, South Africa. After the harvesting, all the diseased, spotted and bruised fruit were removed and the remainder were stored (overnight) in a cold room with temperature and relative humidity settings at 5°C and 85% respectively. On the following day, fruit were removed from the cold room and allowed to reach room temperature before taking mesurements or processing. Fruits were washed, peeled and sliced into quarters and treated with LJ, AA and control (C). LJ treatment was applied as a 1:1 ration with volume of water and 34 g/L of AA. Fruits were dipped for 10 minutes and then dried in the tunnel. Treated and untreated slices were dried separete accordingly using 30 x 60 cm food grade net trays with wooden frames covered in food grade plastic. The trays were placed randomly in the tunnel on wire supports. The fruits were dried to moisture percentage below 15% and removed. Tray mass was determined in every hour until drying was completed. Dried peach slices were stored at room temperature (with hobos in sealed food grade plastic bags) until further tests were conducted a day later.

4.7 Sensory analysis

Fifteen trained panelists voluntarily conducted sensory analysis following a method that was used by Cano-Salazar *et al*. (2013). The sensory analysis test focussed on mouth feel, colour, taste, texture, aroma and overall acceptance quality attributes.

4.8 Results and Discussion

4.8.1 Season one

The variation of ambient temperature from 08:00 AM to 19:00 PM significantly affects the tunnel temperature positively (Figure 4-1). The increasing ambient temperature results in an increase in the tunnel temperature, but the tunnel temperature remains higher than the ambient temperature. A similar relationship is observed as from 20:00 PM to 07:00 AM whereby ambient temperature decreases followed by a decrease in tunnel temperature, with the tunnel temperature still remaining higher that the ambient temperature. At about 05:00 AM, the ambient temperature starts to increase and so does the tunnel temperature. The ambient and tunnel RH (Figure 4-1) appeared to be dependant on temperature. The increasing ambient temperature causes a decrease in ambient RH accompanied by a sharp decrease in the tunnel RH. In addition, the ambient RH was always higher than the tunnel RH, and this was a cause for concern. It is clear that the days have higher tunnel temperatures that do not exceed 45°C, and the lowest relative humidities remain above 40%, whereas the nights have higher ambient RH close to 100% and low ambient temperatures nearing 15°C. Janjai *et al*., (2011) reported their study findings that the lowest RH in the tunnel is during midday. The current study shows the same evidence of the lowest tunnel RH at 13:00 PM, during the day. When the tunnel temperatures drop below 20°C during the night, the RH in the tunnel increases very high above 90%.

Kaewkiew *et al*., (2012) conducted a study on ambient RH and temperature and compared it to tunnel dryer temperature and moisture content and found that the RH inside the dryer was below the ambient RH. Zomorodian *et al*., (2007); Ramos *et al*., (2010) explained that solar drying rate depends on the surrounding RH and temperature. The driving force of water diffusivity is the balance between the water content in each instant and the equilibrium water content. The moisture content of the product being dried should be higher than that of the surrounding environment. The drying rate decreases as the RH increases in the surrounding environment at constant temperature and increases at an increasing temperature and constant RH (Inazu, 2002).

Ramos *et al*., (2015) were able to successfully develop a simulation model by drying grapes on daily RH reaching below 10% during the day and remained below 80% during the night, and average maximum daily temperature of 40°C and minimum 15°C. Fudholi *et al*., (2014) successfully dried chilli in a small 2.4 m x 1.0 m x 0.6 m drying chamber with drying chamber temperature and RH ranging from 28°C to 55°C and 18% to 74%. Kaewkiew *et al* (2012) dried 500 kg of chilli using a 8.0 m wide x 20 m length x 3.5 m high tunnel solar dryer. The moisture percentage of the chilli was reduced to 9% in three days and this was possible because the ambient RH was lower than that in the tunnel. Manaa *et al*. (2013) dried tomato in solar dryer and concluded that the moisture content of the dried product was affected by several parameters including temperature of the air, speed of the air, thickness of the product and pretreatment. They also added that increasing the temperature of the drying air and reducing the thickness of the tomato slice reduces the drying time.

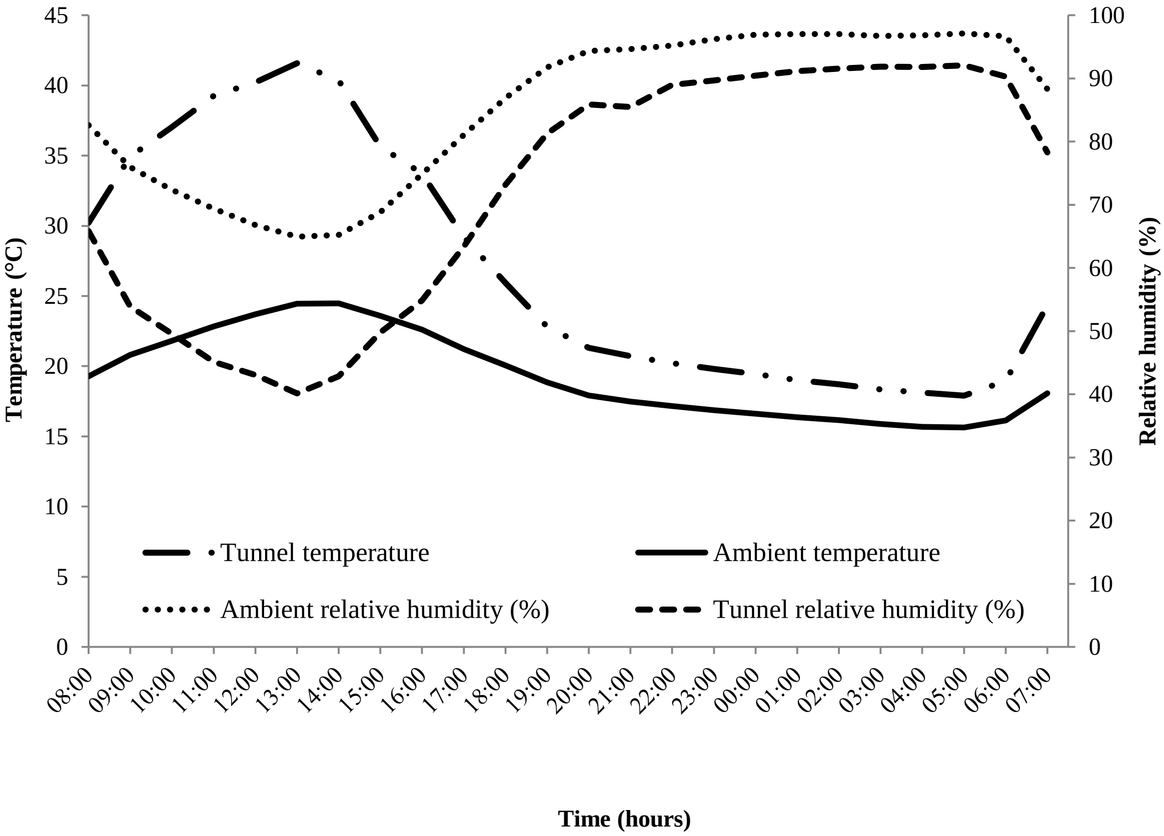

Figure 4-1 Graph showing the relationship of ambient and tunnel temperature and RH mean data collected over a four week period in Season One of the study

The positive relationships of higher drying chamber temperature and lower ambient temperature are related to what the current study has found Figure 4-2 (A). When the ambient temperature increases, the tunnel temperature also increase. The drying tunnel relative humidity was also related to ambient temperature Figure 4-2 (B). When the ambient temperature increases, the tunnel relative humidity decreases. The limitation in the current study was that the average lowest day tunnel relative humidity was >40% and this was too high for drying and thus may result in slow drying rate and spoilage of the product being dried.

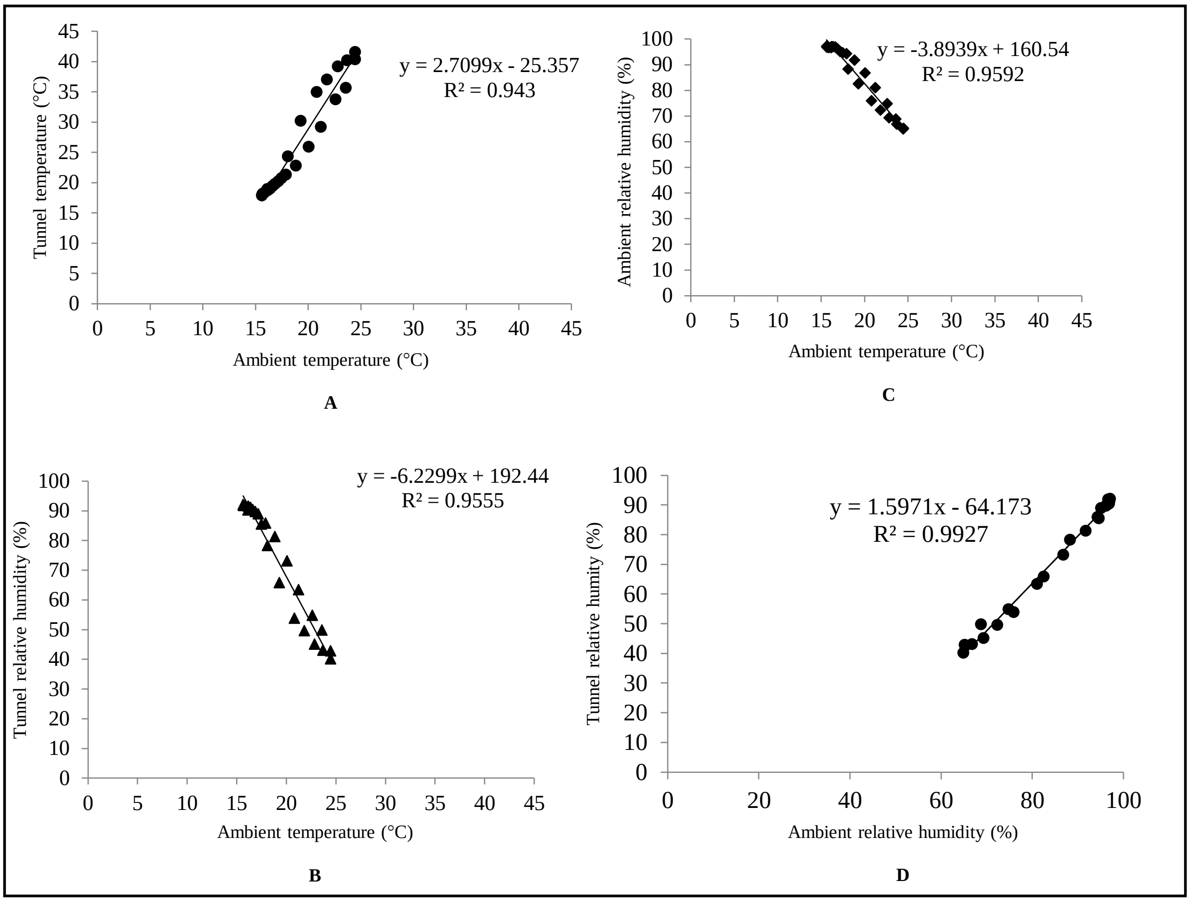

Figure 4-2 Graph showing the relationship between (A) ambient and tunnel temperatures, (B) ambient temperature and tunnel relative humidity (C) ambient temperature and ambient relative humidity and (D) ambient relative humidity and tunnel relative humidity in Season One of the study

The maximum average night RH was above 90% and this may result in remoisturing and spoilage of the product being dried at night, and therefore extra precautions are mandatory and must be in place before drying in the region where the study was conducted. The rainfall and mist have impact on such high moisture content in the region. Ambient relative humidity is also related to ambient temperature, as an increase in ambient temperature leads to a decline in ambient relative humidity Figure 4-2 (C). The saturation of ambient air with high relative humidity strongly affects the tunnel relative humidity, as it also increases Figure 4-2 (D).

