MAKERERE UNIVERSITY

MORPHOLOGICAL CHARACTERIZATION OF VARIOUS SMALL DESSERT YELLOW BANANA VARIETIES IN UGANDA: EXPLORING FRUIT FINGER DIVERSITY

BY

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1800700784

18/U/784

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A RESEARCH REPORT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL PRODUCTION IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE REWARD OF A DEGREE OF BACHELOR OF SCIENCE IN AGRICULTURE FROM MAKERERE UNIVERSITY

AUGUST, 2024

DECLARATION

I Kitaka Henry declare that this is my original work and to the best of my knowledge has never been produced to any university or institution for a degree award.

Signed..Date...05/SEPT/2024...

KITAKA HENRY

APPROVAL

This special research report has been submitted to College of Agriculture and Environmental Sciences for examination with my approval as the academic supervisor.

Signed.. Date....05/09/2024....

DR. NUWAMANYA EPHRAIM

DEDICATION

I dedicate this report to my father Mr. Kato Peter and my supervisor Dr. Nuwamanya Ephraim for the endless support. I also dedicate this report to my aunt Ms. Naluyigga Samalie for the undying love and prayers towards my success, and to my friends for the help, advice and moral support during the entire process.

ACKNOWLEDGEMENT

I would like to start by thanking the Almighty God endowing with health, courage and strength to accomplish this report successfully in time. I would commence to thank my brother, Mr. Kyasi George and sister, Ms Nalule Caroline for their financial support and my friends for encouragement and motivation during this study. I was privileged to have a team of enthusiastic people who helped me from the beginning of this research up to the end of report writing. Dr. Nuwamanya Ephraim is the exceptional researcher and supervisor I have worked with, he was so central in helping me do the research and bringing this report together under his guidance, tireless effort and time given during the period of study. I also appreciate the efforts of the Biotech Lab team at School of Agricultural Sciences led by Ms Phiona who guided and helped me set up all my experiments. May the Almighty God reward them abundantly in all their endeavors.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
EAHB	East African Highland Banana
FAO	Food and Agriculture Organization
HSD	Honestly Significant Difference
NARO	National Agricultural Research Organization
SPSS	Statistical Package for Social Sciences
TA	Titratable Acidity

ABSTRACT

The objective of this study was assessing the morphological differences of 12 selected small dessert fruits in Uganda in which three of each were representing the varieties of KB, KJ, SN and F basing on the characteristics of their fruits (fingers). The varieties were evaluated regarding their fruit length, circumference, length of pedicel, width of pedicel, pH of pulp and total titratable acidity. The variety KB had the highest circumference of 11.80 cm followed by KJ, then SN and F had the smallest of 9.63 cm. The overall mean circumference was 11.05 cm. variety F had the largest length of 12.97 cm and KB the smallest of 9.03 cm. SN had the largest length of pedicel and KB the smallest of 1.87 cm and 0.90 cm respectively. F had the largest width of pedicel of 1.13 cm and KJ the smallest width of pedicel of 0.73 cm. Variety F had the largest pH value of 5.06 and variety KB had the least pH of 4.59. The titratable acidity of the varieties increased in the order F<SN<KB<KJ. Brix (sugar content) was highest in variety SN at 23.8 ± 4.6, followed by F at 19.0 ± 0.4, KJ at 18.3 ± 2.8 and variety KB had the least total sugar content of 17.5 ± 4.0 g $100g^{-1}$. The one-way analysis of variance (ANOVA) showed a statistically significant difference in the morphological characteristics of the different varieties. Except sugar content of the varieties, pH and TA were also statistically significantly different ($p < .05$) among the varieties. The differences in the characteristics evaluated varied due to differences in variety and according to the Tukey post hoc test, variety KB and SN had no significant differences in banana length, KJ and F had no significant differences in their circumference, no statistically significant difference was there in pH of the varieties KJ, F and SN ($p > .05$), no statistically significant differences in pedicel length were as well found among the varieties KJ, F and SN and all the varieties showed no differences in their total sugar content ($p > .05$).

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The Musaceae family, encompassing bananas, plantains, and ornamental bananas, traces its origins to Southeast Asia and adjacent tropical and sub-tropical regions, including New Guinea. When a bunch is newly formed from flowers, the fingers are facing down wards or sideways but with time, due to their positive phototropism that their pericarps are usually green due to presence of chlorophyll, they curve and face upwards towards the sun hence their curved nature. While Africa serves as a secondary center of diversity, the genesis of bananas is believed to be in Southeast Asia, where the process of hybridization and selective breeding led to the emergence of the small dessert yellow banana (Menon, 2016). These edible bananas, evolving through hybridizations involving Musa acuminata and Musa balbisiana subspecies, have been domesticated over time by farmers, resulting in a plethora of genome compositions ranging from diploids to tetraploids (Simmonds, 1959; De Langhe et al., 2010).

Bananas, deriving their name from the Arabic word 'banan' meaning finger, have emerged as a globally popular fruit and the fourth most crucial food crop worldwide, following rice, wheat, and maize. Their outer skin is green, tough, and difficult to peel when unripe. As the banana ripens, the skin changes to yellow. It also becomes progressively easier to peel. Renowned for their nutritional properties and therapeutic applications, bananas play a pivotal role in fulfilling dietary needs across various age groups (Pereira & Maraschin, 2015). Bananas are also nutritional rich, offering substantial quantities of potassium, calcium, magnesium, iron, and dietary fiber, making them ideal for individuals adhering to low-fat, low-sodium, or cholesterol-free diets (Bjarnadottir & Shoemaker, 2021). Their resistance to pests and diseases coupled with their versatility in culinary applications further solidify their importance in global agriculture and nutrition (Robinson, 1996).

Uganda, leading in both the production and consumption of bananas in East Africa, boasts remarkable diversity in banana cultivars uniquely adapted to the region. Notably, East African highland bananas encompass cooking and brewing types, serving as staples for over seven million people and ensuring food security in the region.

