Effect of Storage Temperature on Thermal Properties of mango cv. Nam Dok Mai Si Thong

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Abstract

Mango fruit cv. ‘Nam Dok Mai Si thong’ (Mangifera indica L.) harvested at fully mature-green stage were stored at 5, 13 and 25 ±2 °C. The specific heat and thermal conductivity of mango flesh during storage were determined by Modulated Differential Scanning Calorimeter (MDSC) followed ASTM-E1952–98 method. The results shown that the specific heat of mango flesh stored at 25 ± 2 °C increased in the first 2 days of storage, and remained constant thereafter, whereas those of the ones stored at 13 °C and 5 °C were relatively constant during 25 days of storage (p ≤ 0.05). Thermal conductivity of mango flesh, on the other hand, decreased in 5 days when stored at 13 °C, and increased rapidly afterward. The similar results were found in the fruit that stored at 25 ± 2 °C, however, the thermal conductivity of mango flesh which stored at 5 °C increased in the first 5 days and remained relatively constant during 25 days of storage. The electrolyte leakage of mango flesh showed the similar results with the thermal conductivity for whatever storage temperatures. Chilling injury became visible as pitting and discoloration after 5 days and 20 days held at 5 °C and 13 °C respectively. The electrolyte leakage of mango flesh stored at 13 °C increased continuously but that of 5 °C was relatively constant. Since electrolyte leakage is one of the indicator that being used to determine the chilling injury and the ripening process, the increasing of electrolyte leakage as well as thermal conductivity in the case of 13 °C might be due to chilling injury incorporated with ripening process. It was possible that the thermal conductivity of the fruit could be related to chilling injury symptom and ripeness.

1. Introduction

Mango (Mangifera indica Linn.) is one of the important economic fruit crops in Thailand, and Thailand is one of the major producers and exporters of mango. With an increasing demand and increased percentage of mango fruits being exported aboard, its storage life is a major concern. After harvest, fruits and vegetables including mango remain alive and normal life process continue. The life processes can be controlled to a certain extend by low temperature storage (Moshenin, 1980; Wills et al., 1981). When mango being stored at low temperature for a period of time, there is the risk of physical changes due to chilling injury. The symptoms of chilling injury are either surface pitting, discoloration, internal breakdown or decays (Kader, 1992 and Mitra and Baldwin, 1997). It has been shown that the chilling injury is initiated by a thermally-
induced transition in the structure or phase state of some lipids which constitute the bilayers of cell membrane (Raison and Orr, 1986). Since the thermal properties are also related to the phase transition within a fruit (Aggarwal, 2000, Yahia and Dominguez, 1995) they might be used as an indicator of the chilling injury. The objectives of the study are to determine the effect of storage temperature on thermal properties of mango fruit and to relate these properties to the chilling injury.

2. Material and Methods
Exported graded mangoes cv. ‘Nam Dok Mai Si Thong’ obtained from an orchard in Chachoengsao province, Thailand, were used in this experiment. Fruits were selected by uniformity of shape, color and size. The blemished or infected fruits were discarded. The storage temperature were 5, 13 and 25±2 °C.

2.1 Measurement of specific heat and thermal conductivity
The specific heat was measured at 25°C by Modulated Differential Scanning Calorimeter (MDSC model Q100, TA instrument). A disc of 4.2 mm X 1 mm sample was prepared from mango. The sample disc was placed in a hermetic aluminium pan and the sample weight was determined by a micro-balance (Sartorious MC5), and was sealed with the DSC sample sealer. The sealing step should be completed within 30 second to prevent moisture loss from the mango tissue. The encapsulated test sample was then placed on the sample holder, using an empty hermetic aluminium pan as reference. The thermal conductivity was also measured at 25°C by MDSC followed the method of ASTM E 1952-98 (ASTM, 1998). The cylindrical sample of 6.0 mm diameter, 4 mm long was prepared from mango flesh. The dimension and weight of the sample were determined. The lower end of the sample was touched with silicone oil before placing on the sample holder, whereas the aluminium foil slightly touched with silicone oil was used as a reference. Six replications from 6 fruits were taken for each experiment and then the mean values were reported.

