



The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

MATURITY INDICES OF SPECIFIC MANGO VARIETIES PRODUCED AT MEDIUM ALTITUDE AGRO-ECOLOGICAL ZONE IN KENYA

Muiruri J¹, Ambuko J¹, Nyankanga R¹ and WO Owino^{2*}



Jacinta Muiruri

*Corresponding author email: willis@agr.jkuat.ac.ke

¹Department of Plant Science and Crop Protection, University of Nairobi,
P. O. Box 29053-00625, Kangemi, Nairobi, Kenya

²Department of Food Science and Technology, Jomo Kenyatta University of
Agriculture & Technology, P.O Box 62000-00200, Nairobi, Kenya

ABSTRACT

The high postharvest losses (40 – 50%) reported in the mango value chain are partly attributed to lack of reliable maturity indices. Harvest maturity is dictated by the intended use and the target market for the fruits. The aim of this study was to establish maturity indices of three commercial mango varieties namely ‘Van dyke,’ ‘Kent’ and ‘Tommy Atkins’ in Embu County of Kenya. At least eighteen mango trees (six per variety) were randomly tagged at 50% flowering in each of the three selected small-scale farms in Embu County. Number of days from flowering to different maturity stages were recorded (computational method). 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 (°brix/Total Soluble Solids (TSS), total titratable acidity (TTA) and their ratio) indices of maturity. 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 earlier than others that were large-sized. The weight of the fruits fluctuated as the fruits developed and similar trend was observed on the specific gravity. Flesh firmness decreased gradually with maturity from a mean firmness of 40.54 N to 6.84 N. Tommy Atkins exhibited the lowest firmness levels at stage 4. Kent variety had the lowest ethylene at all stages while 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 highest TSS: TTA values were reported in Kent variety. The results revealed significant differences in maturity indices of the three mango varieties despite similar physical indices. This study confirms the unreliability of physical maturity indices such as size and shape in establishing the right harvest stage of mango fruits. Computational, physiological and biochemical maturity indices should be incorporated in determination of accurate harvest maturity for mango.

Key words: Ethylene, Harvest maturity, ‘Kent’, Maturity indices, Respiration, ‘Tommy Atkins’, ‘Van dyke’

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 [1] 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 [2]. 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 [2]. Improvement of maturity indices is a continuing research matter [3].

Customarily, mangoes are harvested based on the growers' observation on the appearance of the fruits [4,5,6]. 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 [7]. Immature fruits are more likely to be mechanically damaged [8] and of low-grade quality when ripe [9]. Fruits harvested at advanced maturity stage have better aroma quality [10] but reduced storage life [11]. 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 [6]. 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 [12].

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 [12].

Accurate determination of harvest 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 [1]. In Kenya, mangoes take 90 to 160 days after full bloom to reach maturity depending on cultivars and environmental conditions in a given area.

Physical indices that have been used include size, shape, peel/flesh color, peel/flesh firmness and specific gravity (inclusive of weight) [6]. 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 on the prevailing environmental conditions [14]. 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 [12].

As fruits mature, a series of changes like the breakdown of chlorophyll and increase in carotenoid pigments of the pulp occurs [15]. 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 [16]. 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 [17]. It is also a standard measurement for maturity of fruits such as peaches, pears and apples though it is destructive [18].

Physiological indices that are used include ethylene evolution and respiration. There is increased evolution of CO₂ and ethylene when climacteric fruits reach physiological maturity and ripening processes are initiated [1]. The rate of respiration increases with fruit maturity and the increment rate depends on the type of fruit and differs among cultivars. Climacteric fruits such as mango show a notable increment in respiration rate as maturation progresses [19].

Biochemical indices used include soluble solids content, titratable acidity and their ratio [20]. As mango fruits mature, soluble solids content increases while titratable acidity decreases [18]. Fruit maturity is related to total soluble solids (brix) to acid ratio [1]. Sugar content in conjunction with fruit hardness and starch color reaction has been used to determine the optimal time of harvest of apple fruit [1]. Although biochemical indices of maturity are reliable, they are destructive and time-consuming [20].

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.

