TEXTURAL PROPERTIES AND FRUIT CHARACTERISTICS OF DESSERT BANANAS DURING RIPENING

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DECLARATION

I Simon Muganga take responsibility for the contents of this report and source of material or information contained therein. In the same perspective, I hereby declare that the information in this special project report is my original work and has never been produced at any University for the award of the degree of Bachelor of Science in Food Science and Technology.

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DEDICATION

This Research is dedicated to all students and members of staff of the School of Food Technology, Nutrition and Bioengineering. It’s with great optimism that I hope you will find the work within this research relevant to your duties as students and/or academicians. It is therefore my desire that in one way or the other the information in this research contributes to the academic pool of knowledge and/or is utilized to solve a problem.

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ACRONYMNS AND ABBREVIATIONS

TSS – Total soluble solids

TPA- Texture Profile Analysis

FAO – Food and Agriculture Organisation

FAOSTAT – Food and Agriculture Organization Statistics

UBOS – Uganda bureau of statistics

UEPB – Uganda Export Promotions Board

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ABSTRACT

Dessert bananas suffer substantial postharvest losses due to mechanical forces during transport and distribution. This work aimed at determining the textural properties and mechanical strength of three dessert banana varieties at different stages of ripeness. Bunches of three desert bananas varieties (fhia, bogoya and ndiizi) were harvested at mature green stage and kept at room temperature. The changes in their postharvest texture in compression (with or without rind) and abrasion modes together with the physico-chemical properties including pH, acidity, TSS and ripeness scores were then determined every after 48hours. At the sametime, the relative humidity and room temperature were also recorded, from the day of reception of materials until the bananas exceeded stage 7 of ripening.

For all the varieties, textural properties and fruit characteristics changed with the stage of ripening. TSS increased at different rates as ripening progressed, ndiizi had the highest initial TSS, followed by bogoya and fhia that had the similar amounts. Additionally, the TSS for ndiizi increased immediately, that of fhia after 4 days while that of bogoya increased after 6 days. Ndiizi had the highest final TSS, followed by bogoya and then fhia in that order. In all the varieties, the ripening score increased only after day 6 until a constant maximum score after day 14. The pH generally reduced to a minimum and then became constant as in ndiizi or further increased to a constant value as in bogoya and fhia. The acidity of the dessert bananas generally increased to a maximum value and thereafter decreased; fhia reached the highest acidity at day 6, followed by ndiizi at day 8 and lastly bogoya at day 10, respectively as ripening progressed. The textural hardness and toughness for all varieties decreased as ripening progressed; within a variety, the harness and toughness was higher with rind (peel) than without rind.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Bananas are one of the most important and oldest food crops of humankind. They are broadly classified into dessert and cooking types. Dessert types are usually eaten raw when ripe, while cooking (starchy) bananas are usually boiled, fried, brewed, powdered, or roasted before consumption. Plantains are the best known among the cooking bananas and form about one-third of total banana production (Nayar, 2010). Plantains usually contain more dry matter than banana. Several of the plantain and banana cultivars are used in various countries for both dessert and/or cooking use.

Bananas botanically belong to the musaceae family. This family is composed of bananas, plantains and ornamental bananas originally from southeastern Asia, with Africa being a secondary center of diversity. The family is composed of genera “Ensete” and “Musa”. Ensete ranges through Africa and southern Asia; has fruits that are dry, seedy and inedible basically for ornamental purposes. Musa which has its origin in Asia is composed of many cultivars of edible bananas though they all originated from two species namely *M. acuminata* (genome AA) and *M. balbisiana* (genome BB). Hybrids cultivars of the two species above exist with hybrid triploids such as AAA, AAB, ABB as well as tetraploids e.g. AAAA, AAAB, ABBB etc. cultivars with genome AA are characterised with extra ordinary sweetness and fine fruit quality e.g. the Inarbinal and lakatan subgroups from Philippines. The AB genome includes examples such as Kamarangasenge aka “sukari ndiizi” from Uganda and Ney Poovan from India. The AAA genome has most significant subgroups of edible bananas known as the Cavendish with cultivars such as pisang masak, dwarf Cavendish and extra dwarf Cavendish; Gros Michel has cultivars such as highgate (Jamaica), lowgate (hondorus). The lowgate cultivar is the smallest version of “gros Michel” and was used in the breeding programme for FHIA bananas. Most notable among the tetraploid cultivars are those from the FHIA breeding program e.g. AAAA, FHIA-O2, FHIA -17 and FHIA-25. Genome AAAB, FHIA-01 is a dessert type, FHIA-20 and FHIA-21 are plantain varieties. Other genomes such as BB and BBB are not grown significantly. There is no clear demarcation between the banana and plantain, either botanically or genetically.

According to Van Asten etal, (2008) “sukali ndiizi” (apple banana AAB genome) is one of the dessert banana types in Uganda; other dessert bananas on the Ugandan market include the ‘Gros Michel’ (bogoya) and ‘Cavendish’ (both AAA genome). FHIA is another type of banana cultivar with fusarium resistance and comprises of a variety of cultivars such as ‘FHIA-01’, AAAB genome; ‘FHIA-17’, AAAA genome; ‘FHIA-23’, AAAA genome to mention but a few. VEDCO Uganda, (2013) also reported Bogoya, Ndiizi, FHIA-17 and Cavendish as some of the dessert banana cultivars grown in Uganda.

In Uganda, a total of 3,493,110 tonnes of bananas were produced in 2017 (UBOS, 2018). However, statistics show that the quantity of formal banana exports from Uganda has been declining since 2015 (UBOS, 2018). The decline in volume is attributed to improper postharvest, handling, packaging, storage, and distribution practices. The lack of proper means of post-harvest handling of fruits and vegetables at the retail and wholesale levels, results in poor quality of fruits and vegetables at the consumer level (Hailu etal, 2013).

1.2 Problem statement

The East African highlands are home to more than 80 cultivated varieties of locally evolved bananas and constitute a secondary center of banana diversity. Uganda is the leading producer and consumer of banana in the east African region and also enjoys the highest diversity of a group of bananas uniquely adapted to this region. This unique adaptation makes dessert type bananas especially the “sukali ndiizi” native to Uganda. Other banana types in the East African highlands comprise of the cooking and brewing types (Gold, Kiggundu and Karamura, 2002).

