EVALUATION OF MATURITY INDICES OF SELECTED MANGO VARIETIES AND EFFECT ON QUALITY ATTRIBUTES

By

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DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other university.

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DEDICATION

I dedicate this work to my children Andrew, Philip and Elizabeth for their endurance during the entire study period.

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ABBREVIATIONS AND ACRONYMS

AEZs	Agro-Ecological Zones
ANOVA	Analysis of Variance
Ca	Calcium
DAFB	Days after Full Bloom
FAO	Food Agricultural Organization
Fe	Iron
GC	Gas Chromatograph
GDP	Gross Domestic Product
HCDA	Horticultural Crops Development Authority
HLPE	High Level Panel of Experts
HPLC	High Performance Liquid Chromatograph
K	Potassium
KALRO	Kenya Agricultural Livestock and Research Organisation
LSD	Least Significance Difference
Mg	Magnesium
MOA	Ministry of Agriculture
MT	Metric Tons
Na	Sodium
RH	Relative Humidity
TSS	Total soluble solids
TTA	Total Titratable Acidity
SSC	Soluble Solids Contents

ABSTRACT

Mango is one of the most cultivated fruits in Kenya for export and domestic markets. One of the major challenges facing mango producers in Kenya is lack of knowledge of the right harvest maturity for the different markets or uses. Maturity at harvest determines not only the postharvest longevity but also the fruit's nutritional and sensory quality. The present study's objective was to establish maturity indices, quality attributes during the ripening process and the effect of harvest maturity on processed products of 3 commercial mango varieties; 'Tommy Atkins',' Van dyke' and 'Kent'. It was conducted in Embu County, between August 2014 and March 2016. A total of 54 mango trees of varieties 'Tommy Atkins',' Van dyke' and 'Kent', of similar vigor and aged at least 8 years were randomly tagged at 50% flowering in 3 small scale farms. The number of days from 50% flowering to physiological maturity (based on flesh color) was established for each variety as stage 1 from which stages 2, 3 and 4 were established**.** For each maturity stage, the initial physical (size, specific gravity, peel/flesh firmness and peel/flesh color); physiological (ethylene evolution and respiration rates) and biochemical maturity indices were determined. Additionally, nutritional quality attributes of the fruits including Vitamin C, β-carotene, major sugars (sucrose, fructose and glucose) and mineral nutrients (potassium, calcium, magnesium, sodium and iron) were determined for each maturity stage. A random sample of five fruits was also taken from the pool every 3 days to determine the shelf life and nutritional quality changes during storage until a predetermined end stage. At the end stage, the fruits were diced and subjected to sensory evaluation by 34 untrained panellists. Mango fruits harvested at stages 3 and 4 from each variety were solar dried in a small scale green house and analysed for changes in nutritional qualities and physical properties. Data collected was analyzed using Genstat statistical package 13th edition. Means were separated using Fisher's protected Least Significance Difference (LSD) at $P \leq 0.05$. The sensory evaluation data was analyzed using Statistical Package for the Social Sciences (SPSS). The results showed that maturity indices evaluated and ripening related changes were all significantly ($p \leq 0.05$) affected by maturity stage and variety. The 3 varieties attained a comparative physiological maturity (stage 1) at different times, 97, 100 and 114 days after flowering for 'Tommy Atkins', 'Van dyke' and 'Kent' respectively. The physical parameters including size, firmness and color varied significantly ($p \leq 0.05$) with the stage of maturity and variety. Ethylene evolution and respiration rate increased with maturity stages and were significantly different ($p \leq 0.05$) among the varieties. ‘Kent’ had the lowest ethylene levels and respiration rate compared to Van dyke and Tommy atkins varieties.

Total soluble solids increased from 7.19^{0}Brix (stage 1) to 13.93 ^{0}Brix (stage 4) while total titratable acidity decreased from 0.2817 % citric acid equivalent (stage 1) to 0.132 % citric acid (stage 4) depending with the variety. The highest TSS levels were recorded in ‘Kent’ rising from 7.847 ^{0}Brix at stage 1 to 13.93^{0}Brix at stage 4. Higher TTA levels were recorded in ‘Van dyke’ compared to ‘Tommy Atkins’ and ‘Kent’.

Vitamin C, potassium, magnesium, calcium, iron and sodium reduced significantly with advancing maturity and ripening. At the end of ripening period, Van dyke variety had the highest ascorbic acid content of 51.82 mg/100g at maturity stage 1 while Kent variety had the highest potassium contents of 195mg/100g and 119 mg/100g during early and advanced maturities. Beta carotene and the sugars (fructose, sucrose and glucose) increased significantly ($p \leq 0.05$) with ripening. At maturity stage 4, Kent variety had the highest β-carotene contents of 13.354 mg/100g at the end of ripening period. Tree ripe stage scored highest for all the sensory attributes in all the varieties compared to maturity stages 3 and 4 while ‘Van dyke’ variety received highest scores for all sensory attributes except succulence at maturity stages 3 and 4. The color (hue angle) of the mango juice and the solar dried slices was significantly different ($p \leq 0.05$) within the stages. Moisture content was significantly ($p \leq 0.05$) affected by maturity stage and the varietal differences. The results show that maturity indices of mango fruits vary across varieties and that harvest maturity has an effect on the shelf life, nutritional quality and physical properties of the fresh fruits and processed products.

Key words: Mango, Maturity indices, maturity stages, ripening quality changes, quality of processed products

CHAPTER ONE

1 INTRODUCTION

1.1 BACKGROUND INFORMATION

Agriculture is one of the main economic activities in Kenya and contributes 30% of the Gross Domestic Product (HCDA, 2014). It is the second most important foreign exchange earner after tourism (HCDA, 2013) and contributes 60% of the export earnings to the country (MOA, 2008). Agriculture is essential in reducing poverty and hunger especially to the extreme poor in the society (FAO, 2012).

Horticulture has over the years established itself as a major sub-sector within agricultural sector. Within the agricultural sector, the leading subsectors are Dairy, Tea and Horticulture in that order (Economic Survey, 2014). The horticulture sub-sector is an important source of income generation, government revenue, foreign exchange earnings and employment; for farmers, traders and investors (FAO, 2014). Due to its vast diversity, horticulture facilitates diversification in agriculture.

Horticultural commodities covered an area of 23.7 million hectares as at 2014 registering an increase of about 17.3% compared to 20.2 million hectares in 2008. However, with a production of about 268.8 million MT, horticulture production has witnessed an increase of about 24% during the period 2007 to 2013. The significant feature is that there has been improvement of productivity of horticultural crops, which increased by about 7.2% between 2007 and 2013 (HCDA, 2013). The domestic value of horticulture production in 2014 amounted to Ksh.201.3 Billion as compared to 186.9 Billion in 2013. Cultivated area increased by 15 percent from 596,574 Ha to 684,912 Ha with a total production of 8.4 MT in 2014 compared to 7.3 MT in 2013. This was an increase of 16 percent (HCDA, 2014).

Among horticultural crops produced in Kenya, fruits constitute a significant proportion. In 2014, fruits contributed Ksh60.84 billion accounting for 30.3 percent of the domestic value of horticultural produce (HCDA, 2014). In 2012, the area under fruits was 148,295 hectares while in 2013, it was 159,666 hectares (HCDA, 2013). In 2014, 280,192 Ha were under fruit production yielding 43.3 million tons of mangoes (HCDA, 2014). There was an increase in production from 2.4 million metric tonnes to 2.7 million tonnes in 2012 and 2013 respectively

(HCDA, 2013). The area, production and value increased by 30 percent, 31 percent and 21 percent respectively during the year 2014 (HCDA, 2014). The increase in area and quantity was positive for most fruits due to rehabilitation of irrigation schemes which has extended irrigation to fruit crops. The major fruits grown in Kenya in order of importance are; banana (35.6%), pineapples (20%), mango (17%), avocado (6%), paw paw (6%), passion fruit (4%) oranges (3%), water melon (3%) and tangerins (2%) (HCDA, 2014).

Mango is a major fruit in the horticulture industry. As an export crop, mango earns the country foreign exchange while at the same time acts as a source of food and household income for resource poor farmers (HCDA, 2013). Kenya Agricultural and Livestock Research Organisation (KALRO, 2013) have for the last 20 years introduced commercial mango varieties which are high yielding. These varieties include Tommy Atkins, Kensington, Van dyke, Haden, Kent and Apple. The mango production in Kenya is wide spread due to high adaptability of the crop in different agro-ecological zones (AEZs) ranging from sub-humid to semi-arid climates and is dominated by small-scale farmers who constitute about 80 % of the production. Mango fruits produced in Kenya are mainly for the domestic market for fresh consumption and processing. United Arab Emirates constitutes 53%, Tanzania 20%, Saudi Arabia 22% and Bahrain 2% of the less than 1% fruits which are exported (HCDA, 2010).

The potential of most fruits remain unexploited due to various challenges from production to consumption. Overall, the mango supply chain has great potential for growth and expansion that remains largely unexploited. The development of the mango supply chain has been hampered by constraints at various stages along the supply chain. The key stages include; the farm level, the marketing stage, the processing stage and the export stage (MOA, 2010).

The major challenges that farmers face include: low quality planting materials, low yielding seedlings; lack of technological knowhow; inadequate use of fertilizers and pesticides, poor crop management practice, oversupply at harvest time leading to high post harvest losses and low prices (FAO, 2003). Constraints at the marketing stage are poor infrastructure, inadequate market information and lack of finance to support their operations (MOA, 2010). At this stage, lack of proper knowledge on the right harvest maturity causes the farmers to harvest immature or over mature fruits depending on the target market (Yahia, 2011). This leads to rejections at the market due to poor quality of mangoes. For example immature fruits ripen non uniformly, with faded skin color or internal breakdown for over mature fruits (Lee, 2000) results in rejections.

At the processing stage, there are limited plants hence the high quantity of mangoes supplied goes to disposal sites. As a result, the producers incur high losses from the farm to the processors since they may end up selling them at low prices due to their perishability (HLPE, 2014). In Kenya, only 7% of the mangoes are processed (Marc-Peter, 2015). Main challenges include high competition of mango puree and low local demand for dried mangoes and other processed products. Constraints at the exports stage include rejections due to wrong choice of varieties for consignments and sea services, insufficient post harvest handling equipments, and high transport costs (MOA, 2010). Most farmers also lack access to information on the requirements and conditions required to prolong shelf life of the fruits during air or sea transport..

Huge losses of 40% - 50% realized at post harvest stage of the mango value chain are as a result of poor harvesting, handling and storage techniques (KARI, 2010). Lack of proper knowledge on fruit maturity is considered to be one of the major problems contributing to post harvest losses in mango (Gitonga *et al*., 2010).

The major challenge is to establish the correct stage of maturity which the fruit is ready for harvesting (Griesbach, 2003). Subjective methods which are used to verify maturity in mango include fullness of the cheek, color, peel gloss and development of shoulder (Kosiyachinda *et al*., 1984). Through use of subjective indices most mango farmers face the challenge of determining the right maturity stage for the various markets (Yahia, 2000). Other indices used include computational, physical, physiological and biochemical methods. Computational methods include calendar date, days after full bloom (DAFB) to acceptable maturity, mean heat units and T- stage (point at which the angle formed by fruit receptacle and pedicel reaches 90^o). DAFB provides a better maturity index compared to other computational methods, provided the days has been obtained from the location at which will be used as a guide (Sudheer, 2002). Physical methods used include peel/flesh color, peel/flesh firmness, specific gravity and size. As mango fruit matures, it becomes heavier due to accumulation of solid contents during fruit development. Specific gravity generally ranges from 0.97 to 1.04 and can be used as maturity index (Yahia, 1998). Physiological methods used include respiration and ethylene evolution rates. The rate of respiration increases gradually as the fruits advance in maturity. The change in respiratory activity follows a distinct pattern and is dependent on the variety and production conditions (Ouma, 2015). Climacteric fruits such as mango show a remarkable increment in respiration rate as they mature (Vijay *et al.*, 2011). Additionally, as climacteric fruits mature, perceptible amount of ethylene is produced and this leads to more ethylene production and sequent ripening and senescence process. Maturity in mango can as well be established using biochemical indices which include soluble solids and titratable acidity. During fruit maturation, soluble solids (TSS) generally increase while total titratable acidity (TTA) decreases (Khairul *et a*l., 2013)

Farmers often use visual assessment such as size, peel color, peel gloss, shoulder elevation and fullness of cheeks to determine harvest maturity in mango. These indices may not be accurate in establishing the maturity of different varieties as they may differ in their peel color (Lizada, 1993), shoulder development and size (Wang *et al*., 1990). This may lead to harvest of immature fruits which can be easily bruised and of low quality when they ready to eat (Medlicott *et al*., 1988**).** Immature fruits are more venerable to disorders such as injuries (Ledger, 1995). On the other hand over mature fruits are highly susceptible to mechanical damage resulting in quality deterioration (Brecht, 2010).

1.2 PROBLEM STATEMENT

Fruit maturity at harvest affects mango quality attributes and the post harvest shelf life. Fruits harvested prematurely especially those targeting far-flung markets, fail to attain optimal sensory attributes which affects consumer acceptance. Although fruits harvested at later maturity stages attain better sensory attributes, their shelf life is very short because they are highly susceptible to mechanical damage and hence the quality (Yahia, 2011). Additionally, over matured fruit show defects like jelly seeds or jelly pulp after harvest (Kader, 2008).

Harvest maturity not only affects mango fruit longevity and the quality of fresh fruits but also processed products (HLPE 2014). The quality and consistency of processed products such as juices, pulps, jams and dehydrated or dried products is affected by quality of fruits which is in turn affected by harvest maturity amongst other factors. As the fruits changes from mature green stage to tree ripe stage, and during storage, various physical and physiological changes occur and this may affect the quality of both fresh and processed mango products (Brecht *et.al*, 2009).

Farmers often use subjective maturity indices based on visual judgement of size, peel and flesh colour, peel gloss, shoulder elevation, receding 'nose', fullness of 'cheeks'. For example in a previous study, most of the farmers (49.4%) knew that their mangoes were ready for harvesting by feeling with their hands; 41.6% picked the big ones and only 5.2% considered the mango shoulders as an index of maturity (Gitonga *et al.*,2010). Maturity determination based on visual observation is unreliable and also prone to errors because the subjective indices are affected by factors such as production location, variety and cultural practices (Salengke *et al*., 2013)

1.3 JUSTIFICATION

Harvesting at the right maturity stage is critical for all mango value chain actors to ensure high quality of fresh fruits and processed mango products which is critical for market access and consumer acceptance. For the farmers, knowledge of maturity indices will guide them to harvest at the right stage for the target market and/or use, thereby minimizing rejections at the market stage. Sorting based on maturity stage for traders is necessary to improve uniformity of ripening fruits at destination. Knowledge of the stage of maturity is also important for designing the optimal postharvest handling strategies, as fruits at different maturity stages respond differently to post harvest handling (Reid, 2002, Slaughter, 2009). On the other hand, the final consumers are enticing for health benefits from fruits (Ornelas-Paz *et al*., 2007) and different maturity stages and varieties have different levels of important nutrients in mangoes and also during the ripening process.

1.4 OBJECTIVES

1.4.1 Overall objective:

To establish maturity indices for selected mango varieties produced in a medium altitude agro-ecological zone of Kenya and the effect of harvest maturity on the quality of fresh and processed mango products.

1.4.2 Specific objectives:

1. To determine the maturity indices of ‘Van dyke’, ‘Kent’ and ‘Tommy Atkins’ mango varieties produced in Embu County, a medium altitude and high potential agro-ecological zone

2. To determine the effect of harvest maturity on the shelf life and the quality attributes of fresh and dried products of ‘Van dyke’, ‘Kent’ and ‘Tommy Atkins’ mango varieties

1.5 HYPOTHESIS

1. Maturity indices for ‘Tommy Atkins’, ‘Kent’ and ‘Vandyke’ mango varieties are not significantly different for the different harvest stages.

2. The shelf life and quality attributes of fresh fruits and processed products of the mango fruits (‘Tommy Atkins’, ‘Kent’ and ‘Vandyke’) are not significantly affected by harvest maturity stages.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 BOTANY

Mango is a juicy stone fruit belonging to the genus *Mangifera*. It was first found in the foothills of the Himalayas in North Eastern India and domesticated in South and Southeast Asia (Mukherjee and Litz, 2009). Two broad mango cultivars are recognized; Indian and Indian-Chinese. Indian Chinese types have polyembryonic seeds and are usually green to light green to yellow at maturity while Indian types have monoembryonic seeds and are usually more colored (Crane *et al*, 1997). Mangoes are now grown in most tropical countries and some subtropical ones

Mango trees may grow to 45m in height with a broad canopy of around 38m in width, and is normally oval in shape (Jules, 2008). The tree is firmly fixed by a long taproot to a depth of 6-8 m and feeder roots. Immature leaves are reddish-brown and soft while mature leaves are green, simple, aspirally arranged, lanceolate to oblong. Flowers are borne on green, yellow or pinkish coloured large terminal or axillary panicles upto 60cm in length. Each panicle may possess 300-6000 individual flowers (Lyer *et al*., 1997). Pollination of mango flowers is mainly by bees and sometimes fruit setting may occur due to pollination by wind (Jules, 2008).

Mango fruit is irregularly shaped and can be 8-30 cm in length. It is attached on a pendulous stalk at the fullest end. The fruit has a smooth, green - yellow skin color and yellow orange flesh but this depends with maturity stage and the variety of the fruits. Depending with the variety, the flesh may be juicy, fiber- free or with fiber (Mukherjee et al., 2009). Depending with the variety, mango fruit may take 3 to 4 months from fruit setting to maturity (Kader, 2003).

2.2 MANGO VARIETIES

Several mango varieties are grown in Kenya and they include; ‘Van Dyke’, ‘Kent’, ‘Tommy Atkins’, ‘Sensation’, ‘Dodo’, ‘Ngowe’, ‘Apple’, Gesine’, ‘Haden’, ‘Sabre’, ‘Boribo’, ‘Pafin’, ‘Maya’, ‘Batawi’, ‘Kenstone’ and ‘Sabine’ The local varieties are ‘Boribo’, ‘Dodo’, ‘Batawi’ and ‘Ngowe’ (HCDA, 2009). Kenya Agricultural Livestock and Research Organization (KALRO) brought mango varieties from the United States which include ‘Sensation’, ‘Van

Dyke', 'Kent','.Haden' and 'Tommy Atkins'which yield between 1,000 to 1,200 fruits per tree and this was meant to increase mango yields for farmers (KALRO, 2013).

2.2.1 Van dyke

The origin of this cultivar is Florida during the 1960s. It is among the seedlings that are distinguished by a superior resistance to anthracnose, very eye -catching color and longer shelf life and hence easily transported. The fruit has a thick skin with several yellow lenticels. The flesh has an orange yellow color with a pleasing aroma. The seed is mono- embryonic and constitutes about 7% of fruit weight while the trees have a large open canopy and are regular producers (ICRAF, 2003).

2.2.2 Tommy atkins

Tommy atkins variety tree is reported to have grown from a 'Haden' seed which was planted around 1922 on the land of Thomas H. Atkins in Florida (Campbell, 1992). The tree is large and the canopy is round. It has high and consistent production and is highly resistant to anthracnose, powdery mildew but prone to internal breakdown (Griesbach, 2003). The fruits have a tough and thick skin which are orange to yellow in color. The fruits' flesh is yellow to intense yellow in color, and is also firm and juicy and a strong pleasant aroma. The seed of the fruit is mono-embryonic and is covered in a thick, woody stone (Morton, 1987).

2.2.3 Kent

Kent cultivar originated in Miami, Florida in 1940s. The tree is large and vigorous, and has an erect and dense canopy. The fruits are large in size and weigh around 540g. It has a green yellow, thick and tough skin with several yellow lenticels. The flesh has an intense yellow color which has no fibre. The seed is mono-embryonic and is fixed in a thick, woody stone (ICRAF, 2003).

2.2.4 Ngowe

Ngowe mango originated from Zanzibar and was cultivated in Lamu approximately 110 years ago. The trees are small and round in shape. The quality of the fruit may be good or excellent and can be easily transported, however, they are vulnerable to powdery mildew and tend have alternate bearing (Griesbach, 2003). The color of the skin develops from green to yellow to orange as it ripens. The flesh color is an intense yellow with very little fibre while the seeds are polyembryonic.

Figure 2.1. ‘Tommy atkins’, ‘Kent’, ‘Van dyke’ and ‘Ngowe’ mango varieties respectively

2.3 MANGO NUTRITIONAL QUALITY

Mango fruit contains almost all the known vitamins; it is an excellent source of pro-vitamin A, necessary for sustenance of a health skin. Consumption of fruits rich in carotenes is known to protect the body from lung and oral cavity cancers. There are different phytochemicals classes found in mango fruit such as carotenoids, ascorbic acid and polyphenols (Talcott *et al*., 2005). Mango flesh contains, gallic acid, mangiferin, kaempferol, acid, m-coumaric acid among others (Schieber *et al*, 2003). Different varieties contain different levels of nutrients. Kent and Tommy Atkins varieties were reported to contain lower β-carotene content than Haden and Ataulfo mangoes (Ornelas-Paz *et al*., 2007). Potassium, helps to control blood pressure and heart beating rate and is high in fresh mangoes, that is, 100g of fruit constitutes about 156mg of Potassium (Mervyn, 2000).

Mangoes contain 27.7mg/100g of fruit or 46% of recommended daily levels of vitamin C and consumption of foods rich in ascorbic acid helps the body build up resistance harmful and communicable agents. Mango fruits contain 0.134mg/100g of fruit or 10% of recommended daily levels of Vitamin B6 which is required for Gamma-Aminobutyric acid hormone which is produced within the brain (USDA, 2006). Moreover, mangoes contain copper which is 0.110mg/100g of fruit. Copper is essential in the production of red blood cells. The peel of mango is rich in phytonutrients, like carotenoids and polyphenols. Mangoes are also a fairly good source of thiamine, niacin, calcium and iron (Mervyn, 2000).

2.4 MANGO PRODUCTION STATISTICS

2.4.1 Global productions statistics

Most tropical and subtropical countries have weather condusive for growing mangoes. These countries include India, Pakistan, Mexico and China. About 77% of global mango are produced in Asia while Americas and Africa about 13% and 9%, respectively (FAOSTAT, 2007). India is the main mango growing country contributing approximately 47% and 40%of the worlds' area and production respectively (MOA, India 2013). In 2014, India was leading in mango production volume globally with 16,462,000 tonnes followed by China 4,400,000 tonnes, Thailand 2,973,706.67 tonnes, Indonesia 2,188,695 tonnes and Mexico 1,829,924 tonnes (FAOSTAT, 2015). During the same year, (2014) Mexico was leading in world mango exporters with 10.30%, followed by Phillipines 7.80%, Pakistan 7.60%, Brazil 6% and India 5.20% (FAOSTAT, 2015).

Other major exporters included the Netherlands, Peru, Guatemala, France and Haiti. In terms of value, Mexico was leading in 2014 with 13.5% (279.3 million US dollar). It was followed by Netherlands 12.2% (253.9 million US dollar), Thailand 9.6% (199.3 million US dollar), India 9.4% (196.1 million US dollar), and Brazil 7.9% (164.2 million US dollar). Other countries with highest values included Peru, Phillipines, Spain, Pakistan and Cote d'Ivoire (FAOSTAT, 2015).

2.4.2 Kenya production statistics

Different mango cultivars are grown in Kenya. The preferred export varieties are Ngowe, Apple, Kent and Boribo (ITC, 2015). In 2013, the production was under an area of 44,018 ha and 644, 829 tonnes were produced at a value of Kshs 7.67 billion (HCDA, 2013) while in 2014, the area was 47,620 Ha and a production of 744, 639 tonnes, valued at Kshs. 8.9 billion (HCDA, 2014). Production is expected to reach 878,000 tonnes in 2017 and 1,415,000 tonnes in 2022 (USAID, 2014).

The main mango growing areas in Kenya include the Coastal and Eastern regions contributing an average of 85% of total mango production in Kenya. This is followed by Central Region and other emerging producing areas such as Nyanza, Rift Valley, North, and Western Region

(HCDA, 2012). Kilifi County, accounts for the largest mango production in Kenya at 18% followed by Kwale (16%), Machakos (8%), Meru (8%), Makueni (8%), Embu (7%), Migori (5%), Bungoma (4%), and Tana River (4%), and Lamu (4%) (Table 2.1).

Kenya's international mango market has grown considerably. The market is mainly around three regional areas: Asia, Africa and Latin America (Unctad, 2014). Kenya however, remains a smaller player in the global mango trade, exporting approximately 2% of national production or 1% of the fresh mangoes traded on the world market (ITC, 2012). In 2011, Kenya earned Kshs 1 Billion ($ 11.1 Million) from mango exports. Mango exports to the United Kingdom increased in value by 153 percent between 2012 and 2013. During the same period, exports in value to Germany increased by 91 % while the one to Qatar increased by 67 %. A significant percentage of Kenya's mango export has been going to the Middle East Countries (ITC, 2014).

2.5 MANGO FRUIT GROWTH AND MATURATION

2.5.1 Fruit growth

In order to flower profusely, mango trees require mature terminals (stems), resting and a quiescent period induced by either cool non- freezing temperature and /or dry conditions (Jules, 2008). Growth rate and the size of the fruit are determined by cell division and cell enlargement stages. Fruits such as mango, banana, avocado, strawberry expresses a single sigmoid seasonal growth pattern. In a graph of fruit size plotted against time, the growth rate is initially slow and a rapid linear increase of the fruit size follows but towards maturity the growth rate reduces (Tadesse, 1997).

2.5.2 Fruit maturation

A mature mango fruit is one that has attained physiological ability to increase in size and accumulation of dry matter. Change of skin and flesh color as well as textural change of the fruit can occur at any stage of maturation even at pea size stage (Oosthuyse, 1995). Mango, being a climacteric fruit is harvested at a physiologically mature green stage and can be allowed to ripen depending with the market. Fruit maturity triggers various changes which comprise of physical changes which include firmness (fruit becomes softer as it matures), color changes, size and density increases as the fruit matures, Physiological changes which include increment in respiration rate and increase in ethylene production. Biochemical changes include accumulation of carbohydrates in form of starch during maturation, which is broken down into sugar as the fruit ripens while titratable acids decreases as the fruit matures (Salunkhe, 1995).