Uganda's rich banana landscape includes various types, including "Apple" bananas (Musa AB/AAB), Bluggoes, Monthan, Pisang Awak Musa ABB, Gros Michel, and Cavendish Musa AAA, introduced to East Africa during the 1950s (Karamura et al., 2006). Onyango's (2007) study, combining molecular and morphological data, distinguished four distinct AAB "Apple" dessert banana taxa introduced to Uganda in the 1900s, underscoring the country's historical ties to banana cultivation. The introduction and proliferation of exotic banana cultivars in Uganda may have been influenced by establishments like the Botanical Garden at Entebbe (Rossel, 1998), facilitating the crossbreeding between M. acuminata and M. balbisiana Colla, resulting in small-fruited triploid natural hybrids.

Research conducted by Evers (1992) in the Morogoro area revealed the presence of various yellow, small-fruited dessert bananas akin to "Apple," termed "Kisukari." Surprisingly, despite their resemblance to "Apple" bananas, at least eight distinct cultivars spanning different genomes were identified as Kisukari or Sukari in Morogoro. Further investigations by Pillay *et al*. (2001) affirmed the triploid nature of the widely recognized Sukali Ndiizi in Uganda, shedding light on its genetic composition. Moreover, diploid AB varieties such as Kisubi and Gisubi kagogo were identified within the region, adding to the genetic diversity.

In Uganda, "Apple" bananas thrive in various districts including Masaka, Mbale, Mbarara, Bushenyi, Mubende, Luweero, and Wakiso. However, the interchangeable use of terms such as "Apple" banana and "Lady's finger" underscores the challenge of categorizing banana varieties solely based on fruit traits. Marketing misconceptions often blur the distinction between "Apple" bananas and other varieties like the AA Sucrier bananas, complicating consumer understanding.

This research endeavors to delve into the phenotypic characterization of different small dessert yellow banana varieties in Uganda, exploring the nuanced diversity within this beloved fruit category. By examining fruit finger traits and other morphological characteristics, the study aims to contribute to a comprehensive understanding of Uganda's banana biodiversity and its implications for agriculture, nutrition, and local economies.

1.2 Problem statement

Morphological characteristics play a vital role in plant classification, particularly evident in the case of bananas, as highlighted by Sumardi & Wulandari (2010). Understanding the distinct morphological features of mature fruits within different genomic groups is crucial for establishing fruit identity and catering to consumer preferences. Despite the significance of morphological characterization in identifying and documenting diversity among distinct banana varieties, particularly in Uganda, there remains a dearth of research focusing on small-fruited dessert bananas.

Hapsari and Lestari (2016) emphasize the unique characteristics associated with each banana cultivar based on their genomic group, underscoring the importance of distinguishing between varieties. While differences in fruit morphology are discernible to farmers, researchers, and individuals with a vested interest in bananas, the public often struggles to differentiate between types when shopping.

Moreover, the need for fruit morphological information extends beyond mere identification, encompassing various stakeholders such as agribusiness entrepreneurs, food industry managers, and researchers involved in plant breeding, agronomy, post-harvest processing, and biotechnology.

While extensive scientific research exists on bananas and plantains, covering growing methods, diseases, pests, harvest, and post-harvest processes, few studies directly address sensory quality and consumer acceptance. Furthermore, existing morphological characterizations, guided by the "Descriptors for Banana (Musa spp)" from the International Plant Genetic Resources Institute (IPGRI, 1996), primarily focus on broader aspects with limited attention to fruit-level variations, especially concerning small-fruited dessert bananas in Uganda.

Therefore, this study aims to address the gap in research by conducting comprehensive phenotypic characterization, specifically focusing on the fruit finger morphology, of different small dessert yellow banana varieties in Uganda. By utilizing established protocols and leveraging existing research frameworks, this endeavor seeks to enhance our understanding of banana diversity, aid in variety identification, and contribute to the sustainable management and utilization of banana resources in Uganda's agricultural landscape.

1.3 Study objective

1.3.1 General objective

- To assess the morphological differences of selected small dessert fruits in Uganda basing on the characteristics of their fruits (fingers).

1.3.2 Specific objectives

- To determine the morphological characters that define small dessert yellow bananas.
- To determine the chemical characters that define small dessert yellow banana.

1.4 Justification

Small dessert bananas serve various purposes, including juice extraction and the creation of light meals like deep-fried banana chips and pancakes, in addition to being enjoyed raw when ripe as a dessert. These diverse uses often necessitate different varietal characteristics, such as total sugar content, which significantly influences the fruit's shelf life. Given the varying preferences among consumers, it is essential to identify and understand the distinct morphological characteristics of different banana varieties. This understanding not only helps cater to consumer preferences but also incentivizes farmers to cultivate highly preferred varieties, thereby tapping into lucrative market opportunities.

The undertaking of this study is rooted in the existing knowledge gaps within the realm of banana research, specifically pertaining to small-fruited dessert bananas in Uganda. While the importance of morphological characteristics in banana classification and consumer preferences is well-established, there is a notable scarcity of research addressing the unique fruit finger traits of small dessert yellow banana varieties. This study aims to address this gap by conducting a comprehensive examination, with a specific focus on fruit finger morphology, to provide detailed insights into the diverse characteristics of these bananas.

Enhanced the identification of different banana varieties is a crucial aspect for farmers, researchers, and consumers alike. Accurate variety identification empowers stakeholders to make informed decisions related to cultivation practices, marketing strategies, and consumption choices. Additionally, the study recognizes the practical needs of various stakeholders such as agribusiness entrepreneurs, food industry managers, and researchers engaged in plant breeding and agronomy. By delivering reliable fruit morphological information, the study seeks to support decision-making processes, optimize post-harvest processing techniques, and facilitate advancements in biotechnology within the banana industry.

1.5 Hypothesis

- There are observable morphological differences among the selected small dessert yellow banana varieties.
- The selected small dessert yellow banana varieties differ in the chemical makeup of their fruit pulps.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Uganda's banana diversity

Bananas hold a crucial position in Uganda, contributing significantly to both nutrition and agriculture. They provide approximately 30 percent of daily calories, 10 percent of protein, and 5 percent of fat for the population, constituting a quarter of the agricultural output value (Kalyebara *et al*., 2005). Uganda boasts the highest per capita annual banana consumption globally, with an average of 0.70 kg per person per day (Kikulwe *et al.,* 2020). Bananas cover 38 percent of utilized agricultural land, totaling 1.4 million hectares, making them the most extensively cultivated crop in Uganda. The significance of bananas in Uganda extends beyond mere consumption, encompassing economic, cultural, and agricultural dimensions, making them a cornerstone of the country's daily life.