In addition, a study conducted by Whitney et al, (2016) revealed that postharvest losses (as a result of qualitative and quantitative deterioration of the fruit) destroy 20-60% of all food produced in East Africa, exacerbating regional food insecurity. Furthermore, postharvest losses result in direct food and income losses to farmers and consumers globally. Kikulwe et al, (2018) reported that 14.9% of all the cooking bananas that are produced in Uganda suffer postharvest deterioration along the value chain (7.2% of the bananas deteriorate completely and have no residual value, while 7.7% deteriorate partially and are sold at discounted prices) all of which is due to the poor handling, packaging, storage, distribution practices employed. Although specific empirical data is scanty, it is likely that similar postharvest losses occur in dessert type bananas since they are subjected to the same poor postharvest handling practices.

The textural properties and mechanical strength and tolerances of the dessert type bananas grown in Uganda are not established. Yet the postharvest handling practices, packaging, storage and distribution of fresh fruits and vegetables should be informed by empirical data. This lack of empirical information remains a major challenge towards operationalization of strategies to reduce postharvest losses in many countries of the East African region. This study therefore aimed at establishing the textural properties and mechanical strength of three dessert bananas over the ripening period to inform the development of suitable postharvest handling practices.

1.3 Objectives

1.3.1 General objective

To establish the textural properties of three desert type bananas during the postharvest period.

1.3.2 Specific objectives

Specifically, the research sought to determine the:

i. Textural properties and role of rind in dessert type bananas in compression mode.
ii. Textural properties and role of rind in dessert type bananas in abrasion mode.
iii. Total Soluble Solids, pH and ripeness score in dessert type bananas during postharvest period.
iv. Contribution of the rind to mechanical strength of dessert type bananas during postharvest period.

1.4 Hypothesis

- Variety of dessert bananas does not affect their textural properties and mechanical strength.
- Degree of ripeness affects the textural properties and mechanical strength and chemical properties of dessert type bananas.

- Fruit rind does not affect the textural properties and mechanical strength of dessert type bananas during postharvest.

CHAPTER TWO

2.0 Literature review

2.1 Varieties of desert bananas grown in Uganda

Uganda enjoys the highest diversity of a group of bananas uniquely adapted to the East African region (Kyobe, 1981). Kiggundu, Abera and Karamura (2002) studied 120 farmers, at 24 sites throughout the banana-growing region of Uganda to establish the distribution patterns of banana varieties in Uganda; the study revealed Ndiizi ('Ney Poovan` subgroup) and Gros Michel (`Bogoya') as desert banana varieties grown in Uganda. Ndiizi was the most ubiquitous cultivar, being found at all 24 sites and on 102 farms; Gros Michel was found on (24 sites, 72 farms). Bettina et al., (2012) identifies Gross Michel, Kayinja, Kisubi and apple banana, as being the major dessert and juice-producing bananas in the Uganda.

2.2 Production statistics for bananas in Uganda

Precise figures on total global banana production are difficult to obtain as banana cultivation is often conducted by smallholder farmers and traded in the informal sector, which is not easy to ascertain, For example, some 70-80 percent of production in Africa are local bananas that have been present on the continent for over 1,000 years. These are mostly cooking bananas that are a popular and important staple food. Available data also indicates that between 2000 and 2015, global production of bananas grew at a compound annual rate of 3.7 percent, reaching a record of 117.9 million tonnes in 2015, up from around 68.2 million tonnes in 2000. The biggest global producers are India, which produced 29 million tonnes per year on average between 2010 and 2015, and China at 11 million tonnes.

2.3 Economic importance of bananas in Uganda

Banana is the fourth important food crop in terms of economic importance coming after rice, wheat and milk (Bose, Mithra and Sanyal, 1996). The cultivation of bananas is carried out worldwide and provides employment for a large number of people (Rao, 1998). Apart from desert purpose, a number of value added products are prepared from bananas and many of these products serve as materials in confectionary, tanning and beverage, pharmaceutical and animal feed industry (Bose, Mithra and Sanyal, 1996). Additionally, all parts of the banana plant have medicinal applications (Jyothirmanyi and Mallikarjuna, 2015). the flowers in bronchitis and dysentery and on ulcers, young leaves are placed as poultices on burns and other skin afflictions, the astringent ashes of the unripe peel and of the leaves are taken in dysentery and diarrhea and used for treating malignant ulcers, Antifungal and antibiotic principles are found in the peel and pulp of fully ripe bananas, A fungicide in the peel and pulp of green fruits is active against a fungus disease of tomato plants (Sampath et al., 2012). Traditionally, banana leaves are used for everything from umbrellas to construction materials; banana and plantain fibers are used throughout the world to weave ropes, mats and other textiles; Tannins present in ripe banana peel act as tanning agents in leather processing. (Sampath et al, 2012). All banana plants can produce edible fruit, but the fruit taste, seediness, color, size and other characteristics depend on the species or variety (Angela 2019). Angela further reports that bananas can be peeled and eaten raw; baked peeled or unpeeled, made into a puree suitable for infants and used in many other ways. In addition to this plant's highly versatile fruit, peeled stems can be chopped and added to salads or steamed with other vegetables (Sampath et al., 2012).

2.4 The bananas value chain and postharvest losses

The banana value chain in Uganda mainly comprises of producers, collectors (brokers and bicycle traders), wholesalers, exporters, retailers, hawkers and consumers. The chain involves the movement of bananas from the producer to the lorry traders either directly by farmers or through brokers and bicycle traders. Lorry traders transport and distribute the bananas to the retailers who then sell directly to the final consumers or sell to hawkers than finally sell to consumers. Although some bananas move from producers directly to the exporters; who mainly sell to Europe and to the region, especially South Sudan, the volume of export is relatively very small (Nalunga et al., 2015). Other value chain actors include input suppliers that provide such inputs as tissue plantlets and fertilizers to farmers for banana production and local processors that ferment banana juice with sorghum and then distil it to give “waragi”, a local gin (Kiggundu, Abera and Karamura, 2002). The marketing of fresh produce including bananas is complicated by postharvest losses both in terms of quantity and quality between harvest and consumption (Hailu and Workneh, 2013). Both the fresh market and processing plants for fruits are usually located in towns away from farms and producers in rural areas (Nalunga et al., 2015). Nalunga et al., (2015) further reported that the actors along the cooking banana value chain in Uganda face high postharvest losses due to short green life of bananas and damage arising from poor postharvest handling, leading to high physical and economic losses. Additionally, postharvest losses in fruits and vegetables range from 25 to 40% (Raja and Khokhar, 1993) or even greater (Iqbal, 1996) in developed countries.

