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Physico-Chemical Characterization of Keitt Mango and Cavendish Banana Fruits Produced in Mozambique

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Abstract

Mangoes (*Mangifera indica*) and bananas (*Musa acuminata*) are climacteric fruits with a high potential for export due to their exotic aroma and sweet taste. This study aimed to characterize the physical and chemical parameters of Keitt mangoes and Cavendish bananas from different regions of Mozambique. The fruits were collected from Gaza, Manica and Nampula districts of south, central and north parts of Mozambique, respectively. The banana and mango samples were collected in Mid-August 2016 and January 2017, respectively. The fruits collected were at three different maturity stages (green, green-yellowish and yellow). The sample materials were characterised according to their centesimal composition, size, weight, firmness and colour. Analyses of soluble solids and ascorbic acid were, also, performed. The results revealed that the parameters were a good indicator of the maturity stage as well as for multivariate mango and banana applications and consumption. The parameters confirmed that mango fruits with low moisture (green with 83.62%), and fibers (0.44%), high ash (2.05%) crude lipids (0.29%), protein (0.85%) and carbohydrate (13.81%), high total soluble solids (24.60%), and high vitamin C content (14.83 mg/100g) were collected in Nampula with statistic differences ($p < 0.05$) between region of fruit production in Mozambique and stages of fruit maturity. However, banana fruits with low moisture (73.18%) and fibers (0.27%), high crude proteins (3.44%), ash (0.58%), and crude lipids content (4.92%), high total soluble solids (24.50%) and vitamin C content (2.40 mg/100g) were collected in Manica, where statistic differences ($p < 0.05$) were reported. This is the first time that Keitt mangoes and Cavendish bananas fruits have been characterized either in relation to the region of production in Mozambique or in relation to the various stages of maturity.

This information can be exploited by various actors along the mango and banana value chain.

Keywords

Mangifera indica, *Musa acuminata*, Quality, Physicochemical Characteristics, Maturity Stage, Mozambique Geographic Regions

1. Introduction

Mozambique is predominantly an agricultural country. The climate and soil are suitable for a wide range of horticultural and fruit cultivation. More than 100 varieties of vegetables, 70 varieties of fruits and 60 different spices are produced every year [1]. Major fruits produced in Mozambique include various kinds of citrus, jackfruit, mango, pineapple, papaya, guava, banana, water melon and litchi. Of these fruits, about 10 types of fruits are exported to more than 15 different countries increasing significantly the export balance from 20 million USD in 2008/09 to 60 million USD in 2012/13 [2].

Mangoes (*Mangifera indica*) and bananas (*Musa acuminata*) are climacteric [3] and the most popular and commercial fruits in the world [4]. Mango is one of the delicious seasonal fruits grown in the tropics. Botanically, this exotic fruit belongs within the family of *Anacardiaceae* [5]. There are several cultivars of mango that are rich in nutrients and flavonoid antioxidant compounds [6]. The Keitt mangoes are oblong in shape with a pale to dark green skin. Occasionally they have a yellow bluish shade and a tangy sweet flavour with a hint of honey [7].

The banana is, in fact, not a tree but a high herb. Botanically, it belongs to the family of *Musaceae*. [8]. There are several cultivars of banana that comes in different size, colour, weight and taste. The Cavendish bananas are eaten raw, used in baking, fruit salads, and fruit compotes. The outer skin is normally partially green when sold in food markets but turns yellow when it ripens [9]. As it ripens, the starches turn to sugars. This metabolic change causes the fruits to be sweet to taste. The fruit is rich in vitamins, minerals, dietary fibers, flavonoids, phenolic and other phytochemicals [10].

Mango and banana fruits are harvested commercially within a range of maturities including immature green, mature green and ripe. External and internal quality is critical to consumer acceptability while flavour is an important marketing consideration [11]. Ripening can be induced naturally or artificially. The uniformity of ripening can be characterized by measuring texture and the brix (ratio soluble dry extract/titratable acidity) [12]. Reference [13] reported that there is no direct correlation between the maturity of the fruit and the colour of the skin of the fruits.

There are some reports on the physicochemical composition of mango and bananas fruits in the literature. In Martinique (France), physicochemical characteristics of four varieties of mango (*Julie*, *Bassignac*, *Green* and *Moussache*) were examined at three ripening stages [13]. In Egypt, some major local and imported grown mango cultivars were characterized phsico-chemically to assess the genetic variability and heritability [14]. In, Mozambique, Reference [15] worked with 30 mangoes cultivars of an orchard located in the Boane district situated 25 km from Maputo and characterized the respective cultivar morphologically and genetically. The physico-chemical parameters assessed were, fruit length, diameter, brix and tritrable acidity. In Vhembe District of South Africa, comparative profile of the morphological, physico-chemical, and antioxidant properties of three noncommercial banana cultivars were assessed [16]. In Botucatu-SP (Brazil), banana fruit genotypes locally produced were characterized physico-chemically [17]. At Embrapa Genebank of *Musa* (Brazil) 26 diploid, triploid and tetraploid banana accessions were characterized agronomically, physically and chemically [18].