2.2 Electrolyte leakage measurement
For each treatment, the five sample discs (10 mm-diameter x 4 mm length) of the mango flesh were rinsed twice with deionized water for 3 seconds to eliminate the electrolyte at the cut surface. The five samples were then placed in a beaker containing 30 ml of 0.4 M mannitol. After incubating at 25 °C for 3 hours, the electrical conductivity of the solution were measured with a conductivity meter (Sartorious Professional Meter pp-20) as an initial reading. These samples were then autoclave at 121 °C, 15 psi for 30 min. After heating, the conductivity of the solution were measured again (as 100% leakage). The percentage of ion leakage was calculated by the equation:

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\% EL = \frac{\text{initial conductivity}}{\text{Total conductivity}} \times 100
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3. Result and Discussion

3.1 Specific heat \((C_p)\) and thermal conductivity \((k)\)
The specific heat of mango flesh stored at 25±2 °C increased in the first 2 days of storage and remain constant thereafter (Fig. 1A). Whereas those of the ones stored at 13° and 5°C were relatively constant during 25 days of storage (Fig. 1B and C). Thermal conductivity of mango flesh, on the other hand, decreased in 5 days when stored at 13 °C, and increased rapidly
afterward. The similar results were found in the fruit that stored at 25 ± 2 °C, however, the thermal conductivity of mango flesh which stored at 5 °C increased slightly in the first 5 days and remained relatively constant over time. The increasing of thermal conductivity in fruit stored at 25±2 and 13°C result from ripening process. Wbangchai (2001) showed that parenchyma cell of chilled mango cv. Nam Dok Mai stored at 5°C for 2 weeks contained a large number of starch granules and the cell wall were not uniform in thickness which was similar to that of the fruit before storage. The process for metabolism of starch to sugar during ripening was inhibited. The heat transfer mechanism of the fruit at the beginning might be not differ from that of the chilled fruit, and this might be the reason why the thermal conductivity of the fruit stored at 5°C was relatively constant.

When the fruit ripened, the starch granules developed into sugar, the cell wall was degraded by the enzyme, and the integrity of cell wall was lost, as revealed by the increasing of electrolyte leakage. As a result, the resistance to heat of the cell wall would be reduced, that could be seen by the increasing of thermal conductivity of the fruits either stored at 25±2° and 13°C.

3.2 Electrolyte leakage

The electrolyte leakage of mango flesh showed the similar results with the thermal conductivity for whatever storage temperature (Figure 2 A,B, and C). The electrolyte leakage increased significantly after storage, following a similar pattern either stored at 25 ±2°C (control fruit) or 13°C. The electrolyte leakage of fruit stored at 25±2°C increased rapidly, because the fruit were ripened. A characteristic of the ripening process, common to most fruit, is an increase in the activity of the cell wall degrading enzymes responsible for fruit softening and increasing membrane permeability. Ripening process can be retarded to a certain extent by low temperature. So in the first 10 days at 13°C, the electrolyte leakage of mango flesh increased slower than the fruit stored at 25±2°C. After 15day fruit stored at 13°C started to ripen, the texture of the fruit decreased from 46.84 N to 18.81 N, and the soluble solid increased from 7.87 to 15.30°Brix (data not shown). However, by visual observation, the fruit showed internal browning and discoloration occured after 20 days of storage at 13°C.

The electrolyte leakage of the fruits stored at 5°C did not change significantly. While chilling injury became visible as pitting and discoloration after 5 days at this temperature. It has been reported no changes in electrolyte leakage in cucumber stored at 2°C for 22 days (Kuo and Parkin ,1989). Electrolyte leakage increased drastically only after being transfered to 14°C. Sharom et al. (1994) reported the same phenomenon in tomatoes, stored at 5°C for 20 days. The similar trends were observed by Palma et al. (1995). Problems associated with electrolyte leakage measurements have been reported (Cote et al., 1993). These authors suggested that chill-induced demethylation of pectin would lead to excessive binding of leaked ion, which affected ion leakage measurement. It was suggested that electrolyte leakage might be related to ripening process due to changes in cellular permeability.

4. Conclusion

From the results, it could be concluded that the thermal properties of mango flesh were influenced by the temperature and storage time. The thermal conductivity of the fruit which related to chilling injury. It was possible that the thermal conductivity could be used in corporation with electrolyte leakage to determined the chilling injury.

References


Fig. 1 Effect of temperature on the specific heat of mango flesh

Fig. 2 Effect of temperature on the thermal conductivity of mango flesh.