MATERIALS AND METHODS

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 1495 mm with temperatures ranging from 12 °C to 27 °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 1350 m.

Three small-scale farms were selected in Embu County, and on each farm, eighteen 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. 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 in the postharvest laboratory. They were then selected for uniformity and freedom from any damage.

For each variety, a random sample 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 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.

DETERMINATION OF MATURITY INDICES

Sampling

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 immediately washed in cold water which was sanitized using 1% acetic acid for disinfection and disinfestation. The fruits were then selected for uniformity and freedom from 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, °brix and their ratio) maturity indices.

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 (2, 3 and 4) took 7-10 days apart.

Physical maturity indices

Size

The length of three fruits randomly selected from each of the 3 varieties at the different stages was determined using a caliper (Model Mitutoyo, Japan) and the mean size was expressed in centimeters.



Specific gravity

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/cm³.

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 the peel or flesh to a depth of 1.5 cm and the corresponding force required to penetrate this depth was determined. Firmness was then expressed as Newton (N).

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°), formulation where (Hue angle (H°) = $\tan^{-1}(b^*/a^*)$ [21].

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 °C). 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.

Biochemical maturity indices

Total Soluble Solids (°Brix) Content

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

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 50 ml of distilled water. Ten milliliters 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 using the formula;
 $\% \text{ Citric acid equivalent} = \text{Sample reading (ml)} \times \text{Dilution factor (0.0064)} \times 100 / \text{sample weight (ml)}.$

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 is presented as tables and graphs showing various maturity indices for the 3 varieties and 4 maturity stages.

RESULTS AND DISCUSSION

Computational maturity indices

Tommy Atkins mango variety attained physiological maturity (stage 1) earlier than Van dyke and Kent varieties. Although it took up to ten days apart from one maturity 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 1).

Mango, being a climacteric fruit has to be harvested at the suitable stage of maturity since the quality and the post-harvest life of the fruit depend on the maturity stage at harvest [4,5]. Computational method can be effectively used by the farmers in determining maturity stages for Tommy Atkins, Van dyke and Kent mango varieties since no inputs are required. However, proper records have to be kept for accuracy.

Physical maturity indices

Size and shape

The size (length) of 'Tommy Atkins,' 'Van dyke' and 'Kent' varieties was significantly different ($p < 0.05$) for the same maturity stage. During season 1, the length of the fruits was significantly different ($p < 0.05$) among the varieties during early maturity. The range of size of the 3 varieties was: Van dyke 28.27 cm (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 2). During season 2, the size range for Van dyke was between 29.17 cm (stage 1) and 30.50 cm (stage 4), Tommy Atkins 32.70 cm and 41.60 cm and Kent 35.17 cm and 42.70 cm. Tommy Atkins and Kent varieties were generally larger compared to Vandyke variety (Table 3). Fullness of cheek and shoulder development was observed as fruit maturity progressed as shown in figures 1 to 3.

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. Mango size depends on the accumulation of water and dry matter in the various compartments during fruit growth [14]. The skin, the flesh and the stone have specific compositions that appear to accumulate water and dry matter at different rates, depending on environmental conditions [14]. Although fruit size is often used as a

maturity index in crops like capsicum, banana, litchi, size and weight are poor measures of fruit maturity since they depend upon a number of variables such as soil and climatic conditions [1].



Figure 1: Changes in shape in 'Tommy Atkins' variety from maturity stages 1 to 4



Figure 2: Changes in shape in 'Van dyke' variety from maturity stages 1 to 4



Figure 3: Changes in shape in 'Kent' variety from maturity stages 1 to 4

Specific gravity

The specific gravity of the fruits was inconsistent as maturity progressed in all the varieties during the 2 seasons (Tables 2 and 3). Van dyke variety was significantly different ($p < 0.05$) from Tommy atkins and Kent varieties. 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 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.

Specific gravity in mango fruit can vary from year to year [22]. Due to too much inconsistency in specific gravity in mango varieties, the parameter cannot be used as a criterion to predict maturity [23]. However, fruits such as cherries and watermelons have been reported to have their specific gravity increasing as they mature [1].