However, these reports are lacking on the physico-chemical parameters of the respective mangoes and bananas analyzed. The reports generally were limited to comparison of different varieties without taking into account the agro-ecological diversity of the region of the fruit origin. Furthermore, the stage of maturation at the time of fruit harvest was never evaluated vis-à-vis the physico-chemical parameters. No reports are available on the physico-chemical parameters of the Keitt mangoes and Cavendish bananas neither in relation to the region of production in Mozambique nor in relation to the various stages of maturity. Such information will be of interest to the various actors along the mango and banana value chain. The knowledge of the various parameters will inform the handling, packaging, transportation and consumers' preferences.

The new knowledge generated about the mangoes and bananas composition will impact positively the National development of Mozambique due to increased exports of the respective fruit. Thus, the aim of the current work was to characterize and compare selected physico-chemical parameters of Keitt mango and Cavendish banana fruits from different regions of Mozambique at different maturity stage. The parameters characterized and compared were primarily the centesimal composition, size, weight, firmness, colour, total solids soluble and vitamin C content.

2. Materials and Methods

2.1. Site for the Collection of the Mangoes and Bananas

The Keitt mango and Cavendish banana fruits for this research work were collected from Xai-xai district (Gaza Province in the southern part of Mozambique), Macate district (Manica Province in the central part of Mozambique) and Ribawe district (Nampula Province in the northern part of Mozambique). Through the Map accessed from Reference [19], the **Figure 1** shows the location of fruits collection in Mozambique. The geographical coordinates of the collection sites were 23˚44'60" South, 32˚45'00" East; 18˚56'04" South, 32˚52'00" East and 15˚06'59" South, 39˚15'59" East, respectively.

Figure 1. Map of Mozambique showing the site where the mangoes and bananas were collected from.

2.2. Collection of Mangoes and Bananas

Cavendish banana fruits were harvested in mid-august 2016 while the Keitt mangoes were harvested in January 2017. The fruits collected were of uniform size, and at the three different maturity stage (green, green-yellowish an yellow) based on length, diameter, colour and firmness. They were transported to the laboratory of "Technology and Food Analyses", Agriculture Division, Instituto Superior Politécnico de Manica (ISPM). Upon arrival at the laboratory, the pedicels were cut back and further selection carried out based on uniformity of shape, colour and size, absence of visible wounds, blemish and or disease. The selected mangoes and bananas were washed in chlorinated water (100 ppm free chlorine) for 2 min, dried and randomly distributed in different groups for each trial.

2.3. Analyses

2.3.1. Centesimal Composition Determination

The Keitt mango and Cavendish banana fruits were characterised according to its centesimal composition in relation to water content (moisture), ash, lipids, proteins, fibre [20] and carbohydrates. Moisture content was determined in a vacuum oven at 105˚C. Protein content was analyzed by the Kjeldahl method using a conversion factor of 6.25. Lipid content was determined by the Soxhlet method based on ether extraction. The ash content (fixed mineral residue) was measured gravimetrically after calcination of the samples in the muffle furnace (Nabertherm, L5/11/B410 Model, Maximum Temperature of 1200ºC, Bremen, Germany) at 550˚C. The fiber was determined by acid hydrolysis. The sugar fraction, also called saccharides or the non-nitrogen extract (NNE), was determined by the difference between 100 and the total sum of all other constituents.

2.3.2. Length and Diameter Measurement

The fruits were selected on the basis of their appearance and the absence of injuries, rot and characteristic rotting odour. All fruits were first washed to remove surface impurities and sanitized. Some of the sanitized fruits were then separated for characterization. The length and diameter in centimeters of the fruits were determined using a digital caliper ruler. The length was measured from the bottom (pointed end) to the top while the diameter was determined from the centre of the mango and banana fruit or equator.

2.3.3. Firmness Measurements

The mango and banana fruits firmness measurements were determined using a food penetrometer (0.2 kg/cm^2 scale indicator, 10 mm indenter penetration depth and 3.5 mm probe size, ELCOMP (PTY) LTD Midrand, South Africa). The peel firmness (expressed in $\times 10^5$ Pa) is defined as the mean of the pressure applied on the peel for one second to break the peel. Each fruit was compressed 3.5 mm at different locations of the skin around the fruit equator according to the method established by Reference [21].

2.3.4. Colour Measurements

According to the method established by Reference [22], the skin colour of the fruit was measured using a colour differential meter (ZE-2000, Nippon Denshoku, Japan) to determine Hunter Lab's L* value (lightness or brightness), a* value (redness or greenness), and b* value (yellowness or blueness) of the fruit at the equator. The colorimeter was calibrated with a white standard tile.