Khiari *et al*., (2004) reported that an optimum temperature for food water removal is 80°C and food will cook instead of drying in higher temperatures. These authors further explained that low humidity assists the drying process since food contains a lot of water and if the surrounding environment is humid, the drying rate is reduced, and increasing air flow may improve the drying process. The current study temperature remained below 80°C, implying that drying is still possible below 80°C; however, the time to complete drying may be extended with a day and a few hours.

The close relationship between ambient and tunnel solar dryer temperature and relative humidity is much more important. It has been explained by Manaa (2013) on drying tomato to also affect the landraces being dried, When the temperature is above 40°C, different drying patterns of landraces were observed but when the temperature was below 40°C the drying curves were similar.

4.8.2 Season two

The drying conditions data is included included in Figure 4-3, Figure 4-4 and Figure 4-5 below since the leather and slices were dried concurrently in the same tunnel due to extra space availabilitity and the drying conditions that prevailed. Figure 4-6 displays the drying characteristics curves of LJ or AA pre-treatments and an untreated control of the white and yellow peach slices used in the study. The drying of peach slices started at the same time with average moisture between 80 and 85% ($P<0.05$). There was a significant sharp mass and moisture content drop during the first 6 hours for white control and yellow AA slices ($p\leq0.05$). However, the white, lemon treated and white untreated had a significantly different ($P\leq0.05$) mass and moisture content drop in the first six hours, whereas white lemon, white ascorbic, yellow lemon, yellow untreated were not significantly different in the first six hours ($p>0.05$). The yellow AA treated slices average was the least in the decreasing moisture content and mass for the first six hours, it also started as the highest moisture content at 85%, however, it was not significantly different ($P>0.05$) from all other treatments.

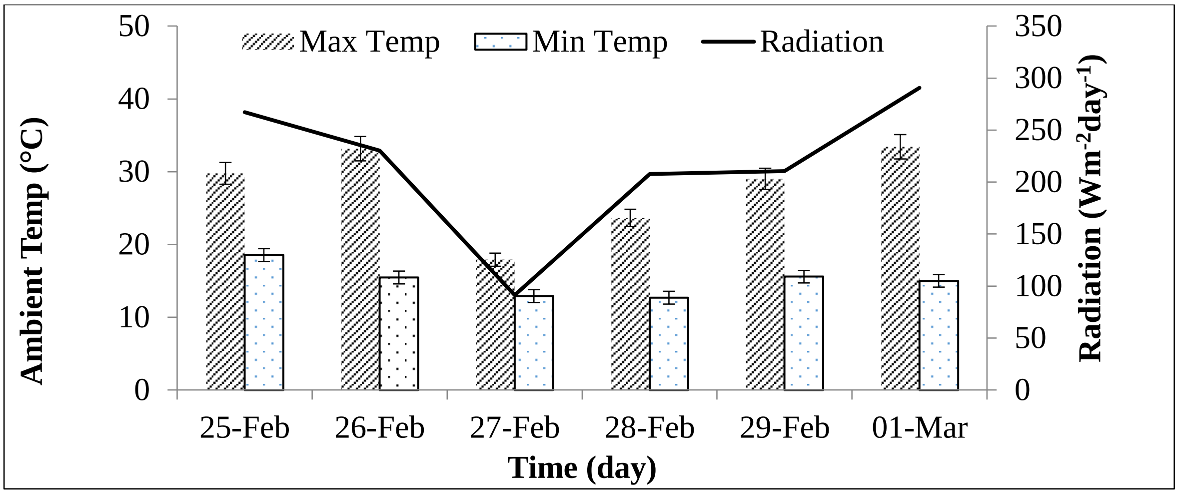

Figure 4-3 Graph showing the ambient min and max temperature, and solar radiation during the period of drying peach leather ($p<0.05$) in Season 2

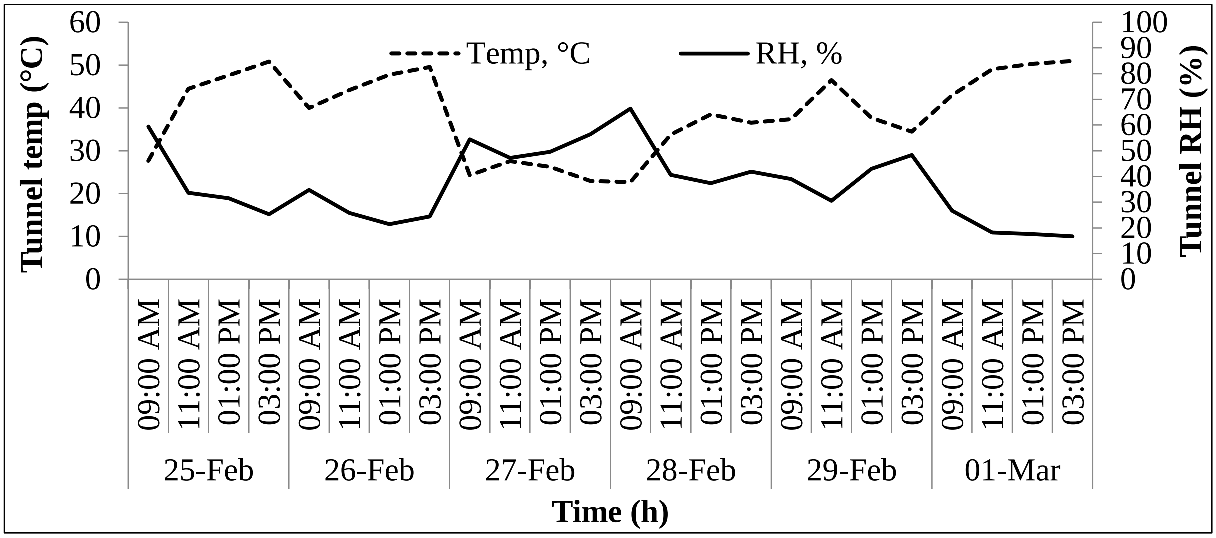

Figure 4-4 Graph showing the tunnel temperature and tunnel relative humidity during drying period of leather ($p<0.05$)

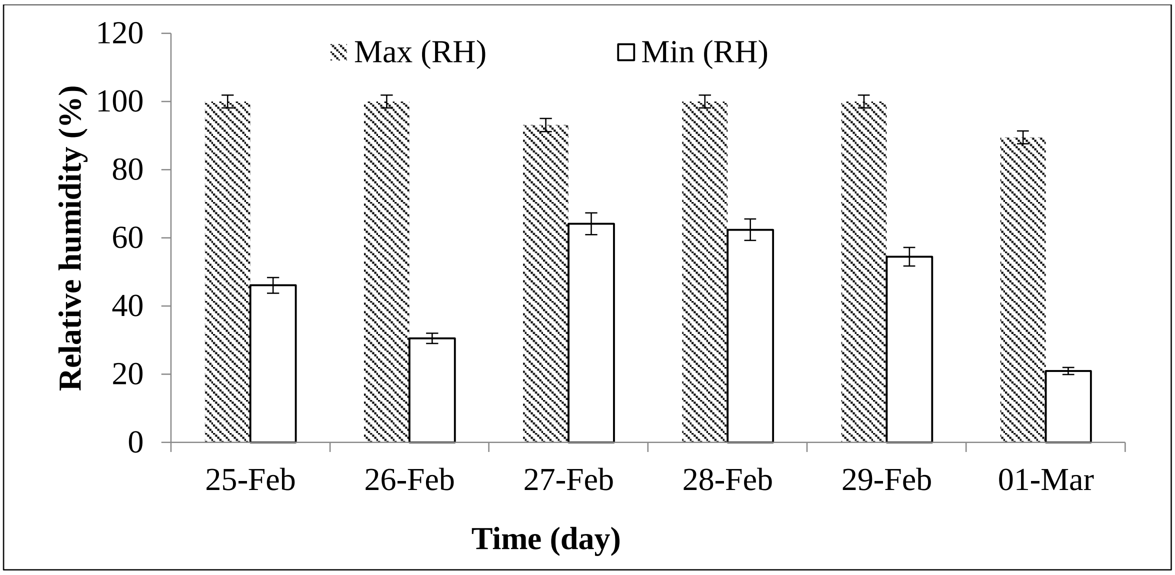

Figure 4-5 Graph showing the ambient minimum and maximum relative humidity in both day and night measurements ($p<0.05$)

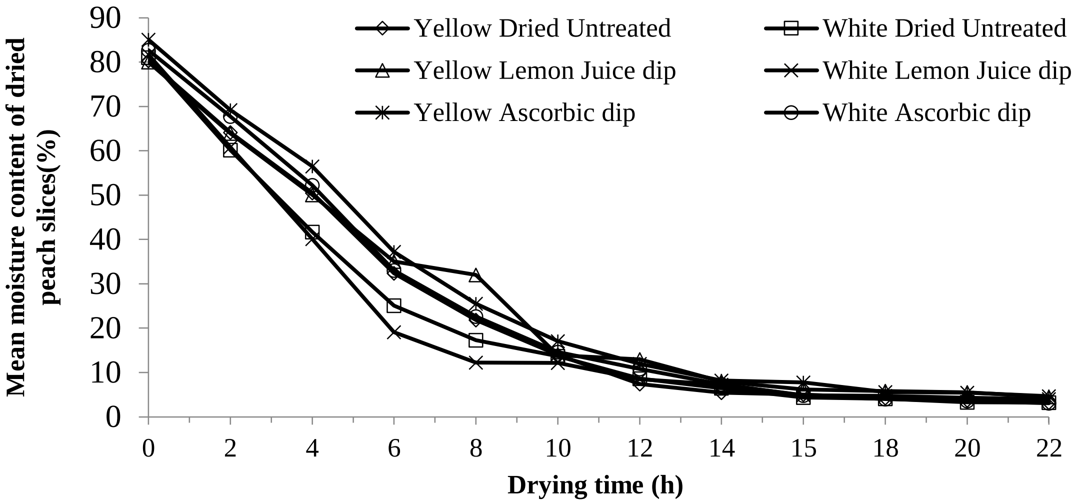

Figure 4-6 Graph showing the drying characteristics curves of different pre-treated and untreated peach slices

The yellow control and the white AA treatment followed similar trends from the start to the 22nd hour of drying ($p>0.05$). With the exception of the yellow control and white AA, all treatments were significantly different on the 8th hour of drying. There was no significant difference ($P>0.05$) in mean moisture content from the 10th hour to the 22nd hour of drying. The drying process stopped at 6% moisture content. White lemon and the yellow lemon treatments were significantly different ($p\leq0.001$) on the drying rate of the peach. The white lemon pre-treated slices dried at the fastest rate in the first 10 hours. The white untreated slices also dried fastest in the first ten hours. In the yellow landrace, treated or non-treated fruit did not show any trend and remained inconclusive in the drying curves.

Figure 4-7 displays the result of nine hedonic scale obtained from a taste testing conducted by 15 trained panellists a day after drying the fruit.

(i) *Colour:* Both controls of white and yellow landraces turned brown during the processing and drying period and hence they scored lowest in colour rating, followed by LJ pre-treated products. AA treatment was significantly different ($P \leq 0.05$) from both lemon and untreated peach for both yellow and white landraces. There was no significant difference ($P \leq 0.05$) between white and yellow slices in the AA treatment. AA treatment was above average and received a score of roughly 6/9 for both landraces.