2.5 Practices responsible for postharvest losses

Kiaya, (2014) defines postharvest losses as the degradation in both quantity and quality of a food product from harvest to consumption. Quality losses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product (Kiaya, 2014). These losses are generally more common in developed countries (Kader, 2002). Quantity losses refer to those that result in the loss of the amount of a product. Loss of quantity is more common in developing countries (Kitinoja and Gorny, 2010). Practices responsible for these high losses include poor storage/inefficient storage facilities, and poor means of transportation (Kebede, 1991; Workneh et al., 2010), employment of improper harvesting methods such as: Rough handling; untimely harvesting; use of poorly-designed harvesting tools, equipment, and harvesting containers that cause damages to product; improper packing and packaging technologies also result in increased mechanical injury during the transit of produce from rural to urban areas thus increasing on the postharvest losses (Kiaya, 2014). This is unison with the fact Bananas are transported to the markets mainly as bunches on bicycles or stacked on trucks and are usually unprotected from harsh weather (Nalunga etal., 2015). Nalunga et al., (2015) also suggests thefts, bruising, finger-plucking and ripening as the major causes of postharvest losses at retail level. Additionally, there is no proper means of post-harvest handling of fruits and vegetables at the retail and wholesale levels, which results in poor quality of fruits and vegetables at the consumer level (Hailu and Workneh, 2013). For the fresh bananas to reach the consumer in a perfect form, a combination of suitable temperature and humidity, appropriate packaging and handling methods as well as good handling during harvesting can minimize mechanical damage and reduce subsequent wastage due to microbial attack (Wills et al., 1998).

2.6 Textural properties and mechanical strength of dessert bananas

Salvador et al., (2007) studied the behavior of two different varieties of dessert bananas from the *Musa Cavendish* AAA group and the *Musa paradisiaca* L. AAB group during storage at 20 °C without any controlled atmosphere. In this study, Changes in instrumental colour and texture, and in a number of a sensory attributes (such as colour and its uniformity quantity of dark spots of banana peel and pulp spots, over-ripe zones, hardness, ripe taste, sweetness, astringency and central fibrosity) by a descriptive sensory panel, and acceptability by a consumer panel of the two varieties over storage were analyzed. During storage, the change in peel colour from green to yellow was gradual in the *M. Cavendish* samples, whereas the *M. paradisiaca* variety presented a different pattern, remaining green for the first 8 days and then changing rapidly to a yellow tone from day 12 onwards. While the flesh texture of the *M. Cavendish* type bananas softened quite rapidly during storage, it evolved more slowly in the *M. paradisiaca* variety and there was little variation in the flesh hardness values over the storage time. Maximum sensory acceptability in the *M. Cavendish* samples was found at 8–12 days' storage, for 90% of consumers, but did not rise above 50% in the *M. paradisiaca* variety.

Textural change is the major event in fruit softening, and is the integral part of ripening, which is the result of enzymatic degradation of structural as well as storage polysaccharides. The process of textural softening is of much importance in packaging, handling and distribution of the fruits as it directly dictates fruit shelf life and consumer acceptability. Cell walls of fruit undergo a natural degradation during fruit ripening, reducing cell wall firmness and intercellular adhesion. This leads firstly to the attainment of a desirable eating texture and then, as senescence begins, to a loss of this desirable texture (Toivonen and Brummell, 2008). Bananas undergo significant textural transformations during ripening process, which in turn influence the eating quality of the fruit. These transformations can be measured by performing a texture profile analysis (TPA) of these bananas during the ripening period so as to establish the textural properties as well as mechanical strength of the bananas (Kajuna et al., 1997).

2.7 Ripening of bananas and associated physiological changes

Ripeness and maturity, when applied to fruits and vegetables are used for defining the appropriate state for harvesting and for eating. Fruit ripening is a highly coordinated, genetically programmed irreversible phenomenon which leads to the development of a soft and edible ripe fruit with desirable quality attributes via a series of physiological, biochemical, and organoleptic changes. Ripeness is usually considered readiness for harvest. It is the result of a complex of changes many of them probably occurring independently of one another. Ripening marks the completion of development of a fruit and the commencement of senescence (Payasi and Sanwal, 2005). From a scientific point of view, fruit ripening is seen as a process in which the biochemistry and physiology of the organ are developmentally altered to influence appearance, texture, flavor, and aroma (Giovanonni, 2004). For the consumers and distributors, the process of ripening corresponds to those modifications that allow fruit to become edible and attractive for consumption (Bouzayen et al., 2010). Fruits can be divided into two groups according to the regulatory mechanisms underlying the ripening process (Bouzayen et al., 2010). Climacteric fruits, such as bananas, tomato, apple, pear, and melon are characterized by a ripening-associated increase in respiration and in ethylene production while non-climacteric fruits, such as orange, grape, and pineapple are characterized by the lack of ethylene-associated respiratory peak (Bouzayen et al., 2010).

The fruit ripening process has been viewed over the last decades as being successively of physiological, biochemical, and molecular nature (Bouzayen et al., 2006). Ripening is accompanied by seed maturation, colour changes, changes in respiration rate, changes in ethylene production, changes in cellular compartmentation and tissue permeability, softening due to changes in composition of pectic substances, organic acid changes, changes in carbohydrate composition etc (Pratt, 1975). These biochemical events, including changes in color, sugar and acidity, texture, and aroma volatiles are crucial for the sensory quality of these fruits (Bouzayen et al., 2010). As the fruit ripens, starch is converted into simple sugars through enzymatic browning process (Maduwanthi & Marapana, 2017). Starch forms about 20 to 25% of the fresh weight of the pulp of unripe bananas. Sugars are present in the green fruit only about 1 to 2% in the fresh pulp which rises up to 15 to 20% at ripeness (Simmonds, 1959). The soluble sugars detected in ripened banana are mainly sucrose, glucose and fructose (Adão and Gloria, 2005). According to Adao and Gloria (2005) the mean level of starch content in ‘Prata’ banana was reduced from 15.7 g/100 g to 3.40 g/100 g during ripening. As well total soluble sugar content was increased from 1.26g/100g to 14.3g/100g. Adewale, Adefila and Adewale (2013) reported that unripe banana (*Musa sapientum)* had highest amylase activity (3900 ± 310 Units/mg protein) and decreased rapidly to a very low value (100 ±15 Units/mg protein) when it was fully ripened. The peel colour changes from green to yellow during ripening of banana fruit (Chen, 2002). The most important compounds responsible for the change in peel color are chlorophylls and carotenoids (Subagio, Morita and Sawada, 1996). Chlorophyll content decreases and then becomes absent in ripe fruit (Maduwanthi & Marapana, 2017). The level of total carotenoids decreases to half the level at the colour break and subsequently again reaches a level similar to that in green fruit (Gross and Flugel, 1982). Maduwanthi & Marapana, (2017) reported the major pattern of pulp carotenoids in bananas being α - carotene (31%), ß- carotene (28°/o) and lutein (33°/o) of total carotenoids. Banana peel contained 3- 4 μg/g carotenoids content as lutein equivalent and ingredients were lutein, ß- carotene, α – carotene violaxanthin, auroxanthin, neoxanthin, isolutein, ß-cryptoxanthin and α- cryptoxanthin (Maduwanthi & Marapana, 2017)

