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Texture and rheological changes of Indian mango cultivars during ripening

V. Eyarkai Nambi[a,*], K. Thangavel[b], K. Ambika Rajeswari[b], A. Manickavasagan[c], V. Geetha[d]

[a] Central Institute of Post-Harvest Engineering and Technology, Ludhiana, India
[b] Department of Food and Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, India
[c] Department of Soils, Water and Agricultural Engineering, Sultan Qaboos University, Oman, Oman
[d] Faculty of Engineering, Avinashilingam University for Women, Coimbatore, India

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A B S T R A C T

Fruit texture is one of the deciding factors determining the ripeness level of mangoes, and rheological characteristics are important for standardization and characterization of several unit operations from pulping to product development. A study was carried out to describe the textural and rheological behavior of three Indian mango cultivars *viz.* 'Alphonso', 'Banganapalli' and 'Neelam' during ripening. The raw mangoes exhibited higher peel strength, stiffness and flesh firmness and these textural parameters decreased as ripening advanced. A logistic model was found suitable for predicting the changes in texture properties during ripening of mangoes. The shear stress and apparent viscosity showed a decreasing trend for shear rates 1–100 s^{-1} during ripening. At higher shear rate, the pulp exhibited higher shear stress and lower viscosity. The Herschel Bulkley model was used to find out the flow behavior index, consistency coefficient and yield stress. Both the flow behavior index and yield stress were found decreasing and the consistency coefficient increased during ripening in all three cultivars. The fully ripe mango pulp did not exhibit a yield stress. Mango pulp exhibited elastic behavior rather than viscous behavior during ripening and the phase angle (δ) was less than 0.5.

1. Introduction

Texture properties are the key factors influencing the acceptability of fruits and its value added products to the consumer. The major texture changes resulting in the softening of the fruit are due to enzyme mediated alteration in the structure and composition of cell wall, partial or complete solubilization and depolymerization of cell wall polysaccharide like pectins and celluloses (Brummell and Harpster, 2001; Lohani et al., 2004; Tucker and Grierson, 1987). These characteristic changes are sequel to physiological and biochemical processes which occur throughout the storage and ripening period (Harker et al., 2010).

Firmness is an important texture characteristic in fruit. Changes in firmness were reported during processing and storage of fruit like apricot and peaches (Brecht et al., 1982), apple (Maini et al., 1985), banana (Boudhrioua et al., 2002; Duan et al., 2008), avocado (Mizrach, 2000) and mango (Jha et al., 2006; Ledger, 1991). However, firmness alone may not be taken as representative of texture, since texture is a multi-parameter attribute and gamut of characteristics (Szczesniak, 2002). Moreover, there are almost no scientific reports about changes in texture properties of mango and their kinetics during ripening. Food rheology is defined as the study of deformation and flow of raw, intermediate and final products of the food industry (White, 1970). Understanding the rheology of food materials is essential for numerous aspects of food science and technology, such as characterization of innovative products and industrial processing (Fischer and Windhab, 2011). Moreover, the flow and deformation properties of foods need to be understood in order to design equipments for handling whether it be conveyor belts, storage bins, pumps, pipelines, spray devices, etc.

Mango (*Mangifera indica* L.) is the most important fruit of the tropics and is recognized as "king of fruit". India ranks first among mango producing countries in the world (FAOSTAT, 2014), accounting for 41.5% of the total mango produced worldwide and the annual production is estimated to be nearly 18 million tons (Saxena and Gandhi, 2015). Mango is processed for the extraction of pulp that is used to manufacture beverages, ice-cream, mango

* Corresponding author.
E-mail address: eyarkainambi@yahoo.co.in (V. E. Nambi).

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leather and other products (Ahmed et al., 2005). The rheology of mango pulp, juice and concentrate has been studied by various researchers (Ahmed et al., 2005; Bhattacharya, 1999; Bhattacharya and Rastogi, 1998; Dak et al., 2007, 2006; Manohar et al., 1990; Pelegrine et al., 2002). However, no information is available on the rheological behavior of mango during ripening.