Table 2.1. Production of Mangoes in Selected Counties in Kenya, 2012-2014

	2012			**2013**			**2014**		
County	**Area (Ha)**	**Quantity (Ton)**	**Value (Kshs-million)**	**Area (Ha)**	**Quantity (Ton)**	**Value (Kshs-million)**	**Area (Ha)**	**Quantity (Ton)**	**Value (Kshs-million)**
Makueni	10,237	44,482	398	10,237	44,482	398	10,737	146,425	1,817
Kwale	2,136	43,196	431	2,636	52,574	525	4,135	91,390	1,365
Kilifi	5,729	101,655	1,017	6,634	116,080	1,152	9,850	134,335	1,160
Machakos	4,825	54,329	630	5,133	51,546	624	5,593	67,320	836
Nyeri	1,833	44,836	763	1,925	50,239	883	1,806	44,727	751
Embu	3,127	109,105	631	2,944	111,480	780	3,044	108,088	730
Meru	4,176	46,010	460	4,135	48,432	484	4,027	41,605	516
Bungoma	935	18,560	209	1,166	23,151	297	1,268	25,211	316
Tharaka Nithi	1,058	22,280	253	1,111	15,984	242	1,067	20,137	239
Elgeyo Marakwet	690	20,072	153	518	11,806	135	618	11,567	209
Others	6,665	69,195	1,271	7,579	119,055	2,149	5,475	53,834	963
Total	**41,411**	**573,720**	**6,216**	**44,018**	**644,829**	**7,669**	**47,620**	**744,639**	**8,902**

SOURCE: HCDA 2014

2.6 FACTORS THAT AFFECT FRUIT GROWTH AND MATURATION

2.6.1 ` Agro-ecological conditions

Mango can be grown under different climatic conditions across Kenya ranging from Sub-Humid to Semi-Arid Zones (Kehlenbeck., *et al*., 2010). Mango's optimum growing temperature is 24ºC–27°C. The growth rate of the mango tree and the fruit are affected by extreme temperatures. The trees can grow over a wide range of rainfall volumes. Mean annual rainfall preferred is between 400 mm- 3600 mm (Griesbach, 1997). Mango tree do not require soils with high nutrient content but the soils must be free draining and deep. The tree can grow at pH ranging 5.5 to 7.5. Too high acidity is harmful to growth. Depending with the mango variety and the prevailing weather conditions, the maturity of mangoes occur at different times (ICRAF, 2003).

Temperature is involved in various processes during fruit growth and especially at the sink level (Léchaudel *et al*., 2005). High temperatures are also reported to lead to early maturity compared to low temperatures in 'apple's (Lasko *et al* 1995) and pears (Lombard et al, 1971). Apple and Ngowe mango fruits varieties grown at 2 locations with 2 contrasting agro ecological zones (AEZ) (high and low temperatures) matured at different times and the conditions of the AEZs also affected final qualities of the mangoes (Ouma, 2015). Studies in other fruits such as *Satsuma mandarin*, show that high temperatures shorten fruit maturation time (Marsh *et al.,* 1999)

Light exposure varies with the position within the canopy of the branch bearing fruit and the fruit. Light has a direct effect of the photosynthetic photon flux on the rate of electron flow (Farquhar *et al*., 1980) and an indirect effect on leaf photosynthetic capacity. Lower leaves have a lower carbon assimilation. Fruit growth declines if the carbon supply is low (Hofman *et al*., 1995). Water stress in mango trees can be defined according to the amount of water shortage or the duration of when stress occurred and this affects the final mango size (Simmons *et al*., 1995). Simmons *et al*., (1995) observed that if irrigation was cut out between flowering and at mid- growing period, water stress occurred and this affected fruit growth rate and final fruit size. Water stress after maturity towards harvesting does not affect the growth rate and the size of the fruit.

2.6.2 Cultural practices

Cultural practices involve all the activities carried out on the farm before, during and after planting of crops. Cultural practices during mango fruit growth include watering, nutrient management, pest and diseases control, pruning, and thinning. Pruning and thinning are essential in reducing fruit load, increasing the size of the fruit as well as allowing circulation of air and water (Kader, 2003). Pruning should be done immediately after harvest.

According to Simmons *et al*., (1995), lack of water supply on mango between flowering and the mid- growing period, may lead to water stress and this may have an effect on the cell number. During prolonged dry periods, irrigation is beneficial to mango tree that is four years and above to enhance plant growth and yields

Most of the cultural practices are not adhered to and the crop depends on the soil nutrients naturally found in the soil. Majority of fruit orchards are neglected and this make it easier for pests and diseases to prevail. Fruit flies attacks mango and interferes with its quality (Kader, 2003). Addition of fertilizers is important for vegetative growth but excess addition of fertilizers may interfere with flowering and fruit setting processes. Fertilizer should be applied to the soil during the rains and immediately after harvesting, (Griesbach, 1997).

2.6.3 Varietal differences

The chromosome number of mango is 2n=40 and n=20 (Mukherjee 1958). There are 11 types of chromosomes of which 8 are different and 3 are intergrading. The related species differ from one another mainly in categorization of these chromosomes types. Mango varieties are different mainly due to gene mutations. They are specific to different climatic factors and hence adaptable over a wide area (Chakrabarti, 2011). Mangoes can either be propagated vegetatively or by seed. Seedlings are grown to produce new cultivars, as rootstocks or to reproduce known polyembryonic cultivars. Mono-embryonic types, however, require vegetative propagation to keep all of the desired characteristics (Griesbach, 1997).

2.7 MATURITY INDICES FOR MANGO FRUITS

Maturity indices for a fruit are measurements used to determine the harvest maturity of a fruit. They are important as they help in economizing labour and available resources during harvest and post harvest procedures. Maturity indices are also crucial in determining the market, whether far or near and the price of the fruit.They can be objective (use of a measurement) or subjective (an evaluation). Though maturity indices should be non-destructive, subjective indices are destructive (Sudheer *et al*., 2002).

Mango fruit maturity at harvest is a critical factor to be considered while determining the storage-life and final fruit quality (Kader, 2001). Harvest maturity is important as the flavor of the fruit improves as the fruit matures and ripening occurs (Kader, 2008). Eating quality of the fruits is achieved when fruits are allowed to mature and ripen on the tree. Mango fruits that are picked immature may shrink and are easily bruised. Their quality deteriorates as they ripen and are susceptible to physiological disorders (Yahia, 1998).

2.7.1 Subjective maturity indices

Mango has always been harvested through physical observation of the fruit by the producer. Subjective maturity indices are involves the producer's experience on the visual appearance of the fruit during growth, maturity or ripening stages. Some of the subjective indices used to determine maturity in mango include fullness of the cheek, color, peel gloss, development of shoulder. According to Wang *et al*., (1990), elevated shoulders can be a maturity index to determine mature mango fruits but varieties such as Kensington Pride have no outstanding shoulders and it can only be picked by observing the flesh color change (Holmes, 1990). Through use of subjective indices most mango farmers face the challenge of determining the right maturity stage for the various markets (Yahia, 1999).

2.7.1.1 Color

Most farmers observe the skin color change from red to green to light green or yellow but this varies with the different varieties (Reid, 2002). Different varieties and maturity stages may have different skin and flesh color. Kent has a skin color of green-yellow and a deep yellow flesh, tommy atkins has a skin color of yellow to orange and a yellow to deep yellow flesh while Vandyke has a skin color of bright yellow ground color and orange yellow color flesh (ICRAF, 2003). Therefore, use of skin color as a maturity index is depended on the experience of the grower (Watkins, 2003).

2.7.1.2 Fruit shape

Shape is a characteristic which determines harvest maturity of fruits. Mangoes change their shape during maturity. As maturity progresses, the shoulders of fruits incline away from the stalk and become level with the point of attachment and may be raised above this point with advanced maturity (Muhammad, 2012).

2.7.1.3 Fruit size

Increase in size and weight of a fruit as it grows are regularly used to assess harvest maturity. Fruit size and weight are poor measurers of maturity as it depends upon a number of variables such as soil, cultivar, nutrient application and climatic conditions which vary from place to place and season to season (Sudheer, 2007). Mango farmers harvest large sized mangoes and this can either be mature or immature. The size of mangoes may vary depending on prevailing weather conditions and the amount of water and solids that have accumulated within the growing duration (Léchaudel *et al*., 2002).

2.7.2 Objective maturity indices

Objective maturity indices enable growers to know whether their commodity can be harvested when the market is buoyant. They are vital for accurate prediction of harvest dates (Kader, 2002). Objective maturity indices are important in determining the post harvest life of the product, hence they must consistently be associated with the quality and shelf life of the product (Dissa *et al*., 2009). Objective maturity indices can be computational, physical, biochemical or physiological.

2.7.2.1 Physical maturity indices

2.7.2.1.1 Color

Skin color has an effect on the final consumers' favorite choice and taste (Tharanathan *et al*., 2006). As the fruit ripens, some mangoes skin color may change from green to yellow. The visual skin color is a very popular maturity index, but not sometimes inaccurate. 'Langra' cultivar, for example, maintain green color even if physiological maturity and even when ripe (Lizada, 1993). Light affects the color of the fruits as this depends on the position of fruit within the canopy of the tree. Decline of fruit exposure to sunlight often leads to fruits with more green color on the skin (Simmons *et al*., 1998a). Fruits that are enclosed to eliminate pathogens have no red color on the skin (Hofman *et al*., 1997). High temperatures (above 46^{o}C) enhance acceleration of skin color development (Sharp, 1994). In mangoes, flesh color change around the seed can be used to determine maturity for mango fruit (Yahia, 1998a).

2.7.2.1.2 Specific gravity

Mango fruit accumulates dry matter during fruit development and becomes denser as it matures. Specific gravity is the ratio of the density of mango to the density of water, and is considered as a possible maturity index (Yahia, 1998a). Specific gravity increases as maturity progresses and can be used to separate crops depending with the maturity stage (Dhatt, 2007). However specific gravity generally ranges from 0.97 to 1.04 and may sometimes be unreliable maturity index (Yahia, 1998a).

2.7.2.1.3 Firmness and texture

This is the degree of softening and fibrousness in mangoes. As fruits mature, the firmness of the fruit reduces and further declines with ripening. Fruit softens as they ripen due to enzymatic degradation of cell walls (Johnston *et al*., 2002). Jha *et al*., (2010) reported that mango fruits firmness did not change over the growth period but reduced after maturity. Textural characteristics such as fruit firmness in fruits like mango, are more perceived by consumers than other aromatic properties (Johnson, 2000). Firmness of mango varies with specific cultivars and varieties (Jarimopas *et al*., 2007).

2.7.2.2 Biochemical maturity indices

2.7.2.2.1 Total soluble solids (TSS)

The main chemical parameters of fruit quality are their total soluble solids content and titratable acidity (Byrne D.H., 2012). As fruits mature, total soluble solids (TSS) increases. This also occurs during the storage period in the ripening stages. Accumulation of sugars and organic acids and hydrolysis of polysaccharides constitutes the increase in sweetness (Tover *et al*, 2000). Mangoes are harvested at about 9–10% soluble solids for majority markets (Mendoza *et al*., 1984).

2.7.2.2.2 Titratable acidity

Titratable acidity is a measure of the buffering capacity of fruit and is generally expressed as % citric acid. Titratable acidity (TA) decreases with fruit maturity (Tharanathan *et al*., 2006). Citric acid is the predominate organic acid found in fruits such as strawberry (Green, 1971) and it reduces upon the development of color. Some markets consider the SSC/TA ratio as an indicator of ripeness and taste, thus, the higher the ratio the sweeter the fruit (Mizrach *et al*., 1999).

2.7.2.3 Physiological maturity indices

2.7.2.3.1 Respiration and Ethylene production

Respiration process involves breaking down of stored organic materials into simple end products and energy is released as well as production of carbon dioxide For most fruits respiratory activity increases gradually after the fruits attain physiological maturity and this depends on the type of fruit and differs among cultivars (Adel *et al*;, 2012). Mango, being a climacteric fruit, exhibits a climacteric pattern of respiration and ethylene production rates increases during ripening process (Lalel *et al*., 2003). Climacteric fruits such as mango show a remarkable increment in respiration rate during maturation (Nirmal, 1995). The highest respiration rate during mango fruit ripening mango fruit happen at the climacteric stage and this parallels the sigmoidal ethylene production pattern (Ketsa *et al*., 1999). The respiration pattern depends on the cultivars, climatic conditions and growing locations (Krishnamurthy *et al*., 1970). After fruit set, respiration is very high and this reduces and remains at a low rate until the fruit begins to ripen. The differences in respiration rates among cultivars are usual due to differences in location, climatic conditions and temperature during postharvest treatment.

Ethylene is a natural plant hormone (phytohormone) associated with the growth, development, ripening and aging of many plants (Yahia, 2008). During fruit maturity, a noticeable amount of ethylene is produced which induces more ethylene production and ethylene related ripening and senescence processes. Ethylene production decreases and cannot be detected for a short span and reappears when ripening begins (Akamine *et al*., 1973). Biale *et al* (1981) included mangoes among fruits in which ethylene rises after carbon dioxide production rises. Ethylene production is at the highest point on the onset of climacteric phase of fruit ripening. The little amount of ethylene present in the fruit at harvest is enough to initiate ripening (Verma, 2000). Carbon dioxide interferes with ethylene action in promoting ripening and therefore the ethylene peak appears immediately after the respiration peak (Yahia, 2008).

2.7.2.4 Computational method

Computational methods include calendar date, days after full bloom (DAFB) to acceptable maturity and mean heat units (Sharma *et al*., 2000). Mangoes take 90 to 160 days to reach maturity but this varies with variety and growth conditions. Mango varieties such as Kent mature late while Tommy Atkins is an early to mid-season cultivar. Climatic difference between locations affects DAFB of even similar varieties. 'Apple' and 'Ngowe' mango varieties grown in Embu, a high potential agro ecological zone (AEZ) and Makueni, a low potential AEZ reached maturity at different times. For Embu and Makueni, Apple variety attained maturity 111 and 107 DAFB respectively while Ngowe variety, 97 and 91 DAFB respectively (Ouma, 2015). According to Ouma (2015), fruits from Makueni matured at an earlier date based on days after flowering than those from Embu and this could have been attributed to the significant climatic differences between Embu and Makueni. Environmental fluctuations and cultural practices such as mulching, irrigation, pruning, fertilization differs within the growing season and the area of production and this interferes with DAFB. Standardization of DAFB method requires a study for many seasons within a given area, location, cultivar and rootstocks. Prolonged blossoming makes definition of DAFB difficult leading to errors in predicting harvest maturity (Verma, 2000). Counting of days from full bloom to physiological maturity varies among cultivars and geographical areas and should therefore be limited to the specific area and location (Debbie, 2012).

2.8 MANGO RIPENING AND ASSOCIATED CHANGES IN QUALITY ATTRIBUTES

Ripening are the biochemical and physiological changes of a fruit to achieve the enviable eating quality which may include color, taste and flavor. Ripening occurs after full maturity of a fruit and a fully matured mango fruit will ripen even after harvest (Bender *et al*., 2000). Several chemical and physiological changes are involved in the ripening of mango fruit. Ethylene production decreases as the fruit matures and increases as the fruit ripens (Akamine *et* *al*., 1973). Ripening is an irreversible process and it improves the eating quality of mango fruit. The postharvest shelf life of the fruit is however reduced upon harvesting.

As mango fruit ripens, the skin color of the fruit may change from green to yellow depending with varieties (Jha *et al* 2007). Most varieties lose the green color while some retain the green color in ripe fruit. Flesh color changes from green- yellow to yellow to orange in most cultivars (Yahia, 2009).

Fruit softening and cell wall changes are key changes associated with mango fruit ripening. Fruit texture is due to changes in cell walls and pectic substances in the middle lamella (Selvaraj *et al*., 1989). Softening of mango fruit is characterized by increased solubility of cell wall pectins (Nasrijal, 1993). Ripening in mangoes begins in the inner mesocarp tissue close to the seed, and progresses outwards (Lazan *et al*., 1993). Starch content increases in chloroplasts during mango fruit development and is hydrolysed to simple sugars during ripening (Ito *et al*., 1997). Sucrose content increases during ripening (Tandon *et al*., 1983) while reducing sugars, mainly fructose, increase slightly during ripening (Castrillo *et al*., 1992).

Mango fruit experience a considerable loss of organic acids during maturation and ripening. The main acids in mature mango fruit are citric, malic, succinic and tartaric acids (Medlicott *et al*., 1985). Citric acid has the highest concentration and the content increases steadily during fruit development until the endocarp begins to harden, and then decreases gradually (Ito *et al*., 1997). Among the more than 300 volatiles found in ripe mangoes, the major volatiles are monoterpenes and sesquiterpenes (Pino *et al*., 2005). Aromatic volatiles are produced at advanced stages of ripening in most fruits (Yahia, 1994).

2.8.1 Changes in soluble sugars (Sucrose, glucose and fructose)

Sweetness is the most important compositional change related to mango flavor. As mango fruit ripens, soluble sugars increases as starch content is hydrolysed to simple sugars during ripening (Ito *et al*., 1997). Ripe mango contains 10–20% total sugars on a flesh weight basis, but this varies with variety and the stage of ripeness. Reducing sugars make up most of the sugar content at the beginning of ripening. Non-reducing constitute 17% while only 3% of reducing in ripe fruit. Vazquez *et al (*1985) observed a steady reduction in glucose and fructose and a continuous increase of sucrose during ripening in Haden, Irwin, Kent and Keitt mango fruits.

2.8.2 Changes in flavor

The balance between the content of sugars and organic acids constitutes the fruit flavour (Medlicott *et al*., 1985). Flavor, determines to a great extent, the consumer acceptance of the fruit and is an important quality trait (Dharini *et al*., 2010). According to Baldwin (2010), flavor comprises taste and odour and is mainly composed of sweetness, aroma and sourness which correspond to sugars, volatile compounds and acids. Changes in fatty acid outline during ripening attributes to the aroma of mango fruit (Dharini *et al*., 2010). The aroma of mango fruits betters during ripening and is usually as a result of production of different volatile compounds.

2.8.3 Changes in vitamins

Vitamins such as ascorbic acid, BI and B2, K and folic acid were detected in different cultivars of ripe mangoes (Tharanathan *et al*., 2006). The most important vitamin for human nutrition is ascorbic acid and is an important food component because of its antioxidant and curative properties (Okiei *et al*., 2009). As mango fruit ripens Vitamin C content decreases (Mamiro.*et al.*, 2007) and according to Aina, (1990) this is due to susceptibility of vitamin C to oxidative destruction during ripening. Unripe fruits have higher ascorbic acid levels than the ripe ones but decreases upon increase in temperature, ripening and time of exposure. Oxygen is the most critical element in mango fruit juice causing degradation of ascorbic acid (Muhammad *et al;*, 2014). According to Muhammad (2014), fructose can also cause ascorbic acid breakdown.

2.8.4 Changes in β-carotenes

The content of total carotenoids increases steadily as mango fruits approach maturity and ripening stages (Joao *et al*., 2010). β-carotene was found to account for 60% of the total carotenoid in most mango cultivars (Tharanathan *et al*., 2006). During the succeeding ripening phase, β-carotene accumulation in mango fruits has been formerly emphasized in terms of interrelationships with flesh color and vitamin A. The yellow – orange color development during post harvest ripening of most mango cultivars consequences the accumulation of carotenoids in the inner tissue, synchronized with a decreasing ripening guide (Vasquez *et al*., 2005).

2.8.5 Changes in mineral nutrients

Minerals such as phosphorous, calcium and sodium has been observed during ripening of Keitt mangoes and they decreased as ripening progressed (Appiah *et al*., 2011). Appiah (2011) reported an increase of magnesium content with ripening on Keitt mango fruits. Immature mango fruits were reported to contain sodium and potassium as the major minerals (Mujahid *et al*., 2013). Mineral levels vary according to the varieties. Potassium levels were found to be highest in Dusheri and Langra mango varieties (Akhtar *et al* 2010). Othman *et al* (2009) noted more potassium in Dodo variety of mango fruits harvested at maturity stage. Calcium content of mango fruits depends on the variety and maturity stage (Akhtar *et al*., 2010).

2.8.6 Changes in firmness

During fruit ripening, fruit firmness decreases due to changes in structure of the pectin polymers of cell wall (Kalra *et al*., 1995), which later stabilized signifying end of ripening process. Hosakote *et al*., (2006) reported ripening of mango accompanied by a series of biochemical changes results in gradual textural softening. Enhanced solubility of cell wall leads to softening of mango fruit (Nasrijal, 1993). Ripening in mangoes begins in the inner mesocarp tissue and advances outwards and this leads to reduced tissue firmness (Lazan *et al*., 1993).

2.8.7 Changes in color

Loss of chlorophyll and an increase in carotenoids in some mango varieties such as Tommy Atkins initiates the. development of yellow color during ripening (Medlicott *et al*., 19888). According to Medlicott *et al*., (1988), chloroplasts undergo extensive disorganization which is linked with the development of large osmiophilic globules.

2.8.8 Changes in acidity

Citric acid content increases steadily during fruit development. Citric and succinic acids decrease during ripening while malic acid shows varying changes with different cultivars

(Lizada, 1993). The decline in acidity during ripening is as a result of starch hydrolysis leading to an increase in total sugars and a decrease in acidity (Fuchs, 1980)

2.9 EFFECT OF HARVEST MATURITY ON MANGO FRUIT QUALITY

2.9.1 Effect on fresh mango quality

Harvest maturity is a vital step which determines the prospective storage life, flavor and consumer approval of mango fruit (Seymour, 1990). Immature fruits are more vulnerable to bruises and injuries due to careless handling (Chonhenchob *et al*., 2003) and are of lesser quality when ripe (Medlicott, 1985). Immature fruits are also more liable to certain post harvest disorders like chilling injury and irregular ripening (Ledger, 1995). Harvesting the fruits at very late stages of maturity may aggravate physiological disorders like jelly seed (Lee, 2000). Better aroma quality is attained if fruits are harvested at advanced maturity but the shelf life is reduced (Seymour, 1990). Immature fruit subjugated to hot water treatments shows extreme heat injury while fruit at advanced maturity are more resistant (Jacobi, 2001). Flavor and aroma may not develop in immature fruits. The preferred harvesting stage for mango fruit is at mature unripe stage to prolong their shelf life and easy transportation.

2.9.2 Effect on processed products

Mango fruit is used at every stage of its growth by the processors. Processed products from mango include; puree, nectar, juice, pickles, chutney, flakes, jams concentrate, fruit bars, mango leather, and mango powder. During early stages of growth, mango sauce used sour chutney and as the fruit matures they can be used for some other products like amchoor, pickles and green mango beverages. Raw mango slices can also be used for pickle and chutney manufacturing (Kalra *et al*., 1995). Ripe mango fruit has a distinctive taste and flavor. Mango puree/pulp is prepared by homogenizing peeled mango slices. Mango can be blended with other fruits for product preparation for example pawpaw, whole/partially skimmed milk, apple, pear or apricot (Salunke, 2001). Firmer fruit tends to be unripe and hence more acidic and the lack aroma and flavor notes. Softer fruits on the other hand, are riper and have a lower acidity and characteristic aroma and flavor notes. Processing mango fruits at the firm ripe stage will score lower as compared to soft ripe fruit (Beaulieu *et al*., 2003).

The quality of processed fruit products depends on their quality at harvest and at the onset of processing and therefore, it is essential to comprehend how maturity at harvest, harvesting methods and postharvest handling procedures affects quality (Kader *et al*., 2005). Processing is considered as an important tool to bound degradative reactions, although some vitamins and minerals however may be lost during processing. β-carotene is both the principal pro-vitamin A carotenoid and the main pigment in mango (Masibo *et al*., 2009). Processing affects the carotenoids content in mango which results in the overall decline of the levels (Chen *et al*., 2007; Lemmens *et al*., 2013). On the other hand as vitamin C decrease with mango maturity, carotenoids content increases. Harvest maturity therefore affects the processing quality of the mango fruits (Kapur et al., 1985).

2.9.3 Effect of harvest maturity on dried mango products

Dried fruits are important healthy snack items around the universe. They can bridge the gap between required intake of fruits and real consumption (Fereidoon *et al*., 2012). The dried slices keep good sensory and biochemical quality for at least 12 months without any visible sign of discoloration (Muhammad *et al;*, 2012). Mango at various stages of ripening can be dried and consumed (Appiah *et al*., 2011).

As mango fruits are dried changes such as color and visual appearance, flavor, nutrient retention, bulk density, shape, texture, water activity and chemical stability occurs. Others include freedom from taints and off odors. Sensory characteristics of dried mangoes are color, flavor, aroma and overall acceptability. However, the vitamin content of dried mango fruits differs from that of fresh fruit (Muhammad *et al;*,, 2014). As mango fruits are dried, some vitamins like riboflavin becomes oversaturated and precipitate from solution and losses are not severe. Ascorbic acid are soluble until the moisture content falls to lower levels and these reacts with solutes at higher rates as drying proceeds. Vitamin C is sensitive to heat, low temperature, oxygen and moisture levels (Fellows, 2009). The dried fruit contains small amounts of iron and calcium and also irreversible loss of ability to rehydration. Carotenoid contents increase with mango fruit maturation and further increases after drying the mango slices (Chen *et al*., 2007).

