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Effect of ripening stage on physical properties and shelf life of "Mabrouka" mango (*Mangifera indica* L.) fruits in Benue State, Nigeria

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ABSTRACT

A study was carried out in 2018 to determine the effect of fruit maturity stage on physical properties of Mabrouka mango fruits in Benue State with a view to establishing appropriate harvest criteria for the variety. Mango orchards for the study were selected from three Local Government Areas (LGAs) of the State, namely, Gboko, Konshisha and Otukpo. Five trees in each location, based on similarities in age and vigour were sampled for data taking. Fruit maturity or ripening stages were based on weeks after flowering (WAF). The experiment was a 3 × 6 factorial arranged in completely randomized design (CRD) and replicated three times. The factors were the three locations (Gboko, Konshisha, Otukpo) and 6 maturity stages (21, 22, 23, 24, 25 and 26 WAF). Analysis of variance showed that location significantly influenced all physical parameters evaluated except specific gravity and pulp: stone ratio. Fruits from Konshisha were heavier and longer but had shorter girths. Fruit ripening stage significantly influenced all the physical traits examined. Most of the traits increased with increase in weeks after flowering except stone percentage and pulp: peel ratio that took the opposite trend. Fruits from Konshisha were also more firm compared to the other locations. Peel firmness, pulp firmness, days to ripening and shelf life were inversely proportional to fruit maturity stage (weeks after flowering). It was generally observed that fruits harvested 26WAF had highest weight and pulp percentage but the shortest shelf life. Fruits harvested 21 WAF had the longest shelf life. It may be concluded that for immediate consumption, fruits could be harvested 26 WAF while for delayed consumption like shipment to distant markets, harvest could be done earlier.

KEY WORDS: *Ripening stage*; *Physical properties*; *Mabrouka mango*; *Shelf life*

1. Introduction

Mango is one of the most important fruit crops in tropical and subtropical regions of the world (Salunkhe and Desai, 1984; Islam *et al.*, 2016). Its fruits are fleshy, generally sweet in taste and vary considerably in size, shape, colour, flavour, and composition (FAO, 2002). Like other tropical fruits, mango is seasonal, with relatively short post-harvest shelf life due to its perishability.

Mango is now cultivated throughout the tropical and subtropical world for commercial fruit

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production, as a garden tree, and as a shade tree for stock (Bally, 2006). World production of mango reached 38.67 million metric tonnes in 2010, an increase from 35.62 million metric tonnes recorded in the previous year (FAOSTAT, 2012). Africa accounts for approximately 10.77% of global mango production while America and Asia accounts for approximately 12.62% and 76.49% respectively (FAOSTAT, 2012). Mango is commercially grown in 90 countries. India is the largest producer among the mango producing countries, accounting for 42.25% of global production in 2010 with a yield of 16.34 million metric tonnes, followed by China and Thailand at 4.35 million metric tonnes (11.25%) and 2.55 million metric tonnes (6.60%), respectively. Other leading mango producing countries and their respective share of world production in 2010 include Pakistan (4.61%), Mexico (4.22%), Indonesia (3.40%), Brazil (3.07%), Bangladesh (2.71%), the Philippines (2.14%), Nigeria (2.04 %), Egypt (1.31%) and Peru (1.18%), respectively (FAOSTAT, 2012).

The stage of development at which a product is regarded as mature depends on its final use (El-Ramady *et al.*, 2015). Harvesting at optimum maturity is a critical step, which determines the potential storage life, flavour and consumer acceptance of mango fruit (Medlicott *et al.*, 1988; Seymour *et al.*, 1990; Singh and Singh, 2011). The degree of maturity at harvest is the most important factor that determines the fruit quality as well the period for which fruit can be stored without losing quality. Kader (1999) asserted that the eating quality of mangoes when ripe depends upon maturity at harvest. Picking of the fruits either earlier or later than proper harvest maturity subjects the fruit to physiological disorders. Immature harvested fruits are subject to shrivelling, mechanical damage and inability to achieve premium quality standards required by consumers. On the other hand, ripe and overripe harvested fruits will be too soft or mealy with tasteless flavour and cannot reach consumers (Kader, 1999). Generally, a compromise between an earlier and a late harvest has to be reached to achieve the premium quality for consumer and in the same time extend post-harvest life for marketing. Mango fruit have better aroma quality (Bender *et al.*, 2000), if harvested at advanced maturation, but reduces the storage potential (Seymour *et al.*, 1990). In order to meet the quarantine requirements, mango fruit must be harvested at optimum harvest maturity to suit to the post-harvest vapour heat or hot water treatments (Jacobi *et al.*, 2001; Jacobi and Wong, 1992). Commercial harvesting decision by farmers are usually influenced towards achieving better shelf life and receiving a good market price by harvesting fruit at appropriate maturity stage. There is a guideline of maturity indices which can be applied to determine fruit maturity (Amarakoon *et al.*, 1999). According to Mitcham and McDonald (1992), six stages of maturity and ripeness of “Keitt” and “Tommy Atkins” mangoes are as follows: (1) Immature- green (underdeveloped shoulders); (2) Mature-green (well-rounded shoulders); (3) Firm (yields slightly under pressure); (4) Fairly-firm (yields significantly under pressure); (5) Soft-ripe (soft fruit); and (6) Over-ripe (extremely soft, mushy).

