Journal of Animal &Plant Sciences, 2013. Vol.17, Issue 3: 2619-2630
Publication date 29/4/2013, http://www.m.elewa.org/JAPS; *ISSN 2071-7024*

Evaluation of chemical and nutritional quality attributes of selected mango varieties at three stages of ripeness, grown in lower Eastern province of Kenya – part 2

Okoth E. M.[1]; Sila D.N [1]; Onyango C. A*[2]; Owino W.O[1]; Musyimi S.M[1], Mathooko F.M[3];
[1]*Department of Food Science and Technology of Jomo Kenyatta University of Agriculture and Technology, P. O. Box 62000-00200, NAIROBI- Kenya*
[2]*Taita Taveta University College, P. O. Box 635 – 80300, VOI, Kenya*
[3]*South Eastern Kenya University, P.O. Box 170-90200, KITUI, Kenya*
**Corresponding author e-mail: cakoth2002@yahoo.co.uk*
Key words: Mango varieties, ecological zones, chemical qualities, ripeness stages

1 SUMMARY

Mango fruits are widely grown in Kenya for domestic and export utilization. Selected chemical and nutritive quality attributes of Apple, *Ngowe* and Kent were evaluated at three stages of ripeness. The cultivars were obtained at the unripe stage from Lower Eastern Province (Kitui and Machakos) of Kenya. Total titratable acidity (TTA), vitamin C, and crude fiber decreased with ripeness, whereas total soluble solids (TSS), TSS/TTA, β-carotene, crude fat, crude protein, fructose, glucose, and sucrose increased with increasing ripeness. The Apple varieties showed superior quality attributes in terms of low TTA of 0.04%, higher TSS of ≥19.50 ºBrix at ripe stage. It registered the highest vitamin C content of 109.35mg/100g (FW) at the unripe stage, lowest moisture content of 79.96% and highest dry matter of 20.04% both at their ripe stages. It also recorded the highest crude fiber content (0.89%) at its unripe stage and had highest crude fat content (0.11%) at its ripe stage compared to other varieties at the same stages of ripeness. The Kent varieties scored lowest in TSS (6.50ºBrix), vitamin C content at all stages, moderately high moisture content and lowest dry matter at their intermediate stage, lowest crude protein at unripe stage, and lowest in fructose of 8.54 mg/ml. Kent variety from Kitui zone also scored poorly in TSS/TTA ratio of 16.67 and had the lowest content in β-carotene at their unripe stage. It had the highest moisture content of 86.32% and the least dry matter of 13.68%. This variety also had low content of crude protein at their unripe stage of 0.02%. *Ngowe* fruit from the two zones scored moderately at the three stages of ripeness on most of the attributes evaluated. The results indicated that Apple mango variety is the most promising for both fresh consumption and processing purposes as it scored highly in most of the chemical and nutritional quality attributes analyzed.

2 INTRODUCTION

Mango (*Mangifera indica L.*) is one of the most preferred, widely distributed, and broadly grown tropical fruit in the world. Mangoes are increasingly of commercial importance all over the world and assume a leading position in among fruits. Their flavor, attractive fragrance and high nutritional value has placed them in a popular position as a source of income to farmers, traders and countries at large, through their local and international markets (Rodriguez. *et al.,* 2012). They balance human diet by providing 64-86 calories of energy per 100g. When consumed regularly; mangoes are a rich source of phytochemical compounds and other nutritional compounds. Vitamin C ranges from 32 to 200mg/100g (Rathore *et al.,* 2007); it falls within the daily intake for both children and adult which ranges from 40-90mg of ages between o to 90 years (Food and Drug Association). The areas where mango is produced have increased over the last decade by about 42.5% as well as their consumption as both fresh fruits and processed products (Malik and Singh, 2006). The world production is estimated to be about 25.1% tones per year and continues to increase yearly (Rodriguez. *et al.,* 2012). Asia produces 76.9% of the total production, America 13.38%, Africa 9%, Europe, and oceanic countries less than 1% (Rathore *et al.,* 2007). In Kenya, mango annual production and earnings has been on the increase e.g. for Eastern province, between 2009 and 2011, it recorded an increase in production of 150,000 to 350,000 MT and earnings of USD 470,548,823, (HCDA/MOA, statistical data report, 2012). A wide range of mango varieties are grown in practically all provinces of the country Losses of between 40-50% are experienced along the mango value chain. Improper pre- and post- harvest handling of the fruits such as mechanical (bruises) damages, pests, diseases and immature harvested fruits, high temperatures are some of the challenges leading to the enormous losses and l this is compounded by minimal processing of locally produced mango varieties which is estimated to be less than 1% (FAO, 2006). There is little or no documented information on their quality characteristics, which could be utilized to compete favorably for export and local markets with the varieties from other parts of the world. This calls for quality profiling of the most commonly grown varieties to assess the possibility of expanding their technological (processing) and nutritional utilization locally and internationally. It will also provide information to farmers on the important varieties to increase in commercial production. Mango varieties differ in flavor, nutritional characteristics, and storage behavior. High market losses, inadequate information on postharvest physiology and biochemistry of cultivars are the main factors limiting international mango trade in developing countries (Isahtiaq *et al.*, 2010).

This study seeks to specifically evaluate selected mango varieties from identified ecological zone for chemical and nutritional quality characteristics at various stages of ripeness to ascertain their suitability for technological and nutritional utilization as fresh and/or processed products for local and export market.