In Uganda, locally known as matooke, bananas play a multifaceted role, serving as a vital crop for food security, income generation, cultural symbolism, and daily needs. Cultivation is mainly for subsistence, with minimal input investment, leading to generally low productivity levels. The southwestern region has emerged as the primary banana-producing area, surpassing the central region, aligning with the evolving dynamics of Ugandan society and agriculture. Matooke stands out as a crucial food security crop, especially in the Central, Western, and Eastern Regions (Kikulwe *et al.,* 2020). The Western Region produces approximately 61 percent of the Ugandan banana crop, followed by the Central Region with 30 percent, and the remainder in the Eastern Region (UBOS 2003).

Most cultivated banana cultivars in Uganda are native to the East African highlands, establishing the region as a significant center of banana diversity. About 85 percent of bananas grown belong to the East African Highland Banana (EAHB) category, specifically the AAA-EA genomic group. These cultivars serve two distinct purposes: cooking bananas, used for making matooke, and beer bananas known as mbidde, with farmers in the Lake Victoria region differentiating based on phenotypic characteristics and intended use.

In addition to endemic bananas, non-endemic varieties, including "exotics" introduced from other regions, and hybrids developed by breeders, are also cultivated. Exotic cultivars include beer and sweet bananas (AB, ABB, and AAA genomic groups) and roasting bananas or plantains (AAB genomic group). Hybrids, tetraploids in genomic groups such as AAAA and AAAB, add to the diversity. This diverse array of banana cultivars in Uganda, each known by various local names, can lead to confusion. Karamura (1998) identified 238 named banana cultivars, later refined to 84 distinct cultivars grouped into five clone sets. Most bananas consumed in Uganda are hybrids of Musa acuminata or Musa balbisiana, with M. acuminata-derived cultivars being dessert bananas and M. balbisiana-derived cultivars being plantains, primarily cooked rather than eaten raw.

2.2 Small dessert yellow banana fruits

Banana and plantain hold significant importance as both staple food and export commodities, particularly in Southeast Asia, recognized as a primary center of origin for bananas (Simmonds and Shepherd, 1955; Perrier, 2011). Bananas and plantains belong to the family *Musaceae* and Genus *Musa*, closely related to *Musella* and *Ensete* (Hapsari, 2014). The term of banana and plantain was firstly specified by Karl Linneaus in 1753 and 1759 (Valmayor *et al*. 2000).

Bananas are recognized as some of the largest herbs globally, characterized by perennial growth with tall aerial shoots emerging from swollen, fleshy corms. The distribution of banana species is influenced by factors such as morphology, chromosome number, and geographical location (Wang et al. 2010). Within the Musa genus, bananas can be categorized into edible cultivars and non-edible wild species. Edible bananas serve dual purposes, being consumed both fresh as desserts and in cooked forms, including varieties suitable for beer making, predominantly originating from Southeast Asia (Perrier *et al*., 2009). In many countries today, bananas are considered part of the Musa and M. *balbisiana Colla* lineage (Simmonds, 1959). The species within this lineage exhibit different ploidy levels, including diploid (AA genome), triploid (AAA genome), and tetraploid (AAAA genome). The various ploidy levels in banana plants result from natural crossbreeding between wild species and environmental influences, leading to the emergence of new species with different ploidy levels, such as diploid, triploid, and tetraploid. For instance, crossing between *M. acuminata* (AAAA genome) and *M. balbisiana* (BB genome) results in triploid levels with genome symbols AAB or ABB (Purseglove, 1979). While the karyotype and chromosome number are generally crucial for classification, it's noteworthy that some plant species with the same chromosome number can exhibit different characteristics. For example, *M. acuminata* (AA genome, 2n=22) produces edible fruit, whereas *M. balbisiana* (BB genome, 2n=22) has many seeds and inedible fruit (Fitri, 2007).

Bananas of the AA group exhibit distinct characteristics, including a small size, an appealing golden-yellow thin peel, a light orange and soft pulp, a predominantly sweet taste with a slight sourness, and an aromatic fragrance. In contrast, bananas of the AAA group are more robust than diploids, producing robust, symmetrical bunches of large fruit that are markedly curved. These bananas have a creamy white to yellow pulp, a soft and fine texture, and offer a sweet taste with an aromatic flavor. AAB group bananas are characterized by their large size, thick coarse peel, orange color, creamy-orange pulp with a coarse texture, and a sweet taste. On the other hand, ABB group bananas have nearly straight, thick, coarse, and waxy peels. These bananas remain starchy when ripe, requiring cooking before consumption (Daniells *et al*., 2001; Espino *et al*., 1992; Hapsari *et al.*, 2015 ; Hapsari & Masrum, 2012; Simmonds, 1959; Vargas & Sandoval, 2005).

2.3 Phenotypic variability

Phenotypic characteristics are the expression and representation of the genetic makeup of an individual that is, they are used for characterizing plant genetic resources. Phenotypic characterization should be based on distinctly identifiable, stable and heritable traits that are expressed consistently and maybe distinguishable by the human eye. Phenotypic variation can be seen in traits such as leaf size and shape, flower color and structure, fruit size and taste, and resistance to diseases or pests. These play a crucial role in evolution and survival.

The diversity of banana cultivars in the region can be distinguished based on the taste, shape, and color of the fruit (Marimo et al. 2020). Alongside the endemic banana varieties, several exotic or introduced cultivars are also present, mainly sold as dessert bananas, although some growers maintain pure stands specifically for beer production. An example of such a cultivar is 'Sukali Ndizi,' characterized by its slender, green-yellow stems and small, short, and plump fruits (Karamura and Karamura 1995). The small dessert yellow bananas, including those in the AB cultivar group such as 'Kisubi,' have been grouped together and classified under the 'Ney Poovan' group (Stover, 1988).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area and Sampling Procedure

The study and experiments were carried out at Makerere University, School of Agricultural Sciences in the Biotech Lab. A purposive sampling technique was employed to select four different small dessert yellow banana varieties each represented with three replicas which were available in the farmer's field.