2.3.5. Brix Degree Measurement

Total soluble solids were determined as °Brix using a refractometer ATAGO hand held type (ELCOMP (PTY) LTD Midrand, South Africa) , which was calibrated with distilled water and maintained at a constant temperature of 25˚C.

2.3.6. Ascorbic Acid Determination

An oxidation-reduction titration was performed according to the method established by Reference [23]. An iodine solution of known concentration was prepared and its concentration verified by titrating a solution of ascorbic acid. The iodine solution thus prepared was, then, used to titrate the respective fruit extracts. The ascorbic acid was expressed as g ascorbic acid per 1000 mL of fruit extract.

2.4. Statistical Analyses

The statistical significance study of the different effects and their possible interactions was conducted through One Way Analysis of Variance (ANOVA) using the LSD (least significant differences) method as the method for multiple comparisons, with a confidence level of 95% (=0.05). The variance analysis was performed with the Statistical Package Stat-graphics System (SPSS) procedure (Version 8.0) to detect the differences between mango or banana fruits from different regions of Mozambique and maturity stage. When significant differences ($p < 0.05$) detected, test of means (Tukey test) data was done to understand which treatments differ.

3. Results and Discussion

3.1. Fruit Centesimal Composition

The centesimal Keitt mango and Cavendish banana fruits composition, in wet weight basis, collected in different regions of Mozambique is presented in Table 1. The moisture content of different mango fruits from different regions at

Table 1. Centesimal composition of Keitt mango and Cavendish banana fruits from different regions at different maturity stage.

	Origin	Stage	Moisture (%)	Ash (%)	Lipids (%)	Protein (%)	Fiber (%)	Carbohydrate (%)
Banana	Gaza	green	76.99 ± 0.04C*a*	0.45 ± 0.02A*a*	1.94 ± 0.11A*a*	3.21 ± 1.05A*a*	3.10 ± 0.28A*a*	14.3 ± 1.09B*a*
		g-yellow	80.34 ± 0.02C*b*	0.39 ± 0.01A*a*	1.94 ± 0.11A*a*	2.80 ± 1.16A*a*	1.71 ± 0.46A*a*	12.18 ± 1.50B*a*
		yellow	79.54 ± 0.03C*b*	0.36 ± 0.02A*b*	2.79 ± 1.10A*a*	2.39 ± 0.20A*a*	1.91 ± 0.40A*b*	13.02 ± 1.17B*b*
	Manica	green	73.18 ± 0.09A*a*	0.58 ± 0.01B*a*	4.82 ± 1.59B*a*	3.44 ± 0.35A*a*	3.21 ± 0.51A*a*	15.57 ± 1.74B*a*
		g-yellow	76.64 ± 0.01A*b*	0.43 ± 0.01B*a*	4.92 ± 1.00B*a*	2.74 ± 1.03A*a*	0.89 ± 0.45A*a*	14.22 ± 1.25B*a*
		yellow	78.87 ± 0.05A*b*	0.42 ± 0.03B*b*	4.27 ± 0.27B*a*	2.21 ± 0.90A*a*	0.27 ± 0.19A*b*	13.93 ± 1.31B*b*
	Nampula	green	70.98 ± 0.02B*a*	0.46 ± 0.01A*a*	1.88 ± 1.11A*a*	2.97 ± 0.63A*a*	4.10 ± 0.10B*a*	19.61 ± 1.12A*a*
		g-yellow	81.21 ± 1.00B*b*	0.31 ± 0.02A*a*	2.27 ± 0.47A*a*	3.15 ± 0.76A*a*	3.31 ± 0.29B*a*	9.75 ± 0.47A*a*
		yellow	81.20 ± 0.06B*b*	0.33 ± 0.01A*b*	2.26 ± 0.48A*a*	3.32 ± 0.92A*a*	2.98 ± 0.26B*b*	9.89 ± 1.59A*b*
Mango	Gaza	green	84.31 ± 0.03D*de*	1.55 ± 0.00D*d*	0.19 ± 0.05D*d*	0.80 ± 0.19D*d*	4.65 ± 0.28DE*d*	8.45 ± 0.14D*d*
		g-yellow	86.35 ± 0.06D*d*	0.28 ± 0.01D*d*	0.16 ± 0.07D*d*	0.69 ± 0.23D*d*	2.57 ± 0.46DE*e*	9.38 ± 1.13D*d*
		yellow	87.01 ± 0.04D*e*	1.35 ± 0.01D*e*	0.09 ± 0.02D*d*	0.48 ± 0.04D*d*	4.04 ± 0.16DE*e*	6.64 ± 0.41D*d*
	Manica	green	86.72 ± 0.08E*de*	1.93 ± 0.01D*d*	0.08 ± 0.04D*d*	0.56 ± 0.07D*d*	6.15 ± 0.01E*d*	4.44 ± 0.52D*d*
		g-yellow	88.42 ± 0.07E*d*	1.66 ± 0.02D*d*	0.10 ± 0.05D*d*	0.55 ± 0.21D*d*	4.97 ± 0.29E*e*	5.32 ± 0.77D*d*
		yellow	90.02 ± 0.05E*e*	1.49 ± 0.00D*e*	0.12 ± 0.03D*d*	0.44 ± 0.22D*d*	4.47 ± 0.16E*e*	3.49 ± 0.38D*d*
	Nampula	green	83.62 ± 0.03F*d*	2.05 ± 0.01E*d*	0.16 ± 0.14D*d*	0.63 ± 0.15D*d*	1.34 ± 0.35D*e*	13.81 ± 0.65D*d*
		g-yellow	84.90 ± 0.03F*e*	0.85 ± 0.01E*e*	0.11 ± 0.03D*d*	0.85 ± 0.19D*d*	0.44 ± 0.19D*e*	13.76 ± 1.08D*d*
		yellow	89.12 ± 0.02F*de*	1.21 ± 0.01E*d*	0.29 ± 0.05D*d*	0.59 ± 0.13D*d*	3.63 ± 0.35D*d*	7.16 ± 0.09D*d*