3 MATERIALS AND METHODS

3.1 Mango varieties used in the study: Three mango varieties namely; Apple, *Ngowe,* and Kent (Plate 1) were harvested at similar maturity stage (mature green) from two different growing zones (Machakos and Kitui) of Lower Eastern Province of Kenya. Kitui ecological zone was found to be hotter and drier most of the year with temperatures ranging from 16 to 34ºC; the rainfall ranged from 500-760mm per year. The soils were found to be of loam type and the altitude ranged between 600-900m above sea levels (Mwingi district development plan 2002-2008; Kitui statistics). On the other hand, Kaiti division, Machakos zone was found to be a low land between several hills namely; Iuani, Mbooni, Kilungu, Makuli, and Nthangu. It was cooler (14-26ºC) than Kitui, with rainfall amounts ranging from 700-1050mm per year. The altitude ranged from 900 to 1100m above sea levels and the soils were found to be of sandy and clay in nature (Sombroek, *et al., 1982).* The harvested mango fruits were transported to Jomo Kenyatta University of Agriculture and Technology in the laboratories of Food Science and Technology. They were stored at ambient temperature of about 25ºC±2 and relative humidity of 65-70%, to simulate the uncontrolled storage conditions (temperature and relative humidity) experienced in most of the mango value chain situations. Stage of ripeness was objectively determined based on chemical parameters namely skin and flesh colour (H°), firmness, total soluble solids content (TSS), total titratable acidity (TTA), and pH.

3.2 Chemical Analyses

3.2.1 Proximate analysis: Moisture, fat, protein, ash and fibre contents of all fresh mango varieties at their three stages of maturity were evaluated. The moisture content was done using an air drying oven (Isuzu type, ASF-113S model, Japan) and expressed on wet basis. The fat content determined using Soxhlet method, protein using Kjeldahl method AOAC (1996); fibre and ash was done using standards methods described in AOAC (1996).

3.2.2 Sugar content: Quantification of specific sugars (fructose, glucose and sucrose) present in the entire mango samples under investigation were determined using High Performance Liquid Chromatography (HPLC) method as described in AOAC (1996). Ten grams of the fruit pulp was refluxed in ethanol for 1 hour. The extract was concentrated by rotary evaporation and diluted with 75% acetonitrile. The standard solutions and the sample extracts were injected into High Performance Liquid Chromatography (HPLC) Model LC-10AS, Shimandzu Corp., Kyoto, Japan) fitted with refractive index detector and having the following: oven 35°C, Flow rate : 0.8 ml/min, injection volume 20 uL, Column – NH2P-50 E. A standard curve was drawn using standard sugar solutions of fructose, glucose and sucrose and the amounts of the same present in the sample quantified.

3.2.3 Total Soluble Solid content: This was determined using an Atago hand refractometer (Model RX 5000, Atago, Tokyo, Japan). A drop of the homogenized mango pulp was placed at the prism of a hand refractometer, which had been calibrated, the lid closed and TSS read directly from the digital scale at 20°C±1 and results expressed in °Brix.

3.2.4 Total Titratable Acidity content: This was determined by titrating the sample with 0.1N sodium hydroxide in the presence of phenolphthalein indicator. T.T.A results were expressed as % citric, which is the main organic acid in mango fruit (Ueda et al., 2000).

3.2.5 β-carotene: Determination was done using a modified chromatographic procedure (Heionen, 1990). A sample of 20g of the pulp was homogenized. A spatula of hydroflorosupercel was added and extraction done using 50.0ml of acetone until the residue became white. Partitioning was done using 25.0ml of petroleum ether in a separating funnel. Saponification was carried out by adding an equal amount of extract in 3.0ml of 10% KOH in methanol and a few drops of 0.1% butylated hydroxytoluene in petroleum ether. The sample was kept in the dark for 16 hours followed by washing with water in a separating funnel until it became clear. Anhydrous sodium sulphate (Na_2SO_4) was added to remove water and further concentration done using a rotary evaporator. The HPLC (Model LC-10 AS, Shimandzu Corp., Kyoto, Japan), which had the following conditions was used: Mobile phase (acetonitrile: Methanol: Dichloromethane = 70:10:20), Flow rate – 1.0 ml/min, column – ODS 150, Injection volume – 10μL, Oven temperature-35°C. A standard curve made from –carotene standard was used to estimate the quantity of β-carotene content in the mango samples.

3.2.6 Ascorbic acid content: This was determined using the AOAC.967.21 (1996) method. Five grams of the pulped mango was diluted with 10% trichloroacetic acid (TCA) to 100.0ml mark of 100ml volumetric flask. 2, 6-dichlophenolindophenol was titrated to 10.0ml of the pulp filtrate. Ascorbic acid was calculated as:

Ascorbic acid, (mg/100g) = (A-B) X C X 100/s X (100/10)

Where A = Volume in ml of indophenol solution used in the sample.

B = Volume in ml of indophenol solution used for the blank

C = Mass in mg of ascorbic acid equivalent to 1 ml of standard indophenol solution.

S = weight of the sample taken (g)

100/10 = total extraction volume / volume of titrated sample

3.3 Statistical data analysis: All the data was statistically analyzed for variance (ANOVA) using Genstat computer, program14th Edition. The comparison for means, standard deviations at 5% level of significant were done using Duncan's Multiple Range Tests (DMRT) as described by Steel *et al.*, 1997.