Vonloesecke (1950) reported the presence of malic, citric, oxalic, and tartaric acids in the banana fruit, with malic acid being the principal acid. Malic and Citric acids are responsible for tartness in the unripe banana while oxalic acid is contributed to astringent taste of the fruit (Seymour, Thompson and John, 1987). According to Vonloesecke (1950), titratable acidity of the pulp increases to a peak during ripening in the case of some varieties, and then declines. Further it has reported that malic acid concentration has been reported to vary between 0.8 and 7.5 meq/100g and it is increasing three to sevenfold during ripening (Vonloesecke, 1950). The controversial results with Vonloesecke were reported in (Soltani, Alimardani and Omid, 2010) where titratable acidity decreased gradually until the fruit reaches to full-ripe (stage-6) then increased at stage-7. According to Malakar, Roy and Kumar and Kulkarni (2015), titratable acidity decreased during the ripening period. According to Wyman and Palmer (1964) malic acid content was 1.36 meq/100g at the pre climacteric stage and it increased up to 5.37 at the climacteric stage and 6.2 meq/100g at the post climacteric stage while oxalic acid content was decreased from 2.33 to 1.37 meq/100g at pre climacteric stage to post climacteric stage. However total organic acidity was increased during ripening.

2.8 Analysis and indicators of textural and mechanical properties of fresh fruits

It is worth noting that different researchers may measure different textural properties during a texture analysis. In a TPA performed by Jaiswal et al., (2014), the ripening period was found to have a significant effect on the textural attributes of bananas such as peel, fruit and pulp firmness, pulp toughness and stickiness; all these were found to be decreasing except stickiness. Loss of firmness or softening during ripening has been linked to the breakdown of starch into sugars, breakdown of cell walls or reduction in cohesion of the middle lamella due to solubilisation of pectic substances (Palmer, 1971) and finally migration of water from the skin to the flesh as a result of osmosis (Smith et al., 1989). While Kajuna et al., (1997) measured parameters as hardness, chewiness, gumminess, cohesiveness, springiness of fruit cylindrical samples, Tapre and Jain (2012) Measured mechanical properties viz. firmness, cohesiveness, chewiness, fracture force, stiffness of the whole fruit. A study conducted by Kajuna et al., (1997) aimed at determining Textural Changes of Banana and Plantain Pulp during Ripening. Here Green banana and plantain fruits were treated with ethylene or kept untreated, then stored in environmental chambers at 13, 16, 20 and 25^{o}C for 8days. On daily basis, cylindrical samples of the fruits were compressed twice at 50 mm min~1 to 75% of the original height. Changes in the textural properties were estimated by the texture profile analysis (TPA) technique, involving such parameters as hardness, chewiness, gumminess, cohesiveness, springiness. In the results, it was discovered that Storage time significantly reduced all TPA parameters except cohesiveness. Untreated bananas were harder than untreated plantains at all stages of storage. In treated fruits, however, the trend was reversed, and bananas softened more than plantains. Generally, treated fruits resulted in reduced TPA parameters as compared to untreated fruits. Untreated fruits of both varieties had a good correlation between pH and hardness-1 while treated fruits did not show any correlation between the two properties. Loss of turgor, degradation of starch and enzyme catalyzed changes to wall structure and composition are the mechanisms which leads fruit softening (Maduwanthi and Marapana, 2017). According to Finney (1967), textural change in banana fruit during ripening is predominantly due to the changes in chemical structure of starch grains. A number of researchers have shown that starch content in the pulp of banana decreases drastically during the short period of ripening and then starch is no longer detected (Barbell, 1943; Charles and Tung, 1973). However, Kojima (1996) suggests that banana pulp softening process is due to the associated process whereby the contents of pectic and hemicellulosic polysaccharides and starch decrease during ripening.

According to Ali (2004) 50% firmness loss was occurred in 3 days during ripening in Mas banana (*Musa acuminata*, AA group). In addition to the fact that dessert bananas are a rich source of energy, vitamins and minerals which are essential for human nutrition, bananas are tropical climacteric fruit, and hence they suffer a lot in terms of post-harvest loss due to poor shelf life. The texture of a banana plays a major role in determining the ripening qualities which determines the shelf life. However little research has been done locally to relate texture of bananas to post harvest losses, Hence a study designed to establish the textural properties of these bananas is fundamental to operationalization of measures to mitigate the causes of postharvest losses incurred.

CHAPTER THREE

3.0 Methodology

3.1 Materials and preparation

Three dessert banana varieties were used in the study. These included FHIA, bogoya and sukali ndiizi. These bananas were obtained from the same farm at National Agricultural Research Organisation in Kawanda. Samples for testing were randomly picked from a full bunch. The cluster chosen randomly on a bunch of each variety was then carefully separated from the bunch using a sharp knife and its fingers labelled with initials according to variety i.e. F, B and N for FHIA, bogoya and ndiizi respectively. The sampled and labelled materials were then used for measurement of test parameters.

3.2 Experimental design/treatments

In this experiment, a completely randomized design was applied. The two independent variables were variety and degree of ripeness of the dessert bananas. The dependent variables were texture and physico-chemical properties of the bananas.

3.3 Analyses

3.3.1 Determination of pH

The pH measurement was done using a digital pH meter (model dzs-706, Wincom Company Ltd, Changsha, China) as described by Saucedo-Pompa et al., (2009). Here, two peeled fingers of each sample were blended at a time in an electric blender; pressed through a cheese cloth to obtain a fine extract which was then centrifuged at 4500 rpm for 10 minutes. The clear supernatant was poured off and then labelled as test solution. The probe of the pH Meter was then dipped into the test solution for each variety, and the value read off on the digital scale end.