CHAPTER THREE

3 MATURITY INDICES OF THREE MANGO VARIETIES PRODUCED IN A MEDIUM ALTITUDE AGRO-ECOLOGICAL ZONE IN KENYA

3.1 ABSTRACT

Harvest maturity significantly affects the overall quality and the shelf life of fruits such as mango. Choice of the harvest maturity is dictated by the target market and use of the fruit and is often a tradeoff between eating quality and shelf life. There are various indices that have been used to determine harvest maturity of mango fruits. The main objective of this study was to evaluate maturity indices of three commercial mango varieties namely 'Van dyke', 'Kent' and 'Tommy atkins' in Embu County of Kenya. A total of fifty four mango trees of the three varieties, of similar vigor and aged 8 years were randomly tagged at 50% flowering in three selected small scale farms in Embu County between 2014 and 2016. The number of days to the earliest maturity stage (mature green), judged by yellowing of the flesh around the seed, were established for each variety as stage 1. Subsequent stages (2, 3 and 4) were determined at regular intervals until the tree-ripe stage. The number of days from flowering to each maturity stage was computed during the two years. For each variety and maturity stage, five fruits were randomly sampled from the pool and analysed for physical (size, density, firmness, colour), physiological (ethylene evolution and respiration rate) and biochemical (^{o}brix, total titratable acidity and their ratio) indices of maturity. Data collected was analyzed using Genstat statistical package 13th edition. Means were separated using Fisher's protected Least Significance Difference (LSD) at $P \leq 0.05$.The results showed that although size increased as the fruits developed, it was not a reliable index of maturity since some small-sized fruits attained advanced maturity (stage 4) earlier than others that were large-sized. At stage 1 and stage 3, Vandyke variety had a length of 29.17cm while at stage 4, 30.50cm. The length of Kent variety increased gradually from 35.17 cm to 42.70cm while that of Tommy Atkins was 32.70cm at stage 1 and 41.60cm at stage 4. The weight (mass) of the fruits fluctuated as the fruits developed and similar trend was observed on the specific gravity. The specific gravity for Van dyke variety was 1.189 g/cm^3 and 1.162 g/cm^3 for stage 1 and stage 2 respectively while for Kent variety; 1.226 g/cm^3 and 1.259 g/cm^3 for stage 1 and stage 4 respectively. The fruits' flesh firmness decreased gradually with maturity from a mean firmness of 40.54 N (stage 1) to 6.84 N (stage 4). Tommy Atkins exhibited the lowest firmness levels (6.84 N) at stage 4. Ethylene production increased with maturity from a mean value of 0.1123 µl/kg/hr (stage 1) to 0.33 µl/kg/hr (stage 4). The 3 varieties were significantly different ($p \leq 0.05$) at maturity stage 3 while Tommy Atkins and Kent varieties were not significantly different at stage 4. Kent variety had the lowest ethylene at all stages which ranged from 0.1123 µl/kg/hr to 0.2943 µl/kg/hr. Respiratory activity also increased with maturity. At stage 1, respiratory rate was significantly different among the varieties while not significantly different at stage 4. Tommy Atkins variety had the highest respiration rate of 21.40 ml/kg/hr at stage 1, which increased gradually to 32.10 ml/kg/hr at stage 4. The TSS: TTA ratio increased from a mean value of 25.57 (stage 1) to 105.5 (stage 4). The highest TSS: TTA values (for all maturity stages) were reported in Kent variety. The results reveal significant differences in maturity indices of the three mango varieties despite similar physical indices. This confirms the unreliability of physical maturity indices such as size and shape in establishing the right harvest stage of mango fruits. Therefore a combination of flesh color, peel and flesh firmness, computational, physiological and biochemical maturity indices is required to establish the accurate harvest maturity for mango fruits.

Key words: harvest maturity, mango, maturity indices

3.2 INTRODUCTION

Maturity is the development stage that gives minimum satisfactory quality to ultimate consumer. Maturity indices are used to determine maturity of a particular commodity. These indices are important for the resourceful use of labor and resources, trade guideline, marketing policy (Sudheer, 2007) and also for ensuring that fruits are harvested at the right maturity stage to provide some marketing elasticity and to ensure the attainment of acceptable consumption quality to the consumer (Verma, 2000). Fruits picked at the wrong stage of maturity may develop physiological disorders in storage and may exhibit poor desert quality. For example, apple picked too early may not ripen properly in storage and may develop superficial scald, bitter pit and extreme shriveling while if harvested after attaining full ripeness on the tree, they are susceptible to senescence breakdown, Jonathan spot and core breakdown (Verma, 2000).

Customarily, mango is harvested based on the growers observation on the appearance of the fruits (Yahia, 1998a). Visual measurement is the most commonly followed subjective method to determine harvest maturity in mango. Use of skin color, rising of shoulders and fullness of cheek are most common (Debbie *et al*., 2012). Immature fruit are more likely to be mechanically damaged (Chonhenchob *et al*., 2003) and of low-grade quality when ripe (Medlicott *et al*., 1988). Fruits harvested at advanced maturity stage have better aroma quality (Bender *et al*., 2000) but reduced the storage life (Seymour *et al*., 1990). The quality and the post harvest life of mango fruits depend on the maturity stage at harvest. Fruits harvested at the right maturity stage develop the most favorable sensory quality attributes and longer post harvest life (Yahia, 1998a). To optimize mango utilization in all stages of maturity and to extend the shelf life of mango fruits, it is important to have the knowledge of reliable maturity indices (Kader, 1999).

Maturity indices that are currently used are based on a compromise between indices that would ensure the best eating quality to the consumer and those that offer the needed elasticity in marketing (Kader, 1999). Subjective method which are used to determine maturity in mango include softness and fullness of the cheek, peel /flesh color, peel gloss and development of shoulder (Kosiyachinda *et al*., 1984). Through use of subjective indices most mango farmers face the challenge of determining the right maturity stage for the various markets (Yahia, 1999).

Accurate determination of harvest of maturity requires a combination of maturity indices. In mango fruits, there are computation, physical, physiological and biochemical parameters that can be used to accurately determine the harvest maturity. Computational method which is based on counting of days from the onset of flowering to physiological maturity can be used but proper records must be kept for accuracy. Days from full bloom (DFFB) is the most reliable index of maturity of fruit crops (Sudheer, 2007). In Kenya, mangoes take 90 to 160 days after full bloom to reach maturity depending on cultivars and environmental conditions in a given area (Griesbach, 2003).

Physical indices that have been used include size, shape, peel/flesh color, peel/flesh firmness and specific gravity (inclusive of weight) (Cristoto, 1995). Some farmers harvest large sized mangoes, mangoes with full cheeks or which have developed shoulders and this can either be mature or immature. The size of mango is reckoned on the amount of water and dry solids in the various mango compartments during fruit growth and this varies depending with the prevailing environmental conditions (Léchaudel *et al*., 2002). However, fullness of cheeks and shoulder development hence change of the mango shape can indicate maturity but this has to be accompanied by other parameters such as change of skin color to determine the harvest maturity stage (Kader *et al*;,2008).

As fruits mature, a series of changes like the breakdown of chlorophyll and increase in carotenoid pigments of the pulp occurs (Ortega, 2000). This leads to color changes from green to yellow. Differences in color between immature and mature green mangoes can be subtle since it depends on the environment and cultivar (Jha *et al.* (2007). Firmness is a consistent indicator of mango maturity at harvest and ripeness during commercial handling. Fruit firmness has been used for many years as a measure of the stage of ripeness of avocado (Whiley *et al*., 2002). It is also a standard measurement for maturity of fruits such as peaches, pears and apples though it is destructive (Bruckner 2008).

Physiological indices that are used include ethylene evolution and respiration. There is increased evolution of CO_2 and ethylene when climacteric fruits reach physiological maturity and ripening processes are initiated (Sudheer, 2007). The rate of respiration increases with fruit maturity and the increment rate depend on the type of fruit and differ among cultivars.

Climacteric fruits such as mango show a notable increment in respiration rate as maturation progress (Nirmal, 1995).

Biochemical indices used include soluble solids content, titratable acidity and their ratio (Kader, 2002). As mango fruits mature, soluble solids content increases while titratable acidity decreases (Bruckner, 2008). Fruit maturity is related to total soluble solids (brix) to acid ratio (Sudheer, 2007). Sugar content in conjunction with fruit hardness and starch color reaction has been used to determine the optimal time of harvest of apple fruit (Sudheer, 2007). Although biochemical indices of maturity are reliable, they are destructive and time-consuming (Kader, 2002).

The maturity indices described above are affected by other factors such as preharvest production conditions and variety. Accurate determination of harvest maturity therefore requires a combination of different indices. The objective of this study was to determine maturity indices of three commercial mango varieties (Van dyke, Kent and Tommy Atkins mango) produced in Embu County of Kenya, a medium altitude agro-ecological zone.

3.3 MATERIALS AND METHODS

3.3.1 Experimental set up

The experiment was conducted in Embu County of Kenya during the month of August 2014 to March 2015 (year1) and during the month of August 2015 to March 2016 (year 2). Embu lies on the windward slopes of Mt. Kenya. Embu County receives an annual rainfall of 1495mm with temperatures ranging from 12^{o}C to 27^{o}C. The soil in the area is volcanic and slightly acidic. They are fertile and rich in organic and nutrient contents such as potassium and nitrogen. The elevation from sea level stands at 1350M.

Fifty four mango trees (eighteen trees per variety) of 'Tommy Atkins',' Van dyke' and 'Kent' varieties, of similar vigor and aged 7-9 years were selected and randomly tagged at 50% flowering in three small scale farms in Embu County. The number of days from 50% flowering to physiological maturity (mature green stage), based on flesh color (yellowing of the flesh around the seed), was established for each variety as stage 1. Subsequent stages (2, 3 and 4) took 7-10 days apart. For each maturity stage, 60 to 100 fruits were harvested and were immediately washed in cold water which was sanitized using 1% acetic acid for disinfection and disinfestation in the postharvest laboratory. They were then selected for uniformity and freedom from any damage.

For each variety, a random samples of 5 fruits was taken to separately establish the indices of maturity based on physical parameters (weight, density, peel and flesh color, peel and flesh firmness), physiological (ethylene evolution and respiration) and biochemical (total soluble solids and titratable acidity) for each of the different stages of maturity for 2 consecutive years.

The experimental design used in the laboratory was Completely Randomized Design (CRD) with a factorial arrangement. The factors were three varieties, 'Tommy Atkins',' Van dyke' and 'Kent' and four stages of maturity.

3.3.2 Determination of maturity indices

3.3.2.1 Sampling

A total of 54 mango trees had been randomly tagged, that is, 18 mango trees per variety (Tommy atkins, Van dyke and Kent). Five sample fruits were randomly harvested from different branches of each tree at early and advanced maturities (season 1) and at four maturity stages (season 2) for each variety. Hence for each maturity stage, a total number of at least 90 fruits were harvested for every variety.

The harvested mango fruits were transported to the Post harvest laboratories of Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology (JKUAT). The fruits were washed immediately in cold water which was 20^{o}Cwhich was sanitized using 1% of acetic acid for disinfection and disinfestation. The fruits were then selected for uniformity and freedom for blemishes or injuries. A random sample of five fruits was taken from the batch of each of the maturity stages, both seasons, and was used to analyse the initial maturity indices including physical (size, specific gravity, peel/flesh firmness, peel/flesh colour), physiological (respiration, ethylene, weight) and biochemical (titratable acidity, ^{o}brix and their ratio) maturity indices.

3.3.2.2 Computational maturity indices

Fifty four mango trees of ‘Tommy Atkins’,’ Van dyke’ and ‘Kent’ varieties, of similar vigor and aged 7-9 years were selected and randomly tagged at 50% flowering in three small scale farms in Embu county. The number of days from 50% flowering to physiological maturity, based on flesh color (yellowing of the flesh around the seed), was established for each variety as stage 1. Subsequent stages were established based on stage 1.

3.3.2.3 Physical maturity indices

3.3.2.3.1 Size

The length of three fruits randomly selected from each of the 3 varieties at the different stages was determined using a tape measure and the mean size was expressed in centimeters.

3.3.2.3.2 Density

Three fruits from each variety and at each stage were weighed using a digital weighing balance (Model Libror AEG-220, Shimadzu Corp. Kyoto, Japan) and immersed in a calibrated beaker containing water and the difference in volume of water was determined. Mean density of the fruit was then calculated as mass per volume and expressed in g/cm^3

3.3.2.3.3 Firmness

Peel firmness was measured at three different spots while flesh firmness was determined from peeled portions of three sampled fruits for all varieties and in all stages. A penetrometer (Model CR-100D, Sun Scientific Co. Ltd, Japan) fitted with a 5 mm probe was used. The probe was allowed to penetrate to a depth of 1.5cm and the corresponding force required to penetrate this depth was determined. Firmness was then expressed as Newton (N)

3.3.2.3.4 Color

The color of both the flesh and peel of 3 mango varieties and at all stages were measured using the Minolta color difference meter (Model CR-200, Osaka, Japan) after calibrating it with a white and black tile. L*, a* and b* coordinates were recorded and the a* and b* values converted to mean hue angle (H°) according to McGuire, 1992 and Mclellan et al., 1995 formulation where (Hue angle (Hº) = $\tan^{-}1(b^*/a^*)$)

3.3.2.4 Physiological maturity indices

Three mango fruits from each variety and in all stages were separately placed in plastic jars of 5775 ml. The jar covers were fitted with a self-sealing rubber septum for gas sampling. The fruits were then incubated for two hours at room temperature (25^0C). Gas samples from the headspace gas was taken thrice using an airtight syringe and injected into gas chromatographs (Models GC-8A and GC-9A, Shimadzu Corp., Kyoto, Japan) for respiration and ethylene production rates, respectively. The gas chromatograph for carbon dioxide determination was fitted with a thermal conductivity detector and a Poropak N column and that for ethylene determination was fitted with an activated alumina column and a flame ionization detector. Rate of carbon dioxide production was expressed as ml/kg/hr at standard atmospheric pressure while ethylene production was expressed as µl/kg/hr

3.3.2.5 Biochemical maturity indices

3.3.2.5.1 Total Soluble Solids (°Brix) Content

Total soluble solids (TSS) content of the juice extracted from three different fruits (from each variety and stage) was determined using an Atago hand refractometer (Model 500, Atago, and Tokyo, Japan). The mean TSS level was expressed as °brix

3.3.2.5.2 Total Titratable Acidity

Total titratable acidity (TTA) was determined by titration of 3 fruit juice samples (each variety and stage). Ten milliliters of the juice extracted was diluted with 50ml of distilled water. 10ml of the diluted juice was used for titration with 0.1N Sodium Hydroxide using phenolphthalein (1% in 95% ethanol) as an indicator. The TTA was expressed as % citric acid equivalent using the formula;

% Citric acid equivalent = Sample reading (ml)*Dilution factor (0.0064)*100/sample weight (ml)

3.4 STATISTICAL ANALYSIS

Data was analyzed using Genstat statistical package 13th edition. Means were separated using Fisher's protected Least Significance Difference (LSD) at $P \leq 0.05$. The data were presented as tables and graphs showing various maturity indices for the 3 varieties and 4 maturity stages.

3.5 RESULTS

3.5.1 Computational maturity indices

Tommy Atkins mango variety attained physiological maturity (stage 1) earlier than Van dyke and Kent varieties. Although it took 7-10 days apart from one stage to another, Kent variety took longer to attain stage 2 characteristics and hence its stage 4 was attained late when Tommy Atkins and Van dyke had already been harvested at stage 4.

Table 0.1. Days after flowering to maturity stages 1 to stage 4 for 'Van dyke', 'Tommy Atkins' and 'Kent' mango varieties

Stages	**Van dyke**	**Tommy atkins**	**Kent**
1	100	97	114
2	110	107	121
3	119	115	164
4	129	124	173

3.5.2 Physical maturity indices

3.5.2.1 Size

The size (length) of 'Tommy atkins', 'Van dyke' and 'Kent' varieties was significantly different ($p \leq 0.05$) for the same maturity stage. During season 1, the length of the fruits was significantly different ($p \leq 0.05$) among the varieties during early maturity. The range of size of the 3 varieties was; Van dyke 28.27cm (early maturity) to 30.40 cm (late maturity); Tommy atkins 31.53cm to 40.20 cm and Kent 35.03 cm to 38.67 cm (Table 3.2). During season 2, the size range was similar with Van dyke ranging between 29.17cm (stage 1) and 30.50cm (stage 4); Tommy atkins 32.70cm and 41.60cm and Kent; 35.17cm and 42.70cm. Tommy atkins and Kent varieties were generally larger compared to Vandyke variety (Table 3.3).

3.5.2.2 Density

The density of the fruits was inconsistent as maturity progressed in all the varieties during the 2 seasons (Table 3.2). Van dyke variety was significantly different ($p \leq 0.05$) from Tommy atkins and Kent varieties which were not significantly different ($p \leq 0.05$) except during season 2 at maturity stage 3. During season 1, the density for Van dyke variety was 1.205 g/cm^3 during early maturity and 1.223 g/cm^3 at advanced maturity. Tommy atkins and kent varieties were not significantly different ($p \leq 0.05$) and the density ranged from 1.263 g/cm^3 to 1.298 g/cm^3. During season 2, density ranged from 1.162 g/cm^3 to 1.203 g/cm^3 at all maturity stages for Van dyke variety while 1.214 g/cm^3 to 1.259 g/cm^3 for Tommy atkins and Kent varieties.

3.5.2.3 Firmness

A decreasing trend for both peel and flesh firmness for the 3 varieties was observed as maturity progressed. In season 1, peel firmness reduced from 50.19 N (early maturity) to 29.68 N (advanced maturity) for Van dyke variety, 47.33 N to 25.84 N for Tommy Atkins and 60.58 N to 27.92 N for Kent variety. In season 2, flesh firmness reduced from 33.92 N (stage 1) to 13.88 N (stage 4), 34.77N (stage 1) to 6.84 N (stage 4) and 40.54 N (stage 1) to 10.82 N (stage 4) for 'Van Dyke', 'Tommy Atkins' and 'Kent' varieties respectively. Kent variety had significantly ($p \leq 0.05$) higher peel firmness compared to Tommy atkins and Vandyke.

Table 0.2 Size (Length in cm), Density (g/cm^3), Peel and Flesh firmness (Newtons) of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits varieties harvested at an early and advanced maturity stages in season 1.

Maturity stage	Variety	Size	Density	Peel Firmness	Flesh Firmness
Early maturity	Van dyke	28.27c	1.205b	50.19b	37.62a
	Tommy atkins	31.53b	1.282a	47.33b	39.23a
	Kent	35.03a	1.298a	60.58a	39.79a
	LSD	0.7997	0.045	4.1783	**ns**
	CV%	1.1	2.4	3.5	4.1
Advanced maturity	Van dyke	30.40b	1.223b	29.68a	12.12a
	Tommy atkins	40.20a	1.263a	25.84b	6.43b
	Kent	38.67a	1.266a	27.92a	12.84a
	LSD	2.5691	0.025	1.7558	1.7686
	CV%	3.1	3.6	2.8	7.5
	Significance level (V*S*)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage

Table 0.3. Size (Length in cm), Density (g/cm^3), Peel and Flesh firmness (Newtons) of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits varieties harvested at four stages of maturity; stages 1, 2, 3 and 4 in season 2

Maturity stage	Variety	Size	Density	Peel firmness	Flesh firmness
1	Van dyke	29.17c	1.189a	48.14b	33.92b
	Tommy atkins	32.70b	1.214b	46.43b	34.77b
	Kent	35.17a	1.226b	53.81a	40.54a
	LSD	1.631	0.015	4.0412	3.3466
	CV%	2.2	3.4	3.6	4.1
2	Van dyke	27.97b	1.162b	41.71a	30.21a
	Tommy atkins	40.00a	1.248a	41.14a	28.58a
	Kent	40.17a	1.247a	43.61a	33.59a
	LSD	2.9	0.023	**ns**	**ns**
	CV%	3.5	2.3	3.4	6.6
3	Van dyke	29.17b	1.181c	33.23b	24.75a
	Tommy atkins	40.50a	1.248b	31.88b	15.69c
	Kent	42.23a	1.254a	36.58a	20.35b
	LSD	2.576	0.031	2.8080	1.4668
	CV%	3.0	3.3	3.7	3.2
4	Van dyke	30.50b	1.203b	28.15a	13.88a
	Tommy atkins	41.60a	1.251a	27.28a	6.84c
	Kent	42.70a	1.259a	27.07a	10.82b
	LSD	2.661	0.012	**ns**	1.5062
	CV%	3.1	2.7	3.9	6.3
	Significance level (V*S*)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, ***** Levels of significance V=Variety and S=Stage.

3.5.2.4 Color

The hue angle on the skin fluctuated depending on the variety but not stage of maturity. At early and advanced maturity stages (season 1), Kent skin color was cool green (135.87^o and 143.21^o) during early and advanced maturity. The varieties had significantly different ($p \leq 0.05$) peel hue angle during early maturity stage where the skin color of Kent variety was cool green while that of Van dyke was lime. Flesh hue angle decreased as maturity advanced for all the varieties in the 2 seasons. In season 2, flesh color ranged from warm green to mid yellow depending on the maturity stage. The flesh hue angle reduced from 105.3^o (stage 1) to 76.63^o (stage 4), 100.0^o (stage 1) to 72.48^o (stage 4) and 98.1^o (stage 1) to 69.34^o (stage 4) for 'Van dyke', 'Tommy Atkins' and 'Kent' varieties respectively. This flesh color changes is clearly shown on plates 4a to 6d.

Table 0.4. Peel and Flesh hue angle (^{o}) of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits harvested during early and late maturities in season 1

Maturity stage	Variety	Hue angle peel	Hue angle flesh
Early maturity	Van dyke	88.5c	112.38a
	Tommy atkins	108.2b	108.73a
	Kent	135.87a	106.51a
	LSD	9.8	**ns**
	CV%	2.7	3.5
Advanced maturity	Van dyke	73.5b	79.23a
	Tommy atkins	115.62a	77.48a
	Kent	143.21a	79.25a
	LSD	31.8	**ns**
	CV%	16.2	3.1
	Level of significance (V*S*)	*	**ns**

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, ***** Levels of significance V=Variety and S=Stage.

Table 0.5. Peel and Flesh hue angle (°) of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits harvested at four stages of maturity; stages 1, 2, 3 and 4 in season 2

Maturity stage	Variety	Hue angle peel	Hue angle flesh
1	Van dyke	80.6b	105.3a
	Tommy atkins	98.1b	100.0b
	Kent	144.6a	98.1b
	LSD	39.786	2.5445
	CV%	16.3	1.1
2	Van dyke	84.933a	96.31a
	Tommy atkins	93.987a	91.48b
	Kent	145.553a	85.96c
	LSD	**ns**	1.1311
	CV%	19.9	0.5
3	Van dyke	64.52a	90.68a
	Tommy atkins	110.33a	82.32b
	Kent	137.787a	80.19b
	LSD	**ns**	7.58
	CV%	30.6	4.0
4	Van dyke	71.6c	76.63a
	Tommy atkins	111.7b	72.48b
	Kent	151.3a	69.34c
	LSD	13.147	2.6087
	CV%	5.2	1.6
	Level of significance (V*S*)	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *****Levels of significance. V=Variety and S=Stage.

Plate 1a Plate 1 b Plate 1 c Plate 1d

Plate 0.1. Flesh color changes for 'Kent' variety at maturity stages one to four

Plate 2a Plate 2 b Plate 2 c Plate 2 d

Plate 0.2. Flesh color changes for 'Tommy atkins' variety at maturity stages one to four

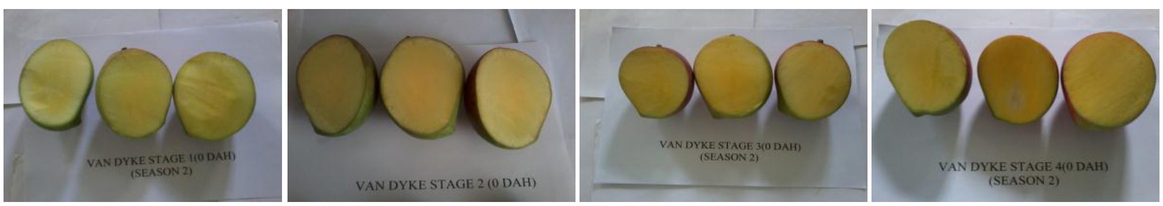

Plate 3 a Plate 3 b Plate 3 c Plate 3 d

Plate 0.3. Flesh color changes for 'Van dyke' variety at maturity stages one to four

3.5.3 Physiological maturity indices

3.5.3.1 Ethylene Production Rate

Ethylene evolution increased gradually with maturity stages as shown in Tables 3.6 and 3.7. Ethylene production was significantly ($p \leq 0.05$) affected by the interaction between variety and stage of maturity. In season 1, ethylene evolution increased from 0.114 µl/kg/hr (early maturity) to 0.3487 µl/kg/hr (advanced maturity) for Van dyke variety and 0.115 µl/kg/hr to 0.3 µl/kg/hr for Tommy Atkins variety. During season 2, Kent variety had the lowest ethylene production rate, 0.1123 µl/kg/hr (stage 1) to 0.2943 µl/kg/hr (stage 4) in all maturity stages ($p \leq 0.05$). There was significance difference ($p \leq 0.05$) among the 3 varieties at maturity stage 3 while there was no significance difference (p≤0.05) between Tommy Atkins and Vandyke varieties at maturity stage 2.

3.5.3.2 Respiration rate

Respiration rate was significantly (p≤0.05) affected by interaction between variety and stage of maturity. As maturity progressed, the respiration rate increased gradually for all the 3 varieties. During season 1, respiration rate increased from 17.97 ml/kg/hr to 34.46 ml/kg/hr during early and advanced maturity respectively for Van dyke variety. During season 2, Kent variety had the lowest respiration rate at maturity stages 2 and 3 (22.69 ml/kg/hr (stage 2) to 25.47 ml/kg/hr (stage 3)) compared to Tommy Atkins and Vandyke (p≤0.05).

Table 0.6. Physiological maturity indices, including; Ethylene evolution (µl/kg/hr) and Respiration rate (ml/kg/hr) of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits harvested at an early and advanced maturity stages in season 1.