3.2 Plant Material Collection

Four specific banana plants of different monotypes were earmarked at the flowering stage in the farmer's field and banana bunches harvested at maturity. Samples (cluster or a hand from middle of the bunch) from each plant were taken and carefully handled to ensure that the fruits were representative of the varieties and were free from physical damage or abnormalities.

3.3 Morphological Traits

The external morphological characteristics of each banana variety assessed, included,

- Shape (longitudinal curvature)
- Presence of prominent finger ridges after transverse section

  It was observed in mature fruits 'ready to eat'- ripe but not over ripe, full yellow stage
- Fruit apex

  It was observed at the distal end of the fruit.
- Remains of flower relicts at fruit apex

  It was observed at the distal end of the fruit.
- Fruit pedicel length (cm)
- Fruit pedicel width (cm)
- Measurements of fruit length, circumference.

  These were measured using a ruler and a string

3.3.1 Acidity

- Acidity was determined by titration, using 0.1N NaOH and phenolphthalein indicator and expressed as a percentage of citric acid. The following formula was used in the determination of the titratable acidity (TA):

$$\% \, of \, acid = \frac{N \times V \times Eq.wt}{w \times 1000} \times 100 \qquad eq(1)$$

$where, N \, is \, normality \, of \, NaOH,$

V is volume of NaOH

Eq.wt is equivalent of weight of acid in pulp (citric acid)

W is pulp weight

3.3.2 pH

- pH was determined by weighing 5.5g of the sample into a falcon tube then 15ml volume distilled water will be added, then will be left to settle for one hour and values were read using the pH meter.

3.3.3 Brix (sugar content):

- Sugar content was determined by weighing 5.5 g of fresh ripe sample and juice was squeezed out, put onto the screen of the refractometer and the available sugars (sucrose) content expressed.

3.4 Experimental Design

The study followed a completely randomized design, with each banana variety considered as a treatment. Three independent replicates were included for each variety to ensure the reliability and accuracy of the data obtained.

3.5 Statistical Analysis

Data collected was subjected to descriptive analysis and analysis of variance to determine significant differences among banana varieties for each trait measured. Mean separation was performed using Tukey's Honestly Significant Difference (HSD) test at a significance level of $p < 0.05$. Statistical analyses were conducted using SPSS statistical software.

CHAPTER FOUR

PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

4.1 Introduction

The following chapter presents the analysis and interpretation of the data that was collected for this study. It presents the raw data of the morphological characteristics of the four different banana varieties of banana length, Ph, circumference, length of pedicel and width of pedicel in form of tables. What follows are the descriptive statistics of the characteristics of the different banana fruit varieties and finally the advanced analysis using ANOVA to assess the statistical differences between the means of characteristics of the banana varieties used. The results have been sectioned basing on the specific objectives of the study as follow:

4.2 Objective 1: Morphological characters that define small dessert yellow bananas

A total of four dessert yellow banana varieties were observed for their physical characteristics, namely; banana length, circumference, pedicel length and width.

Table 1: Morphological properties of the banana varieties in the present study and their descriptive statistics.

Morphological characteristic	Minimum	Maximum	$mean \pm SD$
Banana length	9.03	12.97	10.3500±1.85738
Circumference	9.63	11.80	11.0500±0.98248
Length of the pedicel	0.90	1.87	1.6025±0.47070
Width of pedicel	0.73	1.13	0.8725±0.17671

NB; The initials F, KB, KJ and SN were assigned to the varieties basing on the local names they are called by the natives.

From table 1 above, variety KB had the greatest circumference, followed by KJ, SN and F with the least. Variety F had the largest length followed by SN, KJ and KB with the smallest length. Length of pedicel among the varieties was in the order SN>KJ>F>KB. Furthermore, width of pedicel was in the order F>KB>SN>KJ. The maximum banana length of the varieties was 12.97cm which is below the average length of the banana at maturity which is 24cm (UCDAVIS, 2023). The maximum banana circumference was 11.80 cm which was below the average circumference of a mature banana of 16.5 cm according to UCDAVIS (2023). The minimum and maximum pedicel length were 0.90 and 1.87 cm respectively which were in the maturity average range of 1.1 to 2 cm according to International Plant Genetic Resources Institute and the minimum and maximum width of the pedicel was 0.73 and 1.13 respectively which were also within the maturity range of 0.5 to 1 cm according to International Plant Genetic Resources Institute (IPGRI).

Other morphological characteristics which were evaluated were fruit shape appearance, transverse section appearence, nature of fruit apex and pedicel surface which were later compared to the descriptors list recognized at the international level (IPGRI). The results are presented in tables 1, 2, 3 and 4. Figure 4.1 shows the banana varieties used and their shapes.

Figure 4.1. Shape of banana varieties used

Table 2: Banana variety shape

Banana vareity * Fruit shape Crosstabulation

Count

		Fruit shape			Total
		Straight (or slightly curved)	Straight in the distal part	Curved (Sharp curve)	
Banana vareity	KB	0	0	1	1
	SN	1	0	0	1
	F	0	1	0	1
	KJ	1	0	0	1
Total		2	1	1	4

Variety KB's shape was curved. Both varieties SN and KJ had straight (or slightly curved) shapes where as KJ had a straight shape in the distal part.

Table 3: Appearance of Transverse section of small dessert yellow banana varieties

Banana vareity * Transverse section Crosstabulation

Count

		Transverse section		Total
		Pronounced ridges	Slightly ridged	
Banana vareity	KB	0	1	1
	SN	0	1	1
	F	1	0	1
	KJ	1	0	1
Total		2	2	4

Varieties KB and SN appeared slightly ridged when cut transversely where as varieties F and KJ had pronounced ridges when cut transversely as shown in the figure 4.2 below.