3.3.2 Determination of acidity

The acidity of the fruits was determined through titration as total titratable acidity (Maftoonazad and Ramaswamy, 2008). In this method, two peeled fingers of each sample were independently blended in an electric blender with thorough washing in between samples; pressed through a cheese cloth to obtain a fine extract which was then centrifuged at 4500 rpm for 10 minutes. The clear supernatant was poured off and labelled as the test solution. Five mills of the test solution of each variety was then pipetted into a conical flask and diluted to about 50mls with distilled water. Three drops of phenolphthalein indicator were added to the conical flask and the solution was titrated with 0.1M sodium hydroxide solution till a faint pink colour end point was reached. The volume of the base required to reach the end point was noted. Total acidity was expressed as percentage malic acid.

3.3.3 Determination of degree of ripeness

The degree of ripeness was obtained through awarding visual scores to the samples by manner of comparison against a Standard Banana Colour Chart (score card) by SH Pratt & Co Ltd. The resulting scores awarded to each sample represented the stage and hence degree of ripeness.

3.3.4 Determination of total soluble solids

The total soluble solids content of the centrifuged samples were measured according to Saucedo-Pompa et al., (2009) using a handheld refractometer (WYT-4,Quanzhou Zhongyou Optical Instrument Co, Ltd. Quanzhou, China) and expressed in ^{O}brix. In this method, two peeled fingers of each sample were independently blended in an electric blender with thorough washing in between samples; pressed through a cheese cloth to obtain a fine extract. Two drops of the extract were placed on the prism of the refractometer, the glass cover flipped back and the ^{O}brix was read by looking through the instrument on the opposite side. The readings taken represent amount of grams of sucrose in 100g of sample.

3.3.5 Determination of textural properties

Fruit samples from each of the batches were taken at intervals of 2 days and analyzed for texture using a texture Analyzer (*TA.XTplus Stable Micro-Systems, Surrey, UK*) according to (Yang et al., 2007); with modifications. A load cell of 30kg was used in both modes. Banana samples were positioned in the middle of the Texture Analyzer platform and commanded to start. The forces recorded in form of texture curves were monitored on a Personal Computer (PC) connected to the Texture Analyzer. A total of 12 replicates were analyzed for each sample; i.e. 4 replicates for abrasion, 4 more for compression with rind and lastly, 4 replicates for compression without rind.

- Compression mode

The measurement of compression was performed by penetration using a penetration probe of 6 mm diameter. The Texture Analyzer was set in *Return-to-start* mode with the following test settings:-penetration distance into the sample; 10 mm, pre-test speed;1.0 mm/s, test speed into sample; 2.0 mm/s, post-test speed; 10 mm/s, a trigger force of 0.049 N and calibrated using a 2 kg load.

- Abbrassion mode

The measurement of abrasion was performed using a 75mm probe, with the texture analyzer in return to start mode. The force needed to fracture or penetrate the banana sample was recorded as the first peak under the force-time curves and was taken as the hardness (N) (Jha et al., 2010a; Chillet, Beaute, & Dubois, 2006).

3.3.6 Data Analysis

Data was subjected to analysis of variance (one-way ANOVA) using excel for windows. Results were reported as average values ± standard deviation (SD). The difference in means was determined using the Turkey test); to test which means are significantly different. Statistical significance was set at 95% confidence level.

CHAPTER FOUR

4.0 Results

Table 1. Textural hardness and resilience of three unpeeled dessert banana varieties at different times of postharvest period

Time (days)	**Hardness (N)**			**Resilience (N.mm)**		
	Bogoya	**Ndiizi**	**FHIA**	**Bogoya**	**Ndiizi**	**FHIA**
1	98.8^{e} ± 9.1	83.9^{e} ± 2.1	67.6^{de} ± 4.7	972.6^{de} ± 23.9	1140.2^{de} ± 33.9	737.1^{ef} ± 27.9
4	78.2^{d} ± 5.7	71.3^{d} ± 5.6	60.8^{d} ± 3.9	936.6^{d} ± 81.5	1197.4^{de} ± 58.7	706.3^{ef} ± 19.9
6	74.9^{d} ± 4.3	66.8^{d} ± 4.1	70.6^{e} ± 2.4	927.4^{de} ± 40.5	1165.5^{d} ± 86.7	698.8^{e} ± 29.3
8	52.2^{c} ± 7.2	12.3^{a} ± 8.1	20.2^{c} ± 1.8	555.8^{c} ± 86.6	239.8^{abc} ± 60.6	249.3^{d} ± 17.6
11	12.5^{ab} ± 1.8	8.0^{ab} ± 0.3	8.3^{ab} ± 0.5	151.1^{a} ± 0.2	121.3^{a} ± 18.8	93.63^{a} ± 3.3
13	10.7^{a} ±7.1	14.1^{ab} ± 0.9	6.6^{a} ± 4.5	180.5^{b} ± 28.2	203.3^{bc} ± 20.36	132.4^{c} ± 3.9
15	11.2^{ab} ± 0.7	9.9^{ab} ± 3.5	8.6^{ab} ± 0.88	$175. 1^{b}$ ± 13.9	166.7^{ab} ± 45.7	106.9^{b} ± 4.0

Means with same superscript along columns are not significantly different ($P < 0.05$). Values are means ± standard deviation ($n = 4$).

Hardness in all varieties decreased with increasing number of postharvest days. Hardness initially varied with banana variety. However the variation in hardness among banana varieties generally disappeared with increasing postharvest time. Resilience in all varieties decreased with increasing number of postharvest days. Resilience initially varied with banana variety. However the variation in resilience among banana varieties generally disappeared with increasing postharvest time.

