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Relation of harvesting time on physicochemical properties of Haden, Kent, Palmer and Keitt mango varieties for export and local markets

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ABSTRACT

Purpose: Fruit ages (early, mid, and late harvest stages) of Haden, Kent, Palmer, and Keitt mango varieties were determined through age-control and established for physiological (early harvest) and eat-ripeness stages (mid and late harvests). This was followed by determining physicochemical properties at these stages that could be used as simple harvest indicators for export and local markets. **Research Method:** Randomized Complete Block Design and Completely Randomized Design with four replications in each case were used. For each of the four varieties, five mango trees were sampled at random in each of the four replications of a mango plantation when fruits were physiologically matured. **Findings:** Physiological and ripe maturity index values were 8.94, 6.88, 7.25, and 6.56 ^{o}Brix respectively, for soluble solids; 24.9, 8.5, 35.5, and 23.8 mg.100g^{-1} respectively, for ascorbic acid; 3.25, 3.50, 3.33, and 3.49 respectively, for pH; and 18.5, 17.5, 19.5, and 17.0 ^{o}Brix respectively, for total soluble solids; 8.05, 3.32, 5.52, and 3.66 mg.100g^{-1} respectively, for ascorbic acid; 5.11, 4.08, 5.00, and 5.80 respectively, for pH; respectively. Pulp colour (turning yellow) was nearly the same for the different varieties at physiological maturity but varied when ripe, with uniform consistent texture at both stages. **Limitations:** No limitations to report. **Originality/Value:** Fruit should be harvested after full maturity in order to develop the most adequate organoleptic quality and the longest post-harvest life, and before full ripeness but should never be over-ripe or immature for any purpose unless otherwise.

INTRODUCTION

Mango (*Mangifera indica* L.) is an important fruit and cash crop in Ghana. The commercial production of the crop varies from small scale to large scale (highly organized orchards with appropriate technology) production. As an export fruit crop, mango earns foreign exchange for the country while at the same time acts as a source of household income for the resource-poor farmer (Inkoom & Nanguo, 2011; Okorley et al., 2014). Despite the importance of mango in Ghana, only 15% of total production meet export quality; the bulk is handled by local fresh fruit retailers (47%), local processors (10%), wholesalers (4%), and middlemen (13%); the remaining 11% represent spoilage (Abu et al., 2010). The issue of few exportable mango fruits can be attributed to inappropriate post-harvest handling and the inability of farmers to determine the appropriate time of fruit maturity and these factors are significant contributors to poor quality fruit (Abu et al., 2010; Baloch & Bibi, 2012). Most varieties grown in Ghana for export include Haden, Kent, Palmer, and Keitt; all of Florida origin and have different post-harvest characteristics (Abu et al., 2010).

During the developmental or growth period of fruits there are many physicochemical changes taking place that have a bearing on fruit quality and post-harvest behavior. Thus, the maturity of harvested perishable commodities has an important bearing on their storage life and quality, and may affect the way they are handled, transported, and marketed. According Ambuko et al. (2018) fruit has to be harvested at the ideal stage in order to allow for the development of the most adequate organoleptic quality and the longest post-harvest life. Ambuko et al. (2017) stated that mango fruit should be harvested at physiological maturity if fruits are to be transported by sea or are intended to be sold in distant markets inside the country which needs to be maintained a bit longer before it is consumed, and that harvest should be done at early stages of ripening if fruits are to be transported by air, to where customers are accustomed to ripe fruits and are within a short distance, or for processing. The author, however, added that all two quality criteria or technical methods risk the determination and establishment of appropriate harvest maturity indices in one way or the other.

Abu (2010) indicated that for quality produce, all determinations (early, mid, and late harvest days after fruit-set) should be made in relation to the age control criterion because of its precision in measuring or determining harvest maturity stage. The author, however, added that the age control criterion method is laborious and time-consuming because of the need to obtain baseline data on fruit development and maturation. The baseline data included number of days from anthesis to harvest, external indicators of maturation such as size {fruit weight (g), fruit length (cm), fruit width (cm), fruit volume (cm^3), and fruit density (specific gravity) ($g.cm^{-3}$)}, fruit indentation (cm), exudes of latex (mls), starch test, temperature/heat units (°c), optimum age for harvesting (days), shape, colour, and 'bloom' (Abu, 2010).

