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Characterization of Southeast Asia mangoes (*Mangifera indica* L) according to their physicochemical attributes

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ABSTRACT

Mango (*Mangifera indica* L.) is an economically important fruit crop grown in the tropics. One of the important traits of mango for successful commercial production is the storage quality of the fruit. This study was conducted to evaluate the postharvest qualities of three mango (*Mangifera indica*) varieties namely 'Chokanan', 'Golden phoenix' and 'Water lily' grown in Southeast Asia regions. The study found that variety and ripening stage had an impact on the postharvest qualities. In general, an increase in weight loss, L* value and soluble solids concentration (SSC) along with a reduction in titratable acidity (TA), firmness and hue value as ripening progressed were observed irrespective of the variety. Analysis of variance and multivariate analysis were used to characterize the ripening process. This study provides useful information for devising strategies in postharvest handling and implementation of breeding programs for mango crop improvement.

1. Introduction

Mango *(Mangifera indica* L.) is one of the most important tropical fruit crops with significant commercial value. Mango fruit is widely consumed globally due to its juiciness, delicious taste, exotic flavor and nutritional value. In addition, mango fruit is a rich source of health promoting compounds such as carotenoids, ascorbic acids, quercetin and mangiferin (Lauricella et al., 2017). Currently, Asia is the largest mango-producing region, with a production of 34.6 million tons, which accounts for 74.30% of global mango production. This is followed by America (13.00%; 4 million tons), Africa (11.00%; 3 million tons) and a very little portion from Oceania (0.10%; 0.04 million tons) (FAOSTAT, 2016). There are thousands of mango varieties which are distributed worldwide. Of which, Asia has over 500 fully characterized varieties (Singh et al., 2016). However, only a few of these available mango varieties are traded internationally while most are grown for local consumption (Kuhn et al., 2017). Commercial mango varieties that dominate the global export market include 'Tommy Atkins', 'Haden', 'Ataulfo', 'Kent', 'Keitt' and 'Alphonso' (Bally, 2011; Galán Saúco, 2015; Nassur et al., 2015). Mango varieties in Malaysia include 'Chokanan', 'Harumanis', 'Sala', 'Masmuda' and 'Maha 65' amongst others (MOA, 2016). However, these varieties have not attained equal international popularity as compared to Indian or Floridian varieties due to lack of research attention (Abu Bakar and Fry, 2013).

Fruit ripening involves a spectrum of significant physiological, biochemical and molecular changes that give rise to an edible fruit of desired quality (Barry and Giovannoni, 2007). An increased rate of respiration and ethylene production during ripening has been documented extensively in climacteric fruit such as papaya (Ong et al., 2013) as well as in mango ripening process (Khaliq et al., 2015; Palafox-Carlos et al., 2012; Zerbini et al., 2015). The period of fruit ripening is also characterized with an increase in sugar content and color changes (Palafox-Carlos et al., 2012; Ibarra-Garza et al., 2015). Mango peel color changes facilitate the identification of the appropriate maturity stage for harvesting and consumption albeit not all varieties change from green to yellow/orange upon ripening (Yahia, 2011). Mango ripens within 4–9 days (variety dependent) (Carrillo-Lopez et al., 2000; Srivastava et al., 2016) although there has been reports on 'Alphonso' and 'Banganapalli' mangoes with a ripening duration of 12–18 days from harvest (Deshpande et al., 2017; Nambi et al., 2015). At cold storage (13 °C), mango can be stored for up to 2–3 weeks (Carrillo-Lopez et al., 2000).

As postharvest qualities may differ according to varieties, it is necessary to carry out specific studies on each local mango variety in order to uncover their potential to become a commercial marketable fruit. Such information will provide an insight into the development of postharvest strategies towards mango fruit quality improvement and open new marketing opportunities to the farmers and to the local

Abbreviations: N, Newtons; SSC, soluble solid content; TA, titratable acidity; PCA, principal component analysis

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industry. To date, only a few published results on the physicochemical and physiological profile of locally produced mangoes in the literature are available (Bejo and Kamaruddin, 2014; Mansor et al., 2014; Khaliq et al., 2015; Zakaria et al., 2012). Therefore, the objectives of this study were to evaluate the effect of ripening on the physicochemical characteristics and physiological behavior of 'Chokanan', 'Golden phoenix' and 'Water lily' mango varieties, which are grown in the Southeast Asia regions.

2. Materials and methods

2.1. Mango samples

Mature green mangoes (*Mangifera indica* vars. 'Chokanan', 'Golden phoenix' and 'Water lily') of maturity index 2 (FAMA, 2017) were purchased from a mango farmer in Malacca, Malaysia. Mango fruit were selected for uniformity in size, shape and absence of external injury. After sorting, fruit were washed, dried and allowed to ripen at ambient temperature (25 ± 1 °C, 80 ± 5% relative humidity). Assessment of postharvest quality parameters were observed on arrival (0th day) and at 2 day intervals of the ripening period. At each evaluation time, four replicates consisting of three individual fruit per replicate were randomly sampled for each mango variety. The analyses were conducted at the Postharvest Laboratory, School of Biosciences, University of Nottingham Malaysia Campus.

2.2. Determination of physicochemical parameters

Evaluation of physicochemical parameters was carried out as reported by Ali et al., (2016). Weight loss determination was obtained by weighing mango on the 0th day of storage and at 2 day intervals over the storage period. The percentage weight loss was calculated relative to the initial weight.