Maturity stage	Variety	Ethylene evolution	Respiration rate
Early maturity	Van dyke	0.114a	17.97b
	Tommy atkins	0.115a	20.10a
	Kent	0.112a	20.83a
	LSD	**ns**	1.1847
	CV%	7.1	2.7
Advanced maturity	Van dyke	0.3487a	34.46a
	Tommy atkins	0.3000b	30.83a
	Kent	0.2950b	30.2a
	LSD	0.0307	**ns**
	CV%	4.3	5.6
	Level of significance (V*S*)	*	*

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, ***** Levels of significance. V=Variety and S=Stage.

Table 0.7. Physiological maturity indices, including; Ethylene evolution µl/kg/hr and Respiration rate ml/kg/hr of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits harvested at four stages of maturity; stages 1, 2, 3 and 4 in season 2

Maturity stage	Variety	Ethylene evolution rate	Respiration rate
1	Van dyke	0.1132a	19.04c
	Tommy atkins	0.1145a	21.40a
	Kent	0.1123a	19.82b
	LSD	**ns**	0.6858
	CV%	0.7	1.5
2	Van dyke	0.1660a	23.83ab
	Tommy atkins	0.1637a	25.37a
	Kent	0.1160b	22.69b
	LSD	0.0091	1.8345
	CV%	2.7	3.4
3	Van dyke	0.2830a	28.76a
	Tommy atkins	0.2567b	29.54a
	Kent	0.2187c	25.47b
	LSD	0.0062	1.4025
	CV%	1.1	2.2
4	Van dyke	0.3300a	33.88a
	Tommy atkins	0.3067b	32.10a
	Kent	0.2943b	30.02a
	LSD	0.0198	**ns**
	CV%	2.8	4.1
	Level of significance (V*S*)	*	*

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).
ns -non significance at 5% level, *****Levels of significance. V=Variety and S=Stage.

3.5.4 Biochemical maturity indices

Total soluble solids (TSS), total titratable acidity (TTA) and their ratio were all significantly affected (p≤0.05) by variety and maturity stage in this study. TSS increased with maturity while TTA decreased as the fruits matured. This in turn led to an increase in their ratios as the maturity progressed. During season 1, TSS increased in all the varieties from the range of 7^{o} and 8.097 ^{o} (early maturity) to 13.85 ^{o} and 13.98 ^{o} (advanced maturity). TTA reduced from 0.299% to 0.162% in Van dyke variety and 0.297% to 0.156% in Kent variety. During season 2, TSS in Tommy atkins variety increased from 7.793^{o} (maturity stage 1) to 13.72^{o} (maturity stage 4) while TTA reduced from 0.2360% (maturity stage 1) to 0.1340% (maturity stage 4). Van dyke variety had the lowest TSS and the highest TTA compared to Tommy atkins and Kent varieties.

Table 0.8. Biochemical maturity indices, including; total soluble solids (^{o} brix), titratable acidity (% citric acid) of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits harvested at an early and advanced maturity stages in season 1.

Maturity stage	Variety	Total soluble solids (TSS)	Titratable acidity (TTA)	TSS:TTA
Early maturity	Van dyke	7.000b	0.299a	23.49b
	Tommy atkins	7.320b	0.275a	29.68a
	Kent	8.097a	0.297a	24.75b
	LSD	0.4967	**ns**	3.0960
	CV%	2.9	4.6	5.3
Advanced maturity	Van dyke	13.85a	0.162a	85.49a
	Tommy atkins	13.92a	0.141a	98.72a
	Kent	13.98a	0.156a	89.615a
	LSD	**ns**	**ns**	**ns**
	CV%	1.8	6.3	7.1
	Level of significance (V*S*)	*	*	*

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).
ns -non significance at 5% level, ***Levels of significance. V=Variety and S=Stage.

Table 0.9. Biochemical maturity indices, including; total soluble solids (^{o} brix), titratable acidity (% citric acid) of 'Van Dyke', 'Tommy Atkins' and 'Kent' mango fruits harvested at four stages of maturity; stages 1, 2, 3 and 4 in season 2

Maturity stage	Variety	Total soluble solids (TSS)	Titratable acidity (TTA)	TSS:TTA
1	Van dyke	7.190b	0.2817a	25.57b
	Tommy atkins	7.793a	0.2360b	33.14a
	Kent	7.847a	0.2317b	33.88a
	LSD	0.3590	0.0288	4.9118
	CV%	2.1	5.1	7.0
2	Van dyke	9.89c	0.2090a	47.34c
	Tommy atkins	12.65b	0.1810b	69.97b
	Kent	13.24a	0.1620c	81.98a
	LSD	0.3365	0.0092	5.6525
	CV%	1.2	2.2	3.8
3	Van dyke	12.60c	0.1820a	69.27c
	Tommy atkins	13.40b	0.1447b	92.62b
	Kent	13.77a	0.1387c	99.39a
	LSD	0.3420	0.004	3.1765
	CV%	1.1	1.1	1.6
4	Van dyke	13.88a	0.1473a	94.3b
	Tommy atkins	13.72b	0.1340b	102.5ab
	Kent	13.93a	0.1320b	105.5a
	LSD	0.41	0.0107	8.353
	CV%	0.4	3.4	3.7
	Level of significance (V*S*)	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, *****Levels of significance. V=Variety and S=Stage.

3.6 DISCUSSION

A comparative evaluation was done on various maturity indices for 'Tommy atkins', 'Van dyke' and 'Kent' mango varieties at early and advanced maturity stages during season 1 in the year 2014 and four different maturity stages during season 2 in the year 2015. Computational, physical, physiological and biochemical maturity indices were evaluated at every maturity stage and for each variety. At each maturity stage there were significance differences among the varieties on the various parameters under the maturity indices. Consequently, as maturity of the fruits progressed, significant differences were observed on the same parameters from one stage to another. On the other hand, farmers are currently using subjective maturity indices based on visual features such as fullness of cheek, shoulder development, size and skin color of the fruits (Kosiyachinda *et al*., 1984). These indices are unreliable and prone to errors. It is clear that different mango varieties behave differently as they mature and they also vary in their fruit contents. The knowledge of reliable maturity indices can reduce losses of the fruits at different mango value chain and extend post harvest life of the fruits.

Mango, being a climacteric fruit has to be harvested at the appropriate stage of maturity since the quality and the post harvest life of the fruit depend on the harvest maturity stage (Yahia, 1998). Counting of days after flowering can be useful in determining maturity stages for Tommy atkins, Van dyke and Kent mango varieties but proper records have to be kept for accuracy. Tommy atkins and Kent mango varieties are generally large varieties compared to Van dyke variety as observed in Embu county. However the size of the fruits did not necessarily increase with maturity stages because it could be affected by other factors. Size of fruits depends on the accumulation of water and dry matter during fruit growth (Léchaudel *et al*., 2002). Although fruit size and weight is often used as a maturity index in crops like capsicum, banana, litchi, they are poor measures of fruit maturity since they depend upon a number of variables such as soil and climatic conditions (Indira, 2007).

In the current study, density of the fruits showed fluctuations as the maturity progressed. Van dyke variety was significantly different from Tommy atkins and Kent varieties and this could be attributed to its relatively small size and much less weight (mass) compared to Tommy atkins and Kent varieties. Specific gravity in mango fruit can vary from year to year (Salunkhe *et al*., 1995). Harding (1992) observed too much inconsistency in specific gravity in mango varieties and concluded that it could not be used as a criterion to predict maturity. However fruits such as cherries and watermelons have been reported to have their specific gravity increasing as they mature (Sudheer, 2007).

Peel and flesh color changes of the fruits were influenced by variety and maturity stage. In the current study, skin/peel color hue angle was significantly different among the varieties. Kent variety had a skin color which ranged between warm green and cool yellow depending with maturity stage. Tommy atkins had skin color ranging from warm green, yellow green, lime and cool yellow while Van dyke variety had a skin color ranging from lime, yellow green, cool yellow and mid yellow. This shows unreliability on the skin color as a maturity index. Flesh color hue angle gradually decreased as the maturity progressed in all the varieties. As maturity progressed, flesh color changed from yellow green to lime to cool yellow to mid yellow depending on the variety and stage of maturity. Color is the most important initial impression by a consumer of any food product. Hue is the actual color and it depict a visual sensation according to which an area appears to be similar to one or two of the perceived colors; red, yellow, green and blue (McGuire, 1992). Skin color is observed after the fruit has started to soften, and is usually inconsistent in several mango cultivars. Skin color is also affected by cultural practices and environmental conditions (Harold, 2014). Soil nutrients and management which is inclusive of method of irrigation have an effect on tree and foliage growth which affects fruit qualities such as skin color, yield and soluble solids contents on 'golden delicious' apples (Gormley *et al*., 1982). Pruning can be used very effectively to improve light penetration thereby increasing fruit color throughout the canopy (Michael, 2005). Increased light exposure during fruit growth and development enhances formation of color pigments including anthocyanins and carotenoids (Mercadante *et al*., 1998). Ouma (2015) also reported higher hue angles on fruits harvested from a semi-arid and low potential AEZ compared to a sub-humid and high potential AEZ. Objective measurement of color requires expensive equipment and although the human eye is unable to give a good evaluation of a single color, it is extremely sensitive to differences between colors. Digital color examination is now used in the sorting of mechanically harvested processing tomatoes (Adel, 2002). Therefore, skin color should not be considered as an adequate maturity index.

Peel and flesh firmness reduced as maturity progressed. Kent variety was more firm at maturity stage 1 while at maturity stage 4, Tommy atkins variety was least firm. The firmness of the skin and flesh is strongly depended on the maturity stage. Firmness is a measure of hardness of the mango fruit and it plays a crucial role in postharvest activities like stacking, packaging, transportation and perishability arising from mechanical damages. The fruit is best harvested, transported to the point of use at the maturity stages 1 and 2 when it is firmer and less prone to mechanical injury. The softer the fruit, the more prone it is to mechanical damage when external pressure is applied. Fruit firmness decreases with fruit maturity and fruit ripening. The primary cell wall is composed of numerous polymers. The decrease in firmness with maturity is attributed to steady solubilization of protopectin in the cell wall to form pectins (Tridjaja *et al*., 2000). Skin and flesh firmness varies with different mango varieties. The outer mesocarp of 'Keitt' mango variety remained firm longer than 'Tommy atkins' mango variety and the 'Keitt' variety accumulates more soluble polyuronides and retains more total pectin at the ripe stage than 'Tommy atkins' (Mitcham *et al*., 1992). Flesh firmness is useful in parameter processing. The firmer the flesh of the fruit, the more suitable they are for processed products like mango slices, chips nectar, jam and other preserves. Kent variety would produce better chips, slices or pickles compared to the Tommy Atkins and Van dyke varieties. The softer it is at stage 4, the better it is in making products like mango fruit juices. Therefore, firmness is an important maturity index for mango fruits.

Ethylene evolution rate and respiratory rate increased as maturity progressed in 'Van dyke', 'Tommy atkins' and 'Kent' varieties in the current study. However, these rates varied with the different varieties and maturity stages. Ethylene is a natural plant hormone (phytohormone) associated with the growth, development, ripening and aging of many plants (Yahia, 2008). Respiration on the other hand converts stored sugars or starch to energy and the rate increases with fruit maturity. Climacteric fruits such as mango show a notable increment in respiration rate during maturation (Nirmal, 1995). Respiration rate and ethylene evolution follow a distinct pattern in climacteric fruits such as mango and can therefore be used to establish the stage of maturity (Kanellius, 1997). Ethylene evolution and respiratory activity begins to rise gradually as climacteric fruits mature and begin to ripen. Ethylene production is low in unripe mango fruit (Burdon *et al*., 1996) and it decreases as the fruit matures; then undetectable for a time and reappears upon ripening stage (Akamine *et al*., 1973). The commencement of ethylene production within the fruit coordinates the changes that occur during ripening. These changes include color changes in the peel and flesh, softening of the flesh, and development of aroma (Brecht *et a.,l* 2009). Physiological maturity indices can therefore be used to determine the maturity stage of the fruit depending with the variety.

Total Soluble Solids (TSS) increased as maturity progressed in all the varieties while Total Titratable Acidity (TTA) decreased with maturity in all the varieties. This in turn led to an increase in the ratio between TSS and TTA as maturity progressed. Kent variety was established to have a higher ratio compared to Van dyke and Tommy atkins varieties. TSS and TSS: TTA ratio provides more consistent markers of the right harvest maturity (Crisosto *et al*., 2001). Slaughter *et al*., (2003) reported a non- destructive optical method that can be engaged successfully using near infra red spectroscopy to determine TSS contents in fresh prune. The increase in the TSS: TTA ratio as maturation progresses is as a result of accumulation of sugars and organic acids as well as, hydrolysis of polysaccharides and decreased acidity (Tover *et al*, 2000). From this study it is clear that different varieties have different TSS and TTA contents at different maturity stages hence the observed differences in the TSS:TTA ratio. Therefore, TSS, TTA and TSS:TTA ratio can be used to determine maturity of different varieties.

This study established that different varieties have different physical, physiological and biochemical attributes in their maturity. The study revealed that Kent variety has a prolonged maturity stage 2 hence it attains maturity stages 3 and 4 much later after Tommy atkins and Vandyke varieties have already reached tree ripe stage. Kent variety is hence a late maturing variety. Therefore there can be prolonged supply of mangoes if Kent can be grown alongside early maturing varieties such as Tommy atkins. When harvesting mangoes, the market and fruit usage should be put into consideration. Fruits harvested at stages 1 and 2 should not be used for processing as their TSS: TTA ratios are low but they can be used for far flung markets as their ripening will be longer compared to stages 3 and 4. There is need also to determine maturity indices for other mango varieties and in other locations especially those with different climatic conditions.

CHAPTER FOUR

4 EFFECT OF HARVEST MATURITY ON THE QUALITY ATTRIBUTES OF FRESH AND DRIED MANGO PRODUCTS

4.1 ABSTRACT

Mangoes are fruits with a highly noteworthy economic importance. Harvest maturity affects the fruit's quality attributes and the post harvest shelf life at various stages of mango value chain. The objective of this study was to determine the effect of harvest maturity on the quality attributes of fresh and dried products of three commercial mango varieties; 'Van dyke', 'Kent' and 'Tommy Atkins'. The study was carried out between August 2014 and March 2016 in Embu County, which is a medium altitude, high potential agro-ecological zone of Kenya. The varieties were harvested at 4 different maturity stages (1, 2, 3 and 4) based on the flesh color as the index of maturity. For each maturity stage and each variety, a random sample of 10 fruits were analysed for nutritional qualities which included Vitamin C, β- carotene, major sugars (fructose, glucose and sucrose) and minerals (potassium, calcium, iron, magnesium and sodium) at harvest. The same attributes were evaluated at regular intervals of 3 days until a pre-determined end stage to determine ripening and quality related changes during storage. Additionally, fresh fruits that were harvested at maturity stages 3, 4 and tree ripe were processed into juice and solar dried products. The products were evaluated for juice color, juice pH, Vitamin C, β-carotene, minerals, major sugars, firmness and moisture content. The fruits were diced and subjected to sensory evaluation by 34 untrained panellists at the tree ripe stage and the end stages of maturity stages 3 and 4. Data collected was analyzed using Genstat statistical package 13th edition. Means were separated using Fisher's protected Least Significance Difference (LSD) at $P \leq 0.05$. The sensory evaluation data was analyzed using Statistical Package for the Social Sciences (SPSS). The results showed that vitamin C, potassium, magnesium, calcium, iron and sodium reduced significantly ($p \leq 0.05$) while β-carotene and the sugars increased significantly ($p \leq 0.05$) with advancing maturity and ripening process. During maturity stage 1, Van dyke variety had the highest vitamin C content of 51.82 mg/100g at the end of ripening period. Kent had the highest levels of β- carotene, 13.354 mg/100g, at the end of ripening of fruits harvested at maturity stage 4. Kent variety had also higher levels of fructose, sucrose and glucose contents compared to Tommy Atkins and Van

dyke varieties. Dried products on the other hand had lower levels of ascorbic acid content and higher sugars levels compared to fresh products. Kent variety had the highest vitamin C level of 29.56 mg/100g of the dried slices at tree ripe stage. The moisture content was significantly different ($p \leq 0.05$) among the varieties. Van dyke variety had the lowest moisture content of 10.33% and 14.13% at maturity stages 3 and tree ripe stage respectively. Generally, tree ripe stage and Van dyke variety were most preferred by the panelists. The findings reveal the significant effect of harvest maturity and variety on the nutritional quality of fresh and dried products. The results confirm the importance of harvest maturity as a major consideration for the different uses of mango fruits.

Key words: mango, maturity stage, nutritional qualities, shelf life.

4.2 INTRODUCTION

Mango fruit is an important fruit crop and its production has been on the increase due to increased demand for fresh market fruits, processing and health concerns. The quality as well as the postharvest life of the fruit is influenced by the stage of maturity at harvest (Anjum *et al*., 2006; Jha *et al*., 2007). Harvesting at the right maturity is an important step which determines the potential shelf life, flavor and consumer acceptance of mango fruits (Seymour *et al* 1990). The best quality, taste and flavor of mango can only be assured when fruits are harvested after attaining physiological maturity (Reid, 2002; Slaughter, 2009). There is increasing appreciation that quality means more than just taste, texture and appearance. The nutritional properties of fruit and perceived health benefits like antioxidants (minerals such as iron) are becoming factors in consumer preference (Michael, 2002).

The physiological and biochemical activities of over mature fruits differ from that of mature ones in terms of respiration rate, transpiration, conversion of starch to sugars and storage life (Kader *et al*., 2002). The harvesting stage influences the quality of the fruit such taste and flavor of the variety which cannot be attained unless the fruits are harvested at the right stage of maturity. However, depending with the marketing demand, fruits can be harvested at any maturity stage. As a result, some traders, especially those targeting export and far flung markets harvest mango fruits at early (and often premature stage) to ensure longer shelf life and marketing period. At the destination, such fruits are often forced to ripen using ethylene.

Such fruits may attain the desirable physical attributes such as color and firmness but have inferior sensory and nutritional quality (Sivakumar, 2011).

Various maturity indices have been applied to judge the mango fruit maturity and they include computational, physical, physiological and biochemical maturity indices. Farmers also use subjective maturity indices / visual judgement based on size, peel colour, peel gloss, shoulder elevation, receding 'nose' and fullness of 'cheeks'. Computational method involves counting of number of days from full bloom (DFFB) or fruit set to reach physiological maturity and it varies among cultivars and locations and therefore it should be restricted within a small geographical area (Obasi *et al*., 2004). Physical indices include peel and flesh color, peel and flesh firmness, specific gravity and size. Physiological indices include respiration and ethylene evolution rates while biochemical maturity indices include total soluble solids (TSS) and total titratable acidity (TTA).

During the maturation and ripening of mangoes several important metabolic changes occur and some of those can be used as maturity indices (Ketsa *et al*., 1991). During maturation and ripening, mango fruit undergo a substantial loss of organic acids (Medlicott *et al*., 1985). Mango fruits are a rich source of Vitamin C, but the content decreases during ripening (Vinci *et al*., 1995). Soluble sugars increases as ripening progresses. Similarly, carotenoids concentration increases with fruit ripening resulting to a deep yellow to orange color in mango fruit pulp (Brecht *et al*., 2009). The carotenoid level is also cultivar dependent (Medlicott *et al*., 1988). As mango fruits mature and ripen, there are significant changes in mineral nutrients. The level of mineral nutrients is affected by production location, variety and stage of maturity. Magnesium, calcium and potassium levels decreased gradually in 'Apple' and 'Ngowe' mango varieties as they matured and as the ripening process progressed (Ouma, 2015). Mayer (1997) reported a trend towards lower mineral and dry matter content in fruits, and the most significant reductions were in the levels of magnesium, iron, copper and potassium. Waxes which develop on the epidermis of fruit in the later stages of development serve as a protective later from water loss after harvest. Therefore fruits that are harvested prematurely before development of this waxes often have poor keeping quality dry up faster compared with those harvested at a more advanced stage of development (Yahia, 2006). The quality of mangoes may also be affected by temperature and relative humidity during ripening (Hui, 2006).

Processing mango fruits into shelf-stable products such as juices and other dehydrated/dried products has now been adopted as one strategy to reduce postharvest losses. The quality of such products is significantly affected by the quality of the fruits used. Mango fruits undergo various compositional changes as they mature and ripen. These compositional changes not only affect the fresh quality of the fruits but also resultant processed products. The final quality of processed fruit products is determined by the quality at the start of processing (Kader, 2005). Nutritional qualities such as Vitamins, β-carotene, minerals and sugars change as the fruits mature and they are also affected by drying. Ascorbic acid reduces as fruit advance in maturity (Ouma, 2015). Similarly, the destruction of the ascorbic acid increases during air drying, especially at high temperature (Hui, 2008). As fruit maturity advances, sucrose, fructose and glucose contents increases and this are further concentrated through drying the products (Vaughan, 2003).

The quality of the final dried product is the most important factor in the drying technology (Hui 2006). Direct exposure of products to the sun decrease the quality factors like vitamin preservation. The use of solar energy in an indirect way could improve the quality of the final product (Jayaraman *et al*., 1992). Solar dried products are cost-effective solution to food preservation in hot climate as they reduce storage and transportation costs as well as associated problems due to climatic effects (Whitfield, 2000). The dried mango slices keep good sensory and physicochemical quality for at least 12 months without any visible sign of discoloration. Fully ripened mangoes with well developed flavour, colour and texture are perfect for processing into products such as juices and pulps. On the other hand, immature green mangoes can be made into chutneys, pickles and refreshing mango beverages (Hui, 2006).

4.3 MATERIALS AND METHODS

4.3.1 Experimental set up and sampling

Three mango varieties, namely ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’, were harvested from Embu County at early and advanced maturity stages between the month of December of the year 2014 to the month of March of the year 2015 (season 1) and at five different maturity stages between the month of December of the year 2015 to the month of March of the year 2016 (season 2). The earliest acceptable maturity stage (mature green stage) was judged by flesh color; yellowing of the flesh around the seed and was established for each variety as stage 1. Subsequent stages (stage 2, 3 and 4) were determined at regular intervals, 7-10 days.

Early and advanced maturity stages were selected because most fruits destined for far or export markets are harvested at early maturity stages, for they can last longer; while fruits destined for near or domestic markets are harvested at advanced maturity stages. Depending on the demand of the target market along the value chain, growers may harvest at either early or advanced maturity stages and opt to utilize the fruits fresh from the tree (initial stage) or ripen them to a pre determined stage (end stage).

The fruits were packed in plastic crates which were covered with wet old newspapers and transported to a postharvest laboratory in Jomo Kenyatta University of Agriculture and Technology. The fruits were then washed using cold water treated with 1% acetic acid for disinfection and then left to air-dry.

During season 1, the initial measurements of nutritional qualities were analysed for fruits harvested at early and advanced maturity stages. The quality attributes analysed included Vitamin C, beta-carotene, major sugars (fructose, glucose and sucrose) and minerals (potassium, calcium, iron, magnesium and sodium). The fruits were then left to ripen at ambient room conditions (60±5% relative humidity and temperature $25^{o}C \pm 1^{o}C$) to a pre-determined end stage for each variety at which the same quality attributes were again analysed. During season 2, nutritional quality attributes (as in season 1) were evaluated at four different maturity stages. The fruits were then left to ripen at ambient room conditions. After every three days, 3 fruits (each maturity stage and variety), were sampled for measurement of the same quality changes during storage until the pre-determined end stage.

Fresh fruits harvested at maturity stages 3, 4 and tree ripe, for each variety, were used to determine quality attributes of processed products during the months of February and March. .Juice was blend from 3 fruits which were sampled out from each batch and analysed for color (hue angle) and pH. Another random sample of fruits from each batch was peeled and cut into 2-3 mm thick chips. The chips were then arranged on trays and loaded into a small scale green house solar dryer (figure 4.1). The drying conditions in the solar drier were; average temperature of $45^{o}C$, relative humidity ranged between 21.8% to 63.5 % depending on the moisture content of the slices and the prevailing temperature. The average air speed was 4m/s. The ambient temperature conditions ranged between 25°C to 30 °C (high temperatures) and 17°C to 20 °C (low temperatures). The trays were removed once the sampled mango slices had achieved at least 10% moisture content. The dried mango slices were analyzed for nutritional quality and physical attributes including color, moisture content and firmness. A separate batch of fruits (stages 3 and 4) were left to ripen to a pre determined stage (as the tree-ripened fruits) and together with freshly harvested tree-ripened fruits for each variety, they were diced and subjected to 34 untrained panelists for evaluation of sensory quality attributes.

Figure 4.1. Polythene green house solar drier

The experimental design used was Completely Randomized Design (CRD) with a factorial arrangement. The factors were three varieties ('Tommy atkins', 'Van dyke' and 'Kent') and four stages of maturity.

4.3.2 Determination of nutritional, physical and sensory quality attributes of fresh mango products

4.3.2.1 Ascorbic Acid content

Ascorbic acid content was determined by visual titration according to AOAC methods (1996). Five milliliters of the juice was topped up with 10% trichloroacetic acid (TCA) in 100ml volumetric flask. The indicator used (2, 6-dichlophenolindophenol) was titrated into 10ml of the fruit juice extracted until pink color appeared. Ascorbic acid content was calculated as follows:

Ascorbic acid (mg/100g) = (A-B) X C X 100/S X (50/5)

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 (in ml)

4.3.2.2 Beta- carotene

The β-carotene content was determined by a modified chromatographic procedure (Heionen, 1990). A sample of 5g was crushed in a pestle with a mortar. A spatula of hydroflorosupercel was then added and then extracted using 50ml cold acetone and filtered using glass funnel until the residue became white. Partitioning was done using 25ml of petroleum ether in a separating funnel. Saponification was then done by adding an equal amount of extract into 3ml of 10% KOH in methanol, and a few drops of 0.1% butylatedhydrotoluene in petroleum ether. Sodium sulphate (anhydrous) was added to remove water and further concentration was done using a rotary evaporator. The ß-carotene content was determined using HPLC (Model LC-10AS, Shimadzu Corp., Kyoto, Japan), having the following conditions; Mobile phase: acetonitrile: methanol: dichloromethane (70: 10: 20);, Flow rate: 1.0 ml/min; , Column: ODS 150; ,Injection volume: 10µL; ,Oven temperature: 35 ^{o}C. The β−carotene content was calculated as follows:

β−carotene (mg/100g) = A×Volume (ml) × 104

A1%1cm×sample weight (ml)

Where A= absorbance; volume = total volume of extract (25 ml); A1%1cm = absorption coefficient of β−carotene in PE (2592).