It is shown the mean values and standard deviation (σ) for each centesimal parameter. Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the local of sample collection. In a similar way, the same lower case is not significantly different between maturity stages. Were used *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits.

different maturity stage showed significance difference at $p < 0.05$. Yellow Keitt mangoes from Manica had highest moisture content (90.02%) and the lowest value was found in green mangoes from Nampula (83.62%). For banana fruits moisture content was reported in significance differences between fruits from different regions at different maturity. Green-yellow Cavendish bananas from Nampula had highest moisture content (81.21%) and the lowest value was found in green bananas from the same region (70.98%). The green banana fruits presented lowest moisture content for all regions compared to the bananas in other stages of maturity.

The increase in pulp moisture content during ripening may be due to carbohydrate breakdown and osmotic transfer from the peel to pulp [24] [25]. In these studies, it was reported that moisture content of the fruits increased from 79.75% to 83.11% for mango and 73.68% to 75.91% for banana fruits during ripening. However, the results were lower than those reported in the current work due to differences of the fruit cultivars. But, the reported results corroborate those obtained by Reference [26] for mango and Reference [27] for banana fruits. These researchers observed moisture content varying from 80.80% to 87.33% and 69.41% to 77.28%, respectively. The researchers reported that, besides pulp yield, the water content of bananas influences the yield of concentrated and dehydrated products. Thus, varieties with lower moisture levels are more attractive for making different banana fruit products.

The ash content was found to be highest in green mango fruits from Nampula (2.05%) followed by green mangoes from Manica (1.93%). The lowest ash content value was found in green-yellow mangoes from Gaza (0.28%). The ash content of mangoes from the three regions was significantly different at $p < 0.05$. Similarly, the amounts of fibers were significantly different at $p < 0.05$ ranging from 0.44 to 6.15%. However, the lipid, protein and carbohydrate contents were not significantly different at $p < 0.05$. This observation was maintained even between regions of sample collection or fruit maturity stage, which ranged from 0.08% - 0.29%, 0.44% - 0.85% and 3.49% - 13.81%, respectively.

For the Cavendish bananas, the ash content was found to be highest in green banana fruits from Manica (0.58%) followed by those from Nampula (0.46%). The lowest ash value was found in green-yellow bananas from Nampula (0.31%). The ash content of bananas from the three regions was significantly different at $p < 0.05$. Similarly, the amounts of lipids, fiber and carbohydrate were significantly different at $p < 0.05$. The amounts ranged from 1.88 - 4.92, 0.29% - 4.10% and 9.75% - 15.67% for lipids, fiber and carbohydrates, respectively. However, the protein content which ranged from 2.21% - 3.44% was similar for the bananas from all the regions regardless of the stage of maturity.

Reference [28] reported similar centesimal mango composition as obtained in the current work. Reference [29] reported that the average centesimal composition of *Embul*, *Seeni* and *Kolikuttu* cultivars of banana at the harvest maturity indicated that the moisture, protein and fiber contents of three banana cultivars are not significantly different ($p < 0.05$). Therefore, Mozambique mango and banana fruits present high moisture than reported in some literatures depending on local fruit production and the moisture increases from green to the ripe fruits for all regions. The moisture content of agricultural produce influences their bulk density including other centesimal parameters as reported in this work. Therefore, the mangoes with low moisture content were collected in Nampula while low moisture content banana fruits were obtained from Manica.

3.2. Size, Weight and Firmness Attributes of Keitt Mangoes and Cavendish Bananas from Mozambique

The size attributes of the Keitt mango and Cavendish banana fruits are presented in Table 2. Green Keitt mangoes from Nampula had highest length (10.61 cm) and the lowest value was found in green-yellow mangoes from Manica (9.22 cm).

Although, the mango fruits length from different regions at different maturity stage showed no significance difference, the mangoes from Nampula were found to be longer, thicker and heavy but presented the lowest firmness. For green

Table 2. Size, weight and firmness attributes of Keitt mangoes and Cavendish bananas from different regions at different maturity stage.