According to Ambuko et al. (2017), chronological age is a useful maturity index, obtained from a particular location, and used as a guide since harvest maturity varies with variety, geographical region, and cultivation condition. The authors reiterated that maturity indices are measurements that can be used to determine the maturity of a commodity and are important for efficient use of labour, marketing strategy, and trade regulations. Gill et al. (2017) outlined several methods of determining maturity stage in mango to include assessment of changes in fruit physical characteristics, chemical quality attributes, ripening quality, firmness, flesh/pulp fibre test, and computational calculations.

Flavour, volatiles, taste, and pulp textural-consistency of mango fruit are key components that influence production and acceptability among mango producers and consumers respectively (Baloch & Bibi, 2012). Hence, the need to use consistent physicochemical changes at specific developmental stages of the mango fruit to determine maturity for a

specific variety, growing condition, geographical site, and for a specific market (Salamat et al., 2013). But generally, various indices are independently unreliable as they are greatly affected by other factors (Thompson, 2003; Shin et al., 2008). Since reliable maturity indices are of importance to all supply chain actors and target markets (Ambuko et al. 2017), the study aimed to establish the fruit age at physiological and eat-ripe stages, and determine the physicochemical properties at these stages that can be used as simple harvest indicators for Haden, Kent, Palmer, and Keitt mango varieties cultivated in Ghana for export and local markets.

MATERIALS AND METHODS

Experimental site, period, and plant materials

Field and laboratory studies were conducted at Prudent Export and Import Company Ltd Mango Plantation and at the Bio-chemistry Laboratory of Food Research Institute, Legon, Accra, respectively. The study aimed to establish the fruit age at physiological and eat-ripeness stages, and determine the physicochemical properties at these stages that can be used as simple harvest indicators for Haden, Kent, Palmer, and Keitt mango varieties cultivated in Ghana for export and local markets. These are major export mango varieties which are appreciated by importers of mango from Ghana (Zakari, 2012; Okorley et al., 2014). Prudent Export and Import Company Ltd Mango Plantation is in the Somanya-Dodowa mango production zone of the Dangme West District of Greater Accra Region, Ghana. Two major (April to July) and two minor (December to February) harvesting seasons were considered for the experimental period. Randomized Complete Block Design (RCBD) and Completely Randomised Design (CRD) were used for the field and laboratory experiments respectively, with four replications in each case.

Sampling, and determination of optimum age (days) for harvesting through age control

For each of the four varieties, five mango trees were sampled at random in each of the four replications. For age control (designated as age of fruit from fruit-set to early, mid, or late harvest) studies, date of fruit-set initiation (in each case of either early, mid, or late harvest trial tag) was noted and recorded for each sample tree. On each sample tree, ten different panicles (in each case of either early, mid, or late harvest trial tag), all initiating fruit-set were identified and tagged. The number of days from fruit-set to physiological maturity (green-hard, outgrown shoulders, pit around the stalk-end, turning yellow or showing an apparent break of yellow colour in the pulp/flesh) was calculated and averaged in each case, and for each of the four varieties. The figure obtained represented the number of days the mango fruit took to reach physiological maturity (pre-climacteric stage) from fruit-set (Abu, 2010; Iqbal, 2015). The authors added that the number of days from fruit-set to harvest provides one of the best and reliable indicators of maturity (early, mid or late harvest) and represents the optimum age of the fruit for quality post-harvest behaviour.

Physicochemical analyses

Physicochemical analyses were done on fruits at two stages; physiological maturity or at pre-climacteric stage (green-hard, outgrown shoulders, pit around the stalk-end, skins of many fruits develop wax - giving the fruit a shine or bloom, and showing an apparent break of yellow colour in the pulp) and when the fruits were ripened (eat-ripeness – when the fruit develops the flavour, texture, and apparent aroma that contribute to optimum eating quality) (Abu, 2010; Ambuko et al., 2018).