Maturity at harvest is the most important determinant of storage-life and final fruit quality (Kader and Rolle, 2004). There is no particular parameter for judgment of fruit maturity; it depends on mango type, variety, production conditions, and location (Mitra and Baldwin, 1997). Fruits harvested before they reach full maturity may not be ripened adequately after harvest, or in some cases (when harvested immature) they will never ripen. On the other hand fruits harvested when over-ripe are very sensitive to bruising, decay and to water loss and quality deterioration, and will not have a long post-harvest life (Yahia, 1999). In addition, fruit harvested over-ripe will show defects, such as jelly seeds or jelly pulp very shortly after harvest, and major quantitative and qualitative losses will occur. Jelly seed, which shows in large quantities of fruits and especially those picked over-ripe, deteriorate the internal quality of the fruit (Yahia, 1999). Post-harvest physiologists over the years have distinguished three distinct stages in the life span of fruits and vegetables: maturation, ripening, and senescence (Addo *et al.*, 2015). Maturation is indicative of the fruit being ready for harvest (FAO, 2008; Addo *et al.*, 2015). It must be ensured that properly matured fruits are harvested because maturity stage is the starting point of post-harvest quality management. Fruits should be allowed to reach the appropriate stage of development based on physiological and horticultural maturity before they are harvested (Ahmad and Siddiqui, 2016).

Traditionally mango is harvested based on judgments through the growers by observing the appearance of the fruit. Common criteria for judging maturity include physical attributes such as skin colour, flesh firmness, size, shape and moisture or solid contents; chemical attributes such as sugar, starch or acid contents; estimation of development stage and morphological evaluation (Sultana *et al.*, 2017). Kader and Mitcham (2008) reported that there are several factors which affect fruit quality including maturity at harvest as an important factor in determining eating quality of ripe mangoes. Many maturity indices have been tested however, due to differences among cultivars, production conditions and locations, there is no consensus on maturity indices (Mitra and Baldwin, 1997).

Mabrouka is one of the mango varieties grown in Benue State, due among others, to its taste and high yield. Huge post harvest losses are experienced yearly due to several factors including wrong time of harvesting. In most fruits, quality is maximized when the fruits are harvested more mature or ripe, whereas shelf and storage life are extended if they are harvested less mature or unripe (Toivonen, 2007). Fruits harvested prematurely especially those targeting far-flung markets fail to attain optimal sensory attributes which affects consumer acceptance. Also, their shelf life is very short because they are highly susceptible to mechanical damage (Yahia, 2011).

To optimize fruit quality and enhance shelf life of produce, it becomes pertinent to look at physical attributes of mango fruit that will correctly indicate the right time of harvest of Mabrouka mango fruit. This study was therefore embarked upon to investigate the effects of fruit maturity stage on physical attributes and shelf life of Mabrouka fruit in Benue State, Nigeria.

2. Materials and Methods

Private mango orchards were selected in three Local Government Areas of Benue State, in Southern Guinea Savanna of Nigeria (Latitude.to, 2018). The Local Government Areas were Konshisha (Latitude 7º 01′47.75″ N, Longitude 8º 39’37.33” E) Otukpo (Latitude 7º 16′ 1.06″ N, Longitude 8º 04’3.50” E) and Gboko (Latitude 7º 18′ 58.18″ N, Longitude 8º 54’6.01” E).

Five mango trees of similar age and vigour were selected from each location and tagged at 50% flowering. The number of days from 50% flowering to physiological maturity of fruit (mature green stage), based on flesh colour (yellowing of the flesh around the seed) was established as stage one (1) [21 weeks after flowering or 147 days after flowering]. Subsequent stages were stage two (2) [22 weeks after flowering or 154 days after flowering], stage three (3) [23 weeks after flowering or 161 days after flowering], stage four (4) [24 weeks after flowering or 168 days after flowering], stage five (5) [25 weeks after flowering or 175 days after flowering] and stage six (6) [26 weeks after flowering or 182 days after flowering] were taken seven (7) days apart. At each harvest date, 10 fruits were harvested from all over the tree using a cloth bag attached to a long pole. The fruits were immediately washed in water which was sanitized using 1% acetic acid for disinfection. Only uniform fruits were selected. Selected fruits from each mango tree in the same location were bulked and divided into two lots of 25 fruits each. One lot was analysed as fresh fruits for physical characters while the other lot was analysed after ripening under laboratory conditions to determine physical characteristics and the number of days required for ripening of the fruits. Physical characters were determined in the Physics laboratory of Benue State University Makurdi.

The experiment was a 3 × 6 factorial laid out in Completely Randomized Design (CRD). The factors were:

i. Three locations (Konshisha, Gboko and Otukpo).

ii. Six stages of maturity; defined as 21, 22, 23, 24, 25 and 26 weeks after flowering as stated earlier. The mango variety "Mabrouka" was used for the experiment.

Data were collected on pertinent physical parameters. As such, six fruits were randomly selected from each location at each stage and their lengths and girths were taken using a 100cm measuring tape. The fruits were also weighed using an electronic weighing balance

The specific gravity of mango fruits was determined by dividing the weight of the fruit in air by the volume of the fruits as obtained by water displacement method.

$$\text{Specific Gravity} = \frac{\text{Weight of fruit}}{\text{Volume of fruit}}$$

The pulp, peel and stone percentage were determined by randomly selecting two mango fruits which were peeled and the flesh separated from the stone using a kitchen knife. The peel, pulp and stone were weighed separately and the percentage weights were calculated accordingly and this was repeated three times.