4.3.2.3 Major sugars (fructose, glucose and sucrose)

Sugars were analyzed using AOAC method (1996). Ten grams of the sample was completely blended and 96% ethanol was then added. Refluxing was done for one hour at 100^{o}C and then cooled under running water. The solution was filtered using 42mm whatman filter paper. Rinsing was done using 5ml of 96%ethanol. The solution was rotary evaporated to dryness at 60^{o}C. 5 ml of 50% acetonitrile (ACN) was added and finally micro-filtered (0.45µl). The individual sugars were analyzed using a high performance liquid chromatography (HPLC) (Model LC-20AS, Shimadzu Corp., Kyoto, Japan) fitted with a refractive index detector (RID) and running under the following conditions: Oven temperature: 30^{o}C, Column : NH_2 (5.0 µl) Flow rate: 0.5-1.0 ml/min, Injection volume: 20 µl Mobile phase: Acetonitrile: water (75:25).

The sugars present were identified and their individual concentration calculated using the standards.

4.3.2.4 Mineral nutrients (Potassium, Calcium, Magnesium, Iron and Sodium)

Minerals were analysed using the AOAC (1996) method. Five grams of the pulp was charred in the oven for 30 minutes then put in a muffle furnace at 550°C for eight hours to ash. The ash was allowed to cool and diluted with 10ml of 1N hydrochloric acid. The mixture was then filtered and diluted with 100ml of distilled water. Calcium, Magnesium and iron were analysed using atomic absorption spectrophotometer (Model AA-6200, Shimadzu Corp., Kyoto, Japan) while Potassium and Sodium were analyzed using flame emission photometer (Model FA- 410, Shimadzu Corp. Kyoto, Japan).

4.3.2.5 Juice pH

The acidity or alkalinity of the juice was determined using pH meter (HANNA instruments HI 8519N USA)

4.3.2.6 Juice hue angle

The color of the extracted juice from the 3 mango varieties at maturity stages 3 and 4 were measured as shown in section 3.3.2.3.4

4.3.2.7 Sensory quality evaluation

Fruits harvested at maturity stages 3 and 4 were ripened to the same ripeness as the tree-ripened fruits which were freshly harvested for evaluation of sensory quality of the fruits. The fruits were separately diced and placed on white sensory plates which were incognito coded based on maturity stage (stage 3, stage 4 and tree ripe stage) and variety (‘Kent’ ‘Van dyke’ and ‘Tommy atkins’). A panel of 34 untrained judges was guided on the scoring procedure for various sensory attributes which included color, texture, sweetness, acidity, taste/flavor, mouth feel, succulence and general acceptability. The panelists scored for these attributes on a seven point hedonic scale where 1 = dislike extremely (worst), 2 = (dislike very much), 3 = (dislike moderately), 4 = (neither like nor dislike), 5 = (like moderately), 6= (like very much) and 7= (Like extremely (best).

4.3.3 Determination of nutritional and physical quality attributes of dried mango products

4.3.3.1 Ascorbic Acid content

Ascorbic acid content was determined by visual titration according to AOAC methods (1996) as described in section 4.3.2.1

4.3.3.2 Beta carotene

The β-carotene content was determined by a modified chromatographic procedure (Heionen, 1990) outlined in section 4.3.2.2

4.3.3.3 Mineral content

Minerals were analysed using the AOAC (1996) method as shown in section 4.3.2.4

4.3.3.4 Major sugars (fructose, glucose and sucrose)

Sugars were analyzed using AOAC method (1996) described in section 4.3.2.3

4.3.3.5 Hue angle

The color of dried slices of the 3 mango varieties at maturity stages 3 and 4 were measured using the Minolta color difference meter as described in section 3.3.2.3.4

4.3.3.6 Firmness

Firmness of the dried slices was determined from 3 sampled slices for the 3 varieties and the 2 maturity stages as shown in section 3.3.2.3.3

4.3.3.7 Moisture content

The dried slices were initially weighed (W_o) per variety and maturity stage and put in a preheated oven at 105^{o}C for 8 hours and were then weighed again (W_1). The amount of moisture content in the slices was calculated as follows;

% moisture content = $(W_o – W_1/W_0)$ x 100

4.4 STATISTICAL ANALYSIS

Data was analyzed using Genstat statistical package 13th edition. Comparison of means was done by Analysis of Variance (ANOVA) and Fisher's Protected Least Significance Difference (LSD) at $P \leq 0.05$. The sensory evaluation data was analyzed using Statistical Package for the Social Sciences (SPSS).

The data is presented as tables and graphs based on variety and stage of maturity for 2 consecutive seasons.

4.5 RESULTS

4.5.1 Changes in nutritive quality attributes

4.5.1.1 Ascorbic Acid (Vitamin C)

As maturity and ripening of the mangoes progressed, the levels of ascorbic acid (Vitamin C) reduced in all the varieties. During season 1, ascorbic acid content reduced as maturity progressed and was significantly (p≤0.05) different in both early and advanced maturities among the varieties. At the end of ripening period, fruits harvested at advanced maturity stage had ascorbic acid content ranging between 23.47 mg/100g and 30.65 mg/100g. Kent variety had the highest Vitamin C content which ranged between 47.78 mg/100g to 115.78 mg/100g and 30.65 mg/100g to 49.09 mg/100g at the early and advanced maturities respectively. In season 2, ascorbic acid content was also significantly affected by maturity and ripening processes. Ascorbic acid content reduced with maturity from 145.7 mg/100g (maturity stage 1) to 59.47 mg/100g (maturity stage 4). Ascorbic acid content was significantly (p≤0.05) different among the varieties. Tommy atkins variety had the lowest levels of Vitamin C compared to Van dyke and Kent varieties. Vitamin C content in Tommy atkins variety, at maturity stage 1 reduced from 96.29 mg/100g to 35.13 mg/100g at the end of ripening while at maturity stage 4, Vitamin C content reduced from 35.88 mg/100g to 24.81 mg/100g at the end of ripening period.

Table 4.1. Initial and end stage ascorbic acid content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	114.46a	48.77a	40.20b	29.07a
Tommy atkins	95.36b	28.88b	33.88c	23.47b
Kent	115.78a	47.78a	49.09a	30.65a
LSD	1.51	1.198	1.603	1.76
Significance level (V*S)	*	*	*	*
CV%	0.5	0.97	1.0	1.3

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage

Table 4.2. Changes in ascorbic acid content (mg/100g) of ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Maturity stage	Days after harvest Variety	0	3	6	9
1	Van dyke	115.45a	93.35a	68.42a	51.82a
	Tommy atkins	96.29b	75.67c	47.62c	35.13c
	Kent	116.12a	88.29b	64.24b	49.97b
	LSD	2.011	1.188	1.884	1.1
	CV%	0.7	0.4	0.8	1.0
2	Van dyke	91.54b	80.76a	62.59a	47.56a
	Tommy atkins	78.30c	64.42c	42.17c	28.24c
	Kent	92.64a	78.14b	54.94b	41.38b
	LSD	1.055	2.078	1.383	0.686
	CV%	0.4	0.8	0.7	0.4
3	Van dyke	79.32a	73.61a	50.81a	36.24a
	Tommy atkins	65.27c	47.31c	37.14c	29.90b
	Kent	76.77b	64.68b	47.76b	35.83a
	LSD	2.448	1.319	2.039	2.359
	CV%	1.0	0.6	1.1	1.7
4	Van dyke	43.54b	37.69b	34.04b	30.23a
	Tommy atkins	35.88c	32.27c	29.35c	24.81b
	Kent	49.74a	42.57a	38.39a	31.71a
	LSD	0.910	2.211	2.577	2.146
	CV%	0.6	1.5	1.9	1.8
	(V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).
ns -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

4.5.1.2 Beta – carotene

Beta carotene levels increased as maturity and ripening progressed in ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango varieties during both seasons. The levels were however significantly different ($p \leq 0.05$) among the varieties. During season 1, the end stage of ripening had the highest β- carotene levels in both early and advanced maturities. Beta carotene levels during advanced maturity ranged from 5.155 mg/100g to 12.553 mg/100g while during early maturity. β- carotene levels ranged from 0.747 mg/100g to 3.199 mg/100g. Kent variety had the highest β- carotene levels in both early and advanced maturity compared to Van dyke and Tommy atkins varieties. Initial and end-stage β-carotene levels ranged from 1.473 mg/100g to 3.199 mg/100g and 5.643 mg/100g to 2.553 mg/100g during early and advanced maturity for ‘Kent’ variety respectively. During season 2, β- carotene levels increased from maturity stage 1 to maturity stage 4 and also as ripening progressed until end stage. Beta carotene levels were significantly different ($p \leq 0.05$) among the varieties except during the initial measurements at maturity stage 2 and the end stage of maturity stage 3. Initial β- carotene levels ranged from 0.748 mg/100gto 1.52 mg/100g at maturity stage 1 and 5.539 mg/100g to 6.136 mg/100g at maturity stage 4. At the end of ripening period, β- carotene levels ranged from 2.103 mg/100g to 3.270 mg/100g at maturity stage 1 and 12.476 mg/100g to 13.354 mg/100g at maturity stage 4. Kent variety had the highest β- carotene content which ranged from 1.52 mg/100g to 13.354 mg/100g

Table 4.3. Initial and end stage β- carotene content (mg/100g) of ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	0.747c	1.986c	5.155a	11.812b
Tommy atkins	1.236b	3.174b	5.373a	11.812b
Kent	1.473a	3.199a	5.643a	12.553a
LSD	0.0078	0.0365	**ns**	0.59
CV%	0.2	0.3	2.3	1.5
Levels of Significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.4. Changes in β - carotene content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Maturity stage	Days after harvest / Variety	0	3	6	9
1	Van dyke	0.748c	0.827c	1.527b	2.103b
	Tommy atkins	1.202b	1.307b	1.313c	3.220a
	Kent	1.520a	1.581a	1.619a	3.270a
	LSD	0.01090	0.01578	0.0985	0.074
	CV%	0.3	0.4	1.7	1.5
2	Van dyke	1.924a	2.430b	3.582b	6.447b
	Tommy atkins	1.808a	2.467b	3.635b	6.288b
	Kent	1.961a	2.748a	4.429a	7.104a
	LSD	**ns**	0.3076	0.3984	0.5671
	CV%	3.9	3.6	2.7	2.1
3	Van dyke	2.477b	3.474b	6.720b	10.634a
	Tommy atkins	2.965a	3.664b	6.612b	10.612a
	Kent	3.372a	4.018a	8.346a	10.441a
	LSD	0.5023	0.1458	0.2662	**ns**
	CV%	5.2	1.1	0.9	1.0
4	Van dyke	5.670b	9.115b	12.138c	12.586c
	Tommy atkins	5.539b	9.063c	12.431b	12.476b
	Kent	6.136a	10.679a	13.314a	13.354a
	LSD	0.4712	0.0812	0.1795	0.1085
	CV%	2.2	2.2	0.8	0.2
	Levels of significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.1.3 Major sugars

4.5.1.3.1 Fructose

Fructose content significantly (p≤0.05) increased with advancement of maturity and ripening processes. During season 1, fructose content increased with maturity from 0.98 mg/100g to 2.72 mg/100g. At the end of ripening period, fructose content increased from ranges between 2.085 mg/100g to 3.368 mg/100g. Fructose content was significantly different (p≤0.05) among the varieties. At advanced maturity, Kent variety had the highest amount of fructose which ranged from 2.720 mg/100g to 3.368 mg/100g. During season 2, fructose content increased from 0.992 mg/100g to 2.283 mg/100g at the end of ripening for fruits harvested at maturity stage 1. At maturity stage 4, fructose content increased from 2.689 mg/100g to 3.453 mg/100g at the end of ripening period. Fructose content was significantly different (p≤0.05) among the varieties at various maturity stages. Tommy atkins variety had the highest fructose content at the end of ripening of fruits harvested at maturity stage 1, which was 2.283 mg/100g. Van dyke variety had the lowest amount of fructose compared to Tommy atkins and Kent varieties at maturity stage 4, which ranged between 2.689 mg/100g to 3.329 mg/100g at the beginning and end of ripening period respectively.

Table 4.5. Initial and end stage fructose content (mg/100g) of ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	0.982b	2.085c	2.659b	3.254b
Tommy atkins	1.038a	2.259a	2.691b	3.270b
Kent	0.980b	2.212b	2.720a	3.368a
LSD	0.02	0.04	0.06	0.035
Levels of Significance (V*S)	*	*	*	*
CV%	2.7	3.2	5.1	3.9

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, ***Levels of significance V=Variety and S=Stage.

Table 4.6. Changes in fructose content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Maturity stage	Days after harvest Variety	0	3	6	9
1	Van dyke	0.992a	1.592a	1.796b	2.174c
	Tommy atkins	1.061a	1.589a	1.852a	2.283a
	Kent	0.996a	1.536a	1.777b	2.223b
	LSD	**ns**	**ns**	0.009	0.034
	CV%	0.3	0.6	0.8	0.4
2	Van dyke	1.665c	2.112c	2.473a	2.680c
	Tommy atkins	1.692b	2.142b	2.534a	2.825b
	Kent	1.749a	2.181a	2.592a	2.893a
	LSD	0.023	0.002	**ns**	0.0615
	CV%	0.6	0.8	0.7	0.5
3	Van dyke	2.254c	2.648b	2.675c	2.817b
	Tommy atkins	2.352b	2.706a	2.814b	2.896b
	Kent	2.423a	2.705a	2.836a	2.930a
	LSD	0.028	0.0841	0.01	0.0086
	CV%	0.4	0.9	3.1	0.9
4	Van dyke	2.689b	2.978a	3.272c	3.329c
	Tommy atkins	2.745a	2.977a	3.342b	3.410b
	Kent	2.791a	2.960a	3.376a	3.453a
	LSD	0.0705	**ns**	0.012	0.021
	CV%	0.7	0.6	1.1	0.2
	Levels of significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, ***Levels of significance V=Variety and S=Stage

4.5.1.3.2 Glucose

Glucose content significantly ($p \leq 0.05$) increased with advancement of maturity and ripening processes. During season 1, glucose levels increased as maturity progressed. Glucose levels ranged between 0.873 mg/100g to 0.954 mg/100g and 1.022 mg/100g to 1.212 mg/100g at the beginning of ripening of fruits harvested at early and advanced maturity stages. Glucose content was significantly ($p \leq 0.05$) different among the varieties. Van dyke variety had the lowest amount of glucose at both early and advanced maturities which ranged increased from 0.873 mg/100g to 1.103 mg/100g at the end of ripening period, during early maturity. During season 2, initial glucose content ranged between 0.836 mg/100g to 0.952 mg/100g at maturity stage 1. At maturity stage 4, initial glucose content ranged between 1.046 mg/100g to 1.287 mg/100g compared to 2.289 mg/100g to 2.7 mg/100g at the end of ripening. Glucose content was significantly ($p \leq 0.05$) different among the varieties. Kent variety had significantly ($p \leq 0.05$) higher amount of glucose compared to Tommy atkins and Vandyke varieties. Kent variety had glucose levels which increased from 0.952 mg/100g to 1.326 mg/100g at the end of ripening of fruits harvested at maturity stage 1 and 1.287 mg/100g to 2.7 mg/100g at the end of ripening of fruits harvested at maturity stage 4.

Table 4.7. Initial and end stage glucose content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	0.873c	1.103c	1.022b	2.236c
Tommy atkins	0.906b	1.166b	1.095b	2.364b
Kent	0.954a	1.291a	1.212a	2.667a
LSD	0.02	0.05	0.11	0.1112
Levels of Significance (V*S)	*	*	*	*
CV%	5.7	4.8	2.9	4.2

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, ***** Levels of significance V=Variety and S=Stage.

Table 4.8. Changes in glucose content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Maturity stage	Days after harvest / Variety	0	3	6	9
1	Van dyke	0.836c	1.052c	1.083c	1.120c
	Tommy atkins	0.896b	1.097b	1.134b	1.210b
	Kent	0.952a	1.114a	1.178a	1.326a
	LSD	0.02618	0.02337	0.01125	0.051
	CV%	1.0	0.9	1.2	3.0
2	Van dyke	0.893c	1.171c	1.260c	1.318c
	Tommy atkins	0.923b	1.246b	1.395b	1.430b
	Kent	0.972a	1.301a	1.451a	1.666a
	LSD	0.0199	0.01851	0.0715	0.05125
	CV%	0.7	0.4	1.4	0.8
3	Van dyke	0.990c	1.372c	1.699c	1.806c
	Tommy atkins	1.078b	1.459b	1.744b	1.909b
	Kent	1.172a	1.728a	1.829a	2.267a
	LSD	0.03023	0.02389	0.06045	0.02724
	CV%	0.9	0.5	0.9	0.3
4	Van dyke	1.046c	1.534c	2.002c	2.289c
	Tommy atkins	1.144b	1.645b	2.150b	2.387b
	Kent	1.287a	1.817a	2.291a	2.700a
	LSD	0.03421	0.03890	0.05125	0.06185
	CV%	0.8	0.6	0.6	0.6
	Levels of significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.1.3.3 Sucrose

Sucrose content was significantly ($p \leq 0.05$) affected by maturity stage and varietal differences. During season 1, sucrose content increased as maturity of the fruits progressed. At early maturity sucrose content ranged between 1.625 mg/100g to 1.748 mg/100g at the beginning of ripening while at advanced maturity, sucrose content ranged between 2.586 mg/100g to 2.681 mg/100g at the beginning of ripening. Sucrose content was significantly different ($p \leq 0.05$) among the varieties. Kent variety had the highest amount of sucrose at advanced maturity, which ranged between 2.681 mg/100g to 3.44 mg/100g. During season 2, sucrose content increased from 0.934 mg/100g to 2.131 mg/100g from maturity stage 1 to maturity stage 4 respectively. Sucrose content was significantly different ($p \leq 0.05$) among the varieties. At maturity stage 1, Van dyke variety had the lowest sucrose content compared with Tommy atkins and Kent varieties, which increased from 0.934 mg/100g to 1.695 mg/100g at the end of ripening period of maturity stage 1.

Table 4.9. Initial and end stage sucrose content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	1.720a	2.216b	2.608b	3.373c
Tommy atkins	1.748a	2.240a	2.586c	3.391b
Kent	1.625b	2.249a	2.681a	3.440a
LSD	0.04	0.015	0.011	0.015
Levels of Significance (V*S)	*	*	*	*
CV%	4.8	9.7	8.5	3.5

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, ***** Levels of significance V=Variety and S=Stage.

Table 4.10. Changes in sucrose content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Days after harvest		0	3	6	9
Maturity stage	Variety				
1	Van dyke	0.934c	1.432a	1.640a	1.695b
	Tommy atkins	0.981a	1.430a	1.713a	1.730a
	Kent	0.961b	1.378b	1.653a	1.691b
	LSD	0.015	0.01	**ns**	0.0329
	CV%	0.3	0.7	2.4	0.5
2	Van dyke	0.971c	1.840b	1.961b	1.969c
	Tommy atkins	0.985b	1.866a	2.046a	2.052b
	Kent	1.027a	1.867a	2.087a	2.239a
	LSD	0.02927	0.03998	0.02890	0.0761
	CV%	0.9	0.6	0.5	0.9
3	Van dyke	1.630c	2.056b	2.268b	2.280c
	Tommy atkins	1.669b	2.073b	2.321a	2.335b
	Kent	1.750a	2.134a	2.362a	2.492a
	LSD	0.04406	0.03816	0.05023	0.03998
	CV%	0.8	0.5	0.3	0.4
4	Van dyke	2.016b	2.296b	2.426a	2.833b
	Tommy atkins	2.073b	2.357a	2.457a	2.853b
	Kent	2.131a	2.397a	2.487a	2.919a
	LSD	0.0452	0.04406	**ns**	0.0378
	CV%	1.5	0.5	0.7	0.7
	Levels of significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, ***Levels of significance V=Variety and S=Stage

4.5.1.4 Selected minerals

4.5.1.4.1 Potassium

Potassium content in the 3 varieties was significantly affected ($p \leq 0.05$) by maturity stages and varieties. Potassium content reduced as maturity and ripening progressed. During season 1, potassium levels of fruits harvested during early maturity reduced from 195.0 mg/100g to 100.6 mg/100g at initial and end stages respectively. Potassium content was significantly ($p \leq 0.05$) different among the varieties. Kent variety had the highest potassium content which ranged between 119.1 mg/100g to 195 mg/100g and 88.1 mg/100g to 119.0 mg/100g during early and advanced maturities respectively. During season 2, potassium levels reduced from 200.4 mg/100g (stage 1) to 109.7 mg/100g (stage 4) and 122.4 mg/100g (stage 1) to 87.9 mg/100g (stage 4) at the end of ripening progressed. Kent variety had the highest potassium levels compared to Van dyke and Kent varieties at the end of ripening period of maturity stage 1 fruits (122.4 mg/100g) and maturity stage 4 (92.8 mg/100g).

Table 4.11. Initial and end stage potassium content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	184.4b	103.8b	113.5b	85.7c
Tommy atkins	175.6c	100.6c	108.5c	86.5b
Kent	195.0a	119.1a	119.0a	88.1a
LSD	2.38	0.5853	0.4207	1.081
Levels of Significance (V*S)	*	*	*	*
CV%	0.5	0.1	0.1	0.6

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.12. Changes in potassium content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Days after harvest		0	3	6	9
Maturity stage	Variety				
1	Van dyke	184.7b	150.7b	120.0b	104.1c
	Tommy atkins	176.5c	143.5c	118.0b	107.8b
	Kent	200.4a	165.3a	132.8a	122.4a
	LSD	1.689	0.881	3.410	0.686
	CV%	0.3	0.2	0.7	0.1
2	Van dyke	157.7b	133.2b	112.1a	97.2a
	Tommy atkins	150.2c	129.3c	109.8b	94.9b
	Kent	166.8a	147.3a	102.5c	98.7a
	LSD	2.564	1.964	2.486	2.197
	CV%	0.5	0.4	0.6	0.6
3	Van dyke	142.6a	126.4b	105.4b	92.7c
	Tommy atkins	134.0b	125.0c	105.2b	94.1a
	Kent	141.2a	127.4a	118.7a	93.4b
	LSD	1.910	0.974	1.954	0.549
	CV%	0.4	0.7	0.5	0.4
4	Van dyke	116.7b	105.5b	97.3b	89.8b
	Tommy atkins	109.7c	101.5c	94.9c	87.9c
	Kent	122.1a	110.9a	101.1a	92.8a
	LSD	1.442	3.509	2.029	0.993
	CV%	0.3	0.9	0.5	0.3
	Levels of significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).
ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.1.4.2 Calcium

Calcium levels reduced gradually as maturity and ripening progressed during both seasons in the 3 mango varieties. During season 1, fruits harvested during early maturity had calcium levels of which ranged between 5.88 mg/100g to 7.403 mg/100g. At the end of ripening period the Ca content of fruits harvested at early maturity reduced to ranges between 1.308 mg/100g to 1.511 mg/100g. Calcium levels were significantly different ($p \leq 0.05$) among the varieties during maturation and ripening periods. Tommy atkins variety had the lowest amount of calcium content at advanced maturity which reduced from 2.589 mg/100g to 3.33 mg/100g at initial and end stages of ripening respectively. In season 2, calcium levels reduced from 7.969 mg/100g (maturity stage 1) to 3.66 mg/100g (maturity stage 4). At the end of ripening period calcium levels reduced from 3.662 mg/100g to 2.282 mg/100g depending with the variety. Calcium levels were significantly different ($p \leq 0.05$) among the varieties. Van dyke variety had the highest calcium levels at maturity stage 4 compared to Tommy atkins and Kent varieties which reduced from 4.460 mg/100g to 3.276 mg/100g at the end of ripening period.

Table 4.13. Initial and end stage Calcium content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial calcium	End stage calcium	Initial calcium	End stage calcium
Van dyke	7.059a	1.308c	4.199a	3.141a
Tommy atkins	5.880b	1.511b	3.333c	2.589b
Kent	7.403a	2.085a	3.921b	3.056a
LSD	0.521	0.3087	0.1731	0.2724
Levels of Significance (V*S)	*	*	*	*
CV%	2.8	4.6	1.2	2.3

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.14. Changes in Calcium content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Days after harvest Maturity stage	Variety	0	3	6	9
1	Van dyke	7.612a	5.425b	4.248a	3.662a
	Tommy atkins	6.478b	4.596c	3.567b	3.232b
	Kent	7.969a	6.053a	4.205a	3.533a
	LSD	0.6005	0.2422	0.3014	0.2583
	CV%	2.9	1.4	2.3	3.2
2	Van dyke	6.061a	4.966a	4.061a	3.516a
	Tommy atkins	5.323b	4.291b	3.340b	2.980b
	Kent	6.024a	5.056a	4.023a	3.209a
	LSD	0.2667	0.3662	0.1282	0.4086
	CV%	1.5	2.3	0.9	3.0
3	Van dyke	5.572a	4.806a	3.787a	3.368a
	Tommy atkins	4.833c	4.106c	3.059c	2.618c
	Kent	5.017b	4.445b	3.512b	3.106b
	LSD	0.1247	0.3502	0.1022	0.2392
	CV%	0.7	2.2	0.7	1.8
4	Van dyke	4.460a	3.735a	3.517a	3.276a
	Tommy atkins	3.660c	3.256b	2.826c	2.540b
	Kent	4.120b	3.826a	3.383b	2.282c
	LSD	0.0974	0.2223	0.0999	0.1434
	CV%	0.6	1.6	1.5	1.1
	Levels of significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.1.4.3 Magnesium

Stage of maturity and varieties significantly affected (p≤0.05) magnesium levels in the 3 mango varieties. The levels reduced as maturity and ripening processes progressed. In season 1, magnesium levels reduced from 13.949 mg/100g to 4.809 mg/100g at the end of ripening during early maturity. Magnesium content was significantly different (p≤0.05) among the varieties. Tommy atkins had the lowest magnesium levels of 10.183 mg/100g and 4.809 mg/100g at initial and end of ripening stages, for fruits harvested at early maturity while Kent variety had the highest magnesium levels of 7.861 mg/100g which reduced to 4.311 mg/100g at the end of ripening of fruits harvested at advanced maturity. In season 2, magnesium levels reduced from 15.726 mg/100g (stage1) to 5.309 mg/100g (stage 4) as maturity progressed and at the end of ripening, the levels reduced from 3.883 mg/100g (stage4) to 6.565 mg/100g (stage 1) depending with the variety. Magnesium levels were significantly different (p≤0.05) among the varieties. At maturity stage 4, magnesium levels reduced from 5.775 mg/100g to 4.295 mg/100g, 5.309 mg/100g to 3.883 mg/100g and 8.102 mg/100g to 4.817 mg/100g for Van dyke, Tommy atkins and Kent varieties respectively, at the end of ripening period.