Color

The hue angle on the skin fluctuated depending on the variety but not stage of maturity, at early and advanced maturity stages (Table 4). Kent skin color was cool green (135.87° and 143.21°) during early and advanced maturity. The varieties had significantly different ($p < 0.05$) peel hue angle during early maturity stage where the skin color of Kent variety was cool green while that of Van dyke was lime. This flesh color changes are clearly shown on figures 4 to 6.



Figure 4: Flesh color changes for ‘Kent’ variety at maturity stages one to four



Figure 5: Flesh color changes for ‘Tommy Atkins’ variety at maturity stages one to four



Figure 6: Flesh color changes for ‘Van dyke’ variety at maturity stages one to four

Color is the most important first impression by a consumer of any food product. Hue describes a visual sensation according to which an area appears to be similar to one or proportions of two of the perceived colors: red, yellow, green and blue. The hue angle is thus actual color [21]. Skin color is commonly observed after the fruit has started to soften and is usually not very uniform in several mango cultivars. Skin color is also affected by cultural practices and environmental conditions. Soil nutrients and management which is inclusive of method of irrigation have an effect on tree and foliage growth which can have effect on fruit qualities such as skin color, yield and soluble solids on golden delicious apples [24]. Pruning can be used very effectively to improve light penetration thereby increasing fruit color throughout the canopy [25]. Increased light exposure during fruit growth and development enhances formation of color pigments including anthocyanins and carotenoids [26]. 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 [20]. Therefore, skin color should not be considered as an adequate maturity index.

Firmness

A decreasing trend for both skin 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 ($p<0.05$) higher peel firmness compared to Tommy Atkins and Vandyke while Tommy Atkins had the softest flesh among the 3 varieties ($p<0.05$) (Tables 2 and 3).

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. During fruit ripening, cell wall architecture and the polymers of which it is composed are progressively modified. The decrease in firmness with maturity is attributed to gradual solubilization of protopectin in the cell wall to form pectins [27]. Skin and flesh firmness varies with different mango varieties. The outer mesocarp of 'Kent' mango variety remains firm longer than 'Tommy atkins' mango variety and the 'Kent' variety accumulates more soluble polyuronides and retains more total pectin at the ripe stage than 'Tommy atkins' [28]. 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.

Physiological maturity indices

Ethylene production rate and respiration rate

Ethylene evolution increased gradually with maturity stages as shown in tables 5 and 6. Ethylene production was significantly ($p<0.05$) affected by the interaction between variety and stage of maturity. In season 1, ethylene evolution increased from 0.114 $\mu\text{l/kg/hr}$ (early maturity) to 0.3487 $\mu\text{l/kg/hr}$ (advanced maturity) for Van dyke variety and 0.115 $\mu\text{l/kg/hr}$ to 0.3 $\mu\text{l/kg/hr}$ for Tommy Atkins variety. During season 2, Kent variety had the lowest ethylene production rate, 0.1123 $\mu\text{l/kg/hr}$ (stage 1) to 0.2943 $\mu\text{l/kg/hr}$ (stage 4) in all maturity stages ($p<0.05$). Respiration rate was also 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 ($p < 0.05$) (Tables 5 and 6).

Ethylene is a natural plant hormone (phytohormone) associated with the growth, development, ripening and aging of many plants [4, 5, 6]. Respiration converts stored sugars or starch to energy and the rate normally increases when fruits are maturing. Climacteric fruits such as mango show a remarkable increment in respiration rate in maturation [19]. 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, [29]. Ethylene evolution and respiratory activity begins to rise gradually as climacteric fruits mature and begin to ripen. Ethylene production in unripe mango fruit is very low [30] and it decreases as the fruit matures; then undetectable for a time and reappears upon initiation of ripening. The initiation of ethylene production within the fruit triggers and coordinates the changes that occur during ripening. These changes include color changes in the peel and flesh, softening of the flesh, and development of sweet flavour and aroma [31]. Physiological maturity indices can therefore be used to determine the maturity stage of the fruit depending with the variety.