The pulp, peel and stone were separated, weighed individually and expressed as pulp to peel ratio.

$$\text{Pulp to peel ratio} = \frac{\text{Pulp weight}}{\text{Peel weight}}$$

The pulp, peel and stone were separated, weighed individually and expressed as pulp to stone ratio.

$$\text{Pulp to stone ratio} = \frac{\text{Pulp weight}}{\text{Stone weight}}$$

To estimate moisture and dry matter contents, an empty container was weighed on an electronic micro balance and labelled 'A'. Chopped fresh pulp samples were transferred into the container weighed and labelled 'B'. The samples were placed in an air ventilated electric oven at 100°C for 24 hours (Kushman *et al.*, 1966). The samples were then transferred with the container from oven into a desiccator and cooled at room temperature and then weighed to obtain the dry samples 'C'.

Percentage moisture and dry matter content of the samples was calculated using the following formula;

a. Wet weight of sample = B – A

b. Dry weight of sample = C –A

c. Moisture content (%) = $\frac{\mathrm{D-E}}{\mathrm{E} \times 100}$

A penetrometer was used to determine firmness of fruits. Peel firmness was measured at three different points on the fruit while flesh firmness was determined from the peeled portions of three sampled fruits at all the maturity stages. 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 expressed as kg/square cm.

The colour of both the flesh and peel was measured using WR10 Portable Precise Colorimeter.

The number of days taken for the complete ripening of fruits was determined by counting the number of days from the date on which the fruit was harvested to the day it attained desirable flavour, quality, colour, palatable nature and other textural properties. This was achieved with the help of judges and general appearance of the fruits (Sensory properties are reported elsewhere).

The shelf life (days) of mango fruit from each treatment was recorded during the period of storage. Mango was stored in woven baskets and covered with a cloth. This was calculated from the date of harvesting to last edible stage.

3. Results

A summary of the effect of maturity stage on fruits physical attributes of Mabrouka mango cultivar across the studied locations is presented in **Table 1**. Location exerted significant effect on all the parameters investigated except specific gravity and pulp: stone ratio. The longest fruits with shorter girths were obtained from Konshisha location. They were also comparatively heavier than those from the other two locations, with fruits from Gboko having the least weight. Fruits gotten from Otukpo had higher pulp content (63%) compared to the other locations. Interestingly, fruits from Gboko had the lowest fruit length, fruit weight, and peel percentage, but best pulp: peel ratio. Stone percentage was in the order Gboko > Konshisha > Otukpo.

Fruit ripening stage however significantly influenced all the traits examined. Generally, fruit length, fruit girth, fruit weight, specific gravity, pulp percentage and peel percentage increased with increase in weeks after flowering from 21 to 26. Conversely stone percentage and pulp: peel ratio decreased with increase in weeks after flowering. Pulp: stone ratio on the other hand did not show any defined pattern of change as flowering time increased.

Table 2 summarizes main effects of location and ripening stage on firmness of peel and pulp as

Table 1: Effect of location and ripening stage on physical attributes of Mabrouka mango fruit from Benue State, Nigeria

Treatment	Fruit length (cm)	Fruit girth (cm)	Fruit weight (cm)	Specific gravity	Pulp %	Peel %	Stone %	Pulp: peel	Pulp: stone
Location									
Gboko	18.1	31.1	541.6	1.01	62.6	22.6	14.8	3.04	5.51
Konshisha	18.9	30.8	575.4	1.00	62.1	24.7	13.2	2.48	5.38
Otukpo	18.5	31.0	558.5	1.01	63.0	24.2	12.9	2.70	5.48
LSD $_{(0.05)}$	0.11	0.19	7.49	NS	0.60	0.38	0.77	0.15	NS
Ripening Stage									
21WAF	17.0	29.2	489.8	0.97	58.6	18.2	23.2	4.01	5.78
22 WAF	17.8	30.3	509.9	0.99	60.4	22.5	17.1	2.80	5.39
23 WAF	18.4	30.8	538.3	1.00	62.1	24.0	13.8	2.68	5.71
24 WAF	18.9	31.1	569.4	1.01	63.6	25.2	11.2	2.68	5.40
25 WAF	19.2	32.0	607.2	1.03	64.5	26.1	9.4	2.21	5.19
26 WAF	19.8	32.3	636.7	1.04	66.0	27.1	6.9	2.05	5.22
LSD $_{(0.05)}$	0.14	0.26	5.31	0.01	0.85	0.54	1.69	0.22	0.23

Table 2: Main effect of location and ripening stage on peel firmness, pulp firmness, days to ripening and shelf life of Mabrouka mango fruits

Treatment	Moisture content (%)	Dry matter (%)	Peel Firmness (kg/cm^2)	Pulp Firmness (kg/cm^2)	Days to Ripening	Shelf Life (Days)
Location						
Gboko	76.2	23.8	7.4	2.6	7.2	13.8
Konshisha	76.9	23.1	7.6	3.3	7.1	13.6
Otukpo	75.8	24.2	7.4	3.0	6.9	14.2
LSD $_{(0.05)}$	0.23	0.23	NS	NS	NS	NS
Ripening Stage						
21WAF	71.6	28.4	9.7	4.6	11.4	19.6
22 WAF	72.1	27.9	9.1	4.4	9.8	15.7
23 WAF	73.8	26.2	9.1	3.8	7.6	13.4
24 WAF	79.0	21.0	7.9	2.8	6.6	13.2
25 WAF	80.0	20.0	5.0	1.6	4.7	12.3
26 WAF	81.2	18.8	3.9	0.4	2.4	8.9
LSD $_{(0.05)}$	0.33	0.33	0.32	0.14	0.81	1.57

well as days to ripening and shelf life of Mabrouka fruits. Fruits from Konshisha were more firm than those from Otukpo, the least being the fruits from Gboko. Location did not influence peel firmness, days to ripening and shelf life. In contrast, maturity stage significantly influenced all the attributes considered. There was an inverse relationship between peel firmness, pulp firmness, days to fruit ripening, shelf life and ripening stage.

