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Research Article

Assessment of Maturity of Mango (*Mangifera indices* L.)based on Electrical and Physiochemical Properties during Ambient Storage

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ABSTRACT

Mango is commercial crop in many countries of the world. Nutritionally, it is a rich source of β carotene, vitamin C, and dietary fibre. A detailed study was carried out with the mango cv. Dashehari for exploring the variation of physiochemical and electrical properties with the ambient storage conditions at different stages of maturity. Mango sampling based on randomized block design was adopted. Storing the fruits in corrugated boxes at ambient temperature, parameters such as size, sphericity, total soluble solid (TSS), titrable acidity (TA), colour and electrical properties were studied. Titrable acidityis determined by the AOAC (2005) method. Sensory evaluation of the stored pears is conducted on alternate days starting from the day the pears are plucked. L, a, b color values, pH, and TSS values were found to be increasing with the storage period, while size and TA of fruit decreased.The increase in organoleptic rating was found to be associated with change in fruit color, TSS, acidity and fruit size. There is utmost need to focus on immense potential and scope for assessment of maturity of mango. Thus steps should be taken to enhance shelf life and reducing post harvest losses. The study has implications for development of indigenous instruments for determination of maturity of fruits rapidly and non-destructively on tree itself.

Key words: Maturity, Impedance, Losses, Quality, Physiochemical

Introduction

Mango (*Mangifera indica* L.) is an important tropical fruit having heavy demand in world market. It is consumed both as fresh and in processed form. The storage life of the mango depends on the stage of maturity at which the fruit is harvested. Mango fruits are generally harvested at physiologically matured stage to get optimum fruit quality. Immature fruits display erratic ripening behaviour, may not develop full flavour and aroma, which ultimately leads to their rejection. Losses in terms of quality and quantity of fruits occur at all stages in the postharvest system from harvesting to consumption. Harvesting of immature fruits causes major contribution to these losses. Mango is generally harvested a little earlier than fully mature stage to avoid the onset of climacteric respiration during transportation to distant markets (Jha and Matsuoka, 2000). Usually harvesting is initiated when a few mango fruits on the tree begin to ripen and fall. The maturity level of harvest plays an important role in deciding their end use. The chemical or physiological determination of maturity involves very laborious laboratory techniques. Measuring maturity is of paramount importance to harvest fruit to have good post-harvest quality and is also dependent on physio-chemical quality parameters such as total soluble

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solids (TSS), pH, titratable acidity (TA), and colour. The existing biochemical methods of determination of maturity involve subjective variations and lead to harvest of mature and under mature mangoes (Jha *et al*., 2012). Harvesting at immature stage leads to fruits with uneven ripening, excessive shriveling and low levels of sweetness and flavor. Late harvested fruits, on other hand, result in reduced shelf life with greater susceptibility to spoilage. Mature green mango with fair hardness attains a better eating quality during ripening (Shafique *et al*., 2006). That's why digitized prediction of maturity is of considerable importance for both export and for reducing huge post harvest losses. Knowledge of computing and prediction of maturity will also help in devising marketing, transport and storage strategies. Most consumers determine the maturity by surface firmness, gloss, flavor and other physiological parameters to determine the quality which is often misleading. So the demand for easy, rapid and non-destructive evaluation of quality parameters has gained momentum in past few decades. Non-destructive methods are widely explored to predict the quality of fruits (Slaughter, 2009). Many physical characteristics of fruits and vegetables have been determined using non-destructive techniques. Nuclear magnetic resonance (NMR), X-ray and computed tomography, near infrared spectroscopy (NIRS), electronic nose, machine vision and ultrasound are some of the most recent techniques used for non-destructive quality evaluation of foods(Jha *et al*., 2012). All these techniques are rapid and non-destructive. NIRS, however, is gaining wider acceptance due to its cost effectiveness, ease of operation and on-line applicability. Maturity and sweetness of some mango cultivars based on single property such as firmness and TSS have been predicted with reasonable accuracy and rapidity using visual and near infrared (NIR) spectroscopy.