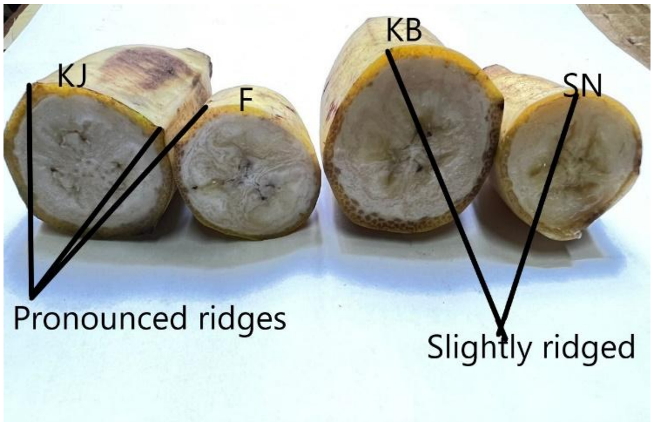

Figure 4.2. Nature of appearance of transverse section of the varieties used

Table 4: Nature of Apices (or Apexes) of the Banana varieties

Banana vareity * Fruit Apex Crosstabulation

Count

		Fruit Apex		Total
		Blunt-tipped	Bottle-necked	
Banana vareity	KB	0	1	1
	SN	1	0	1
	F	0	1	1
	KJ	0	1	1
Total		1	3	4

All varieties KB, F and KJ had bottle-necked apices unlike variety SN that had a blunt-tipped apex. The varieties are shown in the figure 4.3 below.

Figure 4.3. Nature of apex of the varieties used

Table 5: Nature of the pedicel surface of the varieties

Banana vareity * Pedicel surface Crosstabulation

Count

		Pedicel surface		Total
		Hairless	Hairy	
Banana vareity	KB	0	1	1
	SN	1	0	1
	F	0	1	1
	KJ	1	0	1
Total		2	2	4

Varieties KB and F had a hairy pedicel surface where as varieties SN and KJ had a hairless lamina as shown in the figure 4.4 below.

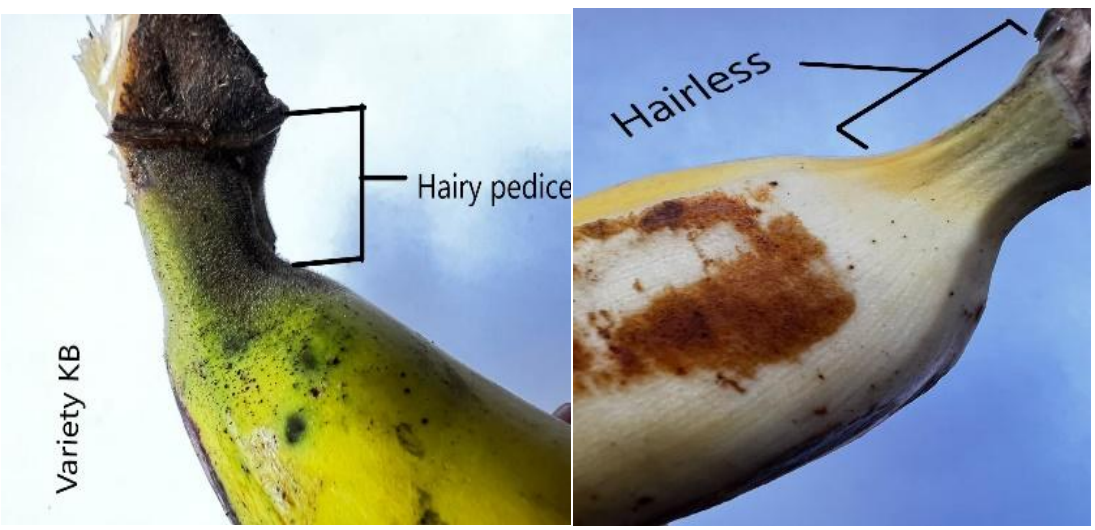

Figure 4.4. Appearance of the pedicel surface of the banana varieties used

4.3 Objective 2: Chemical characters that define small dessert yellow bananas

Among the chemical properties of the varieties that were examined included the pH and the titratable acidity. Determinations of the pH and titratable acidity of banana varieties is used primarily to estimate their eating quality, but pH and titratable acidity could also be used as indicators of fruit maturity or ripeness. Acids make an important contribution to the postharvest quality of fruits, as taste is mainly a balance between the sugar and acid contents; hence the postharvest assessment of acidity is important in the evaluation of fruit taste (Esther, Prudence, & George Amponsah, 2008)

The pH was measured in triplicate using a standard pH meter by making the pulp more slurry and the table 6 below shows the pH and titratable acidity of the dessert yellow banana varieties

Table 6: Sugar content, pH and TA of the banana varieties

Banana variety	**W(g)**	**V of titrant (ml)**	**Titratable acidity (%)**	**pH**	**Brix (Sugar content) (g 100g^{-1})**
KJ	5.9	4.4	0.477	5.1	18.25$\pm$2.84
SN	5.9	3.3	0.358	4.9	23.75$\pm$4.57l
F	5.9	2.7	0.292	5.1	19.00$\pm$0.41
KB	5.9	4.3	0.466	4.6	17.50$\pm$3.99

The results indicated that titratable acidity was highest in variety KJ, followed by banana variety KB, then variety SN and was least in variety F as shown in figure 4.5 below. The variety with the least TA could be attributed to have undergone respiration or conversion to sugars. The mean total sugar content of the banana varieties increased in the order KB<KJ<F<SN. Normally the sugar content at stage green is found to be lower than that at stage 'trace of yellow' (Wanna, Yaakob, Salmah, & Russly, 2001). Generally, during ripening process, the sugar content of bananas increases. Organic acids are important in giving a desired sugar/acid balance, which results in a pleasing fruit taste, during ripening (Esther, Prudence, & George Amponsah, 2008).