Table 4.15. Initial and end stage magnesium content (mg/100gof ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	12.922b	5.176b	5.274b	4.213a
Tommy atkins	10.813c	4.809c	4.765c	3.819c
Kent	13.949a	6.155a	7.861a	4.311b
LSD	0.1195	0.2562	0.4406	0.3023
Levels of Significance (V*S)	*	*	*	*
CV%	0.3	1.2	2.0	1.8

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).
ns -non significance at 5% level, ***** Levels of significance V=Variety and S=Stage.

Table 4.16. Changes in Magnesium content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Maturity stage	Variety (Days after harvest)	0	3	6	9
1	Van dyke	13.467b	9.701b	6.587b	5.693b
	Tommy atkins	12.254c	8.493c	6.341b	5.088c
	Kent	15.726a	11.852a	8.631a	6.565a
	LSD	1.106	0.938	0.3695	0.2520
	CV%	3.4	2.9	1.3	1.1
2	Van dyke	10.524b	8.353b	6.250b	5.508a
	Tommy atkins	9.114c	7.719c	6.033c	5.046b
	Kent	11.347a	9.760a	7.650a	5.586a
	LSD	0.4161	0.5198	0.131	0.3463
	CV%	1.4	2.3	1.2	1.6
3	Van dyke	9.015b	7.713b	6.163b	5.115a
	Tommy atkins	7.173c	6.397c	5.327c	4.818a
	Kent	10.082a	8.799a	6.264a	5.213a
	LSD	0.0810	0.2756	0.783	**ns**
	CV%	0.6	1.0	4.0	3.0
4	Van dyke	5.775b	5.145b	4.658b	4.295b
	Tommy atkins	5.309b	4.767c	4.239c	3.883c
	Kent	8.102a	6.525a	5.846a	4.817a
	LSD	0.709	0.3470	0.0878	0.4045
	CV%	2.8	1.5	0.4	3.4
	Levels of significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.1.4.4 Iron

Iron levels in the 3 varieties were significantly ($p \leq 0.05$) affected by maturity stage and ripening period. In season 1, iron content reduced with maturity. Iron content reduced from 0.208 mg/100g to 0.049 mg/100g, 0.154 mg/100g to 0.03 mg/100g and 0.129 mg/100g to 0.029 mg/100g for Van dyke, Tommy atkins and Kent varieties respectively from early to advanced maturities. During early maturity, Van dyke variety had the highest iron content which ranged reduced from 0.208 mg/100g to 0.1 mg/100g at the end ripening during early maturity. In season 2, iron levels ranged between 0.172 mg/100g to 0.264 mg/100g at maturity stage 1 and 0.043 mg/100g to 0.067 mg/100g at maturity stage 4. At the end of ripening period, iron levels ranged between 0.069 mg/100g to 0.111 mg/100g at maturity stage 1 and 0.012 mg/100g to 0.025 mg/100g depending with stage of maturity and variety. Iron content was significantly different ($p \leq 0.05$) among the varieties. At maturity stage 4, Van dyke variety had the highest iron content which reduced from 0.067 mg/100g to 0.025 mg/100g at the end of ripening.

Table 4.17. Initial and end stage Iron content (mg/100g) of ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	0.208a	0.1a	0.049a	0.028a
Tommy atkins	0.154b	0.078b	0.03a	0.022a
Kent	0.129b	0.066b	0.029a	0.011a
LSD	0.033	0.02618	**ns**	**ns**
Levels of Significance (V*S)	*	*	**ns**	**ns**
CV%	7.2	7.9	19.2	31.5

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, ***Levels of significance V=Variety and S=Stage.

Table 4.18. Changes in Iron content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

	Days after harvest	0	3	6	9
Maturity stage	Variety				
1	Van dyke	0.264a	0.198a	0.148a	0.111a
	Tommy atkins	0.259a	0.15b	0.107b	0.086b
	Kent	0.172b	0.121c	0.088c	0.069c
	LSD	0.04308	0.01511	0.01871	0.01782
	CV%	6.8	3.0	4.2	5.0
2	Van dyke	0.156a	0.123a	0.094a	0.073a
	Tommy atkins	0.131b	0.103a	0.076a	0.060c
	Kent	0.137b	0.113a	0.081a	0.061b
	LSD	0.01511	**ns**	**ns**	0.00841
	CV%	3.3	6.3	8.1	3.1
3	Van dyke	0.104a	0.081a	0.056a	0.042a
	Tommy atkins	0.082b	0.054a	0.040b	0.029b
	Kent	0.059c	0.04a	0.026c	0.019c
	LSD	0.01999	**ns**	0.0067	0.00756
	CV%	7.4	40.8	11.0	6.0
4	Van dyke	0.067a	0.051a	0.038a	0.025a
	Tommy atkins	0.044b	0.033a	0.024b	0.019b
	Kent	0.043b	0.032a	0.018c	0.012b
	LSD	0.01999	**ns**	0.00756	0.00846
	CV%	10.3	0.0	7.0	18.4
	Levels of significance (V*S)	**	*	*	**

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).
ns -non significance at 5% level, ***Levels** of significance V=Variety and S=Stage.

4.5.1.4.5 Sodium

Sodium content in the 3 varieties gradually reduced as maturity and ripening progressed. In season 1, Sodium content reduced from early maturity towards advanced maturity, ranging between 1.722 mg/100g to 2.057 mg/100g (early maturity) and 0.841 mg/100g to 1.095 mg/100g (advanced maturity). Sodium levels were significantly different among the varieties ($p \leq 0.05$). At advanced maturity, Tommy atkins had the lowest sodium levels which were 0.841 mg/100g and 0.672 mg/100g at initial and end stage of ripening respectively. In season 2, sodium levels reduced with maturity from 2.235 mg/100g (stage 1) to 0.907 mg/100g (stage 4). Van dyke variety had the highest sodium levels of 2.235 mg/100g at maturity stage 1 and 1.372 mg/100g at maturity stage 4. At the end of ripening period, Kent variety had the lowest sodium levels at maturity stage 1 (1.134 mg/100g) compared to Tommy atkins and Van dyke varieties while Tommy atkins had the lowest sodium levels at maturity stage 4 (0.662 mg/100g) as compared to Kent and Van dyke varieties.

Table 4.19. Initial and end stage Sodium content (mg/100g) of ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango fruits harvested at early and advanced maturity stages in season 1

Variety	Early maturity		Advanced maturity	
	Initial	End stage	Initial	End stage
Van dyke	2.057a	1.158a	1.095a	0.748a
Tommy atkins	1.821b	1.204b	0.841b	0.672c
Kent	1.722b	1.124c	1.022a	0.715b
LSD	0.134	0.03584	0.1071	0.0248
Levels of Significance (V*S)	*	**	*	*
CV%	2.6	0.8	6.1	1.5

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.20. Changes in Sodium content (mg/100g) of 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits harvested at maturity stages 1, 2, 3 and 4 in season 2

Days after harvest		0	3	6	9
Maturity stage	Variety				
1	Van dyke	2.235a	1.793a	1.366a	1.187b
	Tommy atkins	1.984b	1.582b	1.298b	1.211a
	Kent	1.936b	1.502b	1.216c	1.134c
	LSD	0.1171	0.1430	0.0511	0.02359
	CV%	2.1	2.7	1.4	0.5
2	Van dyke	1.932a	1.514a	1.266a	0.991a
	Tommy atkins	1.697a	1.507a	1.179b	1.007a
	Kent	1.619a	1.441a	1.106c	0.927b
	LSD	**ns**	**ns**	0.1162	0.06115
	CV%	3.2	2.6	2.5	1.5
3	Van dyke	1.646a	1.483a	1.104a	0.939a
	Tommy atkins	1.244c	1.123b	0.931b	0.807c
	Kent	1.356b	1.190c	0.974b	0.863b
	LSD	0.2058	0.01511	0.1350	0.03294
	CV%	4.2	0.3	3.4	0.9
4	Van dyke	1.372a	1.088a	0.861a	0.771a
	Tommy atkins	0.907c	0.766c	0.716b	0.662b
	Kent	1.137b	0.999b	0.876a	0.766a
	LSD	0.119	0.02389	0.06139	0.01772
	CV%	5.1	0.6	1.9	0.6
	Levels of significance (V*S)	*	*	*	*

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, ***** Levels of significance V=Variety and S=Stage.

4.5.1.5 Juice pH

The juice pH increased as maturity progressed. In season 1, the acidity reduced from 3.933 (maturity stage 3) to 4.58 (tree ripe stage). The pH was not significantly different ($p \leq 0.05$) among the varieties. In season 2 the acidity reduced from 3.883 (maturity stage 3) to 5.016 (tree ripe stage) depending with the variety. Kent variety was significantly different ($p \leq 0.05$) from Van dyke and Tommy atkins varieties at tree ripe stage and had the highest pH of 5.016.

Table 4.21. Juice pH for 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3	Maturity stage 4	Tree ripe stage
Van dyke	3.933a	4.113a	4.31a
Tommy atkins	3.940a	4.240a	4.58a
Kent	4.037a	4.233a	4.42a
LSD	**ns**	**ns**	**ns**
Levels of Significance (V*S)	**ns**	**ns**	**ns**
CV%	1.5	1.6	2.3

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

Table 4.22. Juice pH for 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3 ,4 and tree ripe in season 2

Variety	Maturity stage 3	Maturity stage 4	Tree ripe stage
Van dyke	3.883a	4.153a	4.572b
Tommy atkins	4.103a	4.307a	4.851b
Kent	4.090a	4.377a	5.016a
LSD	**ns**	**ns**	0.12
Levels of Significance (V*S)	**ns**	**ns**	*
CV%	3.8	2.5	2.2

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.1.6 Juice hue angle

The hue angle from the extracted juice reduced as maturity progressed and was significantly ($p \leq 0.05$) different among varieties. In season 1, hue angle decreased from 96.97^o (lime) to 73.60^o (cool yellow) for maturity stage 3 and tree ripe stage respectively. Hue angle was significantly different ($p \leq 0.05$) among the varieties at maturity stage 4 and tree ripe stage. Van dyke variety juice was yellow green in color at tree ripe stage while Kent variety was cool yellow in color. During season 2, hue angle decreased from 95.75^o (lime) to 71.74^o (cool yellow) depending with maturity stage and variety. Kent variety juice was cool yellow in color while Van dyke and Tommy atkins were not significantly different ($p \leq 0.05$) at tree ripe stage and were lime in color.

Table 4.23. Juice hue angle content (^{o}) for 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3 ,4 and tree ripe in season 1

Variety	Maturity stage 3	Maturity stage 4	Tree ripe stage
Van dyke	96.97b	90.81c	84.27c
Tommy atkins	93.26a	87.53b	81.52b
Kent	90.45a	82.20a	73.60a
LSD	3.170	1.923	2.367
Levels of Significance (V*S)	*	*	*
CV%	1.5	1.0	1.3

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).

ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.24. Juice hue angle content (^{o}) for 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3 ,4 and tree ripe in season 2

Variety	Maturity stage 3	Maturity stage 4	Tree ripe stage
Van dyke	95.75b	88.53b	82.90b
Tommy atkins	92.44a	84.23ab	89.14b
Kent	89.53a	81.45a	71.74a
LSD	3.053	5.120	2.877
Levels of Significance (V*S)	*	*	*
CV%	1.5	2.7	1.6

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).

ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.1.7 Sensory quality

Sensory scores for Vandyke, Tommy atkins and Kent mango varieties was conducted at maturity stage 3, maturity stage 4 and tree ripe stage. At tree ripe stage, Van dyke variety scored highest in most of the sensory attributes such as color, texture, sweetness, flavor and general acceptability. Kent variety was most succulent. Tommy atkins variety was scored least for sweetness, succulence and general acceptability as shown in figure 4.2. For Van dyke variety, tree ripe stage scored highest in all the attributes. Maturity stage 4 was more preferred for all the sensory attributes except acidity compared to maturity stage 3 (figure 4.3). Fruits harvested at tree ripe stage scored highest in all the attributes for Tommy atkins variety. Fruits harvested at maturity stage 4 were preferred for color, sweetness, flavor, mouth feel and succulence compared to maturity stage 3 (figure 4.3). For Kent variety, tree ripe stage scored highest in all the attributes. Maturity stage 4 was more preferred for sweetness, flavor, mouth feel, succulence and general acceptability compared to maturity stage 3 (figure 4.3).

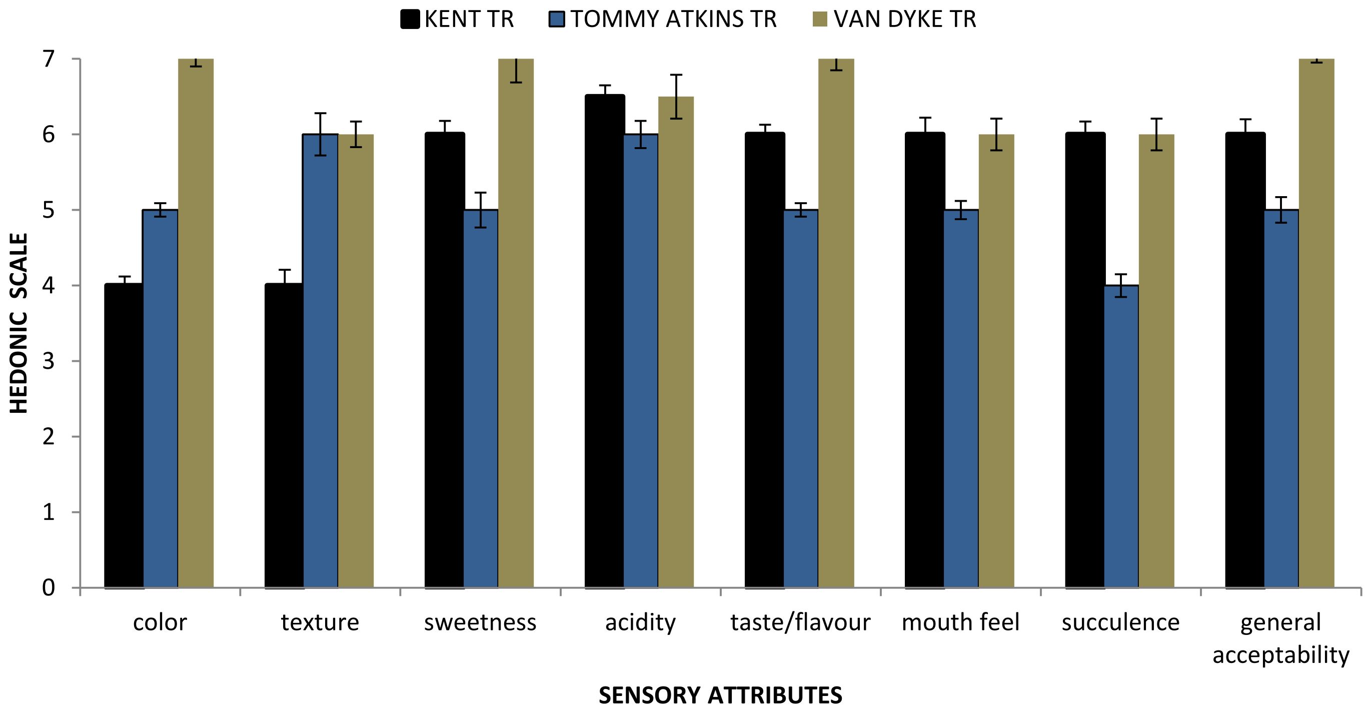

Figure 4.2. Hedonic scores for sensory quality attributes of 'Kent' 'Tommy atkins' and 'Van dyke' mango varieties at tree ripe stage. The values on Y-axis represent scores on a 7-point hedonic scale (1 = dislike extremely (worst), 2 = (dislike very much, 3 = (dislike moderately), 4 = (neither like nor dislike), 5 = (like moderately), 6= (like very much) and 7= (Like extremely)). The vertical bars represent means ± SE. TR stands for tree ripe stage

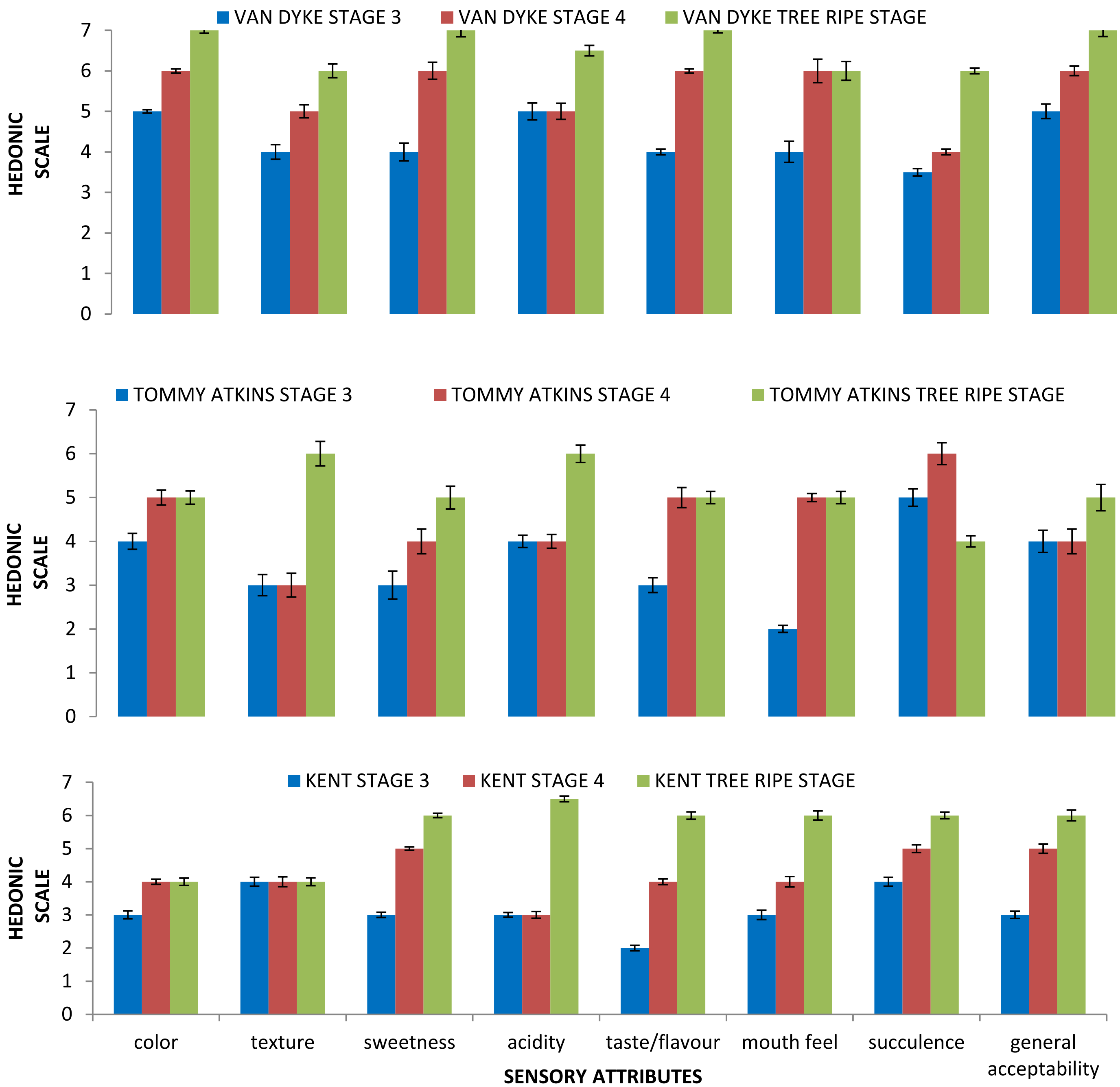

Figure 4.3. Hedonic scores for sensory quality attributes of 'Van dyke', 'Tommy atkins' and 'Kent' mango variety at maturity stages 3, 4 and tree ripe. The values on Y-axis represent scores on a 7-point hedonic scale (1 = dislike extremely (worst), 2 = (dislike very much), 3 = (dislike moderately), 4 = (neither like nor dislike), 5 = (like moderately), 6= (like very much) and 7= (Like extremely)). The vertical bars represent means ± SE.

4.5.2 Nutritional and physical quality attributes of dried mango products

4.5.2.1 Ascorbic acid (Vitamin C)

Drying of the slices had significant ($p \leq 0.05$) effect on the vitamin C content on the fresh samples. Ascorbic acid content reduced after drying the slices in all the maturity stages. Ascorbic acid content in the dried slices reduced from maturity stage 3 to tree ripe stage in both seasons. During season 1, ascorbic acid content reduced from76.11 mg/100g to 29.83 mg/100g at maturity stage 3 and 36.23 mg/100g to 20.86 mg/100g at tree ripe stage after drying the slices depending on the variety. Ascorbic acid content of the dried slices was significantly ($p \leq 0.05$) different among the varieties at all maturity stages. Kent variety had the highest vitamin C level of 36.28 mg/100g and 29.56 mg/100g of the dried slices during maturity stage 4 and tree ripe stage respectively. During season 2, ascorbic acid content reduced after drying the slices from 79.323 mg/100g to 45.85 mg/100g at maturity stage 3 and 49.735 mg/100g to 27.64 mg/100g at maturity stage 4. Ascorbic acid content of the dried slices reduced from 56.13 mg/100g (maturity stage 3) to 19.51 mg/100g (tree ripe stage). Tommy atkins variety had the lowest amount of ascorbic acid content on the dried slices at tree ripe stage compared to Van dyke and Kent varieties.

4.5.2.2 Beta - carotene

Drying of the slices had significant ($p \leq 0.05$) effect on the β-carotene content on the fresh samples. β-carotene content increased after drying the slices in all the maturity stages. Beta carotene levels increased from maturity stage 3 to tree ripe stage in both seasons. During season 1, β-carotene levels increased after drying the slices from 2.42mg/100g to 13.27mg/100g at maturity stage 3 and 3.18 mg/100g to 15.36 mg/100g at maturity stage 4 depending with the variety. β -carotene levels of the dried slices increased from 11.27 mg/100g at maturity stage 3 to 18.32 mg/100g at tree ripe stage. Kent variety had the highest β-carotene levels of the dried slices at all maturity stages. During season 2, β - carotene levels increased from 15.31 mg/100g to 25.09 mg/100g at tree ripe stage after drying. Beta-carotene levels of the dried slices increased from 11.28 mg/100g (maturity stage 3) to 25.09 mg/100g (tree ripe stage). Tommy atkins variety had the highest β- carotene levels of the dried slices during maturity stage 4 and tree ripe stage (18.15 mg/100g and 25.09 mg/100g respectively) while Van dyke variety had the lowest β- carotene levels of the dried slices during maturity stage 4 and tree ripe stage (16.17 mg/100g and 20.28 mg/100g respectively).

Table 4.25. Vitamin C content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	76.11a	34.10b	40.20b	28.72b	31.47b	24.69b
Tommy atkins	63.85c	29.83c	33.88c	26.87c	24.16c	20.86c
Kent	73.31b	35.73a	49.09a	36.28a	36.23a	29.56a
LSD	2.5	0.0236	1.603	1.356	4.3	1.645
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	12.4	6.2	1.0	2.0	3.1	2.9

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).
ns -non significance at 5% level, *Levels of significance V=Variety and S=Stage

Table 4.26. Vitamin C content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3 ,4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	79.323a	51.883b	43.543b	33.547b	32.667b	21.373b
Tommy atkins	65.269c	45.846c	35.876c	27.636c	26.100c	19.513c
Kent	76.773b	56.133a	49.735a	38.703a	36.733a	24.073a
LSD	2.448	1.176	0.91	1.269	3.1	0.0207
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	1.0	1.0	0.6	1.7	4.3	3.8

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

Table 4.27. Beta-carotene content (mg/100g) of dried slices compared to fresh ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	2.42b	11.27b	4.63b	12.58c	10.77c	14.36c
Tommy atkins	2.74a	11.57b	4.76a	13.72b	12.62b	16.50b
Kent	2.88a	13.27a	3.18c	15.36a	13.43a	18.32a
LSD	0.25	0.634	0.4729	0.5747	1.23	0.3352
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	1.7	2.5	2.3	1.6	3.8	0.7

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.28. Beta Carotene content (mg/100g) of dried slices compared to fresh ‘Van dyke’, ‘Tommy atkins’ and ‘Kent’ mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	2.477c	11.283c	5.670b	16.17c	15.31c	20.27c
Tommy atkins	2.965b	11.36b	5.539b	18.15a	16.28b	25.08a
Kent	3.372a	12.22a	6.136a	17.173b	18.09a	23.36b
LSD	0.3023	0.0621	0.4712	0.1191	0.432	1.039
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	5.2	0.3	2.2	0.3	6.4	2.0

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.2.3 Changes in selected minerals

4.5.2.3.1 Potassium

Drying of the slices had significant ($p \leq 0.05$) effect on the potassium content on the fresh samples. Potassium content reduced after drying the slices in all the maturity stages. Potassium content in the dried slices decreased gradually as maturity progressed in both seasons. Potassium content was significantly ($p \leq 0.05$) different among the varieties in both seasons. During season 1, potassium content reduced from 123.3 mg/100g to 109.0 mg/100g at maturity stage 4 and 115.7 mg/100g to 101.2 mg/100g at tree ripe stage after drying the slices. Kent variety had the highest potassium content of the dried slices while Tommy atkins variety had the lowest. During season 2, potassium content reduced from 108.57 mg/100g to 88.4 mg/100g at tree ripe stage, after drying the slices. Potassium content of the dried slices reduced from 120.3mg/100g (maturity stage 3) to 88.4 mg/100g (tree ripe stage). Tommy atkins variety had the lowest potassium content of the dried slices of 120.3 mg/100g at maturity stage 3 and 94.1 mg/100g at tree ripe stage.