(ii) *Taste:* AA pre-treated products also received the highest score in taste. However, the control of white peach displayed significantly different ($p \leq 0.05$) scores than LJ treatment in yellow landrace. White landrace treated with lemon was significantly different from both AA and control for both yellow and white landraces.

(iii) *Aroma:* AA pre-treated products had no significant difference ($P < 0.05$) between the white and yellow landraces and white lemon but was significantly different from LJ treatments for both yellow and white as well as yellow lemon treatment. AA tended to produce better aroma as it did with colour and taste.

(iv) *Texture:* peach slices treated with ascorbic and lemon treatments in both yellow and white was significantly different ($P \leq 0.05$) with white produce a higher score. In addition, white slice was ranked higher than yellow in texture for the lemon treatment. The white slice was rated significantly higher than the control and lemon for both white and yellow landraces.

(v) *Mouth feel:* the white slice of AA and lemon treatments were rated highest scores than the control for both white and yellow landraces and rated higher than AA and

lemon for the yellow landrace. White slice of AA was also rated significantly ($P \leq 0.05$) higher than white slice of LJ.

(vi) *Overall acceptability:* the white and yellow slices with AA were not significantly different but were rated the highest. The LJ white slice was not significantly different ($p>0.05$) from AA treatments applied in both yellow and white peach slices. The LJ treatment in yellow peach was not significantly different from the control of both white and yellow peach slices.

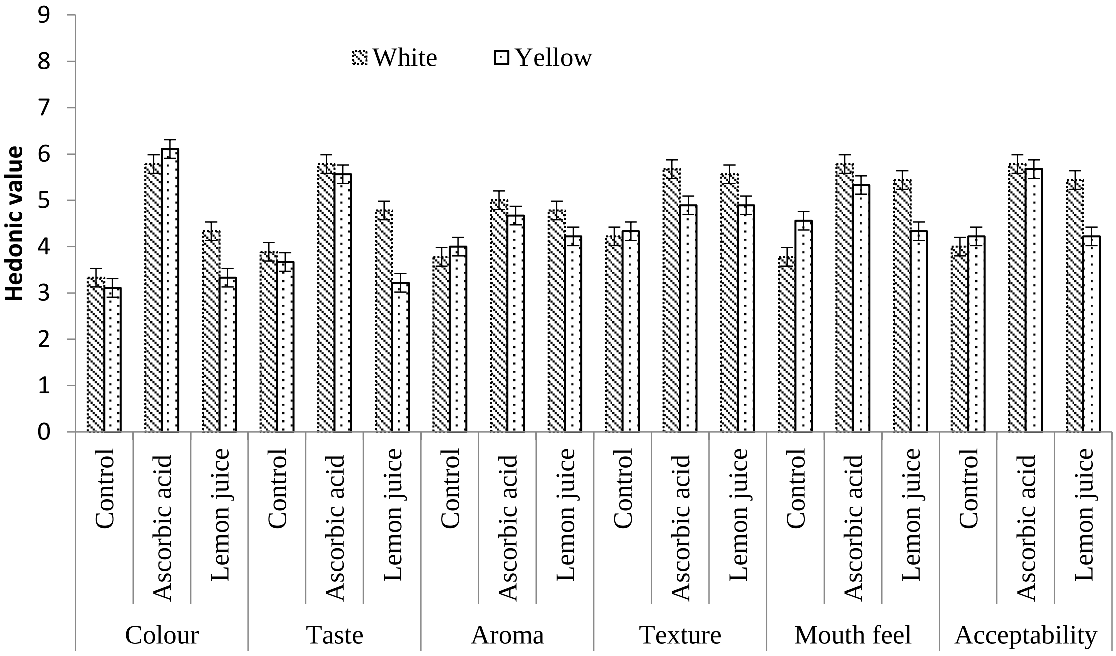

Figure 4-7 Graph showing the nine scale hedonic values obtained from a taste testing conducted with trained panellists over dried peach colour, taste, aroma, texture, mouth feel and acceptability

4.9 Conclusions

The study results concluded that during the day the increase in ambient temperature increases the tunnel temperature. There is a strong,positive relationship between ambient and tunnel temperatures as this was shown in both season one and season two of the study. In addition, the increasing temperature reduces the ambient relative humidity, which is also followed by a decrease of the relative humidity in the tunnel dryer. Farmers that may adopt the solar drying technique would need to remove and keep the product being dried in sealed bags or containers overnight. There were no significant differences ($P>0.05$) related to the use of LJ treatment, AA treatment and no treatment on the drying rate of both yellow and white slices. The white landrace performed much better than the yellow landrace in reference to taste testing. The AA produced better slices than did LJ and lastly was the control of untreated slices. The study further concluded that the drying conditions do allow the use of tunnel solar dryer in the Midlands of KwaZulu-Natal with a caveat that produce needs to be removed during overnight and be stored in sealed containers or plastic bags.

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5. SENSORY AND TEXTURE PROFILE ANALYSIS OF YELLOW AND WHITE FLESHED FRUIT LEATHER DRIED USING TUNNEL SOLAR DRYER.

5.1 Abstract

Due to excessive postharvest losses because of limited storage facilities in less developed countries such as South Africa. Drying of fruits into leather is one of popular and old methods that many small-scale household growers of fruits and vegetables employ in order to preserve their fresh produce. This study aimed to process peach fruit into leather using tunnel solar dryer located in the misty conditions of Midlands in KZN. White and yellow flesh peach landraces were pre-treated with LJ, AA and an untreated control were processed into leathers. Quality of leather were determined objectively and subjectively after drying. Texture profile and sensory analysis methods were also used to determine the quality of leather products. The experiment revealed that white leather moisture was approximately 7% and received the lowest overall acceptability scores from panellists and less quality results according to the texture profile analysis results obtain from Instron machine. In contrast to the yellow peach leather, which was approximately 13%, moisture content, white fleshed leather was harder and less favourable to the panellists. Yellow leather received the highest overall acceptability scores by both texture profile analysis and sensory evaluation tests. Thus, this study suggests that drying is possible in the KwaZulu-Natal Midlands. The product being dried should be removed during the night since there is high moisture with a potential to rewet the product. Furthermore, leather thickness has effects on the quality of the final products and leather processors should ensure uniformity. A 2 mm thickness was used in this study. Yellow peach leather appeared to be appetizing to the panellists because of its yellow colour compared to white peach leather. White leather was harder than the yellow, meaning that the less the moisture percentage, the harder the leather becomes. Following that, the tunnel solar dryer was tested for its functioning. More research work on drying conditions related to leather thickness and further nutritional quality of dried leather is still required in KwaZulu-Natal Midlands.

5.2 Introduction

Studies have shown that rural dwellers in the SSA countries, such as South Africa's KwaZulu-Natal province, harvesting fruits from forests and their small household gardens can avoid poverty by producing and consuming their own food, while creating employment opportunities and generating income through processing and value addition (Mithofer (2004; Saka *et al*, 2004; Akinnifesi *et al*., 2005). Rural households in this region produce many fruit types such as oranges, avocados, peaches, lemons, apples, marula, banana, mango, litchi, apple, nectarine, pawpaw etc. However, unemployment, hunger and postharvest losses are still some of the persisting issues faced by these communities. Fruits have important effects towards the nutritional and economic value of all crops in the world (Ofori *et al*., 2013). Malnutrition is prominent in South Africa (especially in children). Fruit and vegetable consumption is well below global average. Solving nutrition and food security problems in this country, where requires a range of interconnected approaches and appropriate postharvest handling and processing which play a major role in reducing food losses (Ofori *et al*., 2013).

Peach fruit is produced by the rural small-scale sector in KwaZulu-Natal. It is grown in the backyards or small gardens. Regardless of its nutritional value, growers face major postharvest losses during the picking season. The major challenge is the inability of the farmers to cope with overabundant and highly perishable produce during the short harvest periods (December to March) which leads to approximately 45-50% of postharvest losses (Wafula *et al*., 2015). Shackleton *et al*. (2000) states that, most research efforts of fruit trees produced by the rural small-scale sector in Southern Africa has been orientated towards the use of indigenous woodlands, especially in communal areas surrounding rural villages and households. Limited research has been directed towards the processing of the growers' produce, as a result, lack of such research has led to great fruit losses. In order to deal with overabundant supply of peach at a short period, it is very important for farmers to harvest at the correct time and process their fruits using traditional and affordable methods into other products that can be used at later as the fruit is highly perishable. Products such as dried leather are among many other products that are important for value addition, which farmers can process using extra produce that remains after fresh consumption. Processing steps are simple and when coupled with solar energy, it becomes the most affordable method of food preservation.

Drying is defined as, a frequently applied postharvest technology for extending shelf life of agricultural products, which lowers water activity thus preventing spoilage and contamination, by microorganisms during storage, and preserves quality and stability of foods when properly performed and stored post-drying (Akpinar and Bicer, 2005). According to Huang (2005) fruit leather is an economic and convenient value-added substitute for natural fruits as a source of variety of nutrient elements, especially vitamin C, and more importantly, it can be a useful outlet for low-grade fruits and by-products left during fruit processing, since it has less calories than most of the snacks. Fruit leather is made by drying fruit puree on a flat surface in an oven, desiccator or indirect solar dryer. A simple technique for preparing fruit leather is to wash, peel, pulp and however if required the fruit should pre-treated or cooked drying the leather.

There are various methods to prepare puree such as those described by Raab and Oehler (1999) as cold or hot break methods. Cold-break is when the fruit is pureed first and then cooked in a boiler for 10 minutes then dried. A hot-break is whereby the fruit is chopped into pieces and steamed for 15 minutes, pureed and then dried. Preservation of food such as fruits, spices, herbs, meat and vegetables by sun open-air drying is one of the first technological activities undertaken by human kind (Imre, 1997; Banout *et al*., 2011). There are disadvantages related to open-air drying of food such as contamination by insects and dust or spoilage due to adverse weather changes, drying may not be uniform (Chavda and Kumar, 2009; Maiti *et al*., 2011). Due to increasing costs of electricity and fuel, the application of solar energy in drying is one of the solutions to avoid expensive mechanical dryers (Munir *et al*., 2013). Tunnel solar drying can be considered as an advancement of natural open-sun drying and it is a more efficient technique of utilizing solar energy (Janjai *et al*., 2009).

Texture plays an important role in food. It is defined as the sensory expression of food structure and the way in which structure reacts to the forces applied and represents the connection of all the mechanical, geometric, and superficial attributes of a product that are sensed through mechanical, visual, tactile, and hearing receptors (Szczsniak, 1963a). Texture can be measured by means of objective (instrumental) and intrinsic subjective (sensory) tests (Paula and Conti-Silva., 2014). Correlation between sensory and instrumental measurements of texture result in:

a) Finding instruments for quality control of food in industries;
b) predicting consumer response, as the degree of favourability and the overall acceptance of a new product;
c) understanding what is being sensed and perceived in the mouth during the sensory assessment of texture;

d) improving or optimizing instrumental methods to complement the sensory evaluation (Szczesniak, 1987).

It is important to link the sensory analysis to the instrumental tests to match the results of both quality analysis methods of products, as this will help improve the quality. The aim of the study was to prepare and dry peach fruit into leather using tunnel solar dryer, white and yellow flesh peach landraces produced at Impendle in KwaZulu-Natal, South Africa.