Interaction effect of the factors on evaluated traits is summarized in **Tables 3** and **4**. Apart from specific gravity, pulp firmness, days to ripening

Table 3: Interaction effect of location and ripening stage on physical attributes of Mabrouka mango fruit from Benue State, Nigeria

Location	Ripening Stage	Fruit length (cm)	Fruit girth (cm)	Fruit weight (cm)	Specific gravity	Pulp %	Peel %	Stone %	Pulp: peel	Pulp: stone
Gboko	21WAF	16.9	30.0	477.9	0.97	59.1	14.6	26.3	5.0	6.0
	22 WAF	17.6	30.4	505.8	0.99	60.2	21.6	18.2	3.1	5.5
	23 WAF	18.0	30.8	522.2	1.03	60.9	23.6	15.6	2.7	6.2
	24 WAF	18.3	31.4	544.1	1.01	63.3	23.7	13.0	3.1	5.7
	25 WAF	18.7	31.8	578.6	1.04	64.8	25.3	9.9	2.3	4.8
	26 WAF	19.4	32.3	62.2	1.04	67.1	27.0	5.9	2.1	4.8
Konshisha	21WAF	17.1	28.4	501.7	0.98	57.5	20.9	21.7	3.2	5.6
	22 WAF	18.1	30.3	513.9	0.99	59.2	23.0	17.8	2.7	5.3
	23 WAF	18.9	30.6	554.3	0.99	62.2	24.6	13.2	2.7	5.3
	24 WAF	19.5	30.8	595.6	1.01	63.7	26.0	10.4	2.4	5.1
	25 WAF	19.7	32.1	635.8	1.02	64.5	26.7	8.9	2.0	5.6
	26 WAF	20.1	32.3	652.3	1.03	65.3	27.3	7.4	1.9	5.5
Otukpo	21WAF	17.0	29.2	489.8	0.97	59.1	19.2	21.7	3.9	5.8
	22 WAF	17.8	30.3	509.9	0.99	61.3	23.0	15.4	2.6	5.4
	23 WAF	18.4	30.8	538.3	1.00	63.3	23.9	12.8	2.7	5.7
	24 WAF	18.9	31.1	569.4	1.02	63.8	25.9	10.4	2.5	5.4
	25 WAF	19.2	32.0	607.2	1.03	64.5	26.2	9.4	2.3	5.2
	26 WAF	19.8	32.3	636.7	1.04	66.0	27.1	7.4	2.2	5.4
LSD $_{(0.05)}$		0.23	0.45	12.97	NS	1.47	0.93	1.89	0.37	0.41

and shelf life, the rest of the traits considered responded significantly to interaction of the factors. Generally, among traits showing significant response, there was an increase in value of the traits as maturity advanced. The only exception was stone percentage, pulp: peel ratio, pulp: stone ratio, dry matter and peel firmness. The magnitude of change however, appeared to vary with location.

Table 5 presents results of location, maturity stage and their interaction on the peel colour (L* a* b*) of Mabrouka fruits. The lightness (L*) of Mabrouka fruit increased with increase in the number of weeks after flowering in all the locations evaluated. In all the locations, the peel colour of Mabrouka fruit became less green and more yellow as the number of weeks after flowering increased. Similar observation was made for pulp colour.

On a general note, the peel colour of Mabrouka fruits (54.68) from Gboko was lighter than those from Otukpo (52.22) and Konshisha (48.69), respectively. However, Konshisha produced greener fruits (-7.34) than Otukpo (-6.25) and Gboko (-5.74), respectively while Gboko produced more yellowish fruits (47.81) than Otukpo (44.72) and Konshisha (41.40).

Table 4: Interaction effect of location and ripening stage on firmness properties, days to ripening and shelf life of Mabrouka mango fruit from Benue State, Nigeria

Location	Ripening Stage	Moisture content (%)	Dry matter (%)	Peel Firmness	Pulp Firmness	Days to Ripening	Shelf Life (Days)
Gboko	21WAF	72.2	27.8	4.4	9.7	12.0	19.3
	22 WAF	71.8	28.1	4.5	9.1	10.3	16.7
	23 WAF	71.9	26.1	3.5	9.0	7.3	13.7
	24 WAF	70.2	20.8	2.0	8.0	6.3	12.7
	25 WAF	80.0	20.0	0.7	4.6	4.7	11.7
	26 WAF	80.1	19.8	0.3	3.8	2.7	8.7
Konshisha	21WAF	71.5	28.5	4.9	9.7	10.7	17.3
	22 WAF	72.4	27.6	4.3	9.1	9.3	14.7
	23 WAF	74.5	25.5	4.2	9.1	8.3	13.0
	24 WAF	79.6	20.4	3.7	8.2	7.0	14.0
	25 WAF	80.6	19.4	2.4	5.3	4.7	13.3
	26 WAF	82.8	17.2	0.5	4.0	2.3	9.3
Otukpo	21WAF	71.3	28.7	4.6	9.7	11.7	22.0
	22 WAF	71.0	28.1	4.4	9.1	9.8	15.8
	23 WAF	73.1	27.0	3.8	9.1	7.0	13.7
	24 WAF	78.3	21.7	2.8	7.9	6.3	12.8
	25 WAF	79.5	20.5	1.6	5.0	4.7	12.0
	26 WAF	80.7	19.3	0.4	3.9	2.2	8.7
LSD $_{(0.05)}$		0.57	????	0.24	NS	NS	NS