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. Total soluble solids (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° and 8.097° (early maturity) to 13.85° and 13.98° (advanced maturity). Total titratable acidity (TTA) reduced from 0.299 % to 0.162 % in Van dyke variety and 0.297 % to 0.156 % in Kent variety (Table 7). During season 2, TSS in Tommy Atkins variety increased from 7.793° (maturity stage 1) to 13.72° (maturity stage 4) while TTA reduced from 0.2360 % (maturity stage 1) to 0.1340 % (maturity stage 4) (Table 8).

Soluble solids contents and sugar to acid ratio provide more reliable markers of the right harvest maturity [32]. A non-destructive optical method that can be employed successfully using near infra-red (NIR) spectroscopy to determine TSS contents in fresh prune has been reported [3, 33]. The increase in the TSS: TTA ratio as maturation progresses is as a result of gluconeogenesis, hydrolysis of polysaccharides, especially starch, decreased acidity and accumulation of sugars and organic acids with an excellent sugar/acid blend [34]. 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.

CONCLUSION

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. This makes Kent 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 export 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.

Farmers should therefore avoid harvesting mango fruits based on their size or weight but should consider sampling for further confirmation using other maturity indices to avoid losses and maximize their profit.

ACKNOWLEDGEMENTS

The authors would like to offer their gratitude to Kenya Agricultural Productivity and Agribusiness Project (KAPAP) for sponsoring the research work.

Table 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

Table 2: Size (Length in cm), Density (g/cm³), 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	28.27a	1.205b	50.19a	37.62a
	Tommy Atkins	31.53b	1.282a	47.33a	39.23a
	Kent	35.03c	1.298a	60.58b	39.79a
	LSD	0.7997	0.045	4.1783	ns
	CV%	1.1	2.4	3.5	4.1
Advanced maturity	Van dyke	30.40a	1.223b	29.68b	12.12b
	Tommy Atkins	40.20b	1.263a	25.84a	6.43a
	Kent	38.67b	1.266a	27.92b	12.84b
	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 ($p < 0.05$) 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 3: Size (Length in cm), Density (g/cm³), 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	29.17a	1.189b	48.14a	33.92a
	Tommy Atkins	32.70b	1.214a	46.43a	34.77a
	Kent	35.17c	1.226a	53.81b	40.54b
	LSD	1.631	0.015	4.0412	3.3466
	CV%	2.2	3.4	3.6	4.1
2	Van dyke	27.97a	1.162b	41.71a	30.21a
	Tommy Atkins	40.00b	1.248a	41.14a	28.58a
	Kent	40.17b	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	29.17a	1.181c	33.23a	24.75c
	Tommy Atkins	40.50b	1.248b	31.88a	15.69a
	Kent	42.23b	1.254a	36.58b	20.35b
	LSD	2.576	0.031	2.8080	1.4668
	CV%	3.0	3.3	3.7	3.2
4	Van dyke	30.50a	1.203b	28.15a	13.88c
	Tommy Atkins	41.60b	1.251a	27.28a	6.84a
	Kent	42.70b	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<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: Peel and Flesh hue angle (°) of ‘Van Dyke’, ‘Tommy Atkins’ and ‘Kent’ mango fruits harvested during early and late maturities

Maturity stage	Variety	Hue angle peel	Hue angle flesh
Early maturity	Van dyke	88.5a	112.38a
	Tommy Atkins	108.2b	108.73a
	Kent	135.87c	106.51a
	LSD	9.8	ns
	CV%	2.7	3.5
Advanced maturity	Van dyke	73.5a	79.23a
	Tommy Atkins	115.62b	77.48a
	Kent	143.21b	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 ($p < 0.05$) 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 5: Ethylene evolution ($\mu\text{l/kg/hr}$) 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	17.97a
	Tommy Atkins	0.115a	20.10b
	Kent	0.112a	20.83b
	LSD	ns	1.1847
	CV%	7.1	2.7
Advanced maturity	Van dyke	0.3487b	34.46a
	Tommy Atkins	0.3000a	30.83a
	Kent	0.2950a	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 6: Ethylene evolution $\mu\text{l/kg/hr}$ 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	19.04a
	Tommy Atkins	0.1145a	21.40c
	Kent	0.1123a	19.82b
	LSD	ns	0.6858
	CV%	0.7	1.5
2	Van dyke	0.1660b	23.83ab
	Tommy Atkins	0.1637b	25.37b
	Kent	0.1160a	22.69a
	LSD	0.0091	1.8345
	CV%	2.7	3.4
3	Van dyke	0.2830c	28.76b
	Tommy Atkins	0.2567b	29.54b
	Kent	0.2187a	25.47a
	LSD	0.0062	1.4025
	CV%	1.1	2.2
4	Van dyke	0.3300b	33.88a
	Tommy Atkins	0.3067a	32.10a
	Kent	0.2943a	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