All biochemical constituent determinations including pH, total soluble solids (TSS, ^{o}Brix), and TSS/Acidity ratio (AOAC, 2005); ascorbic acid (mg.100g^{-1}) (AOAC, 2002);

titratable acid (TA, % citric acid) (AOAC, 1990); fibre content (%) (USDA, 2004); and colour and consistency of pulp (SAMGA, 2004) were done according to early, mid, and late harvest stages obtained by the age control criterion because of its precision in measuring or determining harvest maturity stage (Abu, 2010).

Statistical analysis

All data were analysed using the Analysis of Variance (ANOVA) technique (Snedecor & Cochran, 1980) with the GENSTAT statistical program. Least Significant Difference (LSD) at 5 % probability was used to determine treatment differences among varieties. Separate analyses were carried out on the data for each of the seasonal trials. The errors for these ANOVAS were tested for homogeneity of variances (Snedecor & Cochran, 1980) and found to be statistically not different at $p>0.05$, so the results for the seasonal experiments were pooled for analysis.

RESULTS

Established harvest stages (ages)/time-ranges for Haden, Kent, Palmer, and Keitt mango varieties

The average physiological maturity ages of fruits at early harvest for Haden, Kent, Palmer, and Keitt varieties were established to be 112, 126, 133, and 140 days after fruit-set, respectively (Table 1). The ages for mid harvest were established to be 119, 133, 140, and 147 days after fruit-set for Haden, Kent, Palmer, and Keitt fruits, respectively. For late harvest, the ages were established to be 126, 140, 147, and 154 days after fruit-set for Haden, Kent, Palmer, and Keitt fruits, respectively (Table 1). Generally, the average maturity ages for early, mid, and late harvests were seven days apart for each of the four varieties. Haden fruits matured earlier than fruits of the other varieties while Keitt fruits matured later.

Physicochemical analyses of Haden, Kent, Palmer, and Keitt mango fruits at physiological maturity stage or at early harvest, and at eat-ripe stage or mid harvest

At physiological maturity, Haden and Keitt fruits recorded similar TA concentrations (1.071 and 1.044 % citric acid, respectively) with a slight preponderance of the former and were statistically higher ($p<0.05$) than that of Kent fruits which recorded the lowest (0.807% citric acid). Titratable acid concentration in Kent fruits (0.807% citric acid) was similar to that of Palmer fruits (0.940% citric acid) with a slight preponderance of the latter (Table 2a). At eat-ripe stage, fruits of Palmer had the highest concentration of TA (0.31% citric acid) and it was statistically different ($p>0.05$) from fruits of the other varieties. Keitt fruits recorded the lowest (0.10% citric acid) but was not significantly different ($p >0.05$) from those of Haden and Kent (Table 3a).

Table 1. Established harvest stages (ages)/time-ranges for Haden, Kent, Palmer, and Keitt mango varieties

Variety	Early harvest (Days from fruit-set)		Mid-harvest (Days from fruit-set)		Late harvest (Days from fruit-set)	
	Range	Mean	Range	Mean	Range	Mean
Haden	109-115	112	116-122	119	123-129	126
Kent	123-129	126	130-136	133	137-143	140
Palmer	130-136	133	137-143	140	144-150	147
Keitt	137-143	140	144-150	147	151-157	154

Palmer fruits showed the highest reading for ascorbic acid content (35.5 mg.100g^{-1}) at physiological maturity and was significantly different ($p<0.05$) from fruits of the other varieties. Kent fruits recorded the lowest ascorbic acid content (8.5 mg.100g^{-1}) and was statistically different ($p<0.05$) from fruits of the other varieties. Haden and Keitt fruits showed similar ascorbic acid concentrations (24.9 mg.100g^{-1} and 23.8 mg.100g^{-1}, respectively) with a slight preponderance of the former, but fruits of both varieties were statistically higher ($p<0.05$) in ascorbic acid concentration than that of Kent fruits (Table 2a). On the other hand, Haden fruits showed the highest ascorbic acid concentration (8.05 mg.100g^{-1}) and Kent fruits the lowest (3.32 mg.100g^{-1}) at the eat-ripe stage. Ascorbic acid concentration was not significantly different ($p>0.05$) among Kent, Palmer, and Keitt fruits but was, in each case, statistically different ($p<0.05$) from that of Haden fruits (Table 3a).