4. Discussion

Data obtained from the study showed that Mabrouka fruit growth in terms of length, girth (breath) and weight increased significantly with increase in maturity. This is consistent with the findings of Wongmetha *et al*. (2015) and Banik and Sen (2003) who also reported an increase in fruit weight, length and width during growth. Fruits such as mango express a single sigmoid seasonal growth pattern (Dutta and Dhua, 2004) which is characterized by an initial slow increase in size after bloom followed by a relatively rapid increase in size and then a slowdown in growth as fruit maturity is approached (Lakso and Goffinet, 2003). Fruit growth also varied with location. Among the locations evaluated, Konshisha produced the highest fruit length and weight but Gboko produced the highest fruit girth. The differences in fruit size among the locations may be due to differences in environmental conditions. Final fruit size is mainly controlled by temperature during the first weeks after bloom, i.e. during the period of cell division (Lurie, 2002; Tromp and Wertheim, 2005). Other environmental factors such as available soil moisture and nutrient availability influence fruit development and final quality.

Table 5: Peel colour of Mabrouka using the CIE-LAB colour co-ordinates as influenced by different locations and maturity stages in Benue State in 2018

Maturity Stage	Peel Colour											
	L*				a*				b*			
	Location				Location				Location			
	Gboko	Konshisha	Otukpo	Mean	Gboko	Konshisha	Otukpo	Mean	Gboko	Konshisha	Otukpo	Mean
21 Weeks After Flowering	49.77	43.36	46.06	46.40	-7.73	-9.25	-8.47	-8.48	46.09	35.88	43.46	41.81
22 Weeks After Flowering	51.76	45.33	48.51	48.54	-7.26	-8.89	-7.80	-7.98	44.63	37.12	40.67	40.81
23 Weeks After Flowering	52.95	47.58	49.63	50.06	-6.28	-7.79	-6.82	-6.96	46.62	39.16	42.44	42.74
24 Weeks After Flowering	56.16	50.33	54.08	53.52	-5.80	-7.27	-6.18	-6.42	48.11	42.10	44.64	44.95
25 Weeks After Flowering	57.57	51.14	56.30	55.00	-4.19	-6.63	-5.08	-5.30	50.18	45.01	47.41	47.53
26 Weeks After Flowering	59.89	54.37	58.74	57.67	-3.19	-4.20	-3.15	-3.51	51.21	49.12	49.71	50.02
Mean	54.68	48.69	52.22	51.86	-5.74	-7.34	-6.25	-6.44	47.81	41.40	44.72	44.64
F-LSD (0.05)												
Location	0.43				0.19				0.84			
Maturity Stage	0.61				0.27				1.19			
Location x Maturity Stage	1.05				0.47				2.07			

Key: L*: Lightness; a*: Red/Green Coordinates (+ = Redder, - = Greener); b*: Yellow/Blue Coordinates (+ = Yellower, - = Bluer)

Location and location x maturity stage had no effect on specific gravity of Mabrouka but maturity stage showed significant effect. The specific gravity of Mabrouka increased with increase in the number of days after flowering and ranged from 0.97 to 1.04. Yahia (1998), reported that specific gravity ranges from 0.97 to 1.04 and may sometime be an unreliable maturity index. Pal *et al*. (1987) concluded that specific gravity of about 1.02 was a good maturity index. This suggests that Mabrouka fruits should be harvested between 24 to 25 weeks after flowering for optimum fruit quality.

The pulp and peel percentage of Mabrouka increased as maturity increased but the stone percentage was observed to decrease with increase in maturity. Kudachikar *et al.* (2003) also noted that both peel and pulp percentage increased as fruit growth advanced towards maturity. Pulp, peel and stone percentage varied with location due to differences in environmental conditions of the locations. Otukpo, Konshisha and Gboko produced the highest pulp, peel and stone percentage respectively.

As maturity proceeded, the pulp to peel ratio of Mabrouka decreased. This contradicts the findings of Amin *et al.* (2015) and Kamol *et al.* (2014) who reported an increase in pulp to peel ratio with advancement in maturity stage in banana and pineapple respectively. The decrease could be attributed to greater increase of sugar in the peel than pulp and/or the osmotic transfer of moisture from the pulp to the peel with physiological advancement of the fruits. The decrease in pulp to stone ratio with advancement in maturity could also be ascribed to transfer of moisture from the pulp to the stone during ripening.

Dry matter percentage of Mabrouka dwindled with advancement in maturity. The maximum dry matter percentage was produced at 21 weeks after flowering while the minimum dry matter percentage was obtained at 26 weeks after flowering. This contradicts the findings of Kapilan and Anpalagan (2015) who reported an increase in dry matter content of Kilichondan mangoes. The decrease in dry matter percentage of Mabrouka with increased maturity period may be due to the increased water accumulation in the pulp.