4.0 RESULTS AND DISCUSSIONS

4.1. Proximate attributes: Data on percent moisture, ash, fat, protein and fibre attributes was obtained on analyzing three mango fruits at three ripeness stages. They were tabulated on table 1.

Table 1*:* Proximate quality attributes of Apple *Ngowe* and Kent mango varieties at three stages of ripeness

Variety	Ecological Zone	Ripeness stage	Moisture Content (%)	Crude Ash (%)	Crude Fat (%)	Crude Protein (%)	Crude Fibre (%)
Apple	Machakos	Unripe	82.77 ± 0.3^{j}	0.26 ± 0.07^{cde}	0.02 ± 0.01^{g}	0.04 ± 0.01^{efg}	0.89 ± 0.5^{a}
		Inter	80.39 ± 1.4^{n}	0.33 ± 0.03^{abc}	0.06 ± 0.01^{fg}	0.08 ± 0.01^{b}	0.63 ± 0.01^{d}
		Ripe	79.96 ± 0.04^{p}	0.24 ± 0.15^{def}	0.07 ± 0.01^{fg}	0.11 ± 0.01^{a}	0.26 ± 0.03^{h}
	Kitui	Unripe	81.19 ± 1.2^{m}	0.32 ± 0.05^{abcd}	0.17 ± 0.05^{d}	0.02 ± 0.01^{g}	0.91 ± 0.03^{a}
		Inter	84.15 ± 0.3^{h}	0.35 ± 0.02^{ab}	0.2 ± 0.05^{cd}	0.03 ± 0.01^{g}	0.68 ± 0.03^{c}
		Ripe	80.46 ± 1.0^{n}	0.26 ± 0.02^{cde}	0.25 ± 0.07^{bc}	0.08 ± 0.01^{b}	0.42 ± 0.04^{f}
Ngowe	Machakos	Unripe	81.25 ± 0.7^{l}	0.4 ± 0.03^{a}	0.03 ± 0.02^{g}	0.02 ± 0.01^{g}	0.45 ± 0.04^{f}
		Inter	84.59 ± 1.8^{f}	0.28 ± 0.01^{bcd}	0.15 ± 0.01^{de}	0.05 ± 0.01^{cde}	0.37 ± 0.04^{g}
		Ripe	83.17 ± 0.02^{i}	0.35 ± 0.04^{bcde}	0.41 ± 0.06^{a}	0.11 ± 0.01^{a}	0.16 ± 0.03^{i}
	Kitui	Unripe	81.77 ± 0.9^{k}	0.31 ± 0.07^{bcd}	0.09 ± 0.08^{ef}	0.02 ± 0.01^{g}	0.52 ± 0.01^{e}
		Inter	85.68 ± 0.1^{c}	0.27 ± 0.03^{cde}	0.16 ± 0.01^{d}	0.03 ± 0.01^{g}	0.44 ± 0.02^{f}
		Ripe	85.42 ± 0.01^{d}	0.25 ± 0.12^{cde}	0.36 ± 0.06^{b}	0.07 ± 0.01^{bc}	0.25 ± 0.03^{h}
Kent	Machakos	Unripe	85.38 ± 0.1^{d}	$0. 24\pm0.03^{def}$	0.19 ± 0.03^{cd}	0.02 ± 0.01^{g}	0.77 ± 0.05^{b}
		Inter	86.3 ± 0.01^{a}	0.19 ± 0.01^{ef}	0.25 ± 0.05^{bc}	0.06 ± 0.01^{cde}	0.64 ± 0.05^{d}
		Ripe	85.29 ± 0.03^{e}	0.16 ± 0.01^{f}	0.27 ± 0.03^{b}	0.08 ± 0.01^{b}	0.39 ± 0.03^{g}
	Kitui	Unripe	84.34 ± 0.2^{g}	0.3 ± 0.02^{bcd}	0.2 ± 0.04^{bc}	0.02 ± 0.01^{g}	0.62 ± 0.05^{d}
		Inter	86.32 ± 0.4^{a}	0.28 ± 0.07^{bcd}	0.36 ± 0.02^{a}	0.04 ± 0.01^{efg}	0.54 ± 0.06^{e}
		Ripe	85.83 ± 0.3^{b}	0.32 ± 0.01^{abcd}	0.37 ± 0.01^{a}	0.06 ± 0.01^{cde}	0.37 ± 0.03^{g}

Mean (±SD) sharing similar superscript letters in a column are insignificant at $P\leq0.05$; (n=5)
Inter: Intermediate stage of ripeness

4.1.1 Moisture content: The highest moisture content and lowest dry matter of 79.96% and 20.04% respectively was exhibited by Apple variety Machakos at their ripe stage while the highest moisture content and the lowest dry matter were 86.36% and 13.68 by the Kent variety from Kitui which was not statistically different from Kent variety, Machakos with 86.30% M.C and 13.75% dry matter. The results of Moisture content agreed with those obtained by Othman, *et al.,* 2009 who analyzed *Dodo and Virige* mango varieties grown in Morogoro, Tanzania found that they had a moisture content ranging from 56.3- 86.1%

4.1.2 Crude ash: It was found to have no defined pattern of behavior with increasing ripeness. *Ngowe* at the ripe stage gave the highest amounts of 0.40% whereas the least was obtained from *Ngowe* (0.16%) at their ripe stage. Ash % content gives a measure of the total amount of inorganic compounds like minerals present within the mango fruit. This is influenced by variables like soil composition and climate condition of the area of mango growth, the variety/ breed and level of farm management practices (tree and soil management especially fertilizers added during planting), thus the variability observed. Ash content of the three varieties was found to be lower than those obtained from fruits like oranges (0.68±0.06/100g, Mbogo *et al.,* 2010).