Peel color was assessed on the basis of the Hunter Lab System using a MiniScan XE Plus colorimeter and presented in the values of L* a* b* and h°. The L* coordinate indicates brightness of color with values ranging from 0 = black to 100 = white. Coordinates, a* and b*, indicate color directions: +a* is the red direction, –a* is the green direction, +b* is the yellow direction, and –b* is the blue direction. From these values, hue angle (h°) was calculated as $h^\circ = \text{tangent}^{-1}\ b^*/a^*$) where 0° = red purple, 90° = yellow, 180° = blue-green and 270° = blue. Fruit firmness was assessed using an Instron Universal Testing Machine (Instron 2519-104, Norwood, MA). Measurements were taken from three points of the equatorial region for each sampled fruit. An average of three readings was obtained and expressed in Newtons (N). The same fruit pulp samples (10 g) used in the firmness evaluation were homogenized using a kitchen blender (Philip, Malaysia) with 40 ml of distilled water, and filtered through a double layer of muslin cloth to extract juice for further analyses. Soluble solid content (SSC) was determined with a droplet of the filtrate using a Palette Digital Refractometer (Model: PR-32α, Atago Co Ltd., Japan) and expressed as a percentage (%). Titratable acidity (TA) was determined by titration of 5 ml of filtrate with 0.1 N NaOH to an endpoint of pH 8.1 by two drops of 0.1% phenolphthalein indicator. The results are expressed as a percentage of citric acid equivalents.

2.3. Respiration and ethylene production

The respiration and ethylene production of mango fruit were carried out as described by Ong et al. (2013). Fruit were placed in a plastic container tightly sealed with a lid. After 1 h of incubation, 1 ml of gas sample was withdrawn from the headspace and analyzed in the gas chromatograph (GC) (Clarus-500 Perkin-Elmer, USA) equipped with a column (Agilent J&W, DB-5MS column: 30 m in length, 0.25 mm in diameter and 0.25 µm in film thickness) with two detectors connected in series; a thermal conductivity detector (TCD) and flame ionization detector (FID) for the quantification of carbon dioxide (CO_2) and ethylene respectively. Helium was used as the carrier gas for thermal conductivity (TCD) and temperatures were 60 °C, 150 °C and 200 °C for the oven, injector and detector respectively. The injector, oven and detector temperatures were 200 °C, 120 °C and 250 °C respectively with nitrogen as the carrier gas for the flame ionization detector (FID). Concentration of the standards used was 1.0% CO_2 and 1 ppm ethylene (C_2H_4). Respiration and ethylene production rate are expressed as nmol $kg^{-1}\ s^{-1}$ according to Banks et al., (1995).

2.4. Statistical analysis

The experiments were conducted according to a completely randomized design (CRD) in four replications. For each replicate, three fruit were randomly selected for analysis at each evaluation time. Data were subjected to analysis of variance (ANOVA) using the GENSTAT (18th edition) software. Means were separated using Duncan's Multiple Range Test (DMRT; $p < 0.05$). Multivariate analysis was carried out using the XLSTAT (Addinsoft, New York, USA). PCA was performed to predict the total variability between days of ripening and mango varieties. The Pearson's correlation coefficient was employed to explore the relationship between the postharvest parameters.

3. Results

3.1. Changes in physical quality parameters

Based on the external appearance and postharvest changes score, 'Golden phoenix', 'Water lily' and 'Chokanan' mango varieties were found to achieve ripeness at 7, 7 and 9 days respectively.

3.1.1. Weight loss

A progressive weight loss was observed during ripening for all the varieties under study (Fig. 1). It increased significantly ($p < 0.05$) over the ambient storage period. 'Chokanan' variety exhibited a 2.3% weight loss after two days of storage (Fig. 1a). The highest rate of weight loss (6.98%) was noticed on the 8th day of ripening for 'Chokanan' (a mean loss of 0.76% per day). As can be seen in Fig. 1b, weight loss in 'Golden phoenix' variety significantly increased ($p < 0.05$) from the 2nd (2.76%) to 4th day (5.78%). The percentage weight loss observed on the 4th day was not significantly different ($p < 0.05$) from that obtained on the 6th day of ripening. At the end of storage, 'Golden phoenix' had lost 7.76% of initial weight with an average of 1.20% per day. 'Water lily' lost 2.48% of its initial weight after two days of storage and this was maintained with significant differences ($p < 0.05$) until the 6th day (Fig. 1c). At the end of storage, it attained an 8.44% weight loss which averaged 1.40% per day.

3.1.2. Peel color

The external appearance of each variety at the beginning and end of storage is presented in Fig. 2. Color parameters as influenced by the ripening period are provided in Table 1. As ripening progressed, the peel color changed from green to slightly or full yellow color depending on variety. The visual skin color of 'Chokanan' changed noticeably to yellow during fruit ripening (Fig. 2). The L* value (lightness) of 'Chokanan' was 53.63 on the 0th day of storage and gradually increased as the fruit ripening advanced (Table 1). When 'Chokanan' was fully ripened after eight days, there was a significant ($p < 0.05$) increase in lightness to 63.78. 'Chokanan' peel color exhibited a decline in hue angle, which started at 118.20 and was maintained with significant differences from the 2nd to 8th day of storage (Table 1). An increasing trend was also observed on the peel a* and b* values during ripening. 'Golden phoenix' showed no conspicuous changes of peel color from green to yellow upon ripening (Fig. 2). Lightness (L*) value of the 'Golden phoenix' peel increased, beginning on the 2nd day and presented no significant changes until the end of storage. Similarly, there