At physiological maturity, Haden fruits showed the highest TSS (8.94 ^{o}Brix) content and was statistically different ($p<0.05$) from fruits of the other varieties. Keitt fruits had the lowest (6.56 ^{o}Brix) even though there were no significant differences among fruits of Keitt, Kent, and Palmer mango varieties (Table 2a). Palmer fruits showed the highest TSS (19.1 ^{o}Brix) content on ripening and Keitt fruits had the least (17.0 ^{o}Brix). Total soluble solids concentration in Palmer fruits was not significantly different ($p>0.05$) from that of Haden fruits but different from those of Keitt and Kent fruits. Total soluble solids concentrations were, however, similar among Haden, Kent, and Keitt fruits (Table 3a).

Kent fruits recorded the highest pH (3.50) content which was significantly different ($p<0.05$) from the fruits of the other varieties at physiological maturity. Haden fruits recorded the least pH (3.25) but was statistically similar to that of Palmer (3.33) and Keitt (3.35) mango varieties (Table 2a). On the other hand, Keitt fruits showed the highest pH (5.80) content at the eat-ripe stage and was significantly different from only Kent fruits which recorded the least (4.08). Haden, Kent, and Palmer fruits were similar in their pH content, just as the content was for Haden, Palmer, and Keitt fruits (Table 3a).

Keitt fruits showed the highest moisture content (84.26%) and was significantly different ($p<0.05$) from only Kent fruits which recorded the least (82.28%) when physiologically mature. Moisture contents were similar for Palmer and Haden fruits but both (in each case) were statistically higher than that of Kent (Table 2a). At the eat-ripe stage, Keitt fruits showed the highest moisture content (81.95%) which was significantly different ($p<0.05$) from only that of Palmer fruits which contained the least (80.25%). Moisture contents were similar among Keitt, Kent, and Haden fruits at eat-ripe stage, just as the content was among Haden, Kent, and Palmer fruits (Table 3a).

At physiological maturity, Kent fruits accumulated the highest dry matter content (17.72%) which was statistically different ($p<0.05$) from fruits of the other varieties. Keitt fruits accumulated the least amount of dry matter (15.74%) but this value was similar to those of Haden and Palmer fruits (Table 2b). Palmer recorded the highest dry matter content (19.75%) but was statistically similar to that of Haden and Kent at eat-ripe stage. Dry matter content for Palmer was, however, significantly different ($p<0.05$) from that of Keitt which had the least (18.05%). Dry matter contents were similar among Haden, Kent, and Keitt fruits (Table 3b).

Keitt fruit showed the highest fibre content at both physiologically mature (0.026 %) and eat-ripe (0.094%) stages but with a slight preponderance of the latter than the former (Tables 2b; 3b). Again, in each case of the physiologically mature and eat-ripe stages, the fibre content of the Keitt fruit was statistically different ($p<0.05$) from that of Haden, Kent, and Palmer fruits which were statistically similar (Tables 2b; 3b).

Pulp colour was nearly the same (turning yellow) for the different varieties at physiological maturity but varied through deep yellow, deep yellow to orange yellow, orange

yellow to lemon yellow for Haden, Kent, Palmer, and Keitt respectively at eat-ripe stage, with uniform consistent texture at both stages (Tables 2b; 3b).

When fruits were physiologically matured, those of Haden (8.3473), Kent (8.5254), and Palmer (7.7128) were similar in their TSS/Acidity ratio levels, with ratio levels for Haden and Kent fruits being statistically higher ($p<0.05$) than in fruits of Keitt (6.2835). Ratio levels of TSS/Acidity were also similar for fruits of Palmer and Keitt (Table 2b).