5.3 Materials and Methods

5.3.1 Experimental site

The study was conducted at Cedara Research Station, Value Adding Section in the KwaZulu-Natal Province, South Africa. The fruit was obtained at Impendle (29°37’04.09”S; 29°51’23.8”E) in the season 2015/2016. Local landraces of yellow and white flesh peach were used in the study. The fruits are organically produced under dry land farming conditions with no use of chemicals, pesticides or fertilizers.

5.3.2 Tunnel design

A parabolic solar tunnel dryer (Figure 5-1) was designed and installed at Cedara Research Station in KwaZulu-Natal, South Africa. The tunnel was constructed using galvanized iron bars and a transparent 200-micron plastic film. The drying tunnel dimensions were as follows: length (l) = 7 m; breadth (b) = 2.95 m; height (h) = 2.65 m; door size = 0.6 m (b) x 2.35 m (h) and triangular ventilation (two at the top of the door), base = 2.1 m and height is 0.6 m. The tunnel air speed averaged at 0.8 m/s; and the same black 200-micron film covered the floor. The wire was used to make tray supports on the sides of the tunnel, to place loaded trays on during the drying process. On top of the front-end door, a curtain was installed to be opened during the drying period to let moist warm air escape from the tunnel. The back vent would allow the dry cool dense air to get into the tunnel through the 0.9 m^2 air vent opening. The total drying area of the tunnel was 20.65 m^2. Wooden trays of 0.3 m x 0.3 m x 0.02 m were constructed and used to dry peach leather.

Figure 5-1 A tunnel solar dryer used in the drying of peach leather products

Tunnel temperature (T) and relative humidity (RH) were determined using four HOBO Pro v2 onset data loggers installed in a tunnel and were moved around to different locations of the tunnel to determine any variation in temperature and RH (Nishizaki and Carrington, 2014). In order to determine ambient temperature and RH, a Campbell Scientific CR10 Data Logger according to Gush (2008) installed in the local weather station was used.

5.3.3 Peach leather preparation and drying

The site where the fruit was handpicked is located at a small-scale peach farming community in Impendle. The area is at an elevation of 1420 m above sea level, with annual average temperature ranging between 12 and 16°C, characterized by 800 – 900 annual average chilling units (CU) (Camp 1999). After harvesting, the diseased, spotted and bruised fruits were removed before the fruit was washed and processed. After washing, fruits were peeled, cut into thin slices then blended and pureed by steam blanching for 10 min to avoid browning. The puree was smashed, poured and spread into wooden trays with a food grade plastic lining to avoid sticking and absorption of unwanted wood properties. The puree was dried in a tunnel solar dryer as explained below. Batches of 622 g white and 630 g yellow fleshed peach samples were dried at a tunnel solar dryer. The number of days depended largely on the ambient temperature, solar radiation and relative humidity parameters. However, the area where the leather was being processed is the mist-belt. The leather pulp was dried for four days in a tunnel solar dryer.

5.3.4 Data collection

5.3.4.1 Total soluble solid

Total soluble solids (TSS) were determined using a refractometer (Atago, Model PR-1, Tokyo, Japan).

5.3.4.2 The pH Value

The pH was determined using a pH meter (Hanna Instruments, Johannesburg, South Africa).

5.3.4.3 Colour measurment

Colour was determined using a Hunter Lab Color Flex EZ Spectrophotometer (Model: 45/0 145 LAV, Reston, VA, USA). Processed products measurements were replicated three times.

5.3.4.4 Organoleptic evaluation of peach leathers

Fifteen trained panellists volunteered to conduct taste testing on peach leather for both yellow and white products. From one being the best to nine being the worst the panellists gave scores (Table 5-1). The organoleptic evaluation of peach leather samples was carried out according to standard methods used by Amerine *et al*. (1965); Chavan and Shaik (2015) on a 9-point Hedonic Scale.

Table 5-1 Nine point Hedonic Scale

Nine point hedonic scale table	
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slight slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

5.3.4.5 Packaging and storage of dried leather

Sealable, non-perforated transparent food grade plastic bags were used to package dried 50 g leather and stored at room temperature around 25°C.

5.3.4.6 Microbial count of peach leather

Microbial counts were recorded according to Chavan and Shaik (2015) as colony forming units (CFU).

5.3.4.7 Texture analysis

Texture profile measurements for white and yellow peach leather products were conducted following a method used by Cherono *et al*. (2016) using a stable microsystems texture analyser (TA.XT plus, stable microsystems, Godalming, Surrey, UK). The texture analyser had a load cell capacity of 30 kg and data processed and recorded by Exponent® system software (TA.XT plus, stable microsystems, Godalming, Surrey, UK). Leather texture was processed using a Warner-Bratzler Blade with a double compression cycle test performed to 50% compression and extension forces according to a method used by Cherono *et al*. (2016). Pre-test speed was 2 mm/s, test speed was 5 mm/s, post-test speed was 5 mm/s distance 30 mm, and trigger force and was 10 g. Experiments were conducted at room temperature 25°C. From the resulting force-time curves, the following parameters were obtained: hardness (N), springiness (mm), cohesiveness (dimensionless), gumminess (≡hardness x cohesiveness [N]), chewiness (≡gumminess x springiness [N mm]), adhesiveness (N s^{-1}) and resilience (dimensionless).

5.3.7 Data Analysis

Statistical data analysis was carried out using the GenStat 14th version statistical package for the analysis of variance (ANOVA) for each of the parameters measured. Significant differences were set at $p < 0.05$ and a multiple range Tukey's test was applied to separate the means.

5.4 Results and Discussion

5.4.1 Tunnel and ambient relative humidity and temperature

Ambient temperature and solar radiation were determined and displayed in Figure 5-2. During the daytime, short wave radiation gets trapped inside the dryer by passing through polythene sheet and thus provides heat in the dryer (Rajkumar *et al*., 2017). There were significant differences between the conditions in the tunnel compared to the ambient environment. During the drying period, solar radiation became less and reached slightly below 100 Wm^{-2}/day^{-1}, as it was cloudy during the first three days. It thent began to increase in the next three days until it reached approximately 300 Wm^{-2}/day^{-1}. A reduction in solar radiation caused by cloud cover had a stronger effect in the reduction of temperature to 13°C with a slight increase in relative humidity (70%) during the day and thus increased the number of drying days as less moisture was removed from the product surface, slight rewetting of the leather products was possible.

Vasquez *et al*. (2016) found that a decrease in radiation level leads to insufficient energy capture by the drying panel that heats the drying air meaning less radiation causes poor drying conditions in solar drying. Since Figure 5-2 displayes a decreasing solar radiation, however, there was green house effects in the tunnel and the temperature remained above the ambient temperature.

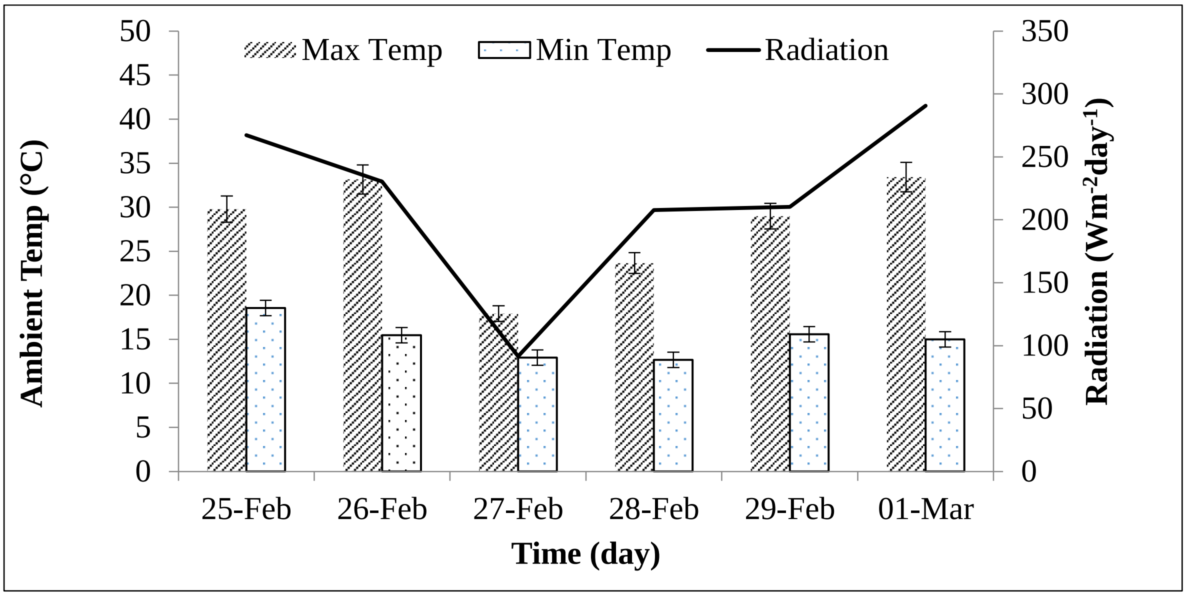

Figure 5-2 Graph showing ambient min and max temperature, and solar radiation during a six day period of drying peach leather ($p \leq 0.05$)

The relative humidity has a strong negative relationship and dependency onto temperature. Figure 5-3 shows results of tunnel testing trend that as temperature increased, relative humidity was reduced. The lowest daylight relative humidity was 20% and the highest daylight relative humidity was 70%. The lowest and highest daylight temperatures were 22°C and 51°C respectively. The higher the temperature the lower the relative humidity and the lower the temperature means the higher the relative humidity. The night ambient relative humidity as diplayed in Figure 5-4 remained the highest, closer to 100% RH; this is because of the misty conditions most of the nights, and could havean influence on rehydration of the product being dried in the tunnel, even though, the tunnel remained closed during the night. These temperature and relative humidity recorded in and out of the tunnel are all related. The tunnel temperature and relative humidity conditions are affected by the ambient the environment. Cloud cover reduces the amount of solar radiation reaching the tunnel surface, consequently reducing the temperature. When temperature is reduced, relative humidity slightly increases. When there is less heat to remove moisture on the surface of the product being dried and the ambient air is slightly saturated, and then there is less movement of moist air to escape out of the tunnel. When the product being dried remains in the tunnel under moist conditions for too long, mould and other contaminations may begin to develop. However, in the current study there was no mould development. Even though the temperature may have been reduced, the tunnel conditions were still warm enough to allow the product to dry within four days. The third drying day (Figure 5-3) displays unfavourable conditions, during this period RH increased while temperature was reduced, favouring contamination. Ideal conditions include high temperature and low relative humidity. Vasquez *et al*. (2016) also explained that decreasing relative humidity while the temperature is raised, increases the drying rate. The relative humidity measurements recorded at night were close to a 100%. This is one of the disadvantages of drying in the mist belt, but by removing and covering the product overnight, drying in this area is possible due to daylight warm temperatures.