4.1.3 Crude fibre: It had a slight decreasing trend with ripening. The highest was 0.91% exhibited by Apple variety Machakos that was not statistically different from Apple variety, Kitui with 0.89%. The lowest was observed on *Ngowe* variety, Machakos of 0.16%. This compared well with *Dodo* and *Viringe* varieties at their ripe stage which had 0.85 and 0.87% (Othman, *et al.,* 2009) respectively, and decreased slightly with ripening. Fiber helps to maintain a healthy gastrointestinal tract, but in excess, it may bind trace elements leading to their deficiencies of iron and zinc in the body (Mbogo, *et al.,* 2010). The slight decrease in fibre could be attributed to a decrease in insoluble pectin associated with an increase in soluble pectin the course of ripening (Mathooko, 2000; Mamiro, *et al.,* 2007).

4.1.4 Crude fat: Occurred in small increasing amounts with increase in ripeness. The lowest fat content of 0.02% which was not statistically different at p≤0.5 from 0.03% exhibited by Apple variety, Machakos and *Ngowe* variety Machakos respectively. The highest content was 0.37% which was not statistically different at p≤0.5 from 0.36% both exhibited by the Kent variety, Kitui at their ripe and intermediate stages of maturity respectively. Crude fat in this context was found to be higher at the ripe stage than those obtained from *Dodo* and *Viringe, which* had 0.2% and 0.22% respectively.

4.1.5 Crude protein: It was found to range from 0.02% exhibited by various varieties namely; Apple variety Kitui, *Ngowe* variety Machakos, Kent varieties from Machakos and Kitui zones to 0.11% by Apple variety, Machakos. The results are in agreement with finding made by Gomez-Lim, 1997; Mamiro, *et al.,* 2007; Mathooko, 2000, who attributed it to dramatic increase in the enzymes required for ripening. The proximate composition of the mango varieties studied was within limits (Mamiro, *et al.,* 2007: Doryappa, *et al.,* 1994) and was mainly influenced by the variety and stage of maturity rather than ecological zone of origin.

4.2 Content of fruit sugars : Fructose, glucose and sucrose contents were analyzed and the results were presented as shown on Figure 1to 3.

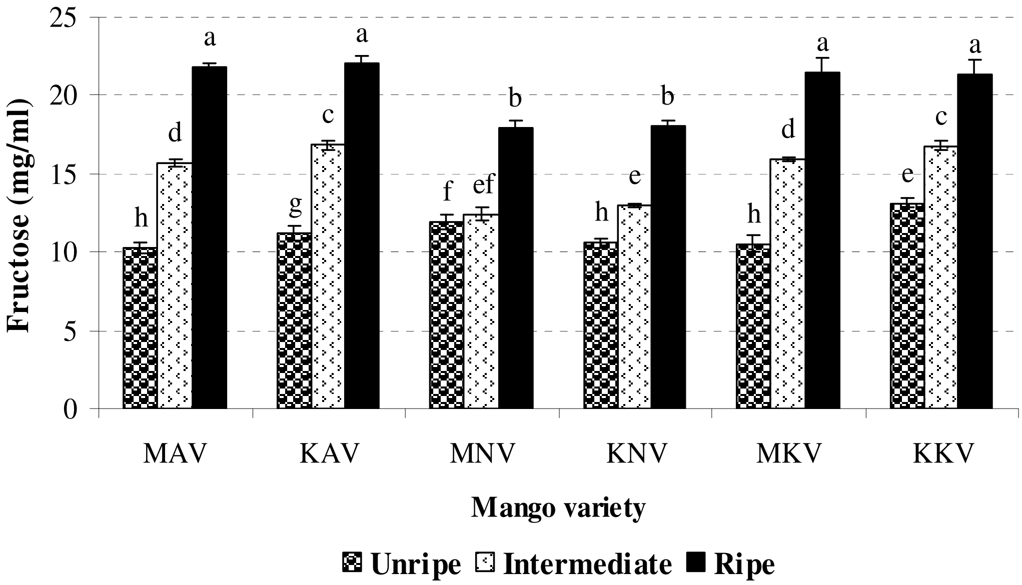

Figure 1: Fructose content in Apple, *Ngowe,* and Kent mango varieties at different stages of ripeness; MAV: Apple Variety Machakos, KAV: Apple Variety Kitui, MNV: Ngowe variety Machakos, KNV Ngowe variety Kitui, MKV: Kent Variety Machakos, KKV: Kent Variety Kitui.