Table 7: Biochemical maturity indices, total soluble solids (° 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	7.000a	0.299a	23.49a
	Tommy Atkins	7.320a	0.275a	29.68b
	Kent	8.097b	0.297a	24.75a
	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 8: Biochemical maturity indices; total soluble solids (° 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	7.190a	0.2817b	25.57a
	Tommy Atkins	7.793b	0.2360a	33.14b
	Kent	7.847b	0.2317a	33.88b
	LSD	0.3590	0.0288	4.9118
	CV%	2.1	5.1	7.0
2	Van dyke	9.89a	0.2090c	47.34a
	Tommy Atkins	12.65b	0.1810b	69.97b
	Kent	13.24c	0.1620a	81.98c
	LSD	0.3365	0.0092	5.6525
	CV%	1.2	2.2	3.8
3	Van dyke	12.60a	0.1820c	69.27a
	Tommy Atkins	13.40b	0.1447b	92.62b
	Kent	13.77c	0.1387a	99.39c
	LSD	0.3420	0.004	3.1765
	CV%	1.1	1.1	1.6
4	Van dyke	13.88b	0.1473b	94.3a
	Tommy Atkins	13.72a	0.1340a	102.5ab
	Kent	13.93b	0.1320a	105.5b
	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 ($p < 0.05$) 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

REFERENCES

1. **Sudheer KP and V Indira** Post harvest technology of horticultural crops. Vol. 7. New India Publishing, 2007.
2. **Verma LR, Joshi VK and LR Verma** Postharvest Technology of Fruits and Vegetables Handling, Processing, Fermentation and Waste Management. Indus Pub., 2000.
3. **Lakshmi SA, Pandey K, Ravi N, Chauhan O, Natarajan G and RK Sharma** Non-destructive quality monitoring of fresh fruits and vegetables. Defense Life Science Journal, 2017; **2 (2)**: 103-110.
4. **Litz RE.** The mango: botany, production and uses. Cabi, 2009.
5. **Singh Z, Singh RK, Sane VA and P Nath** Mango-postharvest biology and biotechnology. **In:** Critical Reviews in Plant Sciences 2013; **32**: 217-236.
6. **Yahia EM** Postharvest biology and technology of tropical and subtropical fruits: fundamental issues. Elsevier, 2011.
7. **Rees D, Farrell G and J Orchard** Crop post-harvest: science and technology, Volume 3. **In:** Perishables. Vol. 3. John Wiley & Sons, 2012.
8. **Chonhenchob V and SP Singh** A comparison of corrugated boxes and reusable plastic containers for mango distribution. Packaging Technology and Science International Journal 2003; **16**: 231-237.
9. **Medlicott AP, Reynolds SB, New SW and AK Thompson** Harvest maturity effects on mango fruit ripening. Tropical Agriculture (Trinidad and Tobago) 1988.
10. **Bender RJ, Brecht JK, Baldwin EA and TMM Malundo** Aroma volatiles of mature-green and tree-ripe Tommy Atkins mangoes after controlled atmosphere vs. air storage. HortScience 2000; **35**: 684-686.
11. **Seymour GB, N'diaye M, Wainwright H and GA Tucker** Effects of cultivar and harvest maturity on ripening of mangoes during storage. Journal of Horticultural Science 1990; **65**: 479-483.
12. **Kader A and B Mitcham** Optimum procedures for ripening mangoes. Fruit ripening and ethylene management, 2008; 48.
13. **Sivakumar D, Jiang Y and EM Yahia** Maintaining mango (*Mangifera indica* L.) fruit quality during the export chain. Food Research International 2011; **44**: 1254-1263.