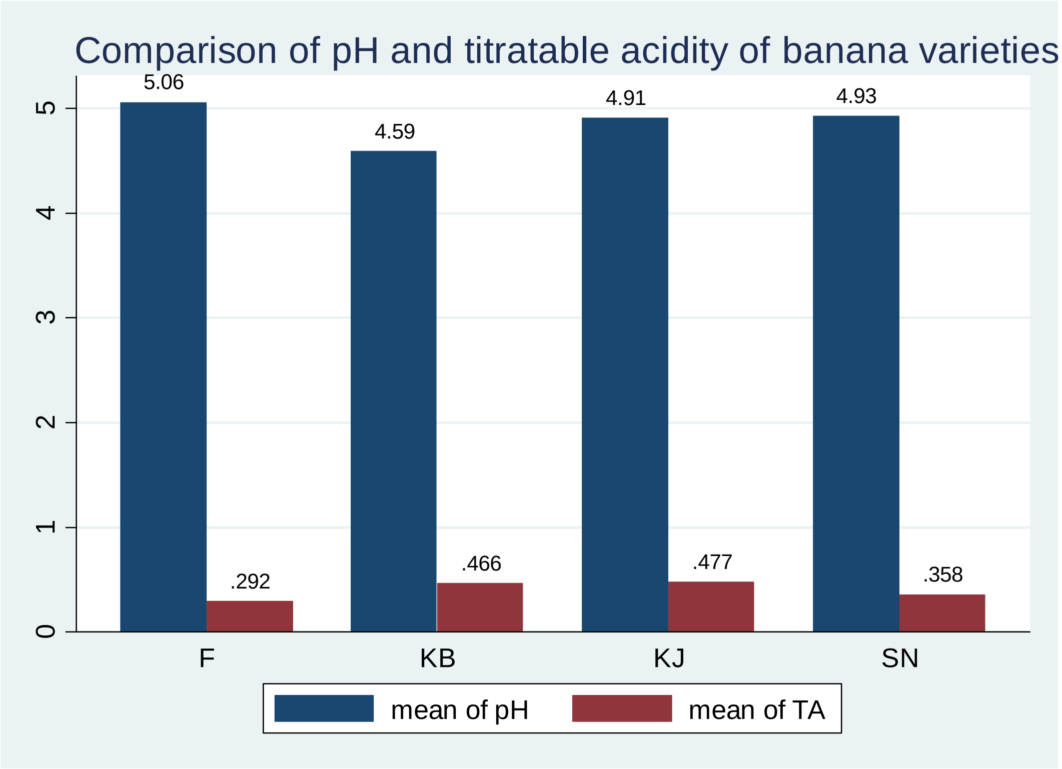

Figure 4.5: Comparison of pH and titratable acidity content (mean±standard deviation) among the banana varieties in the present study.

4.4 Analysis of variance

The one-way analysis of variance (ANOVA) was used to determine whether there were any statistically significant differences between the means of the morphological parameters evaluated of the four varieties of dessert yellow bananas. There was a statistically significant difference between the varieties at the 0.05 level as determined by the one-way ANOVA $p < .05$ with respect to the morphological characteristics as shown in the table below.

Table 7: Analysis of variance for properties of the small dessert yellow banana varieties.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Banana length	Between Groups	30.943	3	10.314	495.093	.000
	Within Groups	.167	8	.021		
	Total	31.110	11			
Circumference	Between Groups	8.657	3	2.886	150.551	.000
	Within Groups	.153	8	.019		
	Total	8.810	11			
pH	Between Groups	.357	3	.119	27.535	.000
	Within Groups	.035	8	.004		
	Total	.392	11			
Length of pedicel	Between Groups	1.980	3	.660	66.000	.000
	Within Groups	.080	8	.010		
	Total	2.060	11			
Width of pedicel	Between Groups	.283	3	.094	18.833	.001
	Within Groups	.040	8	.005		
	Total	.323	11			

However, there were no statistically significant differences in sugar content ($p > .05$) among the four varieties (**Appendix 1**).

4.4.1 Post Hoc Test

Since the analysis of variance revealed that there were statistically significant differences among the varieties, the Post Hoc Test was run to identify the specific varieties with the differences in the morphological and chemical parameters assessed (pH).

A Tukey post hoc test revealed that the banana length was statistically significantly lower for variety KB (9.03$\pm$.21 min, p=.000), SN (9.03$\pm$.06 min, p=.000) and KJ (10.37$\pm$.12 min, p=.000) as compared to variety F (12.97$\pm$.15 min, p=.000). There was no statistically significant difference between variety KB and SN in terms of banana length.

It also revealed that the circumference was statistically significantly lower for variety SN (9.63$\pm$.12 min, p=.000) as compared to other varieties KB, F and KJ. There was no statistically significant difference between circumference of the varieties KJ and F. There was also no statistically significant difference in pH among the varieties KJ, F and SN (p>.05). Tukey post hoc test also revealed that there was no statistically significant difference in length of pedicel among the varieties KJ, F and SN and finally there was also no statistically significant difference in width of pedicel among the varieties KJ, KB and SN at the 0.05 level ($p>.05$) (**refer to Appendix 2**).

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 Introduction

The study investigated the morphological characterization of various small dessert yellow banana varieties in Uganda since these characteristics play a vital role in plant classification as well as understanding the distinct morphological features of mature fruits within different genomic groups to cater for consumer preferences. A purposive sampling technique was employed by the research as a known characteristics of the banana varieties were to be studied extensively. Also, it was employed for reasons of its convenience and low cost.

5.2 Summary of the study

A purposive sampling technique was employed to select different small dessert yellow banana varieties commonly available in Uganda. Four specific banana plants of different monotypes were earmarked at the flowering stage in the farmer's field and banana bunches harvested at maturity. Samples from each plant was taken and carefully handled to ensure that the fruits were representative of the varieties and were free from physical damage or abnormalities. The characteristics assessed were both physical and chemical. The physical characteristics assessed included fruit pedicel length, pedicel width, fruit length and circumference. The chemical parameters assessed were Titratable acidity and pH. The pH was determined by using a pH meter and titratable acidity using the equation (1) as described in chapter 3. Descriptive statistics were performed on the data collected to get the mean banana length, mean circumference, mean pH, mean length of pedicel, mean width of pedicel as well as the titratable acidity of the pulps expressed as a percentage.

5.3 Discussion

The pH of the varieties KJ and F was 5.1 and significantly higher than that of the other varieties KB at 4.6 and SN at 4.9. This result was in close agreement with those of Wanna, Yaakob, Salmah, and Russly (2001) who showed that the pH of varieties Abu at ripening stages were 5.46 and 4.67 and for Nangka at stages 'green' and 'trace of yellow' were 5.54 and 4.88 respectively. Also the present study's results were in close Stoven and Simmonds (1987) who showed that the range of pH values for banana fruits at the early stages of maturity was between 5.0 and 5.8 but decreased to between 4.2 and 4.8. The acidity value (gkg^{-1} as anhydrous citric acid) was lower at stage 'green' than at stage 'trace of yellow' for both varieties.