	Fruit Origin	Maturity Stage	Fruit size		Fruit	Fruit
			Length (cm)	Diameter (cm)	Weight (g)	Firmness (×10^5 Pa)
Banana	Gaza	green	13.00 ± 0.10A*a*	2.97 ± 0.12A*a*	167.03 ± 2.76A*a*	15.00 ± 0.02A*a*
		g-yellow	14.07 ± 0.12A*a*	3.10 ± 0.00A*a*	157.06 ± 4.26A*b*	7.20 ± 1.31A*b*
		yellow	13.27 ± 0.12A*b*	3.27 ± 0.29A*a*	148.03 ± 2.46A*c*	7.33 ± 1.40A*c*
	Manica	green	17.20 ± 0.17B*a*	3.90 ± 0.00B*a*	173.36 ± 2.85A*a*	14.99 ± 0.78A*a*
		g-yellow	15.83 ± 0.12B*a*	3.37 ± 0.06B*a*	162.07 ± 1.44A*b*	14.70+0.30A*b*
		yellow	15.87 ± 0.12B*b*	3.57 ± 0.06B*a*	154.20 ± 2.20A*c*	6.67 ± 1.53A*c*
	Nampula	green	14.77 ± 0.15AB*a*	3.20 ± 0.26B*a*	162.80 ± 1.71A*a*	15.00 ± 0.00A*a*
		g-yellow	15.30 ± 0.20AB*a*	3.17 ± 0.15A*a*	149.03 ± 2.40A*b*	10.33 ± 1.53A*b*
		yellow	13.83 ± 0.12AB*b*	3.00 ± 0.10A*a*	147.46 ± 3.26A*c*	8.27 ± 0.64A*c*
Mango	Gaza	green	10.03 ± 0.22D*d*	7.88 ± 0.97D*d*	576 ± 1.20D*d*	10.00 ± 0.04D*d*
		g-yellow	9.51 ± 1.09D*d*	8.44 ± 0.54D*e*	676 ± 1.30D*d*	8.21 ± 1.33D*e*
		yellow	11.02 ± 0.61D*d*	7.54 ± 0.52D*f*	640 ± 2.33D*d*	8.45 ± 1.52D*f*
	Manica	green	9.57 ± 0.53D*d*	6.45 ± 0.63D*d*	512 ± 0.52D*d*	12.00 ± 0.20D*d*
		g-yellow	9.22 ± 0.90D*d*	7.94 ± 0.14D*e*	667 ± 1.91D*d*	11.70 ± 0.25D*e*
		yellow	9.27 ± 0.81D*d*	7.33 ± 0.57D*f*	526 ± 2.20D*d*	8.67 ± 1.32D*f*
	Nampula	green	10.61 ± 0.91D*d*	8.87 ± 0.07E*d*	617 ± 0.81D*d*	8.33 ± 0.18D*d*
		g-yellow	11.08 ± 0.20D*d*	8.13 ± 0.97E*e*	677 ± 2.51D*d*	7.00 ± 1.33D*e*
		yellow	10.22 ± 1.22D*d*	8.07 ± 0.27E*f*	767 ± 0.34D*d*	5.27 ± 0.58D*f*

It is shown the mean values and standard deviation (σ). Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the local of sample collection. In a similar way, the same lower case is not significantly different between maturity stages. Were used *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits.

mangoes, the mean peel hardness assessed as fruit firmness were 10.11 Pa though not statistically different from the green mango samples from Manica and Gaza. Though the peel of green mangoes harvested in Gaza was not significantly different in hardness from those from Nampula and Manica ($p < 0.05$); the hardness of the green-yellow and yellow maturity stages were significantly different from the Nampula and Manica samples. Reference [21] reported similar size attributes for the various regions of mango cultivars production.

Still, in the **Table 2**, the characteristics of length and circumference of Cavendish banana fruits were found to be significantly different ($p < 0.05$) in the three regions of production. The bananas from Manica were found to be significantly longer and stout compared to those from Nampula and Gaza.

Reference [18] characterizing agronomically, physically and chemically banana fruits reported similar length and diameter values in 26 banana accessions of the active genebank of Embrapa. Average fruit lengths of *Embul*, *Seeni* and *Kolikuttu* cultivars are 10.5 ± 0.86, 10.5 ± 0.86 and 14.3 ± 1.66 cm, respectively according to Reference [29] report. The length values reported were significantly lower than those observed in the current work. But the diameter at the middle of the fruit was similar as reported in this work.

In green bananas, the mean peel hardness assessed as fruit firmness was 15 Pa. The peel hardness were not significantly at $p < 0.05$ for the three regions that Nampula, Manica and Gaza. However, the green-yellow banana fruits showed that Manica's banana fruits are firmer (14 Pa) followed by Nampula's banana fruits (10 Pa). In ripe bananas, the lowest mean peel fruit firmness was 6.67 Pa and the highest was 8.27 without significant differences at $p < 0.05$ for the three regions. The observed results of firmness for the ripe bananas corresponded to a peel fruit firmness loss of more than 50% relative to the green banana firmness.