Table 2. Textural hardness and resilience of three peeled dessert banana varieties at different times of postharvest period

Time (days)	**Hardness (N)**			**Resilience (N.mm)**		
	Bogoya	**Ndiizi**	**FHIA**	**Bogoya**	**Ndiizi**	**FHIA**
1	18.2^{de} ± 12.2	32.0^{de} ± 4.3	18.2^{e} ± 0.9	643.1^{c} ± 52.5	856.1^{de} ± 53.0	456.3^{e} ± 16.5
4	15.2^{acd} ± 11.4	30.5^{d} ± 4.0	19.8^{e} ± 1.7	666.7 c ± 21.2	894.9^{d} ± 68.1	403.8^{d} ± 5.1
6	18.5^{bde} ± 0.6	35.0^{de} ± 4.6	15.3^{d} ± 0.7	566.0^{d} ± 10.9	874.8^{de} ± 75.5	344.2^{c} ± 2.4
8	3.4^{abc} ± 0.5	8.5^{abc} ± 2.1	2.3^{abc} ± 0.1	88.2^{b} ± 4.5	105.7^{bc} ± 10.5	61.2^{b} ± 2.6
11	2.9^{ab} ± 0.1	2.4^{abc} ± 0.2	2.3^{abc} ± 0.3	59.9^{a} ± 3	70.8^{a} ± 5.8	51.2^{a} ± 0.6
13	2.6^{a} ± 1.7	4.5^{a} ± 0.4	1.8^{a} ± 1.1	78.4^{b} ± 6.2	103.7^{b} ± 10.2	55.7^{b} ± 3.2
15	3.3^{ac} ± 0.2	4.2^{ab} ± 0.6	1.9^{ab} ± 1.2	75.8^{b} ± 2.3	109.7^{bc} ± 8.9	47.9^{a} ± 4.4

Means with same superscript along columns are not significantly different ($P < 0.05$). Values are means ± standard deviation ($n = 4$)

Hardness in all varieties decreased with increasing number of postharvest days. Hardness initially varied with banana variety. However the variation in hardness among banana varieties generally disappeared with increasing postharvest time. Resilience in all varieties decreased with increasing number of postharvest days.

Table 3. Abrasive properties of three peeled dessert banana varieties at different times of postharvest period

Time (days)	**Hardness (N)**			**Resilience (N.mm)**		
	Bogoya	**Ndiizi**	**FHIA**	**Bogoya**	**Ndiizi**	**FHIA**
1	-	-	-	-	-	-
4	-	-	-	-	-	-
6	-	-	-	-	-	-
8	66.9^{c} ± 4.8	30.5^{a} ± 2.1	41.4^{b} ± 4.1	4173.8^{c} ± 558.9	1505.6^{abc} ± 79.6	2510.2^{c} ± 211.3
11	36.3^{ab} ± 4.8	24.8^{ab} ± 3.4	14.7^{a} ± 17.0	1548.3^{a} ± 446.1	1181.2^{ab} ± 305.3	1263^{a} ± 581.6
13	36.3^{ab} ± 1.7	26.8^{ab} ± 5.5	33.6^{a} ± 3.6	1540.0^{ab} ± 6.2	1434.7^{abc} ± 67.2	1282.8^{ab} ± 219.0
15	27.1^{a} ± 14.1	21.9^{a} ± 10.0	14.9^{a} ± 14.6	1469.0^{ab} ± 214.7	1178.9^{a} ± 557.6	1399.3^{ab}± 192.8

Means with same superscript along columns are not significantly different ($P < 0.05$). Values are means ± standard deviation ($n = 4$)

Hardness and resilience in all varieties decreased with increasing number of postharvest days. Both hardness and resilience initially varied with banana variety. However the variation in both parameters among banana varieties generally disappeared with increasing postharvest time.

Spaces with dashes represent textural data that could not be collected until day 8. This was because the banana fingers were still so hard that there was an overload of the texture analyzer. This made it impossible to generate results for that period.

4.1.2 pH results

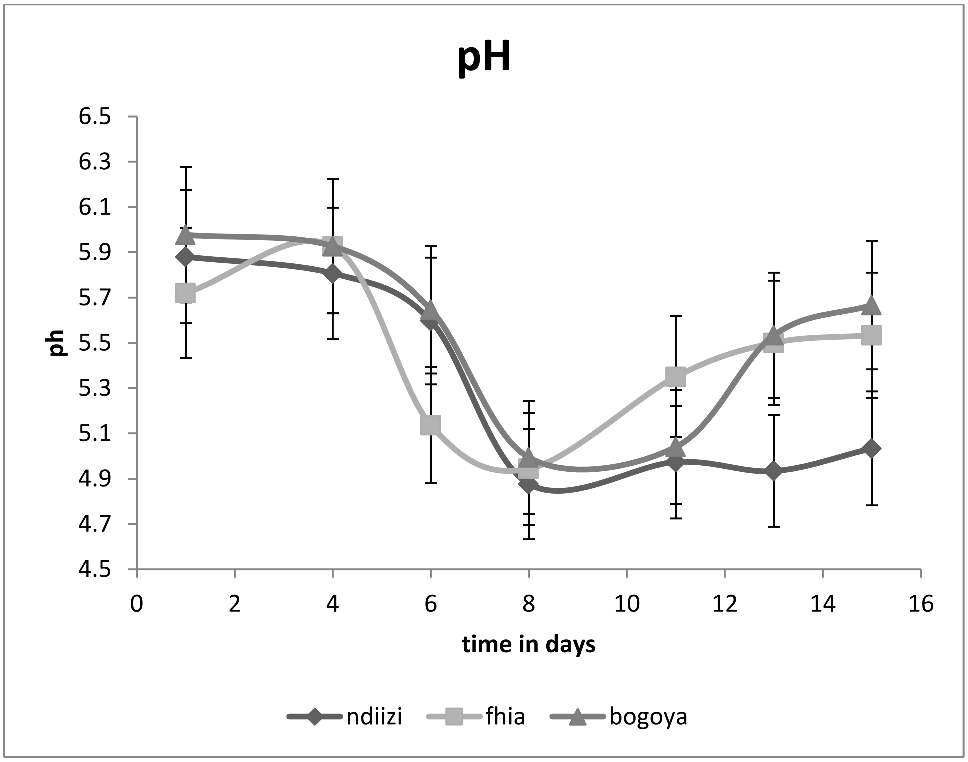

Figure 1 pH values of three dessert banana varieties at different times of the postharvest period

The pH for all varieties generally reduced to a minimum value at 6-8 days and then increased to a maximum at end of postharvest study period.. Ndiizi had the lowest maximum followed by FHIA and bogoya in that order. Additionally, bogoya had the highest final ph, followed by FHIA and lastly Ndiizi