A number of methods have been developed for the non-destructive determination of fruit quality, and several reviews of these technologies are available. In one of the reported studies on detection of freshness of apples, impedance spectrum of fresh (intact) apples and of artificially bruised apples was determined on the surface using ECG electrodes with an LCR meter. It was found that the parameters related to measurement were related to degree of bruises on the apples (Vozary and Benko, 2010). In another reported study on measuring the quality of tomato (*Lycopersicum esculentum)*, near infrared reflectance spectroscopy was used to establish the relationship between nondestructive measured spectra and the fruit physiological properties such as fruit firmness, soluble solids content and acidity(He *et al*., 2005). Often no special steps are taken to separate the crop according to the extent of maturity(Abbott, 1999; Abbott *et al*., 1997). As a result fruits that are sent for storage may already be ripe and ready for consumption and unripe fruit may be offered for sale.Ripe fruits put into cold storage tend to be over-ripe by the time they have been removed from the storage and transported to the retail outlet. Frequently such produce cannot even be sold at all and has to be thrown away. This is a serious problem encountered in perishable horticultural crops. In addition, quality of fruits of improper maturity that are harvested early can never be improved by post-harvest treatments. When a consumer buys such improperly ripe fruits a strong negative impression is received.

The conventional method of assessing maturity of mango is time consuming and destructive. It requires biochemical analysis by skilled personnel. Also, manual sorting and grading is tedious and time-consuming. Non-availability of Indian indigenous portable instruments for determination of maturity of mango has been realized. Present work aims at to study electrical and physiochemical properties of unripe mangoes during ambient storage for further development of some portable instrument for assessing maturity of mango fruit.

Materials and Methods

Sampling of mango

Mango trees (cv. *Magnifera Indica* L.) were selected in PAU Ludhiana, farm orchards based on flowering amount, size of trees and location for the study and randomized block design of sampling was adopted (Jha *et al.*, 2012). Fruiting of mango was continuously observed after full bloom (when more than 60% flowers had opened). One mango from each direction (east, west, north and south) of each tree was manually plucked and brought to laboratory for the study. Twenty mangoes were randomly selected as sample for the experimentation. After plucking, the mangoes were stored in corrugated boxes at ambient temperature. The parameters such as size, sphericity, TSS, pH, TA, colour and electrical properties and sensory attributes were determined during the fruit development and storage as well (Table 1). For the extraction of mango juice, mango pulp was homogenized with distilled water in a blender andthen it was filtered for further dilutions and use.

Physiochemical properties

The parameters such as size, sphericity, TSS, colour and electrical properties were determined during the fruit development and storage conditions.The size was measured along three major axes using a verniercalliper (least count 2 mm) and expressed in terms of geometrical mean diameter as per method described by Moninson, 1980 (Wanitchang *et al.*, 2011),

$$\text{Size} = (abc)^{1/3} \qquad \ldots(1)$$

Where a = longest intercept; *b* = longest intercept normal to *a*; *c* = longest intercept normal to *a* and *b*.

Sphericity was then calculated using the formula,

$$\text{Sphericity} = \frac{\text{Geometrical mean diameter}}{\text{Longest intercept}} \qquad \ldots(2)$$

The colour of mangoes in terms of L, a, b values was determined using Hunter Lab minis can XE Plus colorimeter (HAL, USA, Model 45/0-L). L denotes the lightness or darkness, a, green or red and b, blue or yellow colour of the samples. The nose cone was positioned in the surface of the mango such that the light thrown by the colorimeter did not leak. The colour was measured at four places of each sample and average values were recorded for the study. Before measuring, the colorimeter was calibrated with black and white calibration tiles provided with the instrument.