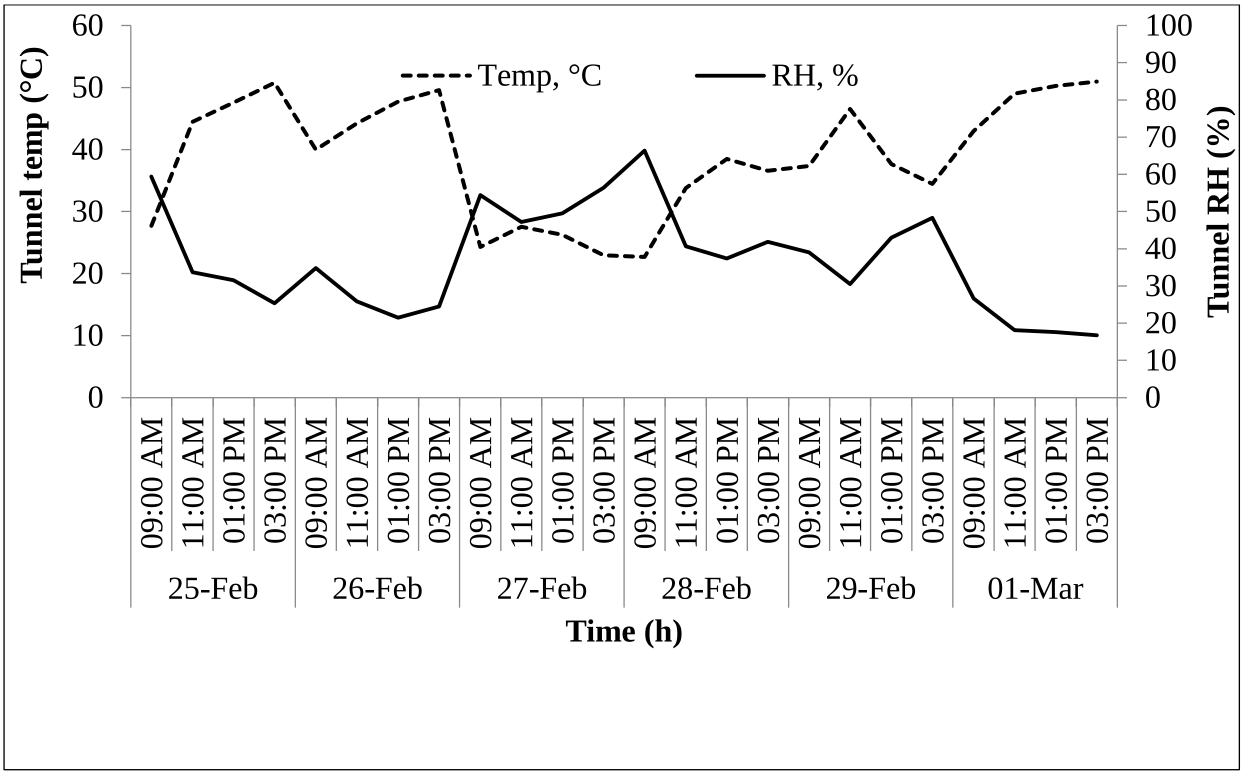

Figure 5-3 Graph showing tunnel temperature and tunnel relative humidity during drying period of leather ($p \leq 0.05$)

Minimum and maximum relative humidity were determined during the study and the results are presented in Figure 5-4. The highest relative humidity represents data collected at night when the temperature was cool, the relative humidity remained close to 100% overnight, and the lowest daylight relative humidity was 20%, though it was variable.

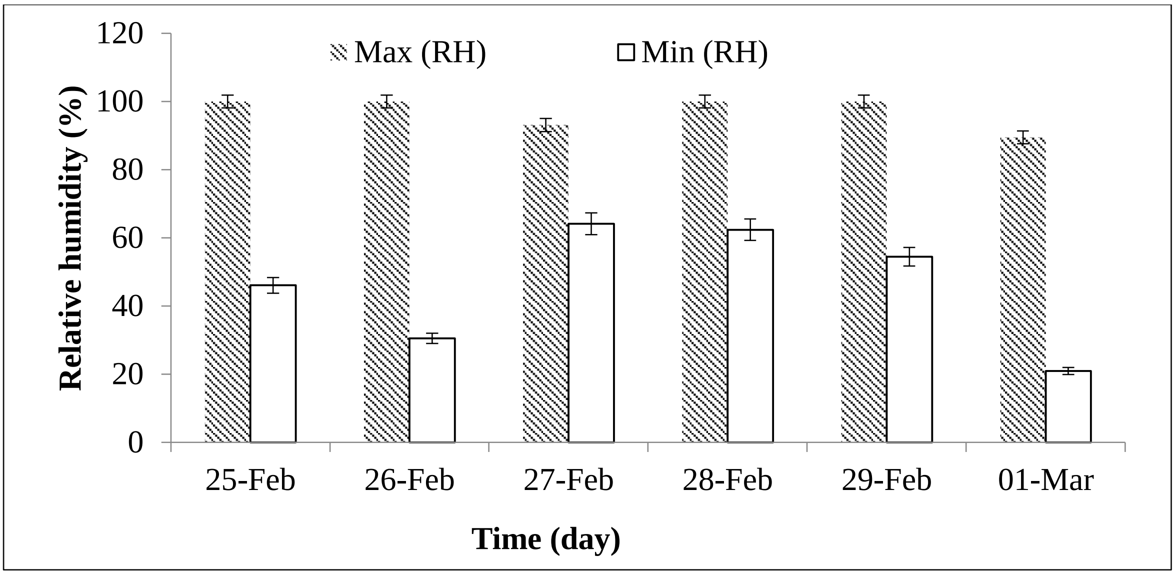

Figure 5-4 Graph showing ambient minimum and maximum relative humidity including both day and night measurements ($p \leq 0.05$).

5.4.2 The colour of leather

The chromatic scale colour attributes are affected by pulping method and drying conditions. The chromatic values of L*, a* and b* for both yellow and white fresh fruit were determined before and after processing peaches into leather and results are displayed in Figure 5-5 below. The lightness (L*) index is an indication of lightness or darkness of food sample and ranges from zero for black to 100 for white.

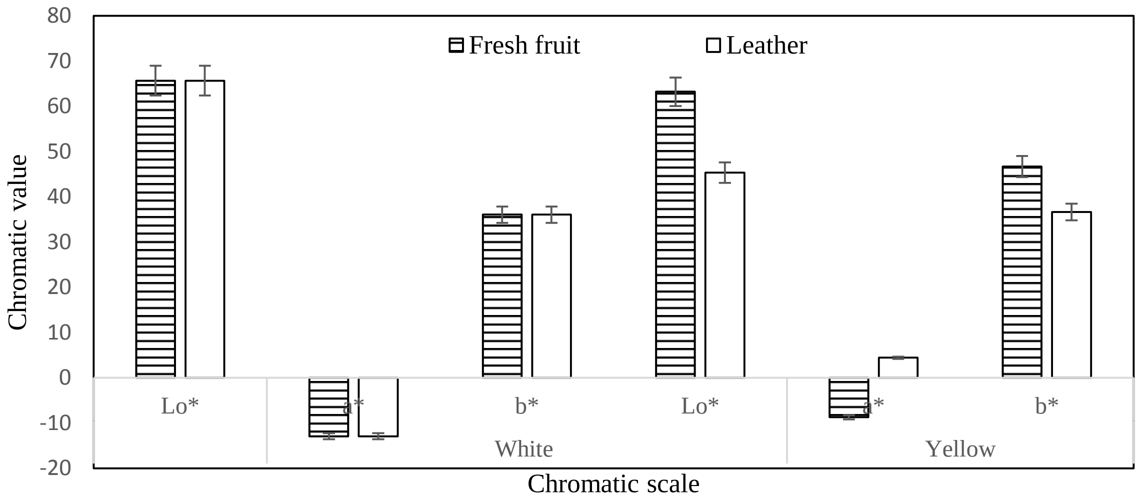

Figure 5-5 Graph showing chromatic scale L_o*, a* and b* of white and yellow fresh fruit and leather value ($p = 0.05$).

The values of a* represent the redness and the greenness of the food sample and range from -60 for green to +60 for red. The values of b* represent the blueness and yellowness of the food sample and range from -60 for the blue and 60 for the yellow. For white peach, there was no significant change ($p>0.05$) before or after drying for L*, a* and b*. However, for the yellow peach fruit both L* and b* decreased significantly whereas a* significantly increased. There were no significant differences ($p>0.05$) for L* before processing for both yellow and white, but after processing L* for yellow significantly decreased, while L* for white remained stable. The chromatic scale a* was significantly higher ($p\leq0.05$) for fresh yellow fruit and further increased after processing into leather. Chromatic scale b* was significantly higher ($p\leq0.05$) for the yellow fresh, but after leather processing it was significantly reduced ($p\leq0.05$), while it remained similar to white leather b* for both before and after processing. It has been previously explained that a loss of AA in dried fruit caused by the presence of furaldehyde and 5-(hydroxymenthly) furaldehyde as the two main compounds that degrade ascorbic acid. After degradation of AA dried product colour changed due to polymerization and oxidation of phenolic compounds that bring in new colour pigments to the product (Kanner *et al*., 1981; Gupta *et al*., 2016). Changes in the chromatic scales may be associated with the reduction of AA as explained above. In addition, non-enzymatic browning such as Maillard reaction could best explain such colour changes, whereby it is defined as the action of amino acids and proteins on sugars (Gupta *et al*., 2016).

5.4.3 Fruit pulp, seed, peel, pH and TSS

The yield of leather was 398g/Kg for yellow fruit and 457 g/Kg for white fruit as displayed in Table 5-2. Chavan and Shaik (2015) reported yields that ranged between 617 – 625 g/Kg for guava fruit leather. The results obtained from the current study showed low pulp yields compared to what Chavan and Shaik (2015) reported, this could been as a result of different peeling and coring methods used. Knife peeling will surely yield different pulp compared to lye peeling. In the study by Chavan and Shaik (2015), the skin of guava fruit was not removed. The initial mass, peel mass, seed mass, pulp mass, pH °Brix of the peach that was used to process leather were determined.

Table 5-2 White and yellow peach leather break down of mass, °Brix and pH

Quality parameter	Fruit mass (g)	Peel (g)	Seed (g)	Pulp (g)	Fresh pH	Leather pH	Initial °Brix	Final °Brix	Final mass (g)	Pulp yield (g/kg)
White peach	1359.50	561.00	176.50	622.00	3.53	3.73	14.30	23.40	431.00	457.00
Yellow peach	1293.00	514.00	149.00	630.00	4.04	3.71	12.40	20.00	496.00	397.00

5.4.4 Fruit moisture percentage

The initial moisture percentages of both yellow and white were not significantly different and averaged at 87%. The final moisture percentages for both yellow and white were significantly different with white leather final moisture at 7.69% and yellow leather at 13.33% ($p<0.05$) (Figure 5-6).

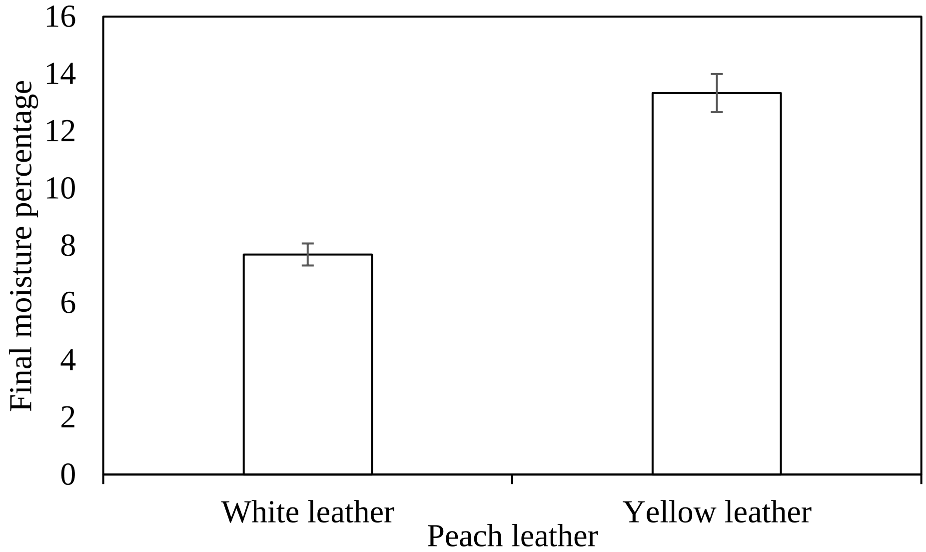

Figure 5-6 Graph showing yellow and white peach leather moisture percentage at the end of drying

The difference in final moisture percentages may have been affected by the slight variation in thicknesses. Deepika and Payel Panja (2017) processed aonla fruit leather. The best quality of leather was obtained at percentage moisture content of 17% and this received the highest score of 8 in overall acceptability. The lowest moisture percentage in their study was 13.23%. Chavan and Shaik (2015) also conducted guava leather processing. The moisture percentage of their leather was between 14.67% and 15.85%. Clearly the current study moisture percentage of the yellow and white peach leathers was reduced far too low and hence the leather was slightly harder, more especially the white leather which received the lowest overall sensory analysis scores. This also means that the four days it took to dry the produce could be reduced to about two days when the moisture percentage of the product being dried is kept approximately at 16%. The study results were not congruent to results of the studies conducted by Chavan and Shaik (2015); Deepika and Payel Panja (2017). Clearly, the current study leather was too dry, and chances of bacterial or fungal contamination were too low compared to the studies by the authors mentioned above. However, too dry of a leather reduces textural quality.

