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Research Article

NON DESTRUCTIVE DETERMINATION OF RIPENESS OF MANGO (*MANGIFERA INDICA L)* BY THERMAL IMAGING

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ABSTRACT

This paper investigates the comparative studies between the destructive and nondestructive methods of ripeness in mango. Ripening is the process by which fruit attains desirable flavour, quality, colour and other textural properties. Most of the methods used for determining fruits and vegetables quality are destructive in nature. Many parameters such as colour, size, density, total soluble solids, etc., were used to measure the ripening stages of mango in destructive methods. Three categories of mangoes such as unripe, mature and ripened mangoes were used for thermal imaging studies. Sensory analyses were conducted for the mangoes using nine point hedonic scales. Thermal images were captured by thermal camera and processed imaging pattern was compared with the results obtained from sensory analysis. As mango is a climacteric fruit, heat was released during ripening and respiration process. This rise in temperature was observed by thermal camera system. Comparison results support that the thermal imaging techniques can be used for estimation of ripeness of mango.

Keywords: *Mangoes, Maturity, Non destructive method, Thermal imaging, respiration, post harvest quality*

INTRODUCTION

India is one of the largest producers of mango in the world. It is known as 'King of tropical fruits'. Mango *(Mangifera Indica L*) is a delicious, interesting and nutritional fruit rich in vitamins A and B (Tharanathan *et al*., 2006). Harvesting mango at the correct stage of maturity is important to provide market flexibility and ensures attainment of acceptable eating quality to the consumers. Mango fruits harvested at unripe or overripe stage could lead to post harvest losses (Kader, 1999), Saranwong *et al*., (2004).

Maturity indices are indication of the fruit and vegetable for harvesting. There are two methods of maturity indices such as destructive and nondestructive methods for determining quality attributes of horticultural crops. Destructive methods are traditional methods for determining fruit ripeness thus cannot be so readily applied, particularly in mass production, labour intensive and biased (Brezmes, 2000). Various physical and biochemical attributes such as size , shape, flesh and skin colour, specific gravity, density, titrable acidity, insoluble solids, total soluble solids, starch : acid ratio and phenolic content are used to determine maturity indices of mango fruit (Narayana *et al*., 1997 ;Ahmed, O. K and Ahmed 2014). Destructive methods are not suitable in fruit and packaging industries as it puncture the fruit tissue and evaluation of whole lot cannot be done.

Non-destructive methods are effective than traditional conventional methods as non-destructive methods are mainly based on physical properties which correlate well with certain quality factors of fruits and vegetables (Khalifa, 2011). Non-destructive methods are advantageous over traditional destructive

methods as they do not rupture the fruit tissue, can be used to assess internal variables of fruits. Various non-destructive methods such as vibration energy, NMR, MRI, Xray, NIR, Acoustic, Ultrasound, Impedance spectroscopy are used in the quality evaluation of fruits (Escarpa, 2012; Cortes *et al*., 2015; Sheeja and Ajay Gokul (2016).

Mechanical properties of fruits used to determine force deformation curve, stiffness and elastic properties which are used to determine the fruit firmness, turgor pressure, water loss, mechanical strength of cell wall and middle lamella (Neto *et al*., 2017).

Colour is one of the indications of ripeness in mango. Some varieties of mangoes remain green even when they are ripe, while others turn golden or bright red or a combination. Hence it is not a reliable method. Thermal imaging is a non-contact technique to convert the radiation pattern of an object into a visible image called a thermogram or thermal image (Ishimwe *et al*., 2014; Manickavasagan *et al*., 2015). Due to variation in the respiration rate, the tissue temperature of the mango will vary. The physical damage to be occurred during the storage and transportation is directly proportional to the stage of ripeness. As mango is a climacteric fruit, the temperature of the pulp will increase during ripening process. Hence an attempt was made to monitor the temperature rise during ripening by capturing the thermal images using thermal cameras and the images were compared with the sensory analysis. The region in the infrared band with wavelengths from 3 to 14 µm is called the thermal infrared region. This band is useful in imaging applications that uses heat signatures.

MATERIALS AND METHODS

Uniform size of Alphonso variety of fresh mango fruits were procured from local farm with average fruit weight of 300 to 350 g. Three different categories such as unripe, matured and ripen mangoes were selected by eliminating fruits with physical blemishes, discolorations, infections and deformities. FLIR SC305 Thermal Imaging system of 320 × 240 LWIR resolution with interchangeable lenses Microscopy operates in the far infrared wavelength spectrum (e.g., 7500-13000 nm) is fixed on a tripod stand for the study. Thermal camera was located 45 cm above the observing area and close-up measurement was used to take thermal imaging of unripe, mature and ripened mangoes. Mangoes were placed in the observing region and a thermal imaging camera was positioned to observe the surface temperature of the mangoes. It conclusively captured the thermal images and sent it to the electronic and controlling unit for further analysis and decision making.

Thermal CAM Researcher software was used for recording thermal images. The image capturing process had been done under standard and controlled environment. After capturing the images, the unwanted image areas were removed by image thresholding/ temperature thresholding as a first step. The second step was blob filtering and analysis processing. In this setting, the immature and ripened mango areas were identified.

Immediately after thermal images were taken the same fruits were given to panel members for sensory analysis. The ripening stages were defined based on a sensory index on a 9 point hedonic scale covering sensory attributes viz., color, aroma, taste and texture acceptability in terms of ripeness.