For study of electrical characteristics during storage of mango at different maturity stages, a two-terminal probe equipped with an LCRQ bridge meter was used. The bulk impedance of mango was measured to characterise the fruit. Effective resistance and effective capacitance vs. frequency characteristics were determined. With the LCRQ Bridge the capacitance and the resistance of mangoes were measured at 100 Hz and 1 KHz. At 100 Hz the value of resistance and capacitance was measured on both series and parallel. Similarly at 1 KHz the value of capacitance and resistance was measured on both series and parallel. ECG (3M) (Electro-cardiography) electrodes were used. The impedance may be used for differentiating between the raw and the ripe mangoes. After the measurement of capacitance and resistance the series and parallel impedance was calculated using the formulas,

$$Z_S = \sqrt{R^2 + X_C^2} \qquad \ldots(3)$$

$$Z_P = \frac{RX_C}{\sqrt{R^2 + X_C^2}} \qquad \ldots(4)$$

Where Z_S is series impedance, Z_P is parallel impedance, R is resistance in series, X_C is the capacitive reactance, and $X_C = \frac{1}{2 f \pi c}$

After measuring the impedance of mango the mango was peeled (about 0.2 mm skin thickness) with the help of a knife and pulp of the mango was grinded in a grinder then the juice of mango was extracted by filtering the mango pulp paste with help of a muslin cloth. New piece of cloth was used for filtering each sample. The TSS was estimated using a hand held refractometer (ERMA, Japan) with a scale of 0–32° Brix (least count 0.2° Brix).The pH of mango juice were measured thrice using digital pH meter (Thermo Fisher Scientific Inc., Singapore), respectively, and the average values were noted.

Titrable acidity of mango pulp juice was determined as per AOAC (2005) method. Mango pulp was taken in a conical flask (5 g) and mixed with 25ml of distilled water. Two or three drops of indicator was added, and the solution was shaken vigorously. It was then filtrated immediately with 0.1N NaOH titration solution till a permanent pink colour appeared. The volume of NaOH solution required for titration was recorded. Percent titratable acidity was calculated by using the formula (Islam *et al*., 2013):

$$\%\text{Titratable acidity} = \frac{T \times N \times V_1 \times E}{V_2 \times W \times 1000} \times 100 \quad \ldots(5)$$

Where T is the titre, N is the normality of NaOH, V_1 is the volume made up, E is the equivalent weight of acid, V_2 is the volume of extract, and W is the weight of sample.

Sensory evaluation of the stored mangoes was conducted on alternate days starting from the day the mangoes were plucked. Fruit was cut into small pieces along equatorial region. Then, the fruit was tasted by five persons selected randomly and were asked to express their rating of the fruit based on flesh colour, sourness, aroma, firmness, crunchiness and juiciness. At last, overall acceptability (OA) was calculated using the average value of flesh colour, sourness, aroma, firmness, crunchiness and juiciness.

Results and Discussion

Size and sphericity

The size of the fruits increased gradually over the period of maturity. Increase in size may be due to physiological growth and the average value of the size at this TSS may be taken as the parameter of harvesting of mango.The matured mango was harvested and stored for a period of ten days. The size of the stored mangoes was observed to be decreased during storage period from 124.36±0.1 mm to 123.59±0.1 mm (Fig. 1a). At the end of the storage period, the size of the stored mangoes decreased to 123.04±0.1 mm. The decrease in the size was due to shrinkage in the fruits because of the moisture loss during storage (Wanitchang *et al*., 2011). The increase in sphericity was not so substantial, and only a slight change was noticed during the growth. It varied from 0.85 to 0.86. As the fruit developed uniformly in all three axes, the sphericity of the fruits remains almost constant.The decrease in the sphericity also shows that shrinkage occurred in the minor axes along breadth and width during storage, which may be useful in calculation of packing requirement of mango for transportation and storage (Shafique *et al*., 2006).

Total soluble solids and titrable acidity

The TSS content of the stored fruits increased during the storage period due to ripening but after the storage period it decreased slightly and remained around 13.3±0.2% (Fig. 2b). Decrease in TSS may be due to excessive ripening and then rotting of mango after the storage period. The titratable acidity of mangoes decreases as the ripeness increases (Monika *et al*., 2016). The value of titrable acidity was found to be 2.3±0.1% in the beginning of the experiment. The value decreased to 0.42±0.1% at the final stage of storage (Fig. 3b).