References [12] and [30] reported that the fruit firmness, rupture energy and hardness decreased as banana fruit ripened. Similar firmness trends were found in this work for both mango and banana fruits. The similar trends were also reported by Reference [21] for mangoes and Reference [31] for oranges. According to Reference [27], peel firmness is a quality considered relevant by most consumers of raw bananas. Decreases in firmness as the fruit ripens were as a result of alteration in the composition of cell wall, solubilization of pectins, and hydration of cell walls. Fruits and vegetables softening is due to alteration in cell wall structure by degrading enzymes, for example, polygalacturonase. The other reported cause of softness was due to the degradation of starch [32] as observed in this work. It can be explained because of the existence of a high degree of turgidity in live fruit and vegetables or whether a relative state of flabbiness develops from loss of osmotic pressure as well as final texture depends on several cell constituents. It is this cell turgidity that is high in yellow banana fruits leading for low peel firmness. Therefore, Mozambique mango higher growth presented as fruit weight, diameter and length was obtained in Nampula but banana fruits higher growth (weight, diameter and length), was collected in Manica.

3.3. Colour of Keitt Mangoes and Cavendish Bananas from Mozambique

The respective Hunter Lab values for mangoes and bananas from the three regions of Mozambique are shown in Table 3. Lightness intensity analysis (L*) on the fruits epidermis showed no significant statistical differences between mangoes and bananas from different regions even fruits at different maturity stage. For all fruits, a luminosity increasing tendency indicates an increase in reflectance, making the colour saturation less pure and therefore more luminous.

The component a* presents a typical change. There is a significant change in the a* value at negative trending to positive over the fruit maturity stage, as a consequence of chlorophyll degradation and the increase in concentration of carotenoid pigments due to an increase in the ethylene concentration. Besides, that carotenoid pigments concentration that together with anthocyanin presence generates the fruit epidermis natural colour. The a* negative values shown in Table 3, revels a change in the epidermis toward less intense green hues, with an increase until maturation, showing more greenness for banana fruits and more redness for mangoes, indicating the loss of green colour and tendency to yellow hues at the end of the organoleptic maturation.

The value of b*, increase in the most advanced maturation stages, as shown by the colour change in the epidermis from yellow to orange. For this reason, b* is considered the main responsible of the external appearance in fruit ripening. In effect for mango fruits, the statistical results for b* are not also significant like those for a*, but for banana fruits they are statically significant ($p < 0.05$).

The luminosity parameter behaviour can be explained by the increase in the concentration of ethylene that breakdown the chlorophyll and starch in these different fruit maturity stages, where a physiologically mature tissue changes to one more visually attractive. Furthermore, a decrease in luminosity is observed

Table 3. L, a*, b* average values of mango and banana fruits from different regions at different maturity stage.

Fruit Origin	Maturity stage	L		a*		b*	
		Banana	Mango	Banana	Mango	Banana	Mango
Gaza	green	43.22 ± 2.03A*a*	42.16 ± 1.68D*d*	−35.87 ± 0.78A*a*	−5.87 ± 0.78D*d*	24.98 ± 2.81A*a*	21.32 ± 0.48D*d*
	g-yellow	44.77 ± 0.95A*a*	42.99 ± 2.10D*d*	−32.51 ± 1.06A*a*	−2.51 ± 1.06D*e*	37.01 ± 0.68A*b*	17.53 ± 0.54D*d*
	yellow	42.43 ± 1.21A*a*	42.87 ± 0.88D*d*	−11.46 ± 0.67A*b*	1.46 ± 0.40D*f*	47.46 ± 0.95A*c*	19.13 ± 0.11D*d*
Manica	green	44.66 ± 1.12A*a*	43.22 ± 2.03D*d*	−38.65 ± 0.50A*a*	−8.65 ± 0.50D*d*	30.38 ± 0.05A*a*	20.05 ± 0.56D*d*
	g-yellow	42.69 ± 1.45A*a*	42.44 ± 1.12D*d*	−36.66 ± 0.84A*a*	−6.66 ± 0.84D*e*	40.97 ± 1.21A*b*	19.31 ± 0.39D*d*
	yellow	45.16 ± 1.10A*a*	42.85 ± 1.45D*d*	−14.64 ± 0.32A*b*	1.06 ± 0.26D*f*	48.75 ± 1.09A*c*	18.75 ± 1.09D*d*
Nampula	green	42.87 ± 1.68A*a*	42.02 ± 1.33D*d*	−33.26 ± 0.63A*a*	−7.25 ± 0.76D*d*	28.47 ± 1.12A*a*	19.47 ± 0.96D*d*
	g-yellow	43.18 ± 0.15A*a*	43.19 ± 2.06D*d*	−37.25 ± 0.70A*a*	−3.26 ± 0.63D*e*	41.59 ± 1.01A*b*	21.59 ± 1.01D*d*
	yellow	41.33 ± 1.06A*a*	44.05 ± 1.35D*d*	−11.89 ± 1.56A*b*	2.00 ± 0.45D*f*	53.43 ± 0.94A*c*	21.76 ± 2.45D*d*