5.4.5 Sensory analysis

There were significant differences in the colour of the peach leather ($p \leq 0.05$) between the white and yellow as displayed in Figure 5-7. Clearly, for white peach, the scores averaged at 5.6. The panellists neither were indifferent to the white peach landrace. However, for the yellow peach leather, the panellists gave colour a score between 6 and 7 meaning they slightly liked the colour of the yellow peach leather, hence the significant difference ($p \leq 0.05$) between the yellow and the white peach leather. The taste for the yellow peach leather also was scored higher than that of white peach leather; the panellists slightly liked the taste of the yellow leather over the white, though there were no significant differences ($p < 0.05$). Thermal processing, a widely implemented method in food industry to avoid enzymatic changes and microbial spoilage Oliveira *et al*. (2010), was used in the current study. Concerns may be the effect of thermal processing on the undesirable biochemical changes that eventually affect the taste of the final product (Aguilar-Rosas *et al*., 2007). In a study that Oliveira *et al* (2010) conducted to evaluate the effect of thermal processing on peaches they found that carotenoid concentration was significantly affected by the heating of the fresh fruit at 100°C for 30 minutes, whereas the phenolic and antioxidant concentrations averaged at 0.7 and 0.6 $\mu g.g^{-1}$ respectively and were not significantly affected by heat treatment. Fresh fruit contained an average of 11.6 $\mu g.g^{-1}$ of total carotenoids. Carotenoids were significantly reduced by 65% to 4.0 $\mu g.g^{-1}$ after heating. A number of studies have reported antioxidant decrease in peach processing that involves heating (Lessin *et al*., 1997; Gama *et al*., 2007; Fratianni *et al*., 2010; Oliveira *et al*., 2010). It is highly possible that in the current study since the temperature reached 50°C during drying that half of the reduction obtained in the study mentioned above affected total carotenoids probably. In addition, it is possible that the total phenolic compounds were not affected in the current study.

5.4.6 Texture profile analysis (TPA)

The results obtained from the curves of the TPA of yellow and white peach leather were used to provide the quality attributes as explained in the typical graph of most food products in Figure 5-7 and attributes as explained in Table 5-3 below. Figure 5-8 is linked and used to explain all attributes explained in Table 5-3. Instrumental texture is similar in textural property which is associated with sense of feel or touch by the human finger or mouth.

Table 5-3 Texture profile analysis according to Texture Technologies (2017)

Parameter	How measured
1. Hardness	Peak Force
2. Fracturability	Peak Force at F1
3. Cohesiveness	Area 2/Area 1
4. Springiness	Distance 2 / Distance 1
5. Gumminess	Hardness x cohesiveness
6. Chewiness	Hardness x Cohesiveness x Springiness
7. Resilience	Area 4 / Area 3

The variation is that an instrument and a probe or blade are used to represent mouth feel and results are expressed graphically (force vs time) as shown in Figure 5-9 and Figure 5-10 below. Figure 5-9 provided quality attribute for yellow peach leather as processed in the Texture Analyser instrument. Table 5-4 and Table 5-5 provide results extracted from the texture profile graphs.

Table 5-4. Hardness, fracturability, cohesiveness and gumminess obtained from the TPA curves of white and yellow leather products (mean data ± SD, n = 18)

Leather	Hardness (N)	Fracturability	Cohesiveness	Gumminess (N)
Yellow leather	63.15±1.02	63.15±1.05	0.3912±0.05	24.70±1.02
Yellow leather	60.80±1.05	60.80±0.99	0.3506±0.05	21.32±1.01
Yellow leather	82.94±0.99	40.92±1.05	0.3439±0.02	28.52±1.05
White leather	181.05±1.08	101.28±1.30	0.4434±0.07	80.27±1.08
White leather	174.10±1.05	174.10±1.05	0.3866±0.01	67.31±1.04
White leather	117.89±1.08	121.89±1.09	0.4328±0.06	51.02±1.08

Table 5-5. Springiness, resilience, chewiness obtained from the TPA curves of yellow and white leather products (mean data ± SD, n = 30)

Leather	Springiness (mm)	Resilience	Chewiness (N.mm)
Yellow leather	0.9985±0.01	0.9985±0.02	24.67±1.03
Yellow leather	0.9988±0.05	0.9988±0.02	21.30±0.981
Yellow leather	0.9990±0.02	0.9990±0.04	28.50±1.07
White leather	0.9997±0.02	0.9997±0.01	80.25±1.19
White leather	0.9993±0.04	0.9993±0.02	67.27±1.10
White leather	0.9997±0.03	0.9997±0.01	51.01±1.09

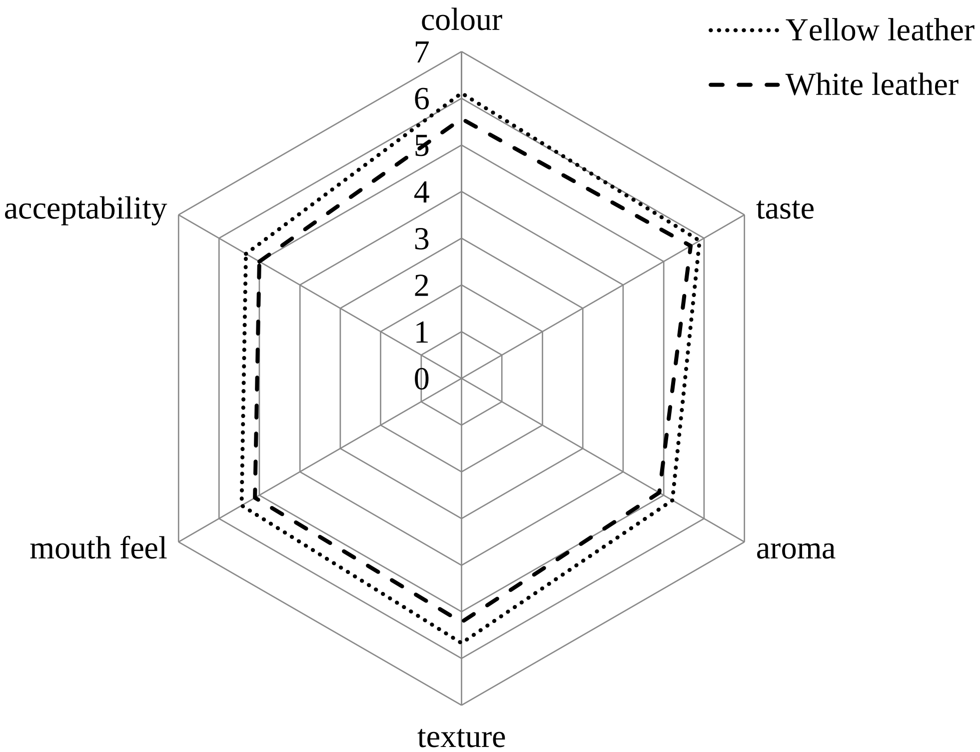

Figure 5-7 Hedonic scores of sensory evaluation conducted by trained panellists which evaluated for colour, taste, aroma, texture, mouth feel and overall acceptability

The white leather hardness values are much larger than yellow hardness leather values. Meaning that white leather required was harder than yellow leather. The same trend was evident with larger values of white leather for fracturability, gumminess, and chewiness. Overall, the white leather was harder than yellow leather. There were no variations between the two dimensionless values of cohesiveness and resilience. The texture of fruit leathers is affected by percentage moisture content and drying temperature, meaning that a longer drying or higher temperature usually causes a harder texture (Momchilova *et al*., 2016).

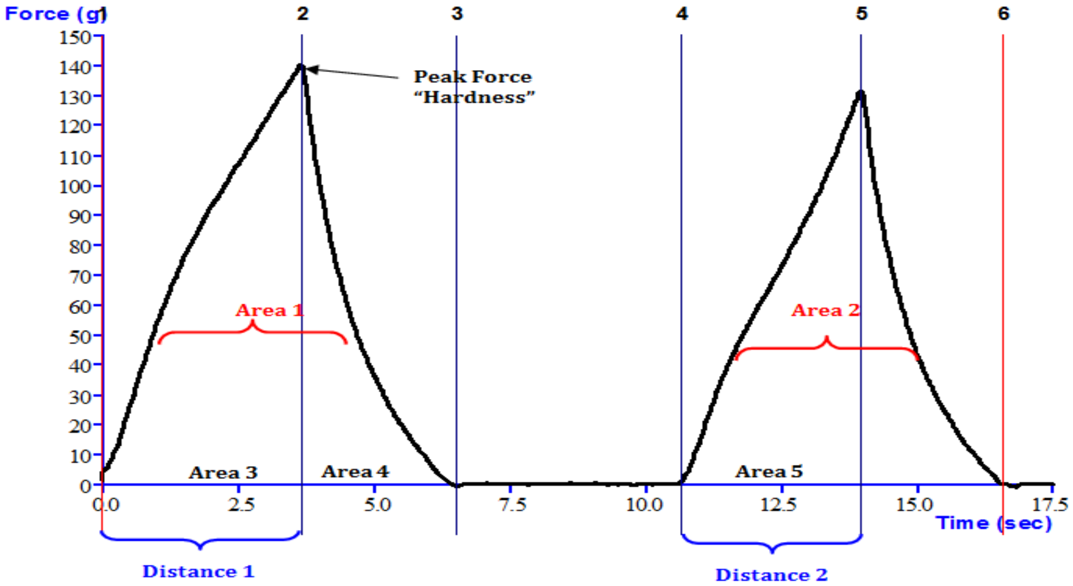

Figure 5-8 Graph showing a typical texture profile analysis curve of food products (extracted from Texture Technologies, 2017)