Percentage moisture content of Mabrouka increased as maturity advanced probably due to accumulation of water in the various compartments of fruit growth. This is consistent with the findings of Tridjaja and Mahendra (2000) who reported an increase in fruit moisture of mango with increased fruit maturity. Mango is a fleshy fruit containing more than 80% water (Lakshimnarayana *et al.*, 1970). Fruit growth after cell division consists in the enlargement of fruit cells characterized by a large accumulation of water that results from the balance between incoming fluxes such as phloem and xylem, and outgoing fluxes such as transpiration (Ho *et al.*, 1987; Léchaudel and Joas, 2007). Otukpo produced the highest dry matter percentage of Mabrouka among the locations studied while Konshisha produced the highest percentage moisture content. The variation in dry matter percentage and percentage moisture content of Mabrouka among the locations is probably due to variation in soil water content, soil fertility, temperature and other environmental factors.

There was a reduction in peel firmness as maturity advanced. The highest and lowest peel firmness was observed at 21 and 26 weeks after flowering respectively. A similar trend was observed with pulp firmness where pulp firmness abated with progression in maturity stage. This is consistent with the findings of Okoth *et al.* (2013a) who reported a decreasing trend with ripening for both skin and flesh firmness. This trend may be attributed to the natural degradation of fruit cell wall. Cell wall degradation is the major factor that causes softening of several fruits. This involves the degradation of cellulose components, pectin components or both (Paliyath and Murr, 2008; Wongmetha *et al.*, 2015). With respect to firmness, panellist scores showed that at harvest, there was a preference for fruits harvested at 24 and 25 weeks after flowering. The variation in pulp firmness observed in the locations evaluated was due to variation in environmental factors.

As maturity progressed, the peel of Mabrouka became lighter, gradually lost its greenness and became more yellowish. The pulp also became lighter and reddish yellowish. This result is in partial agreement with the findings of Okoth *et al.* (2013a). This indicated a synthesis and accumulation of β-carotene (Azzolini *et al.*, 2005) in parallel to degradation of chlorophyll and a possibility of unmasking of the yellow/red colour (Okoth *et al.*, 2013a). Change in fruit colour is the most obvious signal of maturity (Wills *et al.*, 2007). Skin colour has an effect on the final consumers' favourite choice and taste (Tharanathan *et al.*, 2006) and it has been recognized as an acceptable maturity index for many fruits such as mango (Sultana *et al.*, 2017) but sometimes inaccurate. In this study, it was observed that the preferred peel and pulp colour was at 26 weeks after flowering. The peel and pulp colour of Mabrouka varied with location probably due to differences in environmental conditions.

As maturity of Mabrouka advanced, fewer numbers of days were required to ripen. Dick *et al.* (2009) made a similar observation when they evaluated the influence of maturity stage of mango at harvest on its ripening quality. Maturity stage of fruit at harvest has significant effect on the ripening time. Fruits harvested at a less mature stage stay green for a long time before ripening, totally unlike those harvested later. This fact is apparently typical of climacteric fruits, and has been observed on some mango cultivars like Tommy Atkins (Baldwin *et al.*, 1999) as well as papaya (Paull *et al.*, 1997). In this study, panellist preferred the taste of fruit harvested at 26 weeks after flowering and had higher overall acceptability scores for fruits harvested at 25 weeks after flowering. It is important to note that fruits harvested 25 and 26 weeks after flowering have a short shelf life of between 8 to 12 days at ambient room temperature and are not suitable for long distance travel due to low fruit firmness.

The main effect of location and the interaction effects of location × maturity stage were not significant on the shelf life of Mabrouka but shelf-life of Mabrouka significantly abated with advancement in maturity. Shelf life is a period of time which starts from harvesting and extends up to the start of rotting of fruits (Mondal, 2000). Harvesting of fruits at appropriate maturity is vital for improving the shelf life and quality of the fruits (Gupta and Kadam, 1995). Mango being a highly perishable fruit possesses a very short shelf life and reach to respiration peak of ripening process on 3rd or 4th day after harvesting at ambient temperature (Narayana *et al.*, 1996).

The best physical maturity indices can be obtained at 26 weeks after flowering. Fruits meant for short distant markets can be harvested at this stage or even at 25 weeks after flowering for optimum consumer acceptance. However, fruits for long distant markets could be harvested earlier to procure extended shelf life.

5. Reference

Addo, J. K., Osei, M. K., Mochiah, M. B., Bonsu, K. O., Choi, H. S., & Kim, J. G. (2015). Assessment of farmer level postharvest losses along the tomato value chain in three agro-ecological zones of Ghana. *International Journal of Research in Agriculture and Food Sciences, 2*(9), 15–23.

Ahmad, M. S., & Siddiqui, M. W. (2016). *Factors affecting postharvest quality of fresh fruits* (pp. 7–32). Springer International Publishing.

Amarakoon, R., Sarananda, K. H., & Illeperuma, D. C. K. (1999). Quality of mangoes as affected by stage of maturity. *Tropical Agricultural Research, 11*, 74–85.

Amin, M. N., Hossain, M. M., Rahim, M. A., & Uddin, M. B. (2015). Determination of optimum maturity stage of banana. *Bangladesh Journal of Agricultural Research, 40*(2), 189–204.

Baldwin, E. A., Burns, J. K., Kazokas, W., Brecht, J. K., Hagenmaier, R. D., & Pesis, E. (1999). Effect of two edible coatings with different permeability characteristics on mango (*Mangifera indica* L.) ripening during storage. *Postharvest Biology and Technology, 17*(3), 215–226.