4.1.3 Titratable acidity results

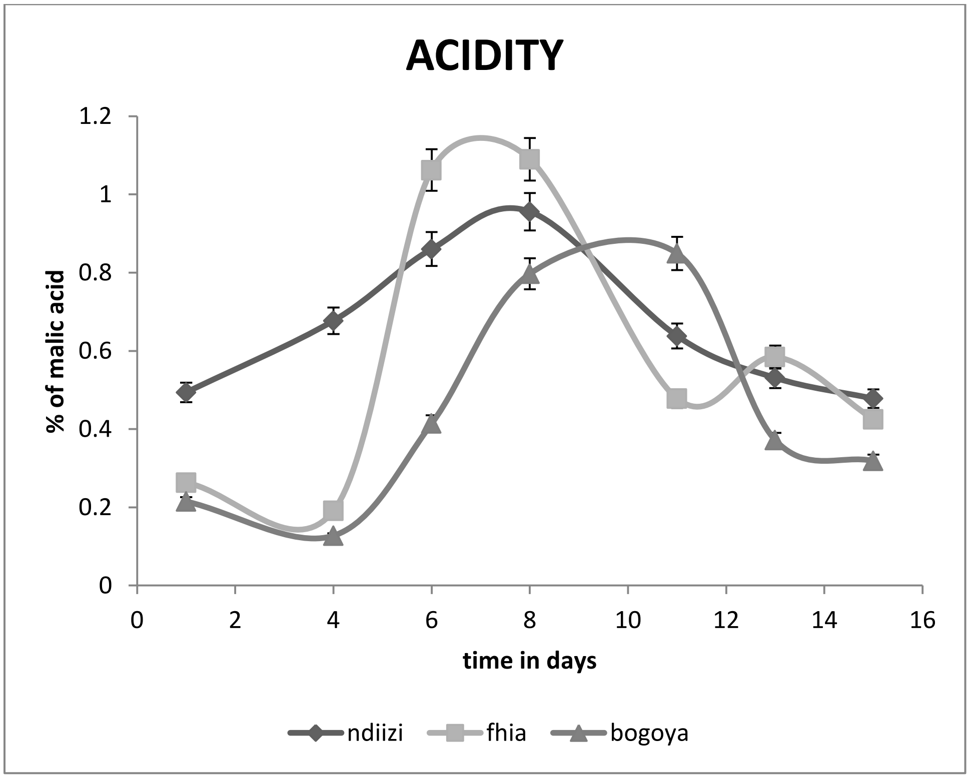

Figure 2. Acidity values of three dessert banana varieties at different times of the postharvest period

The acidity for all varieties generally increased to a maximum value at 6-8 days and thereafter decreased. There was variation in titratable acidity with banana variety.

4.1.4 TSS results

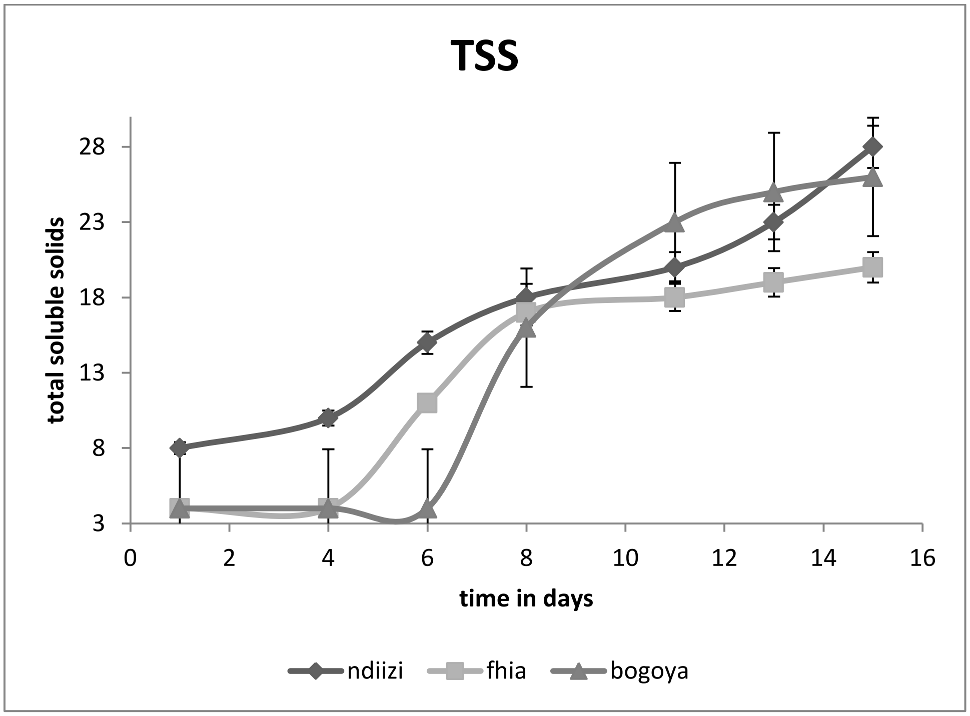

Figure 3. TSS values of three dessert banana varieties at different times of the postharvest

The TSS for all varieties generally increased to a maximum at 16 days postharvest. Ndiizi had the highest TSS followed by bogoya and then FHIA.

4.1.5 Ripeness score results

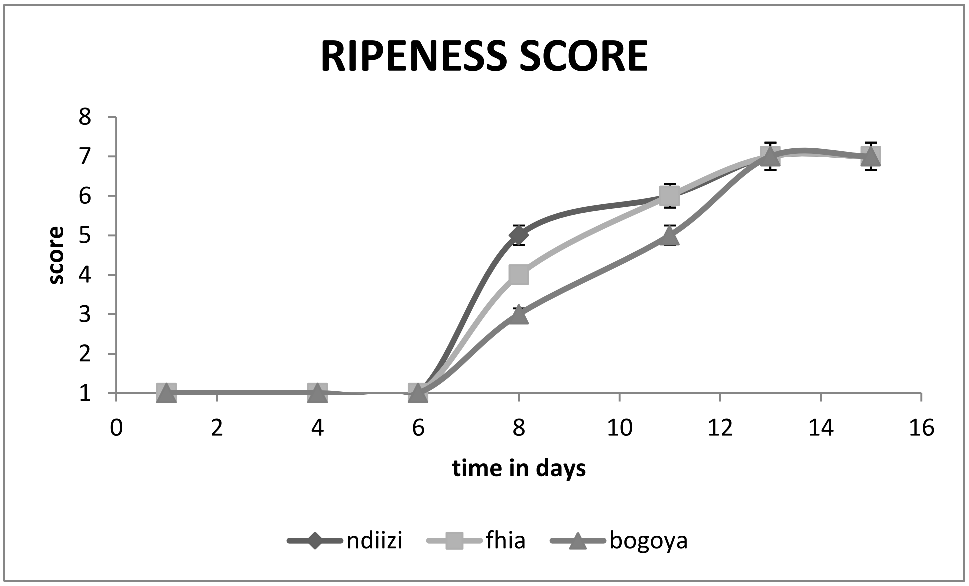

Figure 4. Ripening scores of three dessert banana varieties at different times of the postharvest period

The ripening scores for all varieties generally increased to a maximum value as time after harvest increased. Scores for all varieties were constant between 0-6 days as well as between 14-16 days. Between 6 and 14 days there were some varietal differences in the scores. Ndiizi had the higher rate of change of the score followed by FHIA and then bogoya in that order.