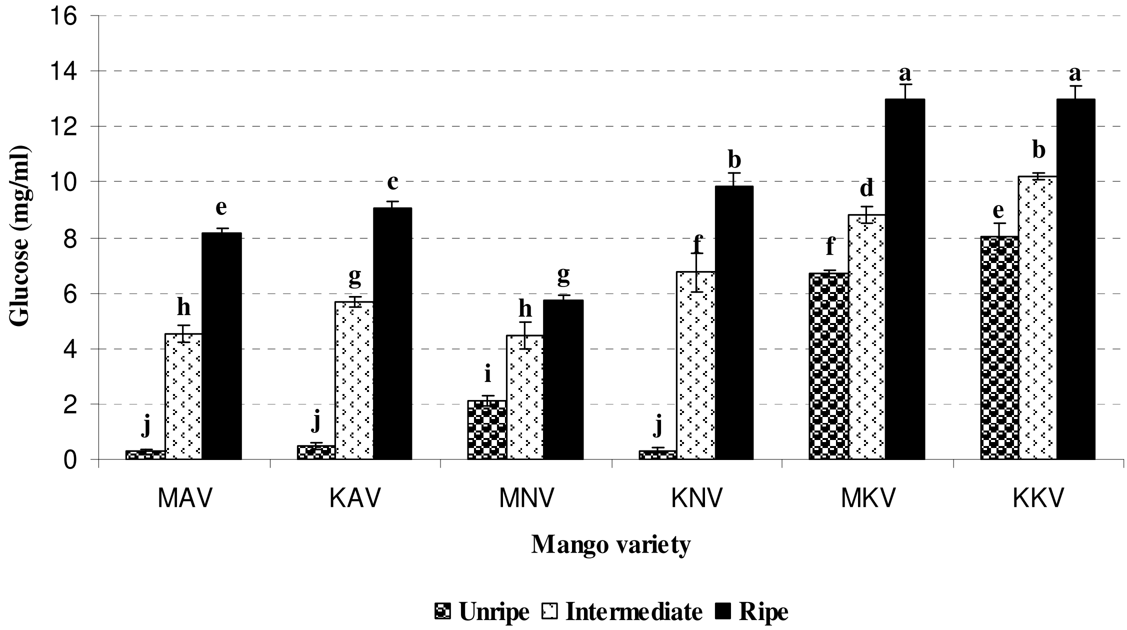

Figure 2: Glucose content in Apple, *Ngowe* and Kent mango varieties at different stages of ripeness; MAV: Apple variety Machakos, KAV: Apple variety Kitui, MNV: *Ngowe* variety Machakos; KNV *Ngowe* variety Kitui; MKV: Kent variety Machakos, KKV; Kent variety Kitui
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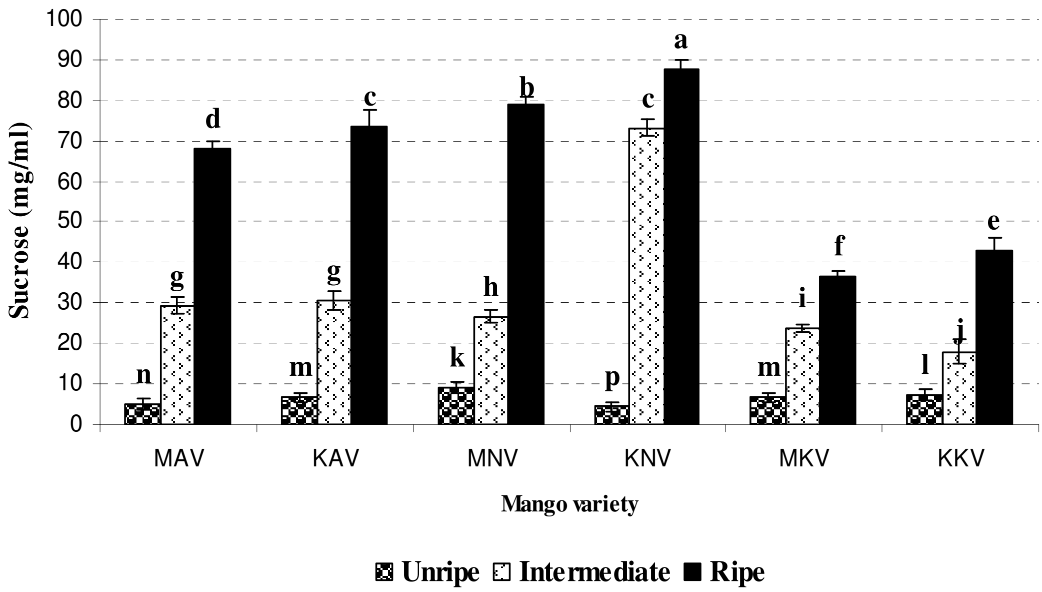

Figure 3: Sucrose content in Apple, *Ngowe* and Kent mango varieties at different stages of ripeness; MAV: Apple variety Machakos, KAV: Apple variety Kitui, MNV: *Ngowe* variety Machakos, KNV *Ngowe* variety Kitui, MKV: Kent variety Machakos, KKV; Kent variety Kitui.

It was observed that the three sugars had an increasing trend with ripening. Sucrose occurred most abundantly of the three followed by fructose then glucose.

4.2.1 Fructose: It ranged from 10.26mg/ml to as was exhibited by Apple variety from Machakos which was not statistically different from the *Ngowe* varieties from Kitui and Machakos zones at p≤0.05 at the unripe stage. The highest fructose content was recorded by the Apple and the Kent varieties at the ripe stage which were not statistically different from each other with a mean value of 21.57mg/ml.