Fruit ripening is a highly coordinated, genetically programmed and irreversible phenomenon involving a series of biochemical and organoleptic changes that lead to the development of a soft and edible ripe fruit with desirable quality attributes (Prasanna et al., 2007). During ripening, fruit undergo a series of biochemical, physiological and structural changes which make them attractive to the consumer (Jiang et al., 1999). Associated changes in biochemical, physiological, compositional and colour properties during ripening have been reviewed and reported by many researchers (Bashir and Abu-Goukh, 2003; Brady, 1987; Charles and Tung, 1973; Chen and Ramaswamy, 2002; Lizada, 1993; Seymour et al., 1993; Stover and Simmonds, 1987)

The changes in textural and rheological characteristics of mango and its pulp during ripening are important for standardization and characterization of several unit operations from fruit selection for pulping to product development. With this background, a study was carried out to determine the changes in textural and rheological properties of mango during ripening.

2. Materials and methods

2.1. Mango sample collection and preparation

Three mango cultivars *viz.* 'Alphonso', 'Banganapalli' and 'Neelam' mangoes at 100–105 DFFB (days from full bloom) were taken for the study. The sample collection and preparation were done as proposed by Nambi et al. (2015). The mangoes were treated with ethylene at 141 mg m^{-3} (0.02%) for 24 h in the ripening chamber at 20 °C with 85% RH. After the treatment, the mangoes were kept in the ripening chamber (at 20 °C with 85% RH) and three mango samples from each variety were taken randomly at particular interval for TSS, textural and rheological measurements. The experiments were continued till the decay of fruit.

2.2. Texture measurement

The texture characteristics of the mangoes were measured using the Texture Analyzer (TA-HDi, Stable Micro Systems, UK) following the method proposed by Camps et al. (2005) and Nambi et al. (2015). A 4 mm cylindrical probe (P/4) was used with 1 mm s^{-1} pre-test speed, 0.1 mm s^{-1} test speed, 1 mm s^{-1} post-test speed, and 10 mm penetration depth. Texture characteristics viz. peel strength, stiffness and flesh firmness were extracted from the

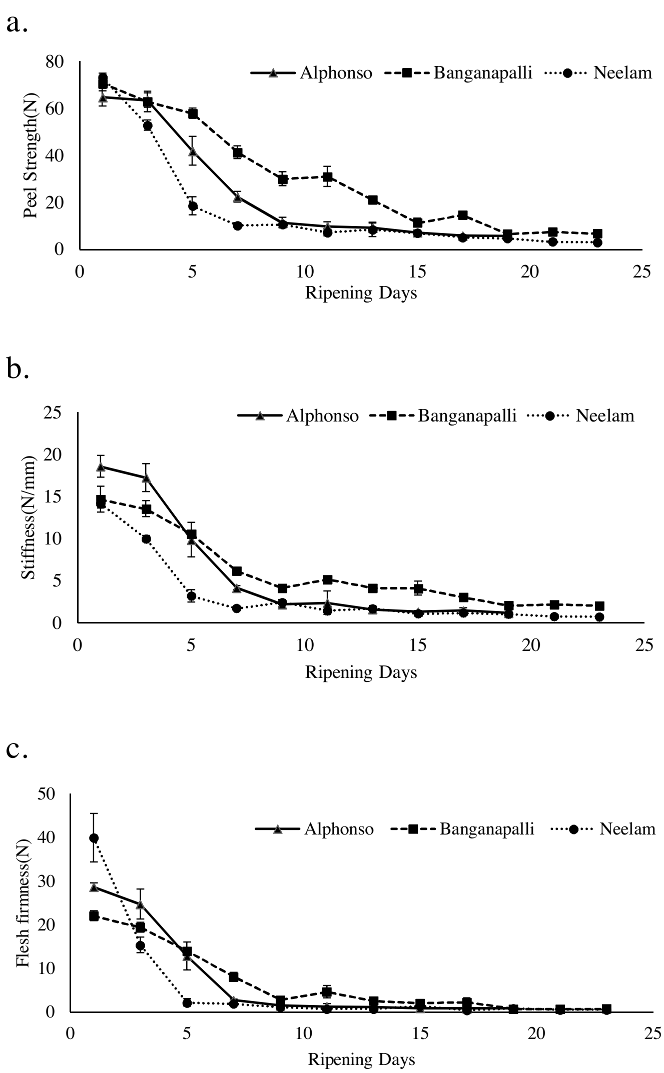

Fig. 1. Changes in texture characteristics with error bars (mean ± SD) for three mango cultivars (a) peel strength (b) stiffness (c) flesh firmness.