In the study of Reynaldi and Titri, three different ratios of banana and water of 1:2, 1:3 and 1:4 had pH of 3.41$\pm$0.52, 3.30$\pm$0.21 and 3.27$\pm$0.02 which were lower than all the pH values of the banana varieities in the present study. In the same study, the total titratable acid of the ratios were 0.84$\pm$0.10, 0.75$\pm$0.06 and 0.61$\pm$0.10 respectively and the acidity was higher than that of the banana varieties in the present study. The varieties of KJ, KB, SN and F had TA values of 0.477, 0.466, 0.358 and 0.292% respectively. The measurement of a low titratable acid and a low pH value indicates that there is no relationship between the pH value and the total titrated acid. Measurements with the use of pH meter only measure free hydrogen ions whereas in the measurement of the TA measures free hydrogen ions and hydrogen bound to organic acid. The cultivars under study by Bugauda et al., (2013) contrasted in acidity since the pH varied from 4.1 t0 5.4 which were nearly related to those of varieties in the present study whose pH ranged from 4.6 to 5.1 refer to table 4.2. They opined that malic acid and citric acids were the major acids at the eating stage, phosphoric acid was the third acid while oxalic, isocitric acids were negligible (Bugauda, Etienne, Mbéguié-A-Mbéguié, Cazevielle, & Lobit, 2013).

The mean banana length was 10.3500$\pm$1.85738 cm, which disagreed with the average banana length of 24 cm as presented by UCDAVIS (2023). Improving pulp content and fruit size is attributed to the presence of potassium nineral which is important for the transfer of carbohydrates from the leaf to the fruit (YARA, 2024). The mean circumference was 11.0500$\pm$0.98248 cm which was like the results of (CÉSAR et al., 2017) whose unripe fruit circumference ranged from 9.37 cm to 15.70 cm and from 8.8 cm to 15.28 when ripe. The differences in fruit circumference or diameter are related to dehydration during the maturation process and this consequently reduces the peel thickness. Similar results were obtained by JESUS (2004). Mean pedicel length and width were 1.6025$\pm$0.47070 and 0.8725$\pm$0.17671 cm respectively. The length of pedicel in the present study agreed with the results of (IPGRI), whose fruit pedicel length was in the range 1.1 to 2 cm. likewise, the fruit pedicel width was also similar in the range 0.5 to 1 cm.

The total sugar contents of the four varieties according to table 4.3 were all higher than those reported by Wanna, Yaakob, Salmah, and Russly (2001) for variety Abu and Nangka at stage green at ripening stage which were at $12.0 \pm 5.5\ and\ 8.1 \pm 1.4$ respectively. However the same same varieties at stage yellow at ripening stage had higher total sugar contents of $31.0 \pm 2.9\ and\ 34.8 \pm 5.6$ respectively. The largest quantitative change in the varieties at stage green and at stage yellow was due to breakdown of carbohydrate polymers. Chiwate, Jadhav, and Nikam (2023) analysed the physicochemical changes during the ripening of Cavendish and Velchi banana in which by the 10^{th} day, Cavendish and Velchi had total soluble solids of 23.7 ± 8.51 g $100g^{-1}$ and 27 ± 2.61 g $100g^{-1}$ respectively. The value for Cavendish was similar to that of variety SN in the current study and that of Velchi was generally higher than the total sugar contents of the varieties in the current study as shown in table 6.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The data presented in this study revealed substantial morphological variations among the banana varieties of different genomic groups which could be attributed to variety and maturation stage. There were significant differences among the morphological characteristics assessed for the four varieties except for KB and SN which were not statistically significantly different in banana length, KJ and F which were also not statistically significantly different in terms of circumference. More still, KJ, F and SN were not statistically significantly different in their pH and length of pedicel and there was also no statistically significant difference in width of pedicel among the varieties KJ, KB and SN. F had the highest pH value and KJ highest TA value. The varieties varied in pH and TA due to differences in the extent of ripening during which pulp acidity changes. Variety KB had the highest circumference, F had the highest value of fruit length, SN had the highest length of pedicel and F highest width of pedicel all the differences being attributed to the maturation differences. The TA increased from F to SN to KB and finally to KJ because at unripe stage, bananas have low acidity, which increases with ripening until reaching a maximum, when the peel is completely yellow, and then decreases, indicating the beginning of senescence (CÉSAR et al., 2017).

6.2 Recommendation

In the present study, consumer preference should be based on the varieties whose morphological characteristics such as fruit length and circumference are outstanding like the KB variety. To the food industry that uses banana as a raw material, morphological characteristics should be considered during the choice of varieties to use including colour, moisture content, etc. that have not been assessed in this study. Due to cost, time limit, the research was unable to carryout this study extensively and therefore recommends the future researchers to carryout an indepth evaluation of other physical, chemical and morphological characteristics of banana varieities in the different markets within kampala in relation to consumer preferences.