4.2.2 Glucose: Portrayed the least occurrence of all, 0.28mg/ml by Apple variety, Machakos which was not statistically different from Apple and *Ngowe* varieties from Kitui at p≤0.05. The most abundant was recorded by Kent varieties at their ripe of ripeness with 13.02mg/ml, Machakos and 12.89mg/ml, Kitui zone which was not statistically different from each other at p≤0.05.

4.2.3 Sucrose: Increased from 4.36mg/ml to 87.73mg/ml in *Ngowe* variety, Kitui unripe and ripe respectively. The Kent varieties recorded the lowest values at the intermediate and ripe stage than the other varieties. Increase in the reducing sugars may be probably due to hydrolysis of starch and sucrose to simple sugars in the ripening processes.

The increase in fructose and glucose came from sucrose hydrolysis. The results were comparable with those obtained by Karnataka, *et al.,* 2010, on analyzing Sapota fruits at different stages of maturity found that simple and total sugars increased from mature green stage to fully ripe; Germain, *et al.,*2008 on analyzing four mango varieties (Amelioree, Keit, Mango and Palmer) grown in Cameroon at their pre-ripe and ripe stages of maturity. He found that the sucrose content increased significantly from pre-ripe to ripe for all the varieties, while glucose increased for three varieties (Amelioree, Keit, and Palmer) and decreased for one (Mango) variety. Ishtiaq *et al.,* 2010 observed that Faiz Kareem, Anwar Ratole and Chaunsa mango varieties had their non-reducing sugars increased from day one to the seventh day of ripening while the reducing sugars had a varying behavior of increase for the first three days, decreased slightly for the next two days and later increased slightly to the seventh day.

4.3 Selected chemical quality attributes :
Results on pH, total titratable acidity (TTA), total soluble solids (TSS) and sugar: acid (TSS/TTA) ratio chemical attributes were presented on table 2.

Table 2: Chemical quality attributes of Apple, Ngowe and Kent mango varieties at three stages of ripeness

Variety	Ecological zone	Stage of maturity	pH	TTA (%)	T.S.S (°Brix)	T.S.S/TA
Apple	Machakos	Unripe	3.00±0.05^{j}	0.21^{d}	7.01 ±0.20^{k}	33.38^{j}
		Inter	3.30±0.1^{g}	0.19^{e}	13.43±0.05^{e}	67.15^{i}
		Ripe	4.60±0.05^{a}	0.04^{i}	19.83±0.70^{a}	495.75^{a}
	Kitui	Unripe	3.10±0.1^{j}	0.24^{c}	7.03±0.30^{k}	29.29^{k}
		Inter	3.60±0.1^{d}	0.14^{f}	15.10±0.10^{c}	107.86^{f}
		Ripe	4.60±0.1^{a}	0.04^{i}	19.50±1.01^{a}	487.5^{a}
Ngowe	Machakos	Unripe	3.20±0.05^{hi}	0.27^{b}	7.30±0.50^{lk}	27.04^{l}
		Inter	3.70±0.05^{c}	0.14^{f}	15.06±0.05^{c}	107.57^{f}
		Ripe	4.60±0.05^{a}	0.08^{gh}	16.43±0.05^{b}	205.38^{c}
	Kitui	Unripe	3.30±0.2^{g}	0.30^{a}	8.00±1.0^{i}	26.67^{l}
		Inter	3.50±0.1^{e}	0.19^{e}	13.10±0.1^{e}	68.95^{h}
		Ripe	4.60±0.1^{a}	0.07^{h}	16.05±0.05^{b}	229.29^{b}
Kent	Machakos	Unripe	3.20±0.05^{ij}	0.13^{f}	6.50±0.50^{l}	50.00^{j}
		Inter	3.40±0.2^{f}	0.11^{g}	12.20±0.20^{f}	110.9^{e}
		Ripe	3.90±0.2^{b}	0.09^{gh}	14.06±0.05^{d}	156.22^{d}
	Kitui	Unripe	3.20±0.2^{hi}	0.15^{ef}	7.00±0.10^{k}	16.67^{m}
		Inter	3.40±0.1^{f}	0.11^{g}	11.33±0.50^{g}	103.00^{g}
		Ripe	4.00±0.2^{b}	0.09^{gh}	14.50±0.10^{d}	155.93^{d}

Mean (±SD) sharing similar superscript letters in a column are insignificant at P≤0.05; n=5;
Inter: Intermediate stage of ripeness

4.3.1 pH: It had a decreasing trend in all the varieties irrespective of the ecological zone of origin. The pH values of the unripe varieties varied from 3.00 to 3.30. The ripe varieties varied from 3.20 to 4.60. Kent varieties were most acid with Apple and *Ngowe* least acidic and not significantly different ($p \leq 0.5$) at their ripe stage. The results obtained were in agreement with those reported by Germain, *et al.,* 2008. pH in the fruit pulp plays an important role in flavor promotion as well as a preservation factor, Saeed *et al.*, 2010.

4.3.2 Total Titrable Acidity Content **(%):** It decreased with increasing ripeness. Percent TTA of unripe fruits ranged from 0.13 to 0.30%, whereas that of the ripe fruits ranged from 0.04 to 0.09%. TTA was observed to differ significantly ($p \leq 0.05$) at different ripeness stages for all the varieties. *Ngowe* and Kent varieties from the two zones had their TTA similar at the ripe stage at $p \leq 0.05$ significant level. Similar results were reported by Rodriquez *et al.,* 2012 who found that stage of maturity had a great influence on TTA content. Reduction in TTA could be due to degradation of citric acid due to increased activity of citric acid glyoxylase during ripening while reduction in acidity may be due to their conversion into sugars and their further utilization in metabolic processes like respiratory climacteric in the fruit. These results were in agreement with those obtained by Rathore, *et al.,* 2007; Doreyappa –Gowdaad Huddar, 2001.