Bally, I. S. (2006). *Mangifera indica* (mango). In *Species profiles for Pacific Island agroforestry*. Permanent Agriculture Resources (PAR).

Banik, B. C., & Sen, S. K. (2003). Physicochemical changes during growth and development of fruits of mango cultivars Fazli and Langra. *Indian Agriculturist, 47*(1–2), 51–55.

Bender, R. J., Brecht, J. K., Baldwin, E. A., & Malundo, T. M. M. (2000). Aroma volatiles of mature-green and tree-ripe 'Tommy Atkins' mangoes after controlled atmosphere versus air storage. *HortScience, 35*(4), 684–686.

Dick, E., N'Da Adopo, A., Camara, B., & Moudioh, E. (2009). Influence of maturity stage of mango at harvest on its ripening quality. *Fruits, 64*(1), 13–18.

Dutta, P., & Dhua, R. S. (2004). A study on physico-chemical changes during growth, maturity and ripening in mango cv. Safdar Pasand. *South Indian Horticulture, 52*(1–6), 297–301.

El-Ramady, H. R., Domokos-Szabolcsy, É., Abdalla, N. A., Taha, H. S., & Fári, M. (2015). Postharvest management of fruits and vegetables storage. In *Sustainable agriculture reviews* (pp. 65–152). Springer. https://doi.org/10.1007/978-3-319-09132-7_2

Food and Agriculture Organization of the United Nations. (2012). *FAOSTAT: Production/crops*. http://faostat3.fao.org/ browse/Q/QC/E

Food and Agriculture Organization. (2002). *Production yearbook*. FAO.

Food and Agriculture Organization. (2008). *Basic harvest and postharvest handling considerations for fresh fruits and vegetables*. FAO.

Gupta, O. P., & Kadam, S. S. (1995). Ber (Jujube). In D. K. Salunkhe & S. S. Kadam (Eds.), *Handbook of fruit science and technology* (pp. 387–395). Marcel Dekker.

Ho, L. C., Grange, R. I., & Picken, A. J. (1987). An analysis of the accumulation of water and dry matter in tomato fruit. *Plant, Cell & Environment, 10*(2), 157–162.

Islam, M. K., Khan, M. Z. H., Sarkar, M. A. R., Hasan, M. R., & Al-Mamun, M. R. (2016). Physiological changes and shelf life of postharvest mango (*Mangifera indica* L.) influenced by different levels of Bavistin DF. *International Food Research Journal, 23*(4), 1694–1699.

Jacobi, K. K., & Wong, L. S. (1992). Quality of 'Kensington' mango (*Mangifera indica* Linn.) following hot water and vapour-heat treatment. *Postharvest Biology and Technology, 1*(4), 349–359.

Jacobi, K. K., Macrae, E. A., & Hetherington, S. E. (2001). Effect of fruit maturity on the response of 'Kensington' mango fruit to heat treatment. *Australian Journal of Experimental Agriculture, 41*(6), 793–803.

Kader, A. A. (1999). Fruit maturity, ripening, and quality relationships. *Acta Horticulturae, 485*, 203–208.

Kader, A. A., & Mitcham, B. (2008). Optimum procedures for ripening mangoes. In *Fruit ripening and ethylene management* (Postharvest Technology Research and Information Center Publication Series No. 9, pp. 47–48). University of California.

Kader, A. A., & Rolle, R. S. (2004). *The role of postharvest management in assuring the quality and safety of horticultural crops* (FAO Agricultural Services Bulletin No. 152). Food and Agriculture Organization of the United Nations.

Kamol, S. I., Howlader, J., Sutra Dhar, G. C., & Aklimuzzaman, M. (2014). Effect of different stages of maturity and postharvest treatments on quality and storability of pineapple. *Journal of the Bangladesh Agricultural University, 12*(2), 251–260.

Kapilan, R., & Anpalagan, V. C. (2015). Determination of optimum maturity of north Sri Lankan Kilichondan Mango fruits (*Mangifera indica* L.) based on their biochemical properties. *Advances in Applied Science Research, 6*(10), 105–113.

Kudachikar, V. B., Kulkarni, S. G., Aradhya, S. M., Prasad, B. A., & Ramana, K. V. R. (2003). Physico-chemical changes in mango (*Mangifera indica* L.) varieties 'Alphonso' and 'Raspuri' during fruit development and maturation. *Journal of Food Science and Technology, 40*(3), 285–289.

Kushman, L. J., Pope, D. T., & Monroe, R. J. (1966). Estimation of intercellular space and specific gravity of five varieties of sweet potato root.

Lakshminarayana, S., Subhadra, N. V., & Subramanyam, H. (1970). Some aspects of developmental physiology of mango fruit. *Journal of Horticultural Science, 45*(2), 133–142.

Lakso, A. N., & Goffinet, M. C. (2003). Fruit growth patterns. In T. A. Baugher & S. Singha (Eds.), *Concise encyclopedia of temperate tree fruit* (pp. 91–99). Food Products Press.

Latitude.to. (2018). *GPS coordinates for any address or location*. https://latitude.to

L'Echaudel, M., & Joas, J. (2007). An overview of preharvest factors influencing mango fruit growth, quality and postharvest behaviour. *Brazilian Journal of Plant Physiology, 19*(4), 287–298.