Colour and pH

In the initial stage of fruit development, the ‘L’ value did not increased much, whereas it marginally increased in later stage due to the appearance of yellowness. The ‘a’ value which

Table 1. Sensory evaluation of mango harvested at different maturity stage and stored at ambient conditions

Parameters	Day 1	Day 2	Day 3	Day 4	Day 5
Flesh colour	Moderate yellow	Moderate yellow	Moderate yellow	Yellow	Deep yellow
Sour	Moderate	Moderate	Moderate	Light	Sweet
Aroma	Light	Light	Moderate	Moderate	High
Firmness	Moderate	Moderate	Moderate	Light	None
Crunchines	High	Moderate	Moderate	None	None
Juiceness	Moderate	Light	Moderate	High	Extreme

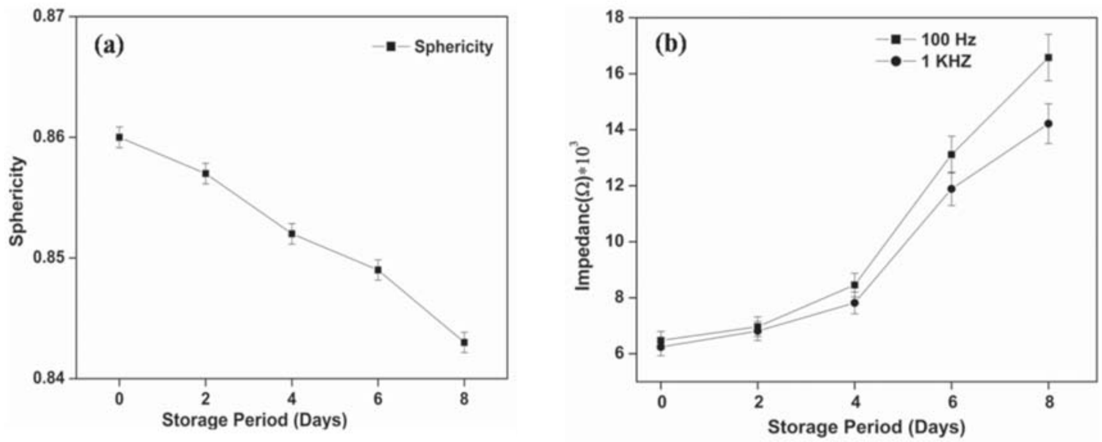

Fig. 1. Graphical representation of variation of (a) sphericity and (b) impedance of mango samples at different frequencies with storage

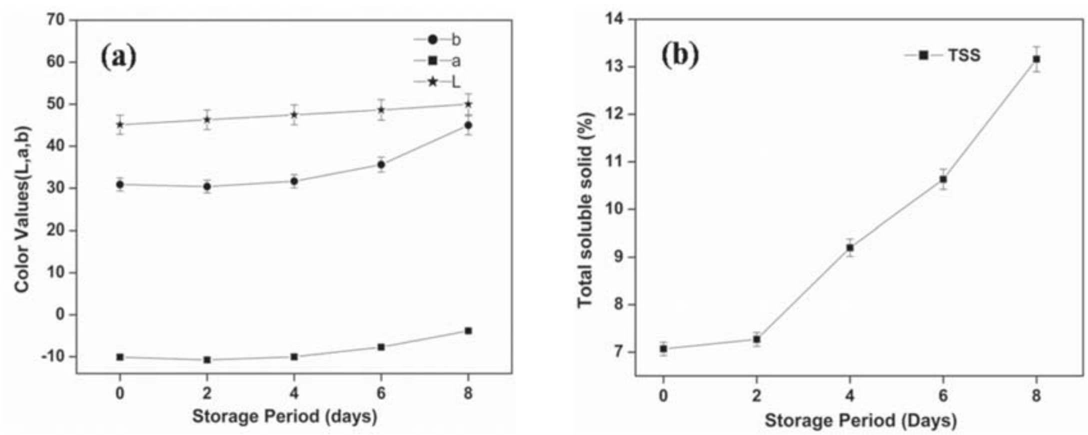

Fig. 2. Graphical representation of variation of (a) color values and (b) total soluble solid content of mango with storage

indicates the green colour of the skin increased from -10.09 to -3.82 over the period of maturity. The presence of yellowness ('b' value) in the surface of the fruits did not increased significantly in the initial stage but then increased in the later stage of maturity (Fig. 2a). This shows the development of dark green colour in the initial stage and the appearance of light yellow colour when the fruits started maturing.The pH of the mangoes increased during the period of storage. As the ripeness of the fruit increases, the acidity decreases. The pH value after harvesting the mango was around 3.0±0.05 and it was seen to be increased from 3.0±0.05 to 4.87±0.05 at the end of the storage period (Fig. 3a). The pH value of the mangoes was measured with a pH meter.