4.3.3 Total soluble solids content (ºBrix): Apple varieties recorded the highest TSS of 19.83 and 19.50ºBrix Machakos and Kitui with respectively, there were statistically same at $p \leq 0.05$. The lowest was 6.50º Brix in Kent variety, Machakos. TSS has a strong implication on the choice of fruit for processing as well as fresh consumption, TSS of 15ºC Brix and above at ripe stage is recommendable for products like fruit juices, nectar and jam products. TSS of 16ºBrix and above is suitable for wine processing. Kent varieties had an average TSS of 14ºBrix, best for processing products of low sugar content and sour taste like mango chutney, mango powders, and canned mango bits that are preserved in cane sugar. The variability in total soluble solids of different varieties at different stages of maturity is attributed to the alteration occurring in structure during ripening processes at various hydrolytic processes enzymatic instigated breakdown complex carbohydrates to smaller ones like sucrose, glucose and fructose (Saeed, *et al.,* 2009; Rathore, *et al.,* 2007). Similar pattern in total solid change was also observed in Alphonso variety by (Key, 1991, Kitur *et al.*, Doreyappa – Gowdaad Huddar, 2001).

4.3.4 TSS/TTA ratio: This gives information on sugar/ acid ratio balance in the fruit. It increased with increase in ripeness. The lowest was exhibited by the Ngowe variety from both zones with a mean value of 26.87 and the highest was >485 by the Apple varieties at the ripe stage of ripeness. Fruits high in this ratio of up to 200 are said to be of high quality due to sweat taste of well balance sugar and acid whereas those with below 100 are of low quality due to a higher sour taste high (acid ratio), (Hafar Hajilou, *et al.,* 2011). The sugar: acid ratio was found to be greatly influenced by the fruit variety and stage of ripeness.

4.4 β-carotene: the results obtained for β – carotenes are as shown on Figure 4.

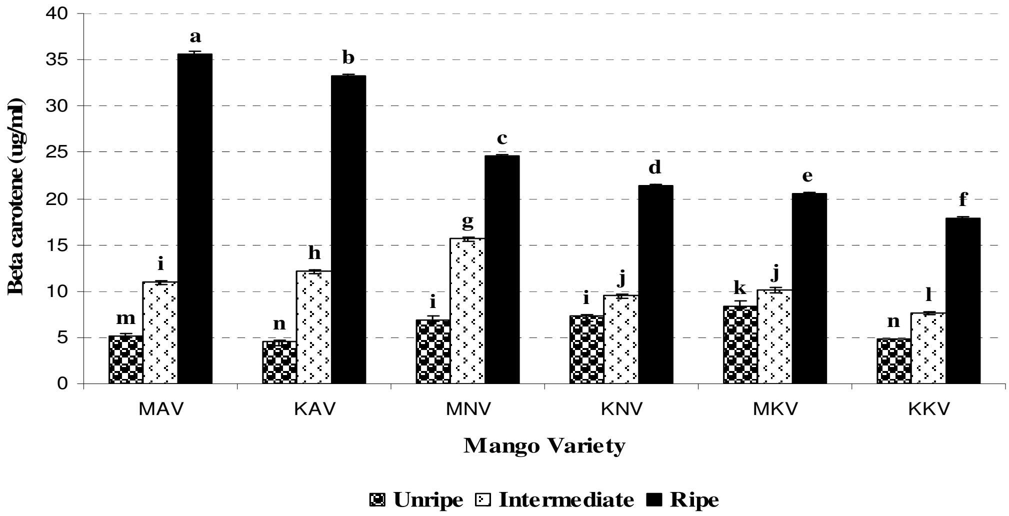

Figure 4: β-carotene content in Apple, Ngowe and Kent mango varieties at different stages of ripeness. MAV: Apple Variety Machakos, KAV: Apple Variety Kitui, MNV: Ngowe variety Machakos, KNV Ngowe variety Kitui, MKV: Kent Variety Machakos, KKV: Kent Variety Kitui.

β-carotene showed an increasing trend with increasing ripeness. It ranged from 4.61μg/g in Apple variety, Kitui at their unripe stage to 35.27μg/g Apple, variety Machakos that was not statistically different from 34.96μg/g in Apple variety, Kitui zone at their ripe stage of ripeness. Variety and stage of ripeness had a strong influence on β – carotene content. These results were in agreement with those obtained by Rodriguez-Amaya, *et al.,* 1998, who observed that β - carotene increased with ripening. Keitt and Tommy Atkins varieties changed from 12.3 to 38.0μg/g and from 17.0 to 51.2μg/g from the mature-green to the ripe stage respectively. High amounts of β – carotene in mango fruits at their ripe stage is an indication of a high nutritive value due to its antioxidant property and as a precursor of vitamin A, thus beneficial to the consumers.

4.5 Vitamin C: It was analyzed from the three mango varieties at three stages of ripeness and results presented on Figure 5.