14. **Lechaudel M, Génard M, Lescourret F, Urban L and M Jannoyer** Leaf-to-fruit ratio affects water and dry-matter content of mango fruit. *The Journal of Horticultural Science and Biotechnology* 2002; **77**: 773-777.
15. **Ortega-Zaleta D and EM Yahia** Tolerance and quality of mango fruit exposed to controlled atmospheres at high temperatures. *Postharvest Biology and Technology* 2000; **20** :195-201.
16. **Jha SN, Kingsly ARP and S Chopra** Non-destructive determination of firmness and yellowness of mango during growth and storage using visual spectroscopy. *Biosystems Engineering* 2006; **94**: 397-402.
17. **Lahav E, Whiley AW, Schaffer B, Wolstenholme BN and AW Whiley** The avocado: Botany, production and uses, 2002.
18. **Brückner B and GS Wyllie** Fruit and vegetable flavour. *Recent Advances and Future Prospects* 2008; **317**
19. **Tharanathan, RN, Yashoda HM and TN Prabha** Mango (*Mangifera indica* L.) The king of fruits —An overview. *Food Reviews International* 2006; **22 (2)**: 95-123.
20. **Kader AA.** Postharvest technology of horticultural crops. Vol. 3311. University of California Agriculture and Natural Resources, 2002.
21. **McGuire RG** Reporting of objective color measurements. *J. of HortScience* 1992; **27**: 1254-1255.
22. **Salunkhe DK and SS Kadam** Cashew. **In:** *Handbook of Fruit Science and Technology*, pp. 525-538. CRC Press, 1995.
23. **Halderson JL, Ojala JC, Harding GW and EV Musselman** Influence of seed placement on Russet Burbank potato yield and grade. *American Potato Journal* 1992; **69**: 31-38.
24. **Wunsche JN and IB Ferguson** Crop load interactions in apple. *Horticulture Review* 2005; **31**: 231-290.
25. **Phillips M** The apple grower: a guide for the organic orchardist. Chelsea Green Publishing, 2005.
26. **Pott I, Marx M, Neidhart S, Mühlbauer W and R Carle** Quantitative determination of β -carotene stereoisomers in fresh, dried, and solar-dried mangoes (*Mangifera indica* L.). *Journal of agricultural and food chemistry* 2003; **51**: 4527-4531.

27. **Tridjaja NO and MS Mahendra** Maturity Indices and Harvesting Practice of Arumanis, Mango Related to The Target Market. *Journal Teknologi Pertanian* 2000; **1** (3).
28. **Ali ZM, Lieng-Hong C and H Lazan** A comparative study on wall degrading enzymes, pectin modifications and softening during ripening of selected tropical fruits. *Plant Science* 2004; **167**: 317-327.
29. **Solomos T and AK Kanellis** Hypoxia and fruit ripening. **In:** *Biology and biotechnology of the plant hormone ethylene*, Springer, Dordrecht 1997; 239-252.
30. **Burdon J, Dori S, Marinansky R and E Pesis** Acetaldehyde inhibition of ethylene biosynthesis in mango fruit. *Postharvest Biology and Technology* 1996; **8**: 153-161.
31. **Brecht JK and EM Yahia** *Postharvest Physiology*. **In:** *The mango*, 2nd edition: Botany, production and uses, CAB International 2009; pp. 484-516.
32. **Felts M** *Evaluation of Fresh-market Potential of Arkansas-grown Fruit: Blackberries, Peaches, Table Grapes, and Muscadine Grapes*. University of Arkansas, 2018.
33. **Slaughter DC** *Non- destructive maturity assessment methods for mango*. University of California, Davis 2009; 1-18.
34. **Tover A, Zernant J, Chugani SA, Chakrabarty AM, and M Kivisaar** Critical nucleotides in the interaction of CatR with the pheBA promoter: conservation of the CatR-mediated regulation mechanisms between the pheBA and catBCA operons. *Microbiology* 2000; **146**: 173-183.