4.5.2.3.2 Calcium

Calcium content reduced after drying the slices in all the maturity stages. Drying of the slices had significant ($p \leq 0.05$) effect on the calcium content of the fresh samples. Calcium levels in the dried slices decreased gradually as maturity progressed. During season 1, calcium content reduced from 5.833 mg/100g to 4.8 mg/100g at maturity stage 3 and 4.543 mg/100g to 3.42 mg/100g at tree ripe stage after drying. Calcium content of the dried slices reduced from 5.6 mg/100g (maturity stage 3) to 3.426 mg/100g (tree ripe stage). Calcium content was significantly ($p \leq 0.05$) different among the varieties. Tommy atkins variety had the lowest calcium content of the dried slices During season 2, calcium content reduced from 4.46 mg/100g to 2.967 mg/100g at maturity stage 4 after drying the slices. Calcium content of the dried slices reduced from 4.767 mg/100g (maturity stage3) to 2.720 mg/100g (tree ripe stage). Kent variety had the highest calcium levels of the dried slices (4.767mg/100g) at maturity stage 3 while Tommy atkins variety had the lowest calcium levels of the dried slices (2.720 mg/100g) at tree ripe stage.

Table 4.29. Potassium content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	140.5b	134.0b	119.5b	117.0b	110.5b	108.3b
Tommy atkins	133.6c	127.0c	112.6c	109.0c	104.2c	101.2c
Kent	145.7a	143.0a	123.3a	120.7a	115.7a	112.4a
LSD	3.1	2.267	0.4207	2.724	2.1	3.03
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	1.3	0.7	0.1	1.0	1.5	0.9

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, ***Levels of significance V=Variety and S=Stage.

Table 4.30. Potassium content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	142.63a	126.00b	116.66b	108.00b	97.67c	88.40c
Tommy atkins	133.97c	120.30c	109.69c	102.10c	101.7b	94.10b
Kent	141.16b	135.67a	122.12a	114.93a	108.57a	99.77a
LSD	0.91	3.294	1.442	2.724	1.67	1.875
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	0.4	1.1	0.3	1.0	0.3	0.8

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, ***Levels of significance V=Variety and S=Stage.

Table 4.31. Calcium content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	5.700b	5.100b	4.450a	4.200a	4.183b	4.100a
Tommy atkins	5.017c	4.800c	4.047c	3.800b	3.930c	3.426c
Kent	5.833a	5.600a	4.333b	4.100a	4.543a	3.983b
LSD	0.087	0.12	0.072	0.02	0.15	0.0643
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	3.1	1.1	1.2	2.9	1.7	2.3

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, ***Levels of significance V=Variety and S=Stage.

Table 4.32. Calcium content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	5.572a	4.267b	4.460a	3.400a	4.337a	3.155a
Tommy atkins	4.833c	4.000c	3.660c	2.967b	3.327b	2.720c
Kent	5.017b	4.767a	4.120b	3.267a	3.277b	2.900b
LSD	0.1247	0.1999	0.0974	0.3023	0.176	0.115
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	0.7	1.7	0.6	3.2	2.8	4.2

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, ***Levels of significance V=Variety and S=Stage.

4.5.2.3.3 Magnesium

Magnesium content reduced after drying the slices in all the maturity stages. Drying of the slices had significant ($p \leq 0.05$) effect on the magnesium content of the fresh samples Magnesium content in the dried slices decreased as maturity progressed. During season 1, magnesium content reduced from 7.247 mg/100g to 4.8 mg/100g at tree ripe stage, after drying the slices. Magnesium content of the dried slices reduced from 9.1 mg/100g (maturity stage 3) to 4.8 mg/100g (tree ripe stage). Magnesium content was significantly different ($p \leq 0.05$) among the varieties at maturity stage 3. Tommy atkins variety had the lowest magnesium levels of the dried slices while Kent variety had the highest. During season 2, magnesium content reduced from 8.102 mg/100g to 4.2 mg/100g at maturity stage 4 and 6.233 mg/100g to 3.08 mg/100g at tree ripe stage, after drying. Magnesium content of the dried slices reduced from 8.267mg/100g (maturity stage 3) to 3.080 mg/100g (tree ripe stage). Magnesium content was significantly different ($p \leq 0.05$) among the varieties. Kent variety had the highest magnesium content of the dried slices which ranged from 8.267 mg/100g (maturity stage 3) to 5.7 mg/100g (tree ripe stage).

4.5.2.3.4 Iron

Drying of the slices had significant ($p \leq 0.05$) effect on the iron content of the fresh samples. Iron content reduced after drying the slices in all the maturity stages. Iron level contents in the dried slices decreased with maturity. During season 1, iron content reduced after drying the slices from 0.083 mg/100g to 0.04 mg/100g at maturity stage 3 and 0.0417 mg/100g to 0.008 mg/100g at tree ripe stage. Iron content of the dried slices was not significantly different ($p \leq 0.05$) among varieties in maturity stage 3 and tree ripe stage. Kent variety was significantly ($p \leq 0.05$) different from Van dyke and Tommy atkins varieties at maturity stage 4. Kent variety contained the highest iron content of the dried slices at maturity stage 4, which was 0.035mg/100g. During season 2, iron content reduced after drying the samples from 0.067 mg/100g to 0.012 mg/100g at maturity stage 4. Iron content of the dried slices reduced from 0.06 mg/100g (maturity stage 3) to 0.012 mg/100g (tree ripe stage). Tommy atkins variety was significantly ($p \leq 0.05$) different from Van dyke and Kent varieties at maturity stage 4. Tommy atkins variety had the lowest iron levels of the dried slices (0.021 mg/100g) at maturity stage 4.

Table 4.33. Magnesium content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	8.800b	8.300b	7.510a	7.200a	7.247a	6.427a
Tommy atkins	8.207c	7.900c	5.467b	5.200b	5.200c	4.800b
Kent	9.413a	9.100a	7.600a	7.300a	6.863a	6.500a
LSD	0.56	0.2618	0.4406	0.2069	1.68	0.156
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	1.8	1.4	2.0	1.4	2.3	1.5

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

Table 4.34. Magnesium content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	9.015b	7.467b	5.775b	4.200b	4.175b	3.503b
Tommy atkins	7.173c	6.100c	5.309b	4.333b	4.317b	3.080c
Kent	10.08a	8.267a	8.102a	6.533a	6.233a	5.700a
LSD	0.181	0.3161	0.709	0.1772	1.45	0.09
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	0.6	1.6	2.8	1.2	3.2	2.5

Means within each column followed by a different letter differ significantly at (p≤0.05) while similar letter(s) in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

Table 4.35. Iron content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	0.053b	0.044a	0.043a	0.02b	0.025b	0.015a
Tommy atkins	0.073a	0.05a	0.021a	0.01b	0.011c	0.008a
Kent	0.083a	0.06a	0.053a	0.035a	0.0417a	0.03a
LSD	0.02	**ns**	**ns**	0.01388	0.012	**ns**
Levels of Significance (V*S)	*	**ns**	**ns**	*	*	**ns**
CV%	15.9	13.1	19.2	28.3	18.7	15.6

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

Table 4.36. Iron content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	0.104a	0.046a	0.067a	0.030a	0.058a	0.020a
Tommy atkins	0.083b	0.060a	0.054a	0.021b	0.047a	0.0121a
Kent	0.059c	0.033a	0.05b	0.039a	0.031a	0.02a
LSD	0.0199	**ns**	0.019	0.0124	**ns**	**ns**
Levels of Significance (V*S)	**	**ns**	*	*	**ns**	**ns**
CV%	7.4	17.2	10.3	20.2	21.3	18.2

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).**ns** -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

4.5.2.3.5 Sodium

Drying of the slices had significant (p≤0.05) effect on the sodium content of the fresh samples. Sodium content reduced after drying the slices in all the maturity stages. Sodium levels in the dried slices decreased gradually as maturity progressed. During season 1, sodium levels reduced after drying the slices from 1.417 mg/100g to 0.6 mg/100g at tree ripe stage. Sodium levels of the dried slices reduced from 1.820 mg/100g (maturity stage 3) to 0.6mg/100g (tree ripe stage). Sodium content was significantly different (p≤0.05) among varieties. Kent variety had the highest sodium levels of the dried slices which ranged from 1.820 mg/100g to 1.240 mg/100g while Tommy atkins had the lowest sodium levels which ranged from 1.3mg/100g to 0.6mg/100g. During season 2, sodium levels reduced after drying the slices from 1.646 mg/100g to 1.047 mg/100g at maturity stage 3 and 1.37 mg/100g to 0.617 mg/100g at maturity stage 4. Sodium levels of the dried slices reduced from 1.047 mg/100g (maturity stage 3) to 0.687mg/100g (tree ripe stage). Tommy atkins variety was significantly different (p≤0.05) from Van dyke and Kent varieties and had the lowest sodium content of the dried slices (0.43mg/100g) at tree ripe stage.

Table 4.37. Sodium content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	1.837b	1.600b	1.443a	1.200b	1.417a	1.100b
Tommy atkins	1.467c	1.300c	0.800b	0.650c	0.933c	0.600c
Kent	1.910a	1.820a	1.510a	1.420a	1.300b	1.240a
LSD	0.051	0.1379	0.2271	0.2032	0.023	0.15
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	4.3	3.9	6.1	7.9	5.9	10.8

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, ***Levels of significance V=Variety and S=Stage.

Table 4.38. Sodium content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	1.646a	1.133a	1.37a	0.867b	1.14a	0.58b
Tommy atkins	1.393b	1.047b	1.24b	0.617c	0.907c	0.43c
Kent	1.356b	1.06b	1.137b	0.88a	1.01b	0.687a
LSD	0.2058	0.6839	0.1099	0.0942	0.118	0.131
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	4.2	4.7	5.1	9.8	8.2	7.8

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).
ns -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

4.5.2.4 Changes in major sugars

4.5.2.4.1 Fructose

Drying of the slices affected the amount of fructose content on the slices. During season 1, fructose contents increased after drying the slices from 1.17 mg/100g to 4.89 mg/100g at maturity stage 3 and 1.92 mg/100 g to 5.07 mg/100g at maturity stage 4. Fructose contents of the dried slices increased as maturity progressed from 4.36 mg/100 g (maturity stage 3) to 5.39 mg/100 g (tree ripe stage). Fructose levels were significantly different ($p \leq 0.05$) among the varieties at maturity stage 4. Kent variety had the highest fructose levels of the dried slices at maturity stage 4 (5.39mg/100g). During season 2, fructose contents increased after drying the slices from 3.227 mg/100g to 5.46 mg/100g at tree ripe stage. Fructose contents of the dried slices increased with maturity. At maturity stage 4, fructose content of the dried slices ranged from 4.62 mg/100g to 5.28 mg/100g while at tree ripe stage, 5.11 mg/100g to 5.46 mg/100g. Kent variety had the highest fructose levels of the dried slices at maturity stage 4 (5.28mg/100g).

Table 4.39. Fructose content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	1.17c	4.357a	1.92c	4.54b	2.767a	5.067b
Tommy atkins	1.877b	4.65a	2.18b	4.86b	2.627c	5.067b
Kent	2.17a	4.89a	2.51a	5.07a	2.719b	5.387a
LSD	0.047	**ns**	0.06	0.27	0.022	0.15
Levels of Significance (V*S)	*	**ns**	*	*	*	*
CV%	3.6	5.1	5.1	3.8	2.6	2.3

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

Table 4.40. Fructose content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	2.254c	3.227a	2.689b	4.620b	3.633a	5.107a
Tommy atkins	2.352b	4.820a	2.745a	4.940a	3.583a	5.137a
Kent	2.423a	4.907a	2.791a	5.280a	3.370b	5.460a
LSD	0.0287	**ns**	0.0705	0.31	0.15	**ns**
Levels of Significance (V*S)	*	**ns**	*	*	*	**ns**
CV%	0.4	2.3	0.7	1.6	2.9	3.9

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *Levels of significance V=Variety and S=Stage.

4.5.2.4.2 Glucose

Drying of the slices affected the amount of glucose content on the slices. During season 1, glucose contents increased after drying the slices from 1.87 mg/100 g to 3.09 mg/100g at maturity stage 4. Glucose contents of the dried slices increased as maturity progressed from 2.21 mg/100 g (maturity stage 3) to 3.36 mg/100 g (tree ripe stage). Van dyke variety had the lowest glucose levels of the dried slices at maturity stage 3 and 4 (2.21 mg/100g and 2.35 mg/100g respectively). During season 2, glucose contents increased after drying the slices from 1.92 mg/100g to 3.42 mg/100g at tree ripe stage. Glucose contents of the dried slices increased with maturity. At maturity stage 3, glucose content of the dried slices ranged from 1.42 mg/100g to 3.05 mg/100g while at tree ripe stage, 3.26 mg/100g to 3.42 mg/100g.

Table 4.41. Glucose content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	1.160b	2.213c	2.090b	2.347b	2.843b	3.173a
Tommy atkins	1.550c	2.647b	1.870c	2.873a	2.583c	3.213a
Kent	2.160a	2.920a	2.323a	3.093a	3.017a	3.357a
LSD	0.022	0.21	0.11	0.25	0.13	**ns**
Levels of Significance (V*S)	*	*	*	*	*	**ns**
CV%	4.2	2.2	2.9	5.3	3.4	2.8

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05).

ns -non significance at 5% level, ***Levels** of significance V=Variety and S=Stage.

Table 4.42. Glucose content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	0.98c	1.42a	1.045c	2.45c	1.92b	3.26a
Tommy atkins	1.078b	2.87a	1.14b	2.95b	2.087b	3.38a
Kent	1.172a	3.05a	1.287a	3.21a	2.42a	3.42a
LSD	0.0302	**ns**	0.0342	0.35	0.21	**ns**
Levels of Significance (V*S)	*****	**ns**	*	*	*****	**ns**
CV%	0.9	1.7	0.8	3.1	1.6	2.5

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.2.4.3 Sucrose

Drying of the slices significantly (p≤0.05) affected the amount of sucrose content on the slices. During season 1, sucrose contents increased after drying the slices from 1.75 mg/100 g to 3.94 mg/100g at maturity stage 3 and 3.533 mg/100g to 6.367 mg/100g at tree ripe stage. Sucrose contents of the dried slices increased as maturity progressed from 3.58 mg/100 g (maturity stage 3) to 6.37 mg/100 g (tree ripe stage). Kent variety had the highest sucrose levels of the dried slices at maturity stage 3 and tree ripe stage (3.94 mg/100g and 6.37 mg/100g respectively). During season 2, sucrose contents increased after drying the slices. At maturity stage 4, sucrose contents increased from 2.016 mg/100g to 4.28 mg/100g after drying the slices. Sucrose contents of the dried slices increased with maturity. At maturity stage 3, sucrose content of the dried slices ranged from 2.33 mg/100g to 4.13 mg/100g. Kent variety had the highest amount of sucrose content of the dried slices which ranged between 4.13 mg/100g to 5.02 mg/100g.

Table 4.43. Sucrose content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	2.613a	3.580b	3.283a	4.717a	4.520a	6.123b
Tommy atkins	2.600a	3.667b	3.153b	5.013a	4.253b	5.930c
Kent	1.750b	3.937a	2.681c	5.253a	3.533c	6.367a
LSD	0.05	0.13	0.011	**ns**	0.12	0.24
Levels of Significance (V*S)	*	*	*	**ns**	*	*
CV%	2.3	2.5	8.5	4.2	4.6	3.7

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, ***** Levels of significance V=Variety and S=Stage.

Table 4.44. Sucrose content (mg/100g) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	1.630b	2.333c	2.016	3.930c	3.517a	4.157b
Tommy atkins	1.669b	3.920b	2.073	4.120b	3.209b	4.430b
Kent	1.750a	4.130a	2.131	4.280a	3.533a	5.020a
LSD	0.044	0.097	**ns**	0.00865	0.21	0.42
Levels of Significance (V*S)	*	*	**ns**	*	*	*
CV%	0.8	1.9	1.5	2.4	3.2	4.5

Means within each column followed by a different letter differ significantly at (p≤0.05) while means with a similar letter in a column do not differ significantly at (p≤0.05). **ns** -non significance at 5% level, ***** Levels of significance V=Variety and S=Stage.

4.5.2.5 Hue angle

Drying of the slices significantly ($p \leq 0.05$) affected the hue angle of the fresh slices. After drying the slices hue angle content increased. Hue angle of the dried slices reduced as maturity of the fruits progressed. During season 1, hue angle content increased after drying the slices from 92.62^o (lime) to 117.6^o (mid green) at maturity stage 3 and 77.48^o (cool yellow) to 89.6^o (lime) at maturity stage 4. Hue angle of the dried slices reduced from 117.6^o (maturity stage 3) to 79.22^o (tree ripe stage). Hue angle was not significantly ($p \leq 0.05$) different among the varieties at maturity stage 4. At maturity stage 3, Kent variety was warm green while Tommy atkins and Van dyke varieties were mid green. At tree ripe stage, the 3 varieties were yellow green in color. During season 2, hue angle increased after drying the slices from ranges between 74.872^o (cool yellow) to 82.36^o (yellow green) at tree ripe stage. Hue angle of the dried slices reduced from 112.9^o (maturity stage 3) to 77.29^o (tree ripe stage). Hue angle was significantly different ($p \leq 0.05$) among the varieties. During tree ripe stage, the color of dried slices of Kent variety was yellow green (82.36^o) while that of Van dyke variety was cool yellow (77.29^o).

Table 4.45. Hue angle (^{o}) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	92.621a	114.4b	79.23a	89.002a	74.193a	78.20a
Tommy atkins	94.317a	117.6c	77.48a	88.700a	72.189a	79.22b
Kent	95.83a	110.4a	79.25a	89.600a	75.316a	80.15b
LSD	**ns**	1.8611	**ns**	**ns**	**ns**	0.9624
Levels of Significance (V*S)	**ns**	*	**ns**	**ns**	**ns**	*
CV%	0.67	0.7	3.1	0.8	0.43	0.5

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.46. Hue angle (^{o}) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	94.464a	112.9c	76.63a	84.29b	74.872a	77.29c
Tommy atkins	98.742a	106.1b	82.13b	91.26 a	75.108a	79.08b
Kent	96.795a	100.8a	77.60a	88.02 ab	76.315a	82.36a
LSD	**ns**	4.0976	4.2139	4.1510	**ns**	1.2508
Levels of Significance (V*S)	**ns**	*	*	*	**ns**	*
CV%	1.9	1.7	2.4	2.1	3.2	0.7

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, ***Levels of significance V=Variety and S=Stage.

4.5.2.6 Firmness

Drying affected the firmness of the slices. The firmness of the dried slices reduced as maturity progressed. During season 1, firmness of the dried slices increased from 13.48N to 37.167N at maturity stage 3 and 9.99 N to 32 N at maturity stage 4. Firmness of the dried slices reduced from 37.167N (maturity stage 3) to 24.267 N (tree ripe stage). Firmness was significantly ($p \leq 0.05$) different among the varieties. Kent variety was least firm (24.267 N) while Tommy atkins variety was most firm (28.033N) at tree ripe stage. During season 2, firmness increased after drying the slices from 6.03N to 31.17 N at tree ripe stage. Firmness of the dried slices reduced from 42.33N (maturity stage 3) to 26.20 N (tree ripe stage). Kent variety was most firm at tree ripe stage (31.17N).

Table 4.47. Firmness (N) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	23.633a	35.667b	12.947a	31.667b	10.513a	26.400b
Tommy atkins	13.480c	37.167a	12.463a	32.000a	9.460b	28.033a
Kent	18.547b	31.333c	9.990b	30.633c	8.420b	24.267c
LSD	3.4	1.5	1.7686	0.32	1.76	0.22
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	5.3	6.2	7.5	5.3	4.2	6.2

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.48. Firmness (N) of dried slices compared to fresh 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3		Maturity stage 4		Tree ripe stage	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Van dyke	24.75a	36.67c	13.88a	29.17c	9.62a	26.20b
Tommy atkins	15.69c	39.17b	6.84c	32.00b	6.03b	26.67b
Kent	20.35b	42.33a	10.82b	34.00a	9.52a	31.17a
LSD	1.4668	1.823	1.5062	1.926	1.86	2.72
Levels of Significance (V*S)	*	*	*	*	*	*
CV%	3.2	5.7	6.3	5.9	6.7	12.3

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$). **ns** -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.5.2.7 Moisture content

As maturity of the fruits progressed, the moisture content of the dried slices increased in both seasons. During season 1, the moisture content increased from 10.20% at maturity stage 3 to 14.97% at tree ripe stage. Moisture content was significantly different ($p \leq 0.05$) among the varieties. Kent variety had the highest moisture content which increased from 11.67% (maturity stage 3) to 14.97% (tree ripe stage). During season 2, moisture content increased from 10.33% to 15.28% depending with maturity stage and variety. The moisture content was also significantly different ($p \leq 0.05$) among the varieties. Van dyke variety had the lowest moisture content of 10.33%, 11% and 14.13% at maturity stages 3, 4 and tree ripe stage respectively.

Table 4.49. Moisture content (%) of dried slices for 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 1

Variety	Maturity stage 3	Maturity stage 4	Tree ripe stage
Van dyke	10.20b	10.77c	13.21c
Tommy atkins	10.60b	11.37b	14.02b
Kent	11.67a	12.17a	14.97a
LSD	0.51	0.38	0.42
Levels of Significance (V*S)	*	*	*
CV%	0.9	1.0	1.7

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

Table 4.50. Moisture content (%) of dried slices for 'Van dyke', 'Tommy atkins' and 'Kent' mango fruits at maturity stages 3, 4 and tree ripe in season 2

Variety	Maturity stage 3	Maturity stage 4	Tree ripe stage
Van dyke	10.33c	11.00c	14.13c
Tommy atkins	10.70b	11.60b	14.86b
Kent	11.70a	12.37a	15.28a
LSD	0.3294	0.2724	0.168
Levels of Significance (V*S)	*	*	*
CV%	1.3	1.0	3.8

Means within each column followed by a different letter differ significantly at ($p \leq 0.05$) while means with a similar letter in a column do not differ significantly at ($p \leq 0.05$).

ns -non significance at 5% level, *****Levels of significance V=Variety and S=Stage.

4.6 DISCUSSION

The effect of harvest maturity on shelf life and quality attributes of fresh and dried mango products was evaluated for ‘Van dyke’, Tommy atkins’ and’ Kent’ mango fruits harvested at maturity stages 1,2,3 and 4. Fruits were also harvested at tree ripe stage to determine organoleptic qualities and the effect of harvest maturity on dried mango products as compared to maturity stages 3 and 4. In the first part of the experiment, (fresh mango products), differences in fruit quality as maturity and ripening progressed were established through instrumental analysis of fruit biochemical parameters including; ascorbic acid content (Vitamin C), β-carotene, minerals (potassium, calcium, magnesium iron and sodium) and major sugars (sucrose, fructose and glucose). The results showed changes in nutrient composition as maturity and ripening progressed and varietal differences. In the second part of the experiment (dried products), nutritional qualities (ascorbic acid, β-carotene, major sugars and minerals), moisture content, firmness and hue angle were determined. The results showed the effects of harvest maturity on the dried products qualities and varietal differences on nutritional qualities.

Ascorbic acid (Vitamin C) content was highest at maturity stage 1 (earliest maturity/ green mature stage) and it reduced in the consecutive maturity stages and also as ripening of the fruits at the various stages progressed. Ascorbic acid levels reduced with harvest maturity for apples, mangoes, peas and citrus (Lee *et al*, 2000). The decline in ascorbic acid could be due to the increase in size which dissolves the total ascorbic acid content. However Appiah *et al*., (2011) reported that the decrease in Vitamin C levels with maturity stage is attributed to degradation of ascorbic acid through oxidation. The observed reduction in ascorbic acid concurs with the findings of Soto *et al*., (2001) who reported that ascorbic acid content of fruits declines with increased duration in storage. In the current study, ascorbic acid content of fresh mango slices reduced after drying. The results of the current study concur with those of Ahmet *et al*., (2014) who reported that increasing drying air temperature causes more loss of vitamin C in the dried Kiwi fruits. Drying concentrates those nutrients that are not heat or light labile and ascorbic acid is the main casualty, often being reduced to a mere trace (Vaughan *et al.*, 2003). From this study it was observed that ascorbic acid content differs from one variety to another despite similar agro ecological conditions.

Beta carotene contents increased as fruits matured from the earliest maturity towards advanced maturity and also as ripening progressed. Beta carotene is one of the initial precursors of vitamin A and is a strong antioxidant which protects against many cancers, aging rapidly and improves visual health by protecting macula and retina. Mango fruit is a rich source of carotenoids (Yahia, 2006). Past research indicates an increase of total carotenoid content with ripening of 'Keitt' and 'Tommy atkins' mango varieties (Mercadante *et al*;, 1998).

In this study, sugars content increased as maturity and ripening progressed on fresh mangoes and further increased when the mango slices were dried. Different mango varieties have different levels of sugar content and Kent variety had the highest sugar content compared to Van dyke and Tommy atkins varieties in the current results. Soluble sugars increases during mango fruit ripening. While starch content increases in chloroplasts during mango fruit development, it is completely hydrolysed to simple sugars during ripening (Ito, 1997). Reducing sugars, mainly fructose, increase slightly during ripening (Castrillo *et al*;, 1992). The proportion of sugars varies depending with cultivars and also depends upon the extent of inter-conversion of sugars. The ratio of fructose to glucose increases during the ripening period (Hubbard, 1991). Similarly; sucrose, fructose and glucose contents increases during the ripening period and are concentrated in fruits, through drying (Vaughan, 2003).