At eat-ripe stage, fruits of Keitt recorded the highest TSS/Acidity ratio (170.000) and was only statistically different from that of fruits of Palmer which recorded the least (61.610). Haden, Kent, and Keitt fruits were similar in their TSS/Acidity ratio levels. However, Kent fruits were statistically different ($p<0.05$) from Palmer fruits in their levels of TSS/Acidity ratio, on comparison (Table 3b).

Table 2a. Physicochemical analyses of Haden, Kent, Palmer, and Keitt mango fruits at physiological maturity stage or early harvest

Variety	Parameter				
	TA (% citric acid)	Ascorbic acid ($mg.100g^{-1}$)	TSS (^oBrix)	pH	Moisture (%)
Haden	1.071	24.90	8.94	3.250	83.55
Kent	0.807	8.50	6.88	3.499	82.28
Palmer	0.940	35.50	7.25	3.328	83.89
Keitt	1.044	23.80	6.56	3.349	84.26
LSD (0.05)	0.167	5.76	1.18	0.135	0.93

Means of four estimations expressed on fresh weight basis.

Table 2b. Physicochemical analyses of Haden, Kent, Palmer, and Keitt mango fruits at physiological maturity stage or early harvest

Variety	Parameter				
	DM (%)	Fibre Content (%)	Pulp/flesh Colour	Pulp consistency	TSS/Acidity ratio
Haden	16.45	0.017	turning yellow	uniform consistent texture	8.3473
Kent	17.72	0.016	turning yellow	uniform consistent texture	8.5254
Palmer	16.11	0.017	turning yellow	uniform consistent texture	7.7128
Keitt	15.74	0.026	turning yellow	uniform consistent texture	6.2835
LSD (0.05)	0.93	0.007	-	-	1.6188

Means of four estimations expressed on fresh weight basis. DM = Dry matter.

Table 3a. Physicochemical analyses of Haden, Kent, Palmer, and Keitt mango fruits at eat-ripe stage or midharvest

Variety	Parameter				
	TA (% citric acid)	Ascorbic acid ($mg.100g^{-1}$)	TSS (^oBrix)	pH	Moisture (%)
Haden	0.14	8.05	18.50	5.11	80.85
Kent	0.12	3.32	17.50	4.08	80.94
Palmer	0.31	5.52	19.10	5.00	80.25
Keitt	0.10	3.66	17.00	5.80	81.95
LSD (0.05)	0.15	3.45	1.51	1.12	1.12

Means of four estimations expressed on fresh weight basis.

Table 3b. Physicochemical analyses of Haden, Kent, Palmer, and Keitt mango fruits at eat-ripe stage or midharvest

Variety	Parameter				
	DM (%)	Fiber Content (%)	Pulp/flesh color	Pulp consistency	TSS/Acidity ratio
Haden	19.15	0.065	deep yellow	uniform consistent texture	132.140
Kent	19.06	0.062	deep yellow to orange yellow	uniform consistent texture	145.830
Palmer	19.75	0.066	orange-yellow	uniform consistent texture	61.610
Keitt	18.05	0.094	lemon yellow	uniform consistent texture	170.000
LSD (0.05)	1.12	0.024	-	-	74.087

Means of four estimations expressed on fresh weight basis. DM = Dry Matter.

DISCUSSION

Established harvest stages (ages) /time-ranges for Haden, Kent, Palmer, and Keitt mango varieties

The physiological maturity dates for Haden, Kent, Palmer, and Keitt fruits as obtained by computing the number of days from fruit-set to harvest showed that, Keitt and Palmer are late maturing varieties; Kent, a medium maturing variety; and Haden, an early maturing variety. The physiologically mature fruit as well as the ripe fruit studied had appropriate accompanying physicochemical constituents as indicated in the results column of this paper.