It is shown the mean values and standard deviation (σ), lightness intensity (L*), redness or greenness (a*) and yellowness or blueness (b*). Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the local of sample collection. In a similar way, the same lower case is not significantly different between maturity stages. Were used *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits.

in green banana fruits, possibly due to the beginning of degradation of chlorophyll pigments by oxidation, which leads to colour darkening and is confirmed by the a* and b* values increase. These results are similar to the reported for Tommy Atkins mangoes by Reference [33] and Cavendish bananas (Grande Naine cultivar) by Reference [30] who attributed this change to the increase in chlorophyll degradation, having a rapid transition from a greenish yellow to yellow leading to carotenoids compounds production. Therefore, Mozambique mango and banana fruits present no lightness intensity differences but the redness or greenness and yellowness or blueness was high as the fruit ripe mainly for fruits from Gaza Province.

3.4. Total Solids Soluble of Keitt Mango and Cavendish Banana Fruits from Mozambique

The total solids soluble (TSS) of Keitt mango and Cavendish banana fruits obtained in different regions of Mozambique is presented in Figure 2. In that Figure 2 is shown that the values of total solids soluble increase during the ripening stage for both crops, ranging from 10.67% (green mango) to 24.60% (yellow mango) and 10.00% (green banana) to 2.50% (yellow banana), that can be associated to the hydrolysis of stored starch in vacuoles and intercellular spaces during the fruit growth.

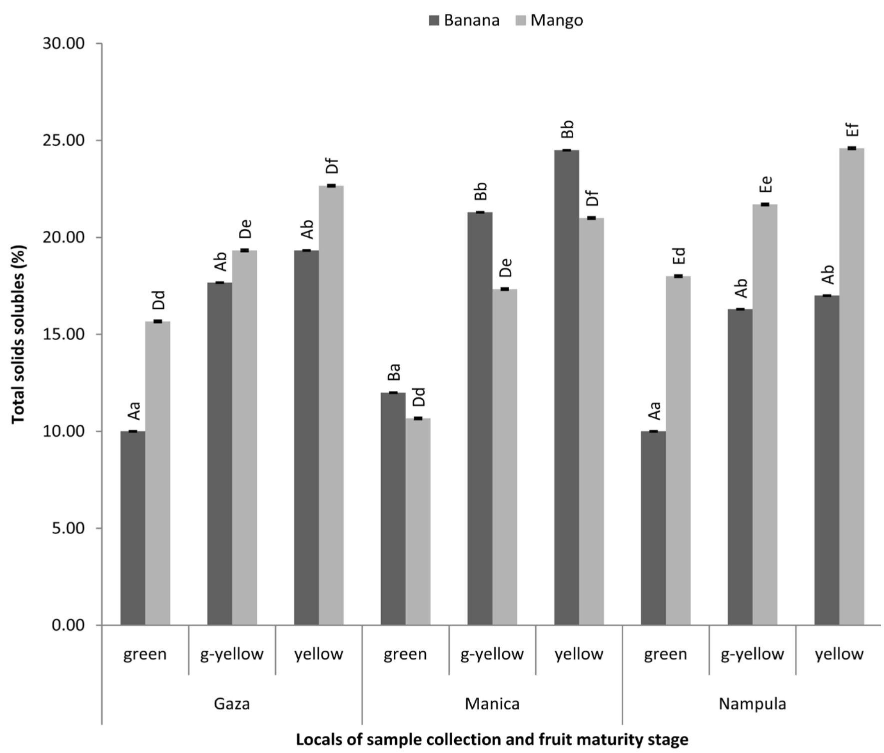

Figure 2. Total solids soluble of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage. Bars followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the local of sample collection. In a similar way, the same lower case is not significantly different between fruit maturity stages. Were used a, b and c for banana and d, e and f for mango fruits.

Significant statistical difference between different maturity stages was reported showing high TSS values of yellow mangoes from Nampula (TSS = 24.60%) and yellow banana fruits from Manica (TSS = 24.50%) and low values of green mangoes from Manica (TSS = 10.67%) and green bananas from Gaza and Nampula (TSS = 10.00%). Therefore, green and green-yellow banana fruits total solids soluble were not statistically different. Mango samples from Nampula presented high TSS followed by Gaza and Manica contrasting to the banana samples that presented high TSS of Manica followed by Gaza and Nampula.

The average TSS of green-yellow mango and banana fruits was slightly lower than that of yellow fruits, thus indicating higher sugar content in the latter. In principle, this could cause less sweetness to be perceived in green-yellow fruits which in turn could influence consumer acceptance. This suggestion however, needs further testing since the difference mango and banana is marginal.