Calcium (Ca), potassium (K), magnesium (Mg), iron (Fe) and sodium (Na) levels gradually reduced as maturity and ripening progressed, and varied among the varieties in the current study. Important fruit minerals include base forming elements which are Ca, Mg, Na and K (Adel, 2003). Mineral contents of fruits show considerable differences not only between species and varieties but also between different batches of the same variety grown under different environmental conditions (Duckworth, 2013). Duckworth (2013) reported that climate, soil and fertilizer practices all have their effects on the levels of minerals in the fruits. Potassium is the most abundant mineral found in fruits occurs often in combination with organic acids. Sodium and potassium were the predominant minerals examined from immature fruits of mango (Akhtar *et al*;, 2010). Calcium and sodium has been observed during ripening of Keitt mangoes and they decreased as ripening progressed (Appiah *et al*., 2011). Hence fully ripe mangoes contain less of the minerals. According to Akhtar (2010), Calcium content of mango fruits vary among varieties and development stage of the fruit. In this study, a lot of variation was observed in calcium content from immature to mature fruits and within the varieties. In the current study, iron levels were very low in all the varieties and the contents further declined as maturity progressed. In this study, drying the mango slices reduced the minerals content further as maturity progressed.

Sensory qualities that were used to perceive consumer acceptance of the 3 varieties and the different maturity stages included color, texture, sweetness, acidity, taste/flavor, mouth-feel, succulence and general acceptability. In the current study, Vandyke variety was the most preferred at all maturity stages while fruits harvested at tree ripe stage were most preferred followed by maturity stage 4 and finally maturity stage 3. Organic acid and sugars ratio creates a sense of taste which is perceived by specific taste buds on the tongue. Sweetness due to sugar and sourness from organic acids are leading components in the taste of many fruits (Kays, 1991). A number of biochemical reactions are involved in the ripening process of mango. These changes lead to ripening of fruit and the texture softens to acceptable quality and they largely contribute towards developing a total sensory profile of the mango fruit (Herianus, 2003).

In conclusion, maturity at harvest is the most important factor that determines shelf life and final quality of the fruit. Harvest maturity has great effect on nutritive value of different mango varieties in fresh and dried forms. All maturity and ripening stages are essential for various mango uses and target market or mango value chain. Mango fruits at early maturity are good sources of vitamins and minerals and will last longer while those harvested at more advanced maturity are good sources of β-carotenes and sugars but will deteriorate more rapidly and are more prone to mechanical injury during post harvest handling.

CHAPTER FIVE:

5 GENERAL DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL DISCUSSION

It is estimated that 40% to 50% of fruits and vegetables produced globally are wasted; the highest wastage rates of any food products (FAO, 2012). These losses occur during harvesting, post harvest, processing, distribution and consumption stages. Post harvest losses levels are currently very high across value chains in sub-Saharan Africa (Rockefeller, 2015). Across Africa, fruits and vegetables feature the highest rate of post harvest losses of approximately 50% (World Food Programme, 2015). In Kenya, post harvest losses account up to 45% of the harvested fruit (KARI, 2011). Reduction in post harvest losses of fruits and vegetables is a complementary means for increasing production. It also has a direct impact on food security, promote efficient resource utilization and to secure livelihoods of small holder farmers (Rockefeller, 2015). Simple and affordable steps like implementing good harvest practices such as harvesting at the right maturity stage and proper handling and storage practices can drastically reduce post harvest losses. Knowledge of maturity indices will guide farmers to harvest at the right stage for the target market and/or use, thereby minimizing rejections at the market stage. In turn, this increases the amount of harvested products, available for household consumption and local markets, which means improved food security and greater resilience for smallholder farmers.

The current study was conducted to establish maturity indices of three different mango varieties; Tommy atkins, Van dyke and Kent and the effect of harvest maturity on quality attributes of the fruits in Embu County of Kenya. The maturity indices established were computational, physical, physiological and biochemical maturity indices. Fruits were harvested at four maturity stages based on computational maturity indices. For each maturity stage and variety, nutritional quality attributes of fresh fruits were evaluated every 3 days to a predetermined end stage while physical and nutritional attributes were conducted on processed products harvested at maturity stages 3, 4 and tree ripe. Sensory evaluation by untrained panelists was also conducted on fruits at tree ripe stage and at the end stage of fruits harvested at maturity stages 3 and 4.In the first experiment, the results showed variations of maturity indices in different varieties of mango fruit, harvested at different maturity stages. Subjective maturity indices used by farmers which include shoulder development, fullness of cheek, nose elevation, size and skin color vary among the varieties. Based on computational maturity indices, the different varieties attained earliest maturity stage at different times. Physical maturity indices revealed varietal differences in the harvested fruits. Fruits harvested at early maturity stages showed higher peel and flesh firmness and higher hue angles compared with advanced maturity stages. Analysis of physiological maturity indices also revealed varietal differences. Fruits harvested at early maturity stages had lower ethylene production and respiration rates compared to those harvested at advanced maturity stages. Total soluble solids and % citric acid varied among the varieties. Fruits harvested at advanced maturity stages had higher total soluble solids content and lower % citric acid compared to those harvested at early maturity stages. The findings of this study concur with the findings of Ouma, (2015) who reported varietal differences of 'Apple' and 'Ngowe' mango varieties in their maturity indices despite similar physical appearance.

Determination of reliable maturity indices for each variety is an important step to ensure prolonged shelf life and quality of the fruits. Postharvest loss management requires a system approach right from production to the marketing stage and proper harvesting practices which includes right maturity is one of the approaches. Maturity indices are crucial in deciding when fruits should be harvested for a target market and /or uses. Inaccurate maturity indices contribute to postharvest losses when the fruits fail to meet the target market/use requirements. Such fruits are either discarded at the market or affect quality of the processed products. With respect to postharvest handling, it is important that the fruits of different maturities be into batched based on the target market and/or use. Mixing of fruits harvested at different maturity stages may hasten deterioration of the entire batch due to differences in physiological activities. Varietal differences can affect the consistency of the maturity indices. Therefore a combination of computational, physical, physiological and biochemical maturity indices can ascertain reliable maturity indices for each mango variety (Salunkhe, 1995).

In the first part of the second experiment of the current study, the results showed significant differences in nutritional quality attributes on fruits harvested at different maturity stages and also during their storage. Fruits harvested at different maturity stages also showed significant differences on sensory quality attributes. As maturity and ripening processes progressed, β-carotene, fructose, sucrose and glucose increased significantly while levels of ascorbic acid, potassium, calcium, magnesium iron and sodium reduced significantly in all the varieties. Fruits harvested at early maturity differed in the nutritional quality attributes from those harvested at advanced maturity. Ascorbic acid content was higher in fruits harvested at early maturity compared with those at advanced maturity. An increase in the ascorbic acid content was noted in Kiwi fruit as maturity progressed (Okuse *et al.*, 1981). Papaya also showed an increase in ascorbic acid content with maturation while mango fruit showed a decrease (Arriola *et al*., 1980). K, Ca, Mg, Na and Fe levels observed in this study were at the highest levels during early maturity stages and also at the beginning of ripening period. Raw mango fruits are rich in minerals like calcium, magnesium, iron, sodium, potassium and phosphorous. Varietal differences observed concurred with previous observations on 'Apple' and 'Ngowe' mango varieties (Ouma, 2015). Ouma (2015) reported that ascorbic acid, β-carotene, potassium, calcium and magnesium contents differed on the 2 varieties at the different maturity stages and ripening periods, regardless of production area.

Sensory panelists preferred fruits harvested at tree ripe stage regardless of the variety. This was reflected in the higher hedonic scale scores for sensory quality attributes which included color, texture, sweetness, acidity, flavor, mouth feel, succulence and general acceptability. Flavor involves the combined effect of acidity soluble solids and aroma volatiles (Harker *et al.*, 2002). Production of aroma volatiles in mango fruits is linked with metabolism at the later stages of maturity (Fellman *et al*., 2003) and hence, fruits picked at a more mature stage have relatively high production of aroma volatiles and hence better flavor quality, which is a consumption quality important to consumer acceptability of mangoes (Malundo *et al*., 1996). These results reveals that while sensory quality attributes increased with harvest maturity, some of the key nutritional quality attributes such as vitamin C reduced with maturity and ripening. This could mean a tradeoff between the two aspects of quality due to consumer perception of health benefits from mango.

Harvest maturity affects the fruits vulnerability to mechanical injury during postharvest handling. Fruits harvested at advance maturity are more prone to injury and consequently postharvest losses compared to those harvested at early maturity (Wojciech, 2014). Shelf life of fruits is a function of harvest maturity. Fruits harvested at early maturity may have a longer shelf life but often have inferior eating qualities (Kader, 2014; Ahmad *et al*., 2016). On the other hand overmature fruits are inferior in quality and spoil more quickly (Siddiqui *et al.*, 2010).

In the second part of the second experiment, the results showed that fruits harvested at different maturity stages resulted in processed products with significant differences in physical and nutritional qualities.. The acidity of fresh juice reduced as maturity progressed while the color changed from yellow green to cool yellow to mid yellow as maturity progressed. Ascorbic acid, potassium, calcium, magnesium, iron and sodium contents reduced significantly after drying the mango slices in all the maturity stages. On the other hand, β-carotene, fructose, glucose and sucrose contents as well as firmness and moisture contents increased significantly after drying the mango slices in all the maturity stages. The color of the dried slices changed from yellow green to cool yellow as maturity progressed. These parameters were also significantly different among the varieties. These results reveal that harvest maturity as well as varietal differences affects physical and nutritional qualities of processed mango products.

Drying of food has been an important method of food preservation. A low content of water inhibits the growth of spoilage micro organisms. Fruits can be dried either by the sun or mechanical dehydrators (Vaughan *et al*., 2003). In the current study, green house solar drier was used to dry the mango slices. Drying of the slices concentrated major sugars (fructose, glucose and sucrose) in the fresh slices. Similar studies showed that 10% of total sugars in fresh apple increased to about 60% in dried apple while in dried pineapple they increased to 70% from 10% (Vaughan *et al*., 2003). Ascorbic acid content of fresh fruits reduced after drying the slices. Ascorbic acid is soluble in water until the moisture content reduces to low levels and these reacts with solutes at higher rates, as drying proceeds (Bakhru, 1990). Extracted fruit juice contains the same range and concentration of nutrients of whole fruits, except dietary fibre and ascorbic acid which varies according to packaging and length of storage (Vaughan *et al*., 2003). Fruits harvested at different maturity stages should not be mixed as this affects the quality of the fruit in terms of taste and flavor and hence the consistency of the processed products such as juice and dehydrated products (Brecht, 2009). Differences in total soluble solids and acidity in fruits as affected by variety and different maturities as shown in this study could affect the processed products. Therefore processors and other mango chain value actors should endeavor to utilize mango fruits separately (maturity stage, ripening stage and varieties) to ensure consistency in processed products and maximum utilization of nutrients in mango fruits.

In conclusion, the findings of this study show the significant differences in objective maturity indices of the various mango varieties which may otherwise have similar subjective maturity indices. There is therefore need to combine the various maturity indices so as to reliably establish the right harvest maturity for different uses or target markets. Harvest maturity also affected nutritional, physical and sensory quality attributes of fresh and processed products. Harvesting fruits at early maturity stages (stages 1 and 2) can prolong their ripening period hence a longer shelf life. However, this compromises their sensory and some nutritional quality attributes. At advanced maturity stages (stages 3 and 4), the fruits have a shorter shelf life but superior nutritional and quality attributes which were corroborated by the sensory panelists. A combination of various maturity indices including computational and physical can be complemented by the subjective indices used by farmers to ascertain harvest maturity for different mango varieties. Since harvest maturity also affects the quality of processed products, all mango supply chain actors especially the processors should aim at utilizing fruits harvested at a maturity stage with maximum levels of nutritional attributes depending with the variety.

5.2 RECOMMENDATIONS

1. Maturity indices vary among the different mango varieties even when produced under the same environmental conditions. Maturity indices should not be generalized but specified for each mango variety by the mango value chain actors. Similar studies should be extended to other commercial varieties such as Dodo, Sensation, Haden and Sabine from similar or different environmental conditions. After harvesting, fruits should be graded according to maturity stage to avoid losses due to high ethylene production rates in the more mature fruits which can lead to deterioration and hence losses in the lesser mature fruits.
2. Mango variety and the harvest maturity has an effect on the shelf life, nutritional and sensory quality attributes of mango fruits. The harvest maturity should therefore be selected depending on the target market and use
3. Harvest maturity has an effect on the physical, sensory and nutritional quality attributes of processed mango products. Mango fruit processors should avoid mixing different mango varieties and maturity stages during processing as this can affect the consistency of the processed products. Fruits harvested at advanced maturity (stages 3 and 4) are best for processing due to their high sugar content and flavor. However, in the case of drying, mango slices from tree ripened fruits should be dried for a longer period due to their higher moisture content.

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APPENDICES

APPENDIX 1: Analysis of Variance (ANOVA) table for Size (length) for Kent, Tommy atkins and Van dyke mango varieties at four stages of maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.202	0.101	0.09	
VARIETIES	2	578.917	289.459	245.83	<.001
STAGES	3	128.670	42.890	36.43	<.001
VARIETIES.STAGES	6	58.663	9.777	8.30	<.001
Residual	22	25.904	1.177		
Total	35	792.356			

APPENDIX 2: Analysis of Variance (ANOVA) table for firmness (peel) for Kent, Tommy atkins and Van dyke mango varieties at four stages of maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	4.204	2.102	0.75	
VARIETIES	2	357.126	178.563	64.13	<.001
STAGES	3	3514.131	1171.377	420.69	<.001
VARIETIES.STAGES	6	281.532	46.922	16.85	<.001
Residual	22	61.257	2.784		
Total	35	4218.251			

APPENDIX 3: Analysis of Variance (ANOVA) table for firmness (flesh) for Kent, Tommy atkins and Van dyke mango varieties at four stages of maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	1.667	0.833	0.43	
VARIETIES	2	195.200	97.600	50.58	<.001
STAGES	3	4236.658	1412.219	731.86	<.001
VARIETIES.STAGES	6	97.780	16.297	8.45	<.001
Residual	22	42.452	1.930		
Total	35	4573.756			

APPENDIX 4: Analysis of Variance (ANOVA) table for CO2 production for Kent, Tommy atkins and Van dyke mango varieties at four stages of maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.163	0.082	0.05	
VARIETIES	2	20.698	10.349	6.53	0.006
STAGES	3	727.476	242.492	152.92	<.001
VARIETIES.STAGES	6	57.001	9.500	5.99	<.001
Residual	22	34.887	1.586		
Total	35	840.225			

APPENDIX 5: Analysis of Variance (ANOVA) table for total soluble solids for Kent, Tommy atkins and Van dyke mango varieties at four stages of maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.5965	0.2982	2.86	
VARIETIES	2	11.8381	5.9191	56.67	<.001
STAGES	3	272.0213	90.6738	868.16	<.001
VARIETIES.STAGES	6	4.4937	0.7490	7.17	<.001
Residual	22	2.2978	0.1044		
Total	35	291.2473			

APPENDIX 6: Analysis of Variance (ANOVA) table for total titratable acidity) for Kent, Tommy atkins and Van dyke mango varieties at four stages of maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.0005621	0.0002810	1.81	
VARIETIES	2	0.0044669	0.0022335	14.35	<.001
STAGES	3	0.0992358	0.0330786	212.49	<.001
VARIETIES.STAGES	6	0.0004301	0.0000717	0.46	0.830
Residual	22	0.0034247	0.0001557		
Total	35	0.1081196			

APPENDIX 7: Analysis of Variance (ANOVA) table for Vitamin C for Kent, Tommy atkins and Van dyke mango varieties at four stages of maturity and four different times after harvest

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.8939	0.4469	1.51	
VARIETY	2	1628.1621	814.0811	2754.08	<.001
STAGES	1	14965.5516	14965.5516	50629.25	<.001
maturity	1	14418.8751	14418.8751	48779.82	<.001
VARIETY.STAGES	2	280.6789	140.3395	474.78	<.001
VARIETY.maturity	2	45.9090	22.9545	77.66	<.001
STAGES.maturity	1	6414.1414	6414.1414	21699.38	<.001
VARIETY.STAGES.maturity	2	17.4470	8.7235	29.51	<.001
Residual	22	6.5030	0.2956		
Total	35	37778.1622			

APPENDIX 8: Analysis of Variance (ANOVA) table for Beta carotene for Kent, Tommy atkins and Van dyke mango varieties at four stages of maturity and four different times after harvest

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.01484	0.00742	0.65	
VARIETY	2	3.81398	1.90699	168.06	<.001
STAGES	1	410.72548	410.72548	36195.60	<.001
maturity	1	155.15276	155.15276	13672.99	<.001
VARIETY.STAGES	2	0.79830	0.39915	35.18	<.001
VARIETY.maturity	2	0.21121	0.10561	9.31	0.001
STAGES.maturity	1	57.02948	57.02948	5025.78	<.001
VARIETY.STAGES.maturity	2	0.33994	0.16997	14.98	<.001
Residual	22	0.24964	0.01135		
Total	35	628.33563			

APPENDIX 9: Analysis of Variance (ANOVA) table for fructose content of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.000551	0.000276	0.11	
DAH	3	104.037006	34.679002	14198.97	<.001
STAGES	3	144.516583	48.172194	19723.62	<.001
VARIETY	2	1.381135	0.690567	282.75	<.001
DAH.STAGES	9	7.377267	0.819696	335.62	<.001
DAH.VARIETY	6	0.169882	0.028314	11.59	<.001
STAGES.VARIETY	6	0.332954	0.055492	22.72	<.001
DAH.STAGES.VARIETY	18	0.133029	0.007391	3.03	<.001
Residual	94	0.229582	0.002442		
Total	143	258.177989			

APPENDIX 10: Analysis of Variance (ANOVA) table for glucose content of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.0017927	0.0008964	3.39	
VARIETY	2	1.2231862	0.6115931	2313.11	<.001
STAGES	3	12.8172300	4.2724100	16158.67	<.001
DAH	3	11.6835778	3.8945259	14729.48	<.001
VARIETY.STAGES	6	0.1630025	0.0271671	102.75	<.001
VARIETY.DAH	6	0.1877866	0.0312978	118.37	<.001
STAGES.DAH	9	3.2565737	0.3618415	1368.52	<.001
VARIETY.STAGES.DAH	18	0.0590977	0.0032832	12.42	<.001
Residual	94	0.0248539	0.0002644		
Total	143	29.4171011			

APPENDIX 11: Analysis of Variance (ANOVA) table for sucrose content of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.0001381	0.0000690	0.14	
VARIETY	2	0.1652660	0.0826330	171.28	<.001
STAGES	3	20.5002447	6.8334149	14164.31	<.001
DAH	3	13.7617905	4.5872635	9508.48	<.001
VARIETY.STAGES	6	0.0830079	0.0138346	28.68	<.001
VARIETY.DAH	6	0.0390651	0.0065108	13.50	<.001
STAGES.DAH	9	1.9891879	0.2210209	458.13	<.001
VARIETY.STAGES.DAH	18	0.0536927	0.0029829	6.18	<.001
Residual	94	0.0453493	0.0004824		
Total	143	36.6377421			

APPENDIX 12: Analysis of Variance (ANOVA) table for Potassium content of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	18.081	9.040	8.82	
VARIETY	2	2528.105	1264.052	1233.71	<.001
STAGES	3	32961.256	10987.085	10723.38	<.001
DAH	3	57369.283	19123.094	18664.11	<.001
VARIETY.STAGES	6	1165.118	194.186	189.53	<.001
VARIETY.DAH	6	427.175	71.196	69.49	<.001
STAGES.DAH	9	7819.328	868.814	847.96	<.001
VARIETY.STAGES.DAH	18	162.886	9.049	8.83	<.001
Residual	94	96.312	1.025		
Total	143	102547.542			

APPENDIX 13: Analysis of Variance (ANOVA) table for Magnesium content of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.05199	0.02599	0.37	
STAGES	3	377.00669	125.66890	1764.97	<.001
VARIETY	2	254.91928	127.45964	1790.12	<.001
DAH	3	368.86101	122.95367	1726.84	<.001
STAGES.VARIETY	6	18.30012	3.05002	42.84	<.001
STAGES.DAH	9	43.54453	4.83828	67.95	<.001
VARIETY.DAH	6	28.10205	4.68367	65.78	<.001
STAGES.VARIETY.DAH	18	9.92569	0.55143	7.74	<.001
Residual	94	6.69295	0.07120		
Total	143	1107.40429			

APPENDIX 14: Analysis of Variance (ANOVA) table for Calcium content of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.28283	0.14141	10.04	
STAGES	3	49.54532	16.51511	1171.96	<.001
VARIETY	2	32.93124	16.46562	1168.45	<.001
DAH	3	92.64499	30.88166	2191.45	<.001
STAGES.VARIETY	6	4.79413	0.79902	56.70	<.001
STAGES.DAH	9	4.06906	0.45212	32.08	<.001
VARIETY.DAH	6	4.56419	0.76070	53.98	<.001
STAGES.VARIETY.DAH	18	3.67935	0.20441	14.51	<.001
Residual	94	1.32464	0.01409		
Total	143	193.83574			

APPENDIX 15: Analysis of Variance (ANOVA) table for Iron content of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.00026337	0.00013169	1.61	
STAGES	3	0.55907924	0.18635975	2285.34	<.001
VARIETY	2	0.05890963	0.02945481	361.21	<.001
DAH	3	0.12254869	0.04084956	500.94	<.001
STAGES.VARIETY	6	0.02188315	0.00364719	44.73	<.001
STAGES.DAH	9	0.01582162	0.00175796	21.56	<.001
VARIETY.DAH	6	0.00245571	0.00040928	5.02	<.001
STAGES.VARIETY.DAH	18	0.00592574	0.00032921	4.04	<.001
Residual	94	0.00766529	0.00008155		
Total	143	0.79455244			

APPENDIX 16: Analysis of Variance (ANOVA) table for Sodium content of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.001089	0.000544	0.24	
STAGES	3	11.023731	3.674577	1596.58	<.001
VARIETY	2	1.722188	0.861094	374.14	<.001
DAH	3	5.226770	1.742257	757.00	<.001
STAGES.VARIETY	6	0.869093	0.144849	62.94	<.001
STAGES.DAH	9	0.196615	0.021846	9.49	<.001
VARIETY.DAH	6	0.561970	0.093662	40.70	<.001
STAGES.VARIETY.DAH	18	0.181249	0.010069	4.38	<.001
Residual	94	0.216344	0.002302		
Total	143	19.999049			

APPENDIX 17: Analysis of Variance (ANOVA) table for moisture content of dried slices of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.028985	0.014493	1.63	
STAGES	2	53.502963	26.751481	3005.47	<.001
VARIETY	2	10.841096	5.420548	608.99	<.001
STAGES.VARIETY	4	0.188859	0.047215	5.30	0.006
Residual	16	0.142415	0.008901		
Total	26	64.704319			

APPENDIX 18: Analysis of Variance (ANOVA) table for Potassium content of dried slices of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	2.717	1.359	1.30	
STAGES	2	3547.445	1773.722	1693.80	<.001
VARIETY	2	761.518	380.759	363.60	<.001
STAGES.VARIETY	4	31.794	7.948	7.59	0.001
Residual	16	16.755	1.047		
Total	26	4360.229			

APPENDIX 19: Analysis of Variance (ANOVA) table for Calcium content of dried slices of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.039471	0.019736	3.18	
STAGES	2	9.280139	4.640069	748.36	<.001
VARIETY	2	1.570774	0.785387	126.67	<.001
STAGES.VARIETY	4	0.447147	0.111787	18.03	<.001
Residual	16	0.099205	0.006200		
Total	26	11.436737			

APPENDIX 20: Analysis of Variance (ANOVA) table for Magnesium content of dried slices of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.02627	0.01314	1.08	
STAGES	2	30.86981	15.43490	1271.72	<.001
VARIETY	2	14.05381	7.02690	578.96	<.001
STAGES.VARIETY	4	2.14761	0.53690	44.24	<.001
Residual	16	0.19419	0.01214		
Total	26	47.29170			

APPENDIX 21: Analysis of Variance (ANOVA) table for Sodium content of dried slices of ‘Kent’, ‘Tommy atkins’ and ‘Van dyke’ mango varieties at three stages of maturity during season 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.026756	0.013378	1.39	
STAGES	2	1.696267	0.848133	87.86	<.001
VARIETY	2	1.648267	0.824133	85.38	<.001
STAGES.VARIETY	4	0.032533	0.008133	0.84	0.518
Residual	16	0.154444	0.009653		
Total	26	3.558267			

APPENDIX 22: Analysis of Variance (ANOVA) table for Iron content of dried slices of ‘Kent’, ‘Tommy atkins’ and ‘Van dyke’ mango varieties at three stages of maturity during season 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.00002719	0.00001359	0.28	
STAGES	2	0.00606363	0.00303181	61.76	<.001
VARIETY	2	0.00182096	0.00091048	18.55	<.001
STAGES.VARIETY	4	0.00027393	0.00006848	1.39	0.280
Residual	16	0.00078548	0.00004909		
Total	26	0.00897119			

APPENDIX 23: Analysis of Variance (ANOVA) table for juice pH of 'Kent', 'Tommy atkins' and 'Van dyke' mango varieties at three stages of maturity during season 1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPS stratum	2	0.009785	0.004893	1.41	
STAGES	2	0.980363	0.490181	141.36	<.001
VARIETY	2	0.092896	0.046448	13.39	<.001
STAGES.VARIETY	4	0.068259	0.017065	4.92	0.009
Residual	16	0.055481	0.003468		
Total	26	1.206785			