Ghana's mangoes (fresh and processed forms) are largely exported by both air and sea freights; where air freights take at most 6 hours and sea freights, a range of 14-21 days (Twum, 2008; Okorley et al., 2014) to Europe. Appropriate harvest stage, therefore, considers both air and sea freights as well as local markets. To simulate sea freight, Haden, Kent, Palmer, and Keitt mango varieties were harvested at 112, 126, 133, and 140 days after fruit-set, respectively, at early maturity (pre-climacteric). Asgharzade et al. (2012) observed that by analogy with apples, the stage of maturity being just before the climacteric rise in respiration, would appear to be a suitable stage of maturity for maximum transport and storage. For air freight, Haden, Kent, Palmer, and Keitt mango varieties were harvested at 126, 140, 147, and 154 days after fruit-set, respectively, at late maturity. Abu (2010) and Ambuko et al. (2018) observed that fruit, especially for export, should be harvested earlier and that the time for harvesting should be established on the basis of the type of market, distance from the orchard or the packing house, and the type of transport to be used. The authors added that fruit has to be harvested at the ideal stage in order to allow for the development of the most adequate organoleptic quality and the longest post-harvest life.

Mid or late harvest stage can be applied for fruit intended for local market, processing or intended to be consumed very close to the orchard. Fruit to be sold in distant markets within the country which needs to be kept for a few days to a week before being sold/consumed should be harvested at early harvest but at the higher side of the time-range (115, 129, 136, and 143 days from fruit-set, for Haden, Kent, Palmer, and Keitt fruits, respectively). Where customers/consumers are accustomed to ripe fruits, and where the distance is short, fruit can be harvested between full maturity and early stages of ripening (mid or late harvest). Thus, fruit should always be harvested at full maturity and before full ripe, but should never be

harvested over-ripe or immature for any market (Abu, 2010; Baloch & Bibi, 2012; Ahmad & Siddiqui, 2015).

Physicochemical analyses of Haden, Kent, Palmer, and Keitt mango fruits at physiological maturity and at eat-ripe stages

Arzani et al. (2008) and Axe (2016) reiterated that there is also the need to use biochemical parameters such as TSS, TA, Ascorbic acid, pH, Moisture, and Dry matter content of the fruit to determine the stages of physiological development during maturation; and that other determining parameters include shelf life/storage life, ripening quality, firmness, and fibre tests.

At physiological maturity, Haden showed a significantly high level of soluble solids (8.94 ^{o}Brix) when the four varieties were compared, indicating that the Haden fruit may be of a higher sugar content than Kent fruit (6.88 ^{o}Brix), Palmer fruit (7.25 ^{o}Brix), and Keitt fruit (6.56 ^{o}Brix), and therefore much more suitable for the fresh market (Arzani et al., 2008; Axe, 2016). However, Singh et al. (2014) reported a higher level of soluble solids (18.9 ^{o}Brix) and TA of 0.22% in Haden indicating that different growing conditions affect the physicochemical attributes of the fruit.

Abu (2010) reported that as maturity advanced in Haden, Kent, Palmer, and Keitt mango fruit varieties, their content of TSS continued to increase whiles that of TA decreased. Similar changes were observed by Khalaj et al. (2015). However, the variability of TSS content in the different varieties might be attributed to the differences in alteration occurring in cell wall structure during maturation processes in the different varieties. Moreover, various hydrolytic enzymes also affect complex carbohydrates, changing them into smaller compounds (Asgharzade et al., 2012) which reflects the conversion of starch into sugars. At advanced maturity, organic acids form salts which contribute to the increase of TSS (Asgharzade et al., 2012). This may also explain the higher concentrations of TSS that occurred at the ripened stage than at the physiologically matured stage. A sharp increase in TSS/acidity ratio was observed at ripening when compared to the physiologically matured stage. For most fruits, a higher TSS/acidity ratio indicates good eating quality (Kishor et al., 2017). The authors added that TSS content of fruit is important both from the stand point of product consistency and processing as well as the quality of the fresh produce, and indicated that high TSS value is desirable because it relates to the yield of processed products.