RESULTS AND DISCUSSION

The thermal images captured by thermal camera is shown in Figures 1,2 and 3. The mangoes are kept in observing area at room temperature.

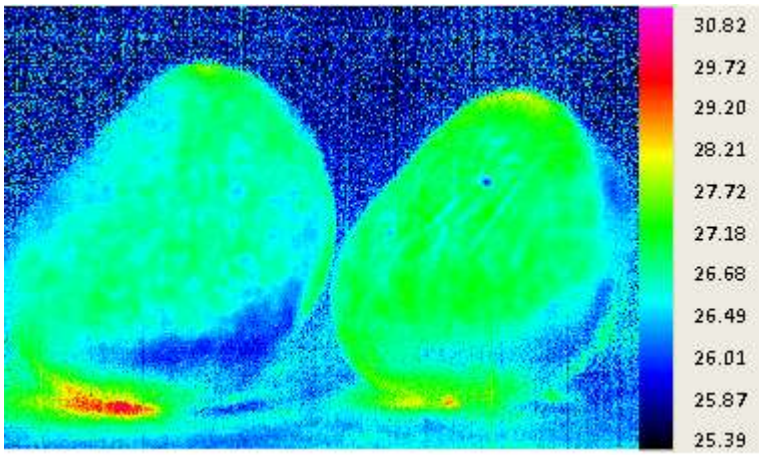

Figure 1: Thermal image of unripen mango (sample A)

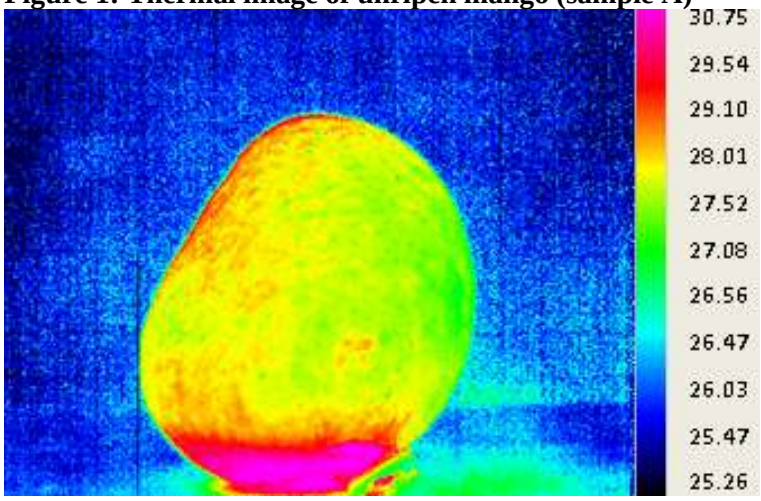

Figure 2: Thermal image of matured mango (Sample B)

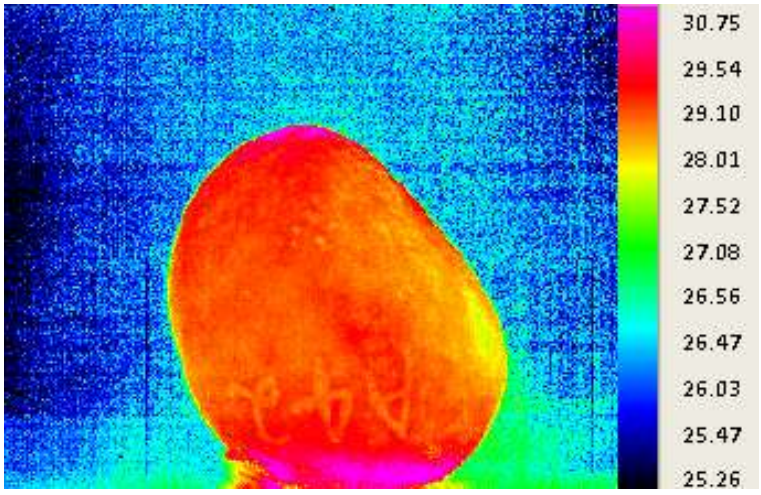

Figure 3: Thermal image of ripened mango (Sample C)

Higher temperature value in thermal pattern was observed in ripened mangoes than matured and unripened mangos. Less temperature distribution pattern was noted in unripened mangoes. The temperature difference of a 4°C was observed between ripened and unripened area.
This difference in temperature between the ripened and ripened fruit was due to the heat released during respiration of mango at ripening (Wills and Golding, 2016).
Various sensory attributes of mangoes is as given in Table - 1.

Table 1: Sensory results of mangoes

Sample	Colour	Firmness	Taste	Flavour	O.A (Ripeness)
A	6	6.5	6	6	6 (Un ripened)
B	7	7.5	7	7	7 (Mature)
C	8	8.5	8.5	8	8 (Ripened)

O.A-Over all acceptability in terms of Ripeness
The results revealed that the mangoes (sample – A) shown in figure 1 was not liked by panel members and was identified as unripened fruits; mangoes (sample – B) shown in figure 2 is moderately liked by panelist and identified as mature fruit and the mangoes (sample – C) shown in figure 3 was liked by panel members and was identified as ripened fruits

CONCLUSION

Thus this study correlated the ripeness estimation between the sensory and thermal imaging pattern of immature, mature and ripened mangoes. It can be concluded that thermal imaging process finds application as a suitable technology in estimating the ripeness level of the mango fruit.

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