Lurie, S. (2002). Temperature management. In M. Knee (Ed.), *Fruit quality and its biological basis* (pp. 107–121). Sheffield Academic Press.

Medlicott, A. P., Reynolds, S. B., & New, S. W. (1988). Harvest maturity effects on mango fruit ripening in Zaire. *Tropical Agriculture*, *65*(2), 153–156.

Mitcham, E. J., & McDonald, R. E. (1993). Effects of quarantine heat treatment on mango fruit physiology. *Acta Horticulturae, 343*, 361–366.

Mitra, S. K., & Baldwin, E. A. (1997). Mango. In S. K. Mitra (Ed.), *Postharvest physiology and storage of tropical and subtropical fruits* (pp. 85–122). CAB International.

Mondal, M. F. (2000). *Production and storage of fruits in Bangla*. Mrs. Afia Mondal.

Narayana, K., Pal, R. K., & Roy, S. K. (1996). Effect of pre-storage treatments and temperature regimes on shelf life and respiratory behaviour of ripe Beneshan mango. *Journal of Food Science and Technology*, *33*, 79–82.

Okoth, E. M., Sila, D. N., Onyango, C. A., Owino, W. O., Musembi, S. M., & Mathooko, F. M. (2013). Evaluation of physical and sensory quality attributes of three mango varieties at three stages of ripeness grown in Lower Eastern Province of Kenya - Part I. *Journal of Animal and Plant Sciences, 17*(3), 2608–2618.

Pal, P., Ghosh, S. K., & Sen, S. K. (1987). Determination of maturity standards in mango (*Mangifera indica* L.) cv. 'Fazli'. *Haryana Journal of Horticultural Sciences*, *16*(1–2), 40–44.

Paliyath, G., & Murr, D. P. (2008). Biochemistry of fruits. In G. Paliyath, D. P. Murr, A. K. Handa, & S. Lurie (Eds.), *Postharvest biology and technology of fruits, vegetables and flowers* (pp. 19–50). Wiley-Blackwell.

Paull, R. E., Nishijima, W., Reyes, M., & Cavaletto, C. (1997). A review of postharvest handling and losses during marketing of papaya (*Carica papaya* L.). *Postharvest Biology and Technology, 11*(3), 165–179.

Salunkhe, D. K., & Desai, B. B. (1984). Mango. In *Postharvest biotechnology of fruit* (Vol. 1, pp. 77–94). CRC Press.

Seymour, G. B., N'diaye, M., Wainwright, H., & Tucker, G. A. (1990). Effects of cultivar and harvest maturity on ripening of mangoes during storage. *Journal of Horticultural Science, 65*(4), 479–483.
https://doi.org/10.1080/00221589.1990.11516082
Cited by: 62

Seymour, G. B., N'Diaye, M., Wainwright, H., & Tucker, G. A. (1990). Effects of cultivar and harvest maturity on ripening of mangoes during storage. *Journal of Horticultural Science, 65*(4), 479–483.

Singh, Z., & Singh, R. K. (2011). Mango. In E. M. Yahia (Ed.), *Postharvest biology and technology of tropical and subtropical fruits* (pp. 370–399). Woodhead Publishing.
https://doi.org/10.1533/9780857092885.370

Sultana, F. M. I. M., Galib, S. M. D., Hasan, F. M. D., & Jerin, A. S. (2017). Digital measurement of maturity indices of mangoes using selected image features. *Journal of Food Processing & Technology, 8*(11), 1–7.

Tharanathan, R. N., Yashoda, H. M., & Prabha, T. N. (2006). Mango (*Mangifera indica* L.), "The king of fruits": An overview. *Food Reviews International, 22*(2), 95–123.

Toivonen, P. M. A. (2007). Fruit maturation and ripening and their relationship to quality. *Stewart Postharvest Review, 2*(8), 1–4.

Tridjaja, N. O., & Mahendra, M. S. (2000). Maturity indices and harvesting practice of 'Arumanis' mango related to the target market. In G. I. Johnson, L. V. To, N. D. Duc, & M. C. Webb (Eds.), *Quality assurance in agricultural produce* (Proceedings No. 100, pp. 129–133). Australian Centre for International Agricultural Research.

Tromp, J., & Wertheim, S. J. (2005). Fruit growth and development. In J. Tromp, A. D. Webster, & S. J. Wertheim (Eds.), *Fundamentals of temperate zone tree fruit production* (pp. 240–266). Backhuys Publishers.

Wills, R. B. H., McGlasson, W. B., Graham, D., & Joyce, D. C. (2007). *Postharvest: An introduction to the physiology and handling of fruit, vegetables and ornamentals* (5th ed., pp. 29–50). University of New South Wales Press.

Wongmetha, O., Ke, L., & Liang, Y. (2015). Changes in physical, biochemical, physiological characteristics and enzyme activities of mango cv. Jinhwang during fruit growth and development. *Wageningen Journal of Life Sciences*, *72–73*, 7–12.

Yahia, E. M. (1998). *Postharvest handling of mangoes* (Technical Report). Agricultural Technology Utilization and Transfer Project.

Yahia, E. M. (1999). *Postharvest handling of mango* (Technical Report, pp. 57–61). Agricultural Technology Utilisation and Transfer (ATUT).

Yahia, E. M. (2011). Mango (*Mangifera indica* L.). In E. M. Yahia (Ed.), *Postharvest biology and technology of tropical and subtropical fruits: Cocona to mango* (Vol. 3, pp. 492–550). Elsevier.