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APPENDICES

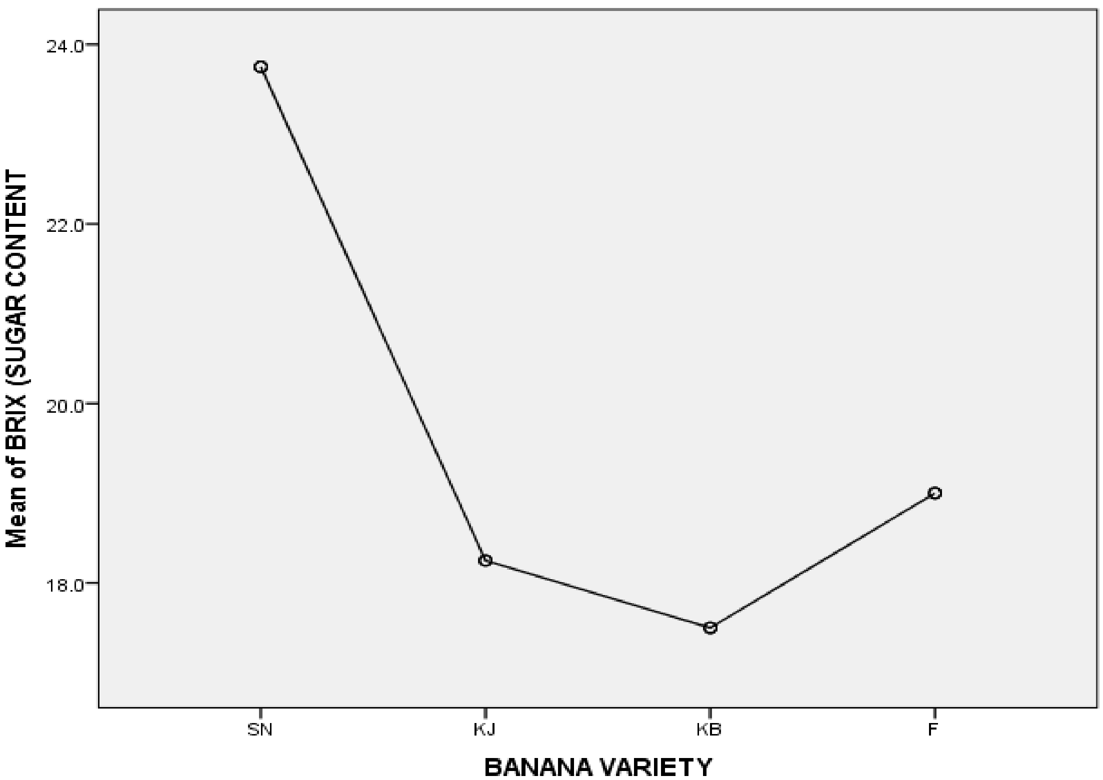
Appendix 1: Analysis of variance to show whether there were significant differences in sugar content among the four varieties

ANOVA

BRIX (SUGAR CONTENT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	95.250	3	31.750	2.664	.095
Within Groups	143.000	12	11.917		
Total	238.250	15			

Appendix 2: Graph showing the mean sugar content of the four varieties



Appendix 3: Post Hoc Test

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Banana variety	(J) Banana variety	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Banana length	KB	F	-3.93333*	.11785	.000	-4.3107	-3.5559
		KJ	-1.33333*	.11785	.000	-1.7107	-.9559
		SN	.00000	.11785	1.000	-.3774	.3774
	F	KB	3.93333*	.11785	.000	3.5559	4.3107
		KJ	2.60000*	.11785	.000	2.2226	2.9774
		SN	3.93333*	.11785	.000	3.5559	4.3107
	KJ	KB	1.33333*	.11785	.000	.9559	1.7107
		F	-2.60000*	.11785	.000	-2.9774	-2.2226
		SN	1.33333*	.11785	.000	.9559	1.7107
	SN	KB	.00000	.11785	1.000	-.3774	.3774
		F	-3.93333*	.11785	.000	-4.3107	-3.5559
		KJ	-1.33333*	.11785	.000	-1.7107	-.9559
Circumference	KB	F	-.43333*	.11304	.021	-.7953	-.0713
		KJ	-.63333*	.11304	.002	-.9953	-.2713
		SN	1.53333*	.11304	.000	1.1713	1.8953
	F	KB	.43333*	.11304	.021	.0713	.7953
		KJ	-.20000	.11304	.353	-.5620	.1620
		SN	1.96667*	.11304	.000	1.6047	2.3287
	KJ	KB	.63333*	.11304	.002	.2713	.9953
		F	.20000	.11304	.353	-.1620	.5620
		SN	2.16667*	.11304	.000	1.8047	2.5287
	SN	KB	-1.53333*	.11304	.000	-1.8953	-1.1713
		F	-1.96667*	.11304	.000	-2.3287	-1.6047
		KJ	-2.16667*	.11304	.000	-2.5287	-1.8047
pH	KB	F	-.46667*	.05370	.000	-.6386	-.2947
		KJ	-.32333*	.05370	.001	-.4953	-.1514
		SN	-.34333*	.05370	.001	-.5153	-.1714
	F	KB	.46667*	.05370	.000	.2947	.6386
		KJ	.14333	.05370	.106	-.0286	.3153
		SN	.12333	.05370	.178	-.0486	.2953
	KJ	KB	.32333*	.05370	.001	.1514	.4953
		F	-.14333	.05370	.106	-.3153	.0286
		SN	-.02000	.05370	.981	-.1920	.1520
	SN	KB	.34333*	.05370	.001	.1714	.5153
		F	-.12333	.05370	.178	-.2953	.0486
		KJ	.02000	.05370	.981	-.1520	.1920
Length of pedicel	KB	F	-.86667*	.08165	.000	-1.1281	-.6052
		KJ	-.96667*	.08165	.000	-1.2281	-.7052
		SN	-.96667*	.08165	.000	-1.2281	-.7052
	F	KB	.86667*	.08165	.000	.6052	1.1281
		KJ	-.10000	.08165	.630	-.3615	.1615
		SN	-.10000	.08165	.630	-.3615	.1615
	KJ	KB	.96667*	.08165	.000	.7052	1.2281
		F	.10000	.08165	.630	-.1615	.3615
		SN	.00000	.08165	1.000	-.2615	.2615
	SN	KB	.96667*	.08165	.000	.7052	1.2281
		F	.10000	.08165	.630	-.1615	.3615
		KJ	.00000	.08165	1.000	-.2615	.2615
Width of pedicel	KB	F	-.33333*	.05774	.002	-.5182	-.1484
		KJ	-.03333	.05774	.936	-.2182	.1516
		SN	.06667	.05774	.669	-.1182	.2516
	F	KB	.33333*	.05774	.002	.1484	.5182
		KJ	.30000*	.05774	.004	.1151	.4849
		SN	.40000*	.05774	.001	.2151	.5849
	KJ	KB	.03333	.05774	.936	-.1516	.2182
		F	-.30000*	.05774	.004	-.4849	-.1151
		SN	.10000	.05774	.369	-.0849	.2849
	SN	KB	-.06667	.05774	.669	-.2516	.1182
		F	-.40000*	.05774	.001	-.5849	-.2151
		KJ	-.10000	.05774	.369	-.2849	.0849

*. The mean difference is significant at the 0.05 level.

Appendix 4: Laboratory Titration for determination of TA

Appendix 5: Prepared samples in laboatory for pH measurement and Total sugar content determination

Appendix 6: Dessert banana varieties collected