The variability in pH among the four varieties corresponded to the changes in the acidity of the respective varieties as they went through the different maturity stages. This variation in acidity among the various varieties may be attributed to the extent of degradation of citric acid as a function of the activity of citric acid glyoxalase during maturation/ripening (Buchert et al., 2005; Rathore et al., 2007; Islam et al., 2013). Islam et al. (2013) and Hossain (2016) also reported similar changes in pH and acidity in mangoes during maturation/ripening processes. The authors ascribed such changes to the stage of maturity of mangoes. Singh et al. (2017) reported that in most mango varieties studied the results showed a rise and fall in pH values, but generally a decreasing trend in acidity during maturation similar to that obtained for other fruits such as the apple (Asgharzade et al., 2012). This pattern of change in acidity was observed by Hossain (2016). The mean acidity at maturity was similarly higher for Haden and Keitt varieties with a slight preponderance of the former, indicating that the two varieties are suitable for processing since acids are not only important as major taste components, but also play important role in the satisfactory processing of products. A considerable decrease in the acidity of mango was observed during ripening with a pH shift from 3.25, 3.499, 3.328, and 3.349 to 5.11, 4.08, 5.00, and 5.80 for Haden, Kent, Palmer, and Keitt mango fruits respectively, indicating that the fruits are mildly acidic like most other mango varieties (Litz, 2003; Islam et al., 2013; Chan, 2016).

Mango fruits are rich sources of vitamin C (ascorbic acid) (Chan, 2016). Singh et al. (2017) reported that for Haden, Kent, Palmer, and Keitt mango varieties, ascorbic acid concentration increased throughout development and maturation with a decreasing trend during ripening. The decrease in ascorbic acid concentration during ripening could be attributed to its susceptibility to oxidative destruction as impacted by the ripening environment (Ahmad & Siddiqui, 2015). Ascorbic acid content is considerably greater in the green mature fruit than in ripe fruit, although the ripe mango fruit is an excellent source of the vitamin (Chan, 2016), particularly the Palmer variety (Abu, 2010). Earlier on, Bhatnagar and Subramanyam (1973), working with the Alphonso mango variety found 250 $mg.100g^{-1}$ ascorbic acid in the unripe fruit, 90 $mg.100g^{-1}$ ascorbic acid in the partially ripe fruit, and 165 $mg.100g^{-1}$ ascorbic acid in the ripe fruit. Soule and Harding (1956) also earlier on found 79 $mg.100g^{-1}$ ascorbic acid in unripe fruit and 25 $mg.100g^{-1}$ ascorbic acid in ripe Haden mango fruits, indicating that different growing conditions affect the biochemical attribute of the fruit. According to Ayele and Bayleyegn (2017) the retention of ascorbic acid is an index of quality and nutritive value in fruit. Emongor (2015) and, Ayele and Bayleyegn (2017) indicated that loss of ascorbic acid can occur during storage in the raw state and that losses are accelerated by high temperatures and high rates of wilting. They further stated that bruising and mechanical damage greatly increase the rate of loss of ascorbic acid because it is highly susceptible to oxidation, either directly or through an enzyme (ascorbic acid oxidase) which is widely distributed in plant tissues. Hence, the need for proper handling and restoration of the mango fruit.

Moisture content was comparatively lower at ripening (80.85, 80.94, 80.25, and 81.95% for Haden, Kent, Palmer, and Keitt mango fruits, respectively) than at physiological maturity (83.55, 82.28, 83.89, and 84.26% for Haden, Kent, Palmer, and Keitt mango fruits, respectively) which account for their high perishability. The low moisture content at ripening is a change that has been explained in terms of a maximum rise in water loss as maturation advanced due to degenerative changes of the skin, resulting from both respiration and transpiration sources (Dhir, 2016). However, a USDA (2004) source indicated 81.71% as general moisture content for mango fruit at physiological maturity. This disparity in moisture content may be attributed to environmental differences as well as differences in production conditions (Ledesma et al., 2016). Reduced water content and related increase in soluble solids concentration at the ripe stage is desirable in processing mango fruits, where mango pulp paste production is the objective (Kordylas, 1991). Thus, leading to the recommendation of Palmer and Haden fruits for the purpose since they have the potential as processing varieties.