High TSS has been associated with high sucrose content in banana pulp [34]. It has been reported that the average starch content drops from 70% to 80% in the pre-climacteric period to less than 1% at the end of the climacteric period [35], while sugars, mainly sucrose, accumulate to more than 10% of the fresh weight of the fruit [36].

Starch hydrolysis occurs by the great increase in the activity of enzymes α-amylase, β-amylase and starch phosphorylase which transform starch into reducing sugars [37] [38]. Besides, there is a direct increase with the maturation stage in which the fruits were harvested. So, the data obtained in this investigation are similar from those reported by References [24] [34], there will be a higher concentration of total soluble solids in the samples harvested in later maturation stages than in those fruits that were collected in an early maturation stage. Therefore, Nampula mango fruits presented high TSS than fruits from other regions of Mozambique showing starch solubility, sugar availability and physiology maturity (above 10% according to Reference [39]) of these samples but banana with high TSS were collected in Manica.

3.5. Vitamin C of Keitt Mango and Cavendish Banana Fruits from Mozambique

The vitamin C content expressed as ascorbic acid of Keitt mangoes and Cavendish bananas obtained in different regions of Mozambique is presented in **Figure 3**. In this **Figure 3**, the values of vitamin C content increase during the ripening stage for both crops, ranging from 8.53 mg/100g (green mango from Manica) to 14.83 mg/100g (yellow mango from Nampula) and 1.13 mg/100g (green banana from Nampula) to 2.40 mg/100g (yellow banana from Manica). Significant statistical difference between different maturity stages was reported showing high vitamin C content when the fruit was ripe. With statistical difference at $p < 0.05$, mango samples from Nampula presented high vitamin C content followed by Gaza and Manica. However, for the banana samples, the high vitamin C content was reported in Manica followed by Gaza. Generally

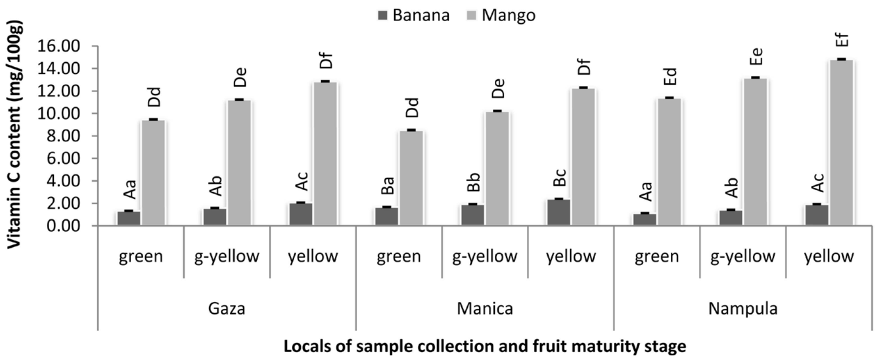

Figure 3. Vitamin C content of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage. Bars followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the local of sample collection. In a similar way, the same lower case is not significantly different between fruit maturity stages. Were used a, b and c for banana and d, e and f for mango fruits.

reporting, the average vitamin C content of mangoes was slightly higher than banana fruits.

The ascorbic acid amounts found for Keitt mango fruits were lower than those reported by Reference [13] who presented vitamin C content ranging from 16 mg/100g to 34 mg/100g. But Cavendish banana fruits in this study were similar to those found by Reference [23] for banana fruits unripe, half-ripe and ripe, respectively using liquid chromatographic determination of vitamin C and 0.1% oxalic acid extraction. However, in this current study, the green bananas contained less vitamin C than the yellow bananas. Reference [40] described vitamin C content of 2.1 ± 0.8 mg/100g for ripe banana, although in this study the banana cultivar was not specified.

These differences between Keitt mango and Cavendish banana fruits reported in this work comparing with the literature could be attributed to the variation in vitamin C content among cultivars and the pre-harvest factors [41]. Therefore, Keitt mango fruits with high vitamin C content were collected in Nampula but Cavendish banana fruits with high vitamin C content were collected in Manica showing good adaptability of these crops in the respective regions of Mozambique.

4. Conclusion

The results obtained in the present study demonstrated that there are differences between mangoes and bananas of the same variety, produced and marketed in different regions of Mozambique. All evaluated fruits have very close physicochemical characteristics, with desirable qualities for consumption, whether in their native state or processed. Since mango lipids, proteins and carbohydrates were not statistically different, fruits with low moisture and fibers and high ash and lipids values with also, higher growth (weight, diameter and length), total solids soluble and vitamin C content were collected in Nampula but banana fruits with low moisture, proteins and fibers and high ash, lipids and carbohydrates values with also, higher growth (weight, diameter and length), total solids soluble and vitamin C content were collected in Manica. It was observed that these physicochemical characteristics are statistically different between fruits maturity stages.

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