CHAPTER FIVE

5 Discussion

5.1 Texture analysis

The texture attributes changed as the bananas ripened. This manifested through softening of the banana tissue as indicated by the reduction in both hardness and resilience in both compression and abbrassion texture modes. Similarly, the rates of these changes differ according to variety. This was partly in agreement with Kajuna et al., (1997) who reported that texture hardness of banana and plantain reduced as the number of days in ripening progressed. The observed changes are attributed to physiological and biochemical changes such as degradation of pectin, cellulose, hemicellulose and other cell wall polysaccharides by enzymes (Salvador et al., 2007), migration of water from the skin, hydrolysis of starch to sugars (Prabha & Bhagyalakshmi, 1998) and Shiga et al., 2011) during ripening. These changes can result in an increase in osmotic pressure in banana flesh, hence reduction in turgor pressure thus softening of tissues during ripening (Palmer, 1971; Smith *et al.,* 1989). The final result is a decrease in firmness of the fruits as the ripening progresses.

The differing rates of change of textural properties of desert banana are attributed to the fact that these changes could be cultivar dependent (Shiga et al., 2011). Additionally, Soares et al. (2011) reported that the starch granule structure differs with varieties and so does its degradation during ripening. This means that the changes that bananas undergo during ripening are complex and variety dependent. This change in texture that occurs as the ripening period progresses implies that different ripening stages make the bananas suitable for different applications; for example desert consumption of bananas is best before they approach stage 7; above stage 7, these bananas can be used for other purposes such as incorporation in dough for baking cakes as well as making juices and wines.

The hardness and resilience of each variety is higher in the unpeeled form than in the peeled form regardless of the mode of texture analysis. This difference between the textural properties of peeled and unpeeled bananas is evidence that the peel has a significant contribution to the integrity and capacity of the banana inorder for them to withstand a certain degree of mechanical forces. This difference in the magnitude of the textural properties also indicates that each of the three the varieties can with stand a certain amount of mechanical abuse, owing to the role of the rind (peel).

4.2.2 Ripening score

In the ripening scores in this study are in agreement with those of Tapre and Jain, (2012) who reported increase in the scores of bananas as ripening progressed. As acids disappear during ripening, more than just tartness of fruits is affected. Since many plant pigments are sensitive to acid, fruit color would be expected to change as the organic acid content changes (Potter and Hotchkiss, 1998). Xuewu, Daryl and Yueming (2007) report ripening as a transient burst in ethylene production which co-ordinates the whole ripening associated processes. One of these processes is known as peel degreening which is a physical indicator of ripening. Degreening is characterized by loss of green colour and appearance of yellow. The loss of green colour is due to chlorophyll degradation from about 50-100mg/g of freshweight to almost none (Seymour 1993).

During ripening there is the development of the enzymes to catalyse the formation of pigments such as β-carotene, xanthophyll esters, xanthophylls and lycopene (Thompson, 2008). These pigments formed are responsible for the progressive appearance of the yellow colour on fruit ripening. This implies that for better consumer acceptability, harvested desert bananas maybe stored under natural conditions or treated in some way so that the right peel colour is attained.

4.2.3 PH and Titratable acidity

In this experiment, the amount of malic acid for all the varieties increased until a maximum at stage 4, and later decreased above stage 5, while the ph reduced in the same period. These findings were in agreement with those of Palmer (1971) as well as Jayasena and Cameron (2008). The decline in acidity after stage 5 is presumably due to the utilization of acids as respiratory substrates (Hailu, Workneh & Belew, 2013). The fruit pH could thus be used as an index of ripening (Dadzie and Orchard, 1997).

In addition to the fact that the amount of acid and sugars present in a fruit is crucial in determining its flavour (Madamba, Baes, & Mendoza, 1977). This makes the sugar-acid balance a quality factor for consumer acceptance of fruits.

. 4.2.4 TSS

The TSS increased as ripening progressed. This is in agreement with the findings of Dadzie (1998). This is because in both experiments, the amounts of sugars, hence the TSS increased due to breakdown of starch to sugar as ripening progressed (Yap etal. 2017). Ndiizi however had the highest TSS, compared to bogoya and FHIA. This implies that for uses of bananas that require high TSS, (such as juice extraction and consumption as dessert), the most appropriate period for such operation when these bananas are the late stages of ripening such as stage 7 due to the high TSS accompanied with these.

4.3 CONCLUSIONS

In conclusion, it is worth noting that;

The Variety of dessert bananas does affect their textural properties and mechanical strength owing to the differing fruit characteristics across varieties.

The degree of ripeness does not only affect the textural properties and mechanical strength of bananas but also the chemical properties of these dessert type bananas such as total Soluble Solids, pH and ripeness score in dessert type bananas during postharvest period..

The fruit rind does affect the textural properties and mechanical strength of dessert type bananas during postharvest. The rind has a significant contribution to mechanical strength of dessert type bananas during postharvest period

These observed changes dictate the intended use of banana, for example, use of bananas for desert purposes is preferable at between stage 5 and 6 due to the comparable amount of acid and sugars present in the fruits, giving a good acid: sugar ratio that the consumers desire. Additionally, banana fruits at stage 7 are preferable for use in purposes such as sweetening dough for cakes or even extraction of juice owing to the high TSS their pulp posseses at this point.

4.4 RECOMMENDATIONS

1. It is recommended that dessert bananas in the postharvest handling chain should be left unpeeled (with rind) as much as possible before final consumption to reduce losses due to physical forces.
2. The measurement of post-harvest textural attributes of dessert bananas in abbrassion mode is recommended to commence once the bananas have reached atleast stage 3 of ripening.

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Changes In peel colour during ripening


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