Ripened fruits contained comparatively higher amount of dry matter when compared to physiologically matured fruits. Saranwong et al. (2005) and, Ahmad and Siddiqui (2015) reported that fruit harvested at the advanced stage of maturity were high in soluble solids, dry matter, and starch contents than those harvested earlier, as reported in the present study. Selection of soluble solids, dry matter, and starch as harvesting indices is thus appropriate since starch is the source of sugar production at the ripe stage. Accumulating a sufficient amount of starch would allow the ripe fruit to be able to synthesize a large amount of sugar since significant activities of starch break-down and sugar synthesis occur during ripening (Islam et al., 2013). Saranwong et al. (2005) and, Ahmad and Siddiqui (2015) reiterated that the increase in dry matter content suggests the accumulation of organic substances needed for completing the ripening processes.

Haden, Kent, Palmer, and Keitt mango fruits are comparatively virtually fibreless. Litz (2003) earlier on reported that any mango fruit compares favourably with those of Indian, Indo-Chinese, and Philippine cultivars for their large size, attractive red blush, and high content of tasty and virtually fibreless pulp. In contrast with the United States Department of

Agriculture (USDA) National Nutrient Database for Standard Reference, Release 17, on mango fruit fibre content standard (3.7 g fibre/average size mango fruit), Haden, Kent, Palmer, and Keittmango fruits contain a much desirably far less fibre when compared. These varieties are virtually fibreless, internationally acceptable, of required characteristics for the fresh market, and thus imply good market for Ghana (Okorley et al., 2014).

Pulp color was nearly the same (turning yellow) for the different varieties at physiological maturity but varied through deep yellow, deep yellow to orange yellow, orange yellow to lemon yellow for Haden, Kent, Palmer, and Keitt fruits respectively when ripe, but with uniform consistent texture at both stages. Hossain et al. (2014) indicated that peel/skin color does not show a consistent trend during maturation whereas flesh/pulp color changes from white to bright yellow as maturity advanced. On the other hand, in most mango cultivars including Haden, Kent, Palmer, and Keitt, flesh/pulp color changes are some-what uniform when fruit advances in maturity. Unfortunately, this is a destructive index, but more consistent and more utilized than skin color change. Bhatnagar and Subramanyam (1973) again, earlier on reported that for "Alphonso" and "Pairi" mango cultivars, it usually takes 110 to 125 days after fruit set for the flesh color to change from white to pale-yellow which indicates harvest maturity. Kitinoja and Kader (2015) indicated that flesh color is commonly used as a maturity index in several mango growing regions. Several growers rely on the changes of peel from green to yellow color as a sign of maturity but laborious and costly, and fruits so harvested ripen within a few days and cannot be shipped or stored for long periods (Baloch & Bibi, 2012). This is, however, not applicable to mangoes that are harvested at the hard-green (physiological maturity) stage such as with Haden, Kent, Palmer, and Keitt mango varieties. Teutsch (2018) reported that peel color, flesh color, shape/fullness of cheeks, changes in the color of the pedicel-end, starch content, leathery fruit peel or "bloom", ridges at the stem-end, and development of lenticels are some of the changes associated with maturity of mango fruits.

Mangoes grown in the various seasons did not primarily display any significant variation in any of the biochemical attributes tested when seasonal averages were compared, indicating that the season of production has less/little or no influence on most of the biochemical attributes of the mangoes grown in Ghana. Singh et al. (2017) observed that in several mango cultivars, changes in maturity indices are either irregular or too small.

CONCLUSION

Average maturity ages at physiological and eat-ripe stages were established to be 112, 126, 133, and 140 days; and 119, 133, 140, and 147 days and 126, 140, 147, and 154 days respectively, for Haden, Kent, Palmer, and Keitt mango fruit varieties. From the study, TA, Ascorbic Acid, TSS, pH, Moisture, DM, Fibre, Pulp/flesh Colour, Pulp Consistency, and TSS/Acidity ratio have all been established as physicochemical indices that could be used as harvest indicators at both physiological and eat-ripe stages for Haden, Kent, Palmer, and Keitt mango varieties cultivated in Ghana for export and local markets. But generally, the various indices are independently unreliable as they are greatly affected by cultivar/variety, location, season, physicochemical composition, production region and ecological variables such as temperature and rainfall and even nutrition. It should therefore be apparent that a single harvest maturity index-figure would not always reflect the harvest index in all giving situations.

Conflict of interest

The authors have no conflict of interest to report.

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