Electrical characteristics

Impedance is a measure of the opposition to the flow of an electric current through a circuit of alternating current. It arises from the combined effect of ohmic resistance and reactance. The impedance was calculated at two frequencies i.e. 100 Hz and 1 KHz in both series sand parallel mode. The impedance at 100 Hz and 1 KHz in series mode was 7.2 ±0.4 KΩ and 6.9±0.4 KΩ respectively. The impedances were seen to increase during the storage period (Fig. 1b). It increased to 16.6±0.6 KΩ and 14.8±0.6 KΩ for 100 Hz and 1 KHz respectively in series mode.The impedance for 100 Hz and 1 KHz in parallel mode was 7.0±0.4 KΩ and 6.9±0.4 KΩ

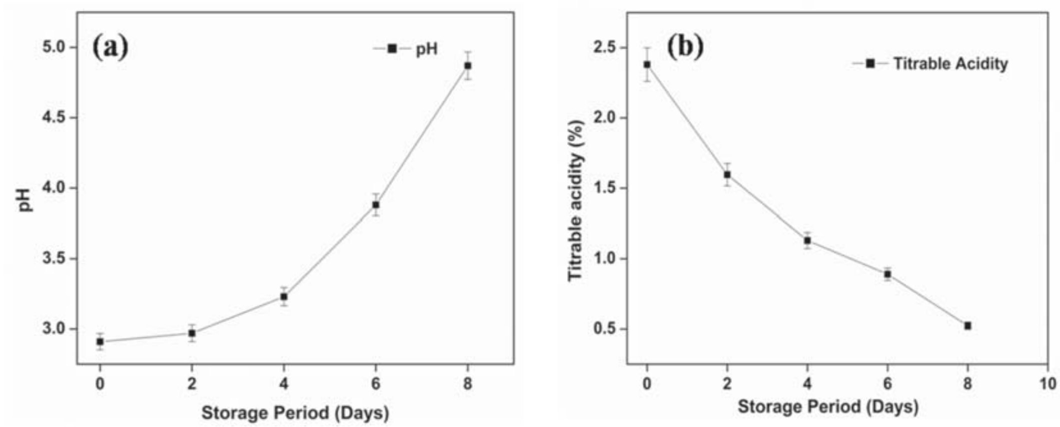

Fig. 3. Variation of (a) pH and (b) titrable acidity of mango samples harvested at different maturity stages with storage period

respectively. The impedances were seen to increase during the storage period. It increased to 16.6±0.6 KΩ and 14.2±0.6 KΩ for 100 Hz and 1 KHz respectively in parallel mode. It has been observed that in series and parallel mode the impedance did not vary significantly. So the series and parallel mode did not matter in studying the variation of impedance with storage period. Moreover at lower frequencies (100 Hz) the penetration of signals in cells is better that ultimately led to high impedance (Bera *et al*., 2016).

Conclusion

The impedance spectroscopy technique has been used for the characterization of the mango ripeness at different maturity stage at two different frequencies. Moreover the physio-chemical properties have also been studied and explored. By measuring the effective resistances, effective capacitances and impedance of the fruits, at a particular frequency, raw and ripe conditions may be established. The characterization, through impedance spectrometry, will be simpler and low cost at lower frequencies. The study highlights the significance of using low frequencies for studying impedance characteristics. Based on presented work further detailed experimentation can be done with respect to reliability and repeatability. The work can also be generalized and analyzed for other fruits also. Based on research findings a microcontroller based system can be developed to pluck the fruits at impedance which is related to appropriate maturity for commercial purpose.

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