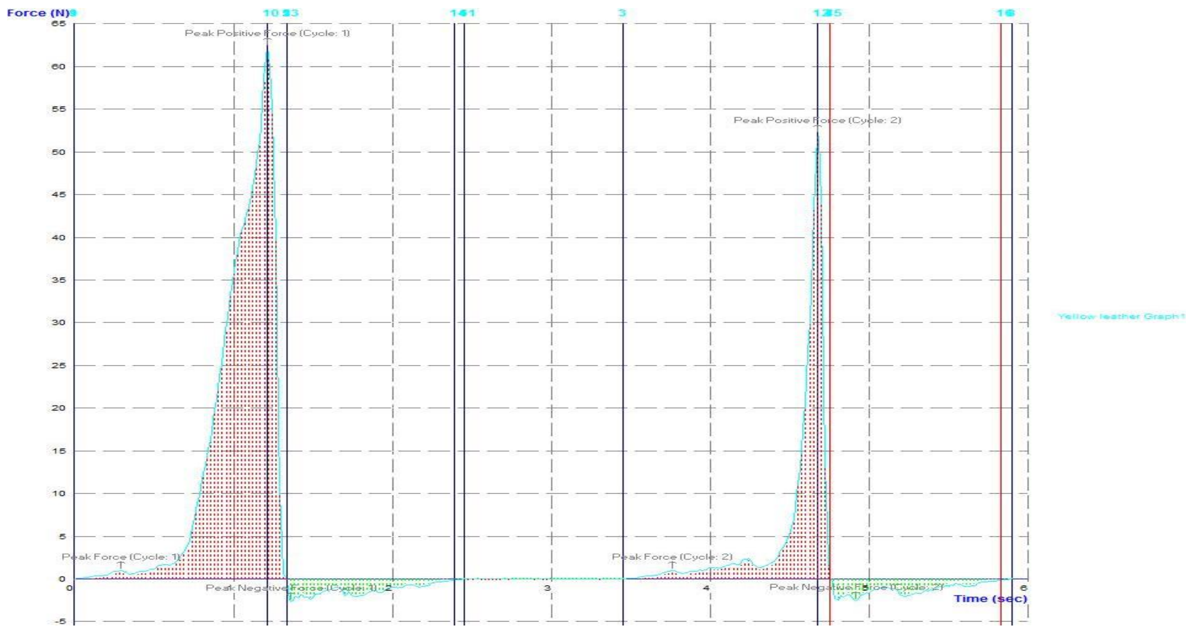

Figure 5-9 A graph of TPA of yellow leather obtained from the current study and used to formulate attributes in Tables 4 and 5 below

The yellow leather recorded less hardness values that ranged between 60.80 N and 82.94 N for the yellow and 117.89 N and 181.05 N for the white leather which proved to be harder than yellow (P≤0.05). Fracturability value for white leather were again larger than the values for yellow leather and ranged between 101.28 N and 174.10 N and the yellow leather range was 40.92 and 63.15 (P≤0.05). There were no significant differences between white and yellow leather cohesiveness, resilience and springiness (P>0.05). The gumminess values were significantly different with white leather ranging between 51.02 N and 80.27 N and 21.70 N and 28.52 N for the yellow leather (P≤0.05). There were significant differences between the yellow and white leather chewiness. White leather ranged between 24.67 N.mm and 28.50 N.mm and yellow leather ranged between 51.01 and 80.25 N.mm.

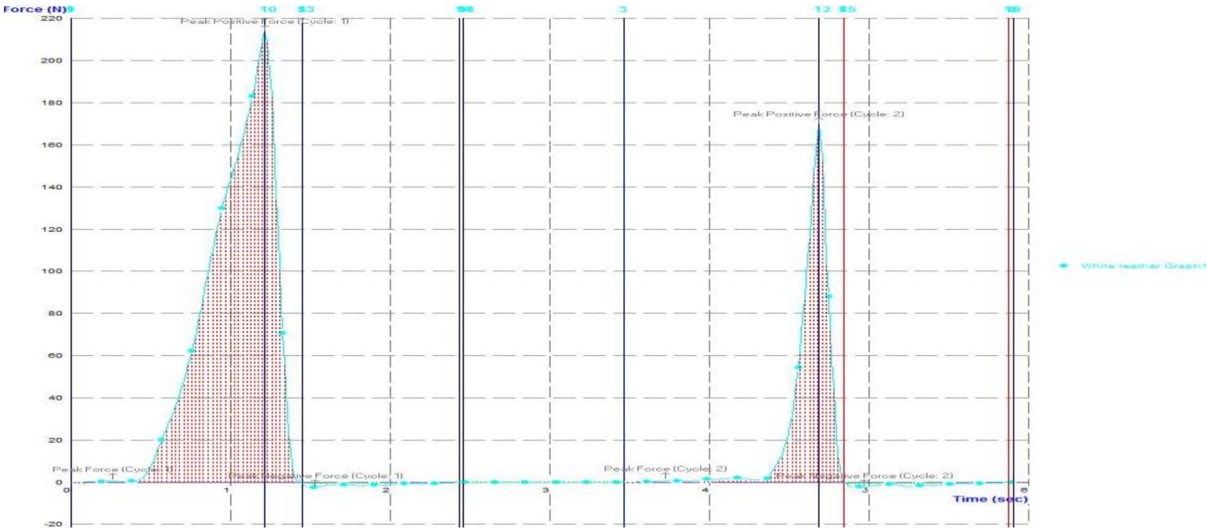

Figure 5-10 Graph showing TPA of white leather obtained in the current study and used to formulate attributes in Tables 4 and 5 below

The study results are in agreement with this explanation since the leather received approximately 13% better objective and subjective results than the leather, which was approximately 7%. The genetic make-up of the fruit also has a role to play as well as the rate of water absorption from the surroundings or protein content of the fruits and sugar; this could explain why yellow and white leather of equal thicknesses produced different moisture percentages (Momchilova *et al*., 2016). The texture of leather products can be improved by adding nuts, also the drying process causes colour and appearance changes for the final product. The lighter leather product tends to be darker and turns brown because pigments are sensitive to temperature. Browning of leather may also be related to the non-enzymatic vitamin C oxidation of polyphenols as well (Momchilova *et al*., 2016).

5.4.7 Microbial analysis

The count of the colony forming units under a microscope was recorded as nil. This could be related to heating of the leather during pulping, due to heat sterilization effects that heating may have. A day after drying this test was conducted. There are possibilities of not getting microbial spoilage in leather and these results are in agreement with what Chavan and Shaik (2015) found in their study of drying guava fruit into leather.

5.5 Conclusions

Fruit leather processing using tunnel solar drying as an energy efficient and affordable value addition method is one of the possible means to reduce postharvest losses to fruits in the KwaZulu-Natal Province of South Africa. The mist-belt conditions in Midlands of the province get wet often enough for an open sun drying to be successful but the use of tunnel solar dryer to protect the product being dried from moisture and contamination has been a success in the current study. Drying under tunnel solar dryer is possible, since the temperature in the drying tunnel becomes higher than the ambient temperature and the tunnel relative humidity becomes lower than the ambient relative humidity. The greenhouse effect in the tunnel dryer that allows for radiation to increase temperature and under such conditions, products that were dried successfully. However, the night relative humidity is very high and closer to 100% and therefore products dried must be sealed overnight to avoid rewetting. The two peach landraces of yellow and white fruits dried in a tunnel solar dryer into leather produced different quality products. Based on the organoleptic and instrumental tests conducted. A sensory analysis was conducted with semi-trained panellists and clearly, the yellow leather received higher scores and regarded as of high quality compared to the white peach leather product. The TPA conducted using a Texture Analyser and Warner-Bratzler blade results were congruent to those of sensory analysis. White leather values of hardness, fracturability, gumminess, and chewiness were much higher than those of yellow leather. The yellow peach leather was much better than white peach leather. The final moisture content of the white leather (7.69%) was significantly lower than that of the yellow (13.33) leather product. However, both yellow and white fleshed leather products of the current study were too low compared to moisture percentage obtained from other studies (14% and 17% average). The yellow leather received the higher scores in sensory analysis. Its moisture percentage was closer to the one obtained from the studies conducted by Deepika and Payel Panja (2017). No microbial spoilage was present in the leather products. There was a strong relationship in the explanation of the subjective method compared to the objective method. The study results of sensory analysis and TPA were congruent, that yellow leather was softer than the white leather products. This agrees to what the panellists obtained as they gave higher scores for yellow than white leather products. There is a linkage in explaining what goes on in the sensory evaluation as a subjective method supported by objective method. The values obtained in subjective method cannot always be the same; from the same panellists depending on issues such as how they are able to judge per specific day, whereas objective results will be able to give specific constant trends and results of higher accuracy.

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6. GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The South Africa small-scale peach grower industry evidently does rely on peach produce for supplementary nutrition. The challenge they are faced with are vast losses suffered by farmers during the picking season since from limited storage facilities. There is a misunderstanding with maturity and ripening which has been perceived as one of the factors adding to postharvest losses. Moreover, the lack of simple and affordable technologies to preserve and add value to their fruit is one of the contributing factors. The use of solar energy drying in the region of KwaZulu-Natal Midlands has been tested for fruit dehydration processes as a value addition and preservation technique. The null hypothesis was rejected in the study since the results were congruent with the alternative hypothesis that peach fruit grown in the small-scale sector industry do possess the processing ability. The tunnel solar dryer was tested and it produced results that proved that despite misty conditions in the Midlands of KwaZulu-Natal, solar drying is possible when tunnel dryer is used.

6.2 Conclusions

6.2.1 Postharvest losses

Postharvest losses intensify the food insecurity and welfare loss of farming communities in less developed countries (Humble and Reneby, 2014; Kitinoja and Kader, 2015; Kasso and Bekele, 2016; Tesfaye and Tirivayi, 2016). Sheahan and Barrete (2016) reported that according the United Nations (UN) in September 2015, there is a plan to half-worldwide food waste and substantially reduce food losses by 2030 as part of its Sustainable Development Goals (SDG). Sheahan and Barrete (2016) clearly state that the pledge by the UN is in line with renewed international attention focusing on reducing the edible losses and waste incurred between a farm and the end user’s fork in a worldwide system. This is particularly relevant to the SSA, where most of the rural population depend heavily on food production for the income and food purchases make up a large portion of expenditure in both rural and urban areas and the dialogue is focussed around the theme ‘post-harvest losses’. The literature review of the study found that there are challenges globally regarding food losses and wastage (Kiaya, 2014; Humble and

Reneby, 2014; Kitinoja and Kader, 2015; Kasso and Bekele, 2016; Delgado *et al*., 2017). The review also demonstrated that there are more losses in developing countries such as in Africa, than the losses in developed countries. The difference is that in developed countries there is wastage, whereby a consumer purchases fresh produce and keep in the refrigeration for too long until it goes off and then the consumer throws it away. Contrasting to developing countries, there is very little fresh produce reaching the fork, since losses occur on farm in the field due to poor resource input and then during postharvest due to limited proper cooling transportation, storage facilities and processing skills (Delgado *et al*., 2017) . Losses in the small-scale peach industry require to a clear understanding from days after full bloom to maturity. It was shown how long it takes this process to take place and the quality parameters as they change with maturity and ripening process. The processing ability of the fruit was determined by the drying process into leather and dehydrated slices; the quality was determined using objective and subjective methods.

6.2.2 Peach growth and development

The current study evaluated the growth and development of the peach fruit in the small-scale growers industry and found that the landraces of white and yellow peach grown by these farmers takes about 129 days from flowering to fruit maturity and this was congruent with what Sutasinee *et al* (2005) reported. Farmers did not seem to understand that the fruit maturity and ripening and two different physiological processes. Farmers believed that the fruit is ready to pick when it has begun to change colour, although, the current study found that the white landraces of Impendle does not change colour significantly during ripening. Clearly, the colour change was found by objective measurements rather than subjective measurements, and this creates a confusion since farmers are not always able to identify the physiological maturity or ripening for the white landraces due to lack to of clear colour change that can be picked up visually. The yellow landraces is the one that farmers can easily tell when the fruit is ripe. However, they also cannot tell when the fruit reaches physiological maturity.