Journal of Animal &Plant Sciences, 2013. Vol.17, Issue 3: 2619-2630
Publication date 29/4/2013, http://www.m.elewa.org/JAPS; ISSN 2071-7024

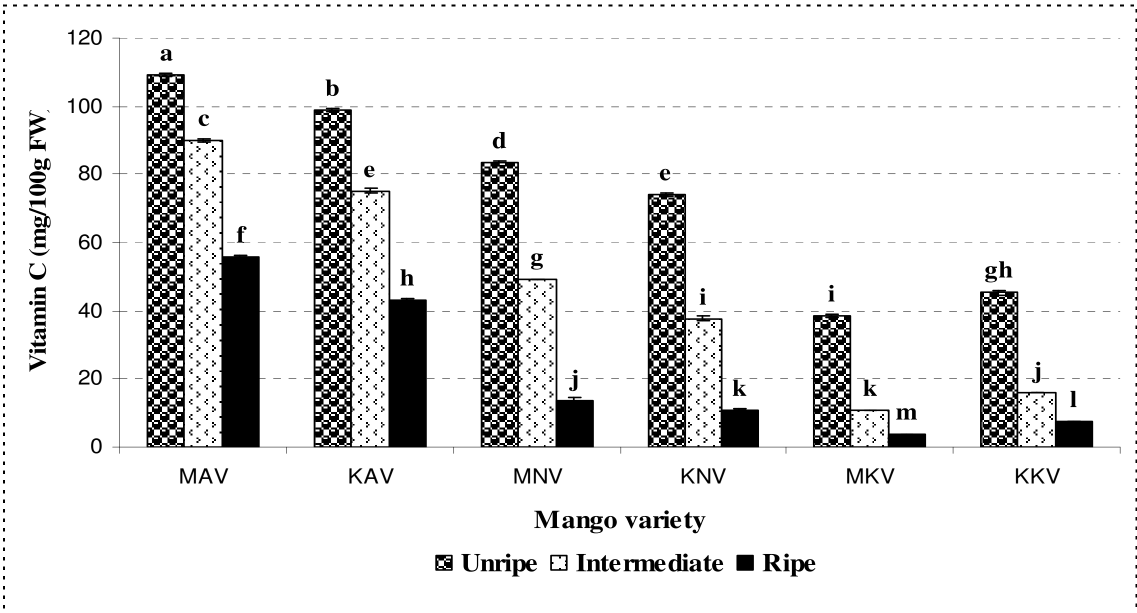

Figure 5: Vitamin C content in Apple, *Ngowe,* and Kent mango varieties at different stages of ripeness MAV: Apple Variety Machakos, KAV: Apple Variety Kitui, MKV: Kent Variety Machakos,KKV: Kent Variety Kitui.

Regarding vitamin C, Apple varieties recorded higher levels at their three levels of maturity compared to other two varieties. The highest being Apple variety from Machakos with 109.35 mg/100g (FW) followed by Apple Kitui with 99.07mg/100g (FW) at their unripe stage. This data compared well with data that was obtained by Ishtiaq, *et al.,* (2010), from Pakistan analyzed three varieties (Faiz Kareem, Anwar Ratole and Chaunsa), which were ripened for even days at ambient temperature 28±2°C. The superior varieties with vitamin C at the intermediate stages were the Apple from Machakos and Kitui and the *Ngowe* from Machakos. Tommy Atkins registered the lowest content in vitamin C at the three stages of ripeness. Ascorbic acid is highly susceptible to oxidative destruction at ambient temperatures Ishtiaq *et al.,* (2010) as well as freezing temperatures; this could have contributed to the decreased trend in vitamin C with ripening and storage. Vitamin C is a precursor component in nutrition. It helps the body develop resistance against infectious agents and it is an excellent anti oxidant against cancerous agents. Vitamin C is an essential component in human diet required for prevention of scurvy, presents biological functions in collagen formation, inorganic iron absorption, inhibition of nitrosamine formation and immune system enhancement. It acts as an antioxidant protecting the body against oxidative stress related diseases (Padayatty *et al.,* 2003).

CONCLUSION

Based on mango variety characterization, Apple and *Ngowe* varieties were most suitable for the manufacture of high viscous and sweeter mango products like puree, wine, mango juice, nectar, and jam products. This is because they had the highest >16 °Brix at their ripe stages. They also registered higher TSS/TA ratio. Kent varieties on the other hand had lower TSS contents of up to 14.50 °Brix as well as lower TSS/TA ratio and would require addition of sugar from external sources to attain same mentioned products as Apple and Ngowe. Kent was best suitable for utilization in making of chutney and mango chips in sugar syrup due to its low TSS as mentioned and a relatively higher titratable acidity at their ripe stages of 0.90 compared to that of Apple and Ngowe varieties which were 0.04 and 0.07 respectively. At the ripe stage, the three varieties would be best utilized for fresh consumption due to their TSS of above 12°Brix and TSS/TA ratio of above 100 which gives the best sensory thresh hold as earlier discussed.

ACKNOWLEDGEMENT

We are grateful to the Horticultural Crop Development Authority (HCDA) and The Ministry of Agriculture for their collaboration and facilitation of mango sample collection, the Department of Food Science and Technology, JKUAT for allowing us to carry out all the analytical work in their laboratories and lastly to Jomo Kenyatta University and Technology (JKUAT) and National Council of Science and Technology (NCST) for funding the research work

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