6.2.3 Peach properties

The average mass was 80 g and the average volume was 53 cm^3. The fruit is evidently smaller than the commercially available peaches with improved rootstocks and scions, receiving irrigation, pesticides and fertilizers. However, there were significant differences in mass recorded at different maturity stages between green to fully developed white colour. The average L*, a* and b* were 61.4, 5.54 and 38.41 respectively. Kim *et al*., (2014) found L*, a* and b* to be ranging between 45.59-66.67; -12.00—13.52 and 24.04-27.35 respectively, but these were harvested before reaching full maturity and ripening stages although the current study started from green to white maturity stages. Kim *et al*. (2014) further explained that colour development in peaches is attributed to anthocyanins, which contain antioxidants and are beneficial to for cardiovascular diseases. Hue angle calculated in the study was 39.00 and within the range of 16.90 – 91.40 reported by Forcada *et al* (2014). The percentage moisture content of the study was 83% average. Fruit firmness decreased from 79.00 N for green immature to 24.70 N for fully mature white fruit. The TSS increased with maturity averaged at 19.00 °Brix at fully ripe stage. The fruit pH decreased from 3.4 to 4.0 as the fruit was maturing and ripening. The overall TSS: TA ration was between the ranges of 21.11-35.84.

6.2.4 Solar drying

After many fruit processing methods, the literature review showed that solar drying is one of the simplest and cheapest methods to apply in peach processing. Thus has led to peach slice and leather processing. The challenge was that open solar drying is not always possible in the misty conditions in the Midlands of KwaZulu-Natal and therefore the option was to use a tunnel solar dryer that would be able to keep moist air out of the tunnel avoiding rewetting of the product drying. However, a lower concentration of moisture in the ambient environment and a higher concentration of moisture in tunnel is a requirement for drying. The moist air is able to move from a high to a lower concentration of moisture. The temperature in the tunnel must be higher than the ambient temperature. Higher temperature is able to dry the air, which then absorbs the moisture on the surface of the products, and escape from the tunnel with moisture, allowing the product to dry. The challenge with solar drying in the Midlands of KwaZulu-Natal occurs at night where there is high ambient moisture content that increases the chances of rewetting the produce being dried. Rewetting is not recommended as it brings product contamination and spoilage. The study results showed that when the sun rises in the morning and the ambient temperature starts increasing the tunnel temperature also start increasing, making conducive environment for drying. When the ambient temperature decreased the tunnel temperature also decreased, reducing the drying conditions in the tunnel. The cloud cover intensity also affected both ambient and tunnel temperatures with tunnel temperature always higher than the ambient temperature.

6.2.5 Peach slice drying

The yellow and white fruit landraces produced peach slices. Different product treatments provided different results. AA pre-treatment to white and yellow peach slices received the highest scores from the taste testing panellist, followed by LJ pre-treatment and lastly the control (untreated slices). The slice treatments affect the quality of the slice by reducing the browning effects and the taste of the slice. The texture of the slice is affected by the thickness and number of hours it takes to dry. Thin slices tended to develop a darker colour during the drying process. They also shrink compared to thicker slices. If the slices are too thick, they take longer to dry and eventually chances of mould development are higher. AA also produced the best peach slice colour after drying, according to the taste-testing panellist.

6.2.6 Peach leather drying

Peach leather was processed using both white and yellow peach landraces. The yellow peach produced the best leather compared to the white landrace. However, this was largely affected by final moisture percentage in the leather product. White leather was dried to approximately 7% and yellow approximately 13%. The differences in moisture percentages affected the product hardness, texture and colour. The yellow leather recorded less hardness values that ranged between 60.80 N and 82.94 N for the yellow and 117.89 N and 181.05 N for the white leather which proved to be harder than yellow ($P \leq 0.05$). Fracturability value for white leather were again larger than the values for yellow leather and ranged between 101.28 N and 174.10 N and the yellow leather range was 40.92 and 63.15 ($P \leq 0.05$). There were no significant differences between white and yellow leather cohesiveness, resilience and springiness ($P > 0.05$). The gumminess values were significantly different with white leather ranging between 51.02 N and 80.27 N and 21.70 N and 28.52 N for the yellow leather ($P \leq 0.05$). There were significant differences between the yellow and white leather chewiness. White leather ranged between 24.67 N.mm and 28.50 N.mm and yellow leather ranged between 51.01 and 80.25 N.mm.

The study results agree with this explanation since the leather approximately 13% received better objective and subjective results than the leather that was approximately 7%. The genetic make-up of the fruit also has a role to play, as well as the rate of water absorption from the surroundings or protein content of the fruits and sugar. This could explain why yellow and white leather of equal thicknesses produced different moisture percentages (Momchilova *et al*., 2016). The study results of sensory analysis and TPA were congruent in that yellow leather was softer than the white leather products. This agrees to what the panellists obtained as they gave higher scores for yellow than white leather products. There is association in explaining occurs in the sensory evaluation as a subjective method aided by objective method. The values obtained in subjective method cannot be consistently repeated(even from the same panellists) as it is affect by the human factor such as how they are able to judge on a given day but objective results will be able to give specific consistent trends making them results of higher accuracy and dependency compared to subjective method.

6.3 Recommendations

The study recommendations are targeting fruit growers in KwaZulu-Natal Midlands. The processing of peach into leather and slice aimed at reducing food losses. The aim was to add value to the fruit for later use. Based on the study results several recommendations are proposes to combat the issues faced.

6.3.1 Lessons to farmers in relation to fruit maturity and ripening

There is a misconception amongst farmers that do not understand that maturity is different from fruit ripening. Fruit ripening is a later stage event that takes place after physiological maturity. By knowing the number of days, farmers can be able to estimate physiological maturity and link that with a few easily available instruments such a refractometer, which will be able to tell the TSS level and therefore the farmer, would be able to tell the fruit is ready. If the fruit has been on the tree for about 129 days and the TSS reaches 13 °Brix and above, the fruit must be physiologically mature and ready to be harvested. The firmness of the fruit at 35 N must also be an indication that the fruit is getting ready to be harvested. Towards the end of ripening process, the TSS may reach around 19 °Brix and firmness reaching approximately 24 °Brix. This would be the latest stage at which the fruit can be used and after that, it is waste. There are needs to educate farmers about postharvest handling of fresh produce. They need to know and understand the climacteric status of the fruit in order to handle it properly. Farmers can keep fruits together that are ripening and releasing ethylene together with fresh fruits that have just been picked and in the early maturity stages. As a result, all fruits reach the end of ripening stage too soon, thus increasing wastage.

6.3.2 Improved fruit landraces

Farmers in the small-scale farming sector are still using very old unimproved fruit landraces that have low yields due to fruit size being very small. Improved landraces with larger fruit size are required. However, the small-scale peach landraces are tolerant to drought and some diseases. Plant height is also another challenge. Farmers are not able to pick the fruit at the highest branch of the tree. As a result, top branches of the tree add to food waste and losses because that fruit is not picked. Pruning is one of the methods that farmers can employ to reduce losses on top branches. The challenge however is that goats prune the branches and leaves at the bottom part of the trees. As results, trees bear fruits at about 1.5 m above ground where goats may not reach.

6.3.3 Fruit quality properties

Chemical, physical and chemical properties were determined during the study. The average volume of the fruit was 53 cm^3 with the average mass at 80 g. The study results clearly showed that as the fruit matures, the pH decreases and the TSS increases. The moisture content of a mature fruit averaged at 83%. The TSS: TA ration averaged at 35; this was slightly higher since some peach fruit reach about 25. Fruits that were harvested at early stages to check the properties suffered from shrinkage due to cells being underdeveloped and moisture losses. Fruit storage at room temperature showed that the fruit lasts only three days with proper quality, after that it starts to shrink. Conclusively, the fruit does not have long shelf life capabilities and deserves immediate consumption or processing without storage requirements exceeding three days.

6.3.4 Fruit drying

Due to high moisture content in the KwaZulu-Natal Midlands, it is recommended that farmers do not apply open sun drying because their produce will be spoilt by grey mould due to high moisture and sugar content. Nevertheless, farmers can use solar drying methods by adopting tunnel dryers for large scale or cabinet dryers for small scale drying purposes. The product will be protected from the moist ambient environment and foreign matter such as dust and birds. It is also highly recommended that even when the tunnel or cabinet dryers are used, the product be removed and placed in a moisture free environment at night, due to high moisture percentage that will rewet the products being dried and increase chances of contamination.

6.3.4.1 Peach slice drying

Between the white and yellow landraces, the yellow landrace was the best peach to process due to its colour property. It produced appetising peach slice products that were preferred by taste panellist over white peach slice product. It is recommended that white fruit be processed into a mixture of products whereby properties such as colour of the white peach do not appear in the final blended product. AA produced the best products of dried slices in terms of colour as it avoided browning of slices compared to lemon, which was followed by the control. When farmers are not able to source AA effortlessly, it is still advisable to use LJ to avoid browning. The slice thickness need to be on average 5 mm thickness. Any slice below the 5 mm thickness may start to shrink during the drying process. Shrinking reduces the visual appearance scores of the product. In addition, when the product is below 5 mm, there are chances that it will turn darker and become harder, also reducing the quality of the produce. Slices thicker than 5 mm need to be dried as quickly as possible to avoid mould development. It is recommended that moisture content be kept at approximately 15% for the fruit slices.

6.3.4.2 Leather processing

Fruit leather was processed using both white and yellow fruit landraces. The quality of the leathers was different with yellow peach receiving high scores compared to white. The yellow leather had a higher moisture content (approximately 13%) whereas the white had approximately 7%. There were significant difference in both subjective and objective measurements in terms of the quality of the products. White leather turned slightly dark after drying, whereas yellow leather became lighter and received highest overall acceptance scores from the taste-testing panellist compared to white leather. The objective analysis pointed out that yellow leather was much better than white leather.

It is recommended that farmers utilize the inexpensive solar dryers in the midlands of KwaZulu-Natal. Since drying was a possibility in mist belt which was regarded as the worst-case scenario. It is important to consider the period of drying. Between December and March, there are rains in the Midlands and mist, but close monitoring of weather patterns does allow drying to take place. A farmer would need at least three to four days of no rain, depending on the slice thickness of their produce. Slices thinner than 4 mm shrink and change to black colour, it is recommended to use peach quarters or slice thicker than 5 mm. To remove the product being dried at night to avoid rewetting, which causes grey mould during the drying period if the product was not removed is also recommended. This work stresses that farmers need to have a clear problem before they can accept and implement some of the research output.

6.4 Further Research

These recommendations are targeting fruits produced in the small-scale industry, whose fruit research is lagging, compared to commercially available fruit cultivars with improved characteristics. The current study aimed at evaluating the properties and the processing ability of the fruit due to its properties and the environmental conditions in the Midlands, but the following studies are still recommended:

- To do further research on the nutritional properties of white and yellow fruit before and after processing;
- to test different leather and peach thicknesses and quality relations;
- to test different peach slice treatments at different concentrations to evaluate which one yields the best results;
- to test how different treatments and thickness affect the drying hours for both leather and slice; and
- to evaluate shelf life period for the dried products.
- to test fruit leather blended to other crops for improved nutritional value and quality.
- Further research on the following topics:
- Humidity ratio of the air,
- Ambient weather (temperature, relative humidity and solar radiation) to psychometric properties of the tunnel interior,
- Derive models for Extension purposes to predict suitable drying conditions without carrying experiments again,
- Determine the distribution of lateral and vertical microclimate in the tunnel and
- Determine the spectral properties of the film since they affect the colour of the dried product.

6.5 Bibliography

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