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Research note

Variation in fruit chilling injury among mango cultivars

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Abstract

Mango (*Mangifera indica* L.) fruit of six cultivars ('Kaew', 'Rad', 'Okrong', 'Tongdum', 'Nam Dok Mai' and 'Nungklangwun') were stored at 4, 8 and 12 °C (85–90% RH) and randomly sampled every 5 days. Chilling injury was manifested initially as a gray to brown discoloration of the peel, followed by a color change in the pulp and the endocarp (seed coat). The seed tissue of most cultivars became brittle during storage at 4 and 8 °C for as little as 5 days, and the seeds did not germinate. In all cultivars studied, storage life was limited by skin discoloration. If acceptable skin color (no discoloration of more than 10% of the skin surface) after 5 days of shelf life at room temperature (about 30 °C) was taken as a criterion, fruit of all cultivars, except 'Rad' and 'Okrong', could be not be stored for more than 5 days. According to this criterion, 'Rad' fruit could be stored at 12 °C for 15 days and 'Okrong' fruit for as long as 25 days. This variation in chilling injury (CI) sensitivity may be useful in breeding cultivars with improved storage life at low temperatures.

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1. Introduction

Harvested mango fruit have a short postharvest life at ambient temperature (Pantastico et al., 1984; Pesis et al., 2000) and are susceptible to chilling injury (CI) if exposed to temperatures below 13 °C (Thompson, 1971; Mitra and Baldwin, 1997; Acosta et al., 2000). CI symptoms include skin browning and pulp discoloration (Paull, 1990; Koolpluksee et al., 1993). Because of their sensitivity to CI transport of mangoes

to the most distant international markets is generally only successful if it occurs by air (Saucedo-Veloz et al., 1977).

The leading mango cultivars in Thailand are 'Okrong', 'Nam Dok Mai', 'Tongdum', 'Nungklangwun', and 'Rad'. Other important cultivars include 'Kaew' (Kusumo et al., 1984). Preliminary data showed that fruit of some of these cultivars were considerably less susceptible to CI than fruit from other cultivars. The aim of this study was to monitor the development of CI symptoms and fruit quality, both during and after low temperature storage.

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2. Materials and methods

Mango (*Mangifera indica* L.) fruit used in this study were from the cultivars 'Kaew', 'Rad', 'Okrong', 'Tongdum', 'Nam Dok Mai', and 'Nungklangwun'. Fruit were harvested at their commercial maturity. This stage is based on shape and color of the fruit and its specific gravity. The day of harvest was also specified as number of days after full bloom (DAFB). Flower panicles that were in full bloom were tagged and the days until harvest were recorded. The fruit were harvested at the following DAFB: 'Kaew' 100, 'Rad' 70, 'Okrong' 100, 'Tongdum' 102, 'Nam Dok Mai' 100, and 'Nungklangwun' 115. Although the differences between the cultivars may change with fruit maturity, we considered that the most practicable first comparison between cultivars was that of fruit at normal harvest maturity.

All fruit were obtained from one mango orchard. Fruit from each cultivar was picked from several trees, randomized, and transported to the laboratory within 3 h of harvest. The fruit was selected for uniformity of size and color, cleaned in a solution of 200 $\mu\text{l l}^{-1}$ chlorine bleach, allowed to dry in air at ambient temperature, then placed in corrugated cardboard boxes and stored at 4, 8 and 12 °C (85–90% RH). Every 5 days, 10–15 fruit were randomly sampled.

The degree of CI and fruit quality was determined both immediately after removal from cold storage and daily during shelf life at room temperature (29–31 °C, 68–70% RH). Fruit were cut longitudinally in half. Visible characteristics of CI were: discoloration to gray and brown of the skin, discoloration to purple or gray of the pulp and the fibrous part around the endocarp, and discoloration to gray, red or brown of the endocarp. These color changes were assessed using a scale of 0–4.

Skin color was rated as: (0), normal skin color; (1), discoloration covered less than 10% of total skin surface; (2), discoloration of 10–20% of total skin surface; (3), discoloration of 20–30% of total skin surface; and (4) discoloration more than 30% of total skin surface. Similarly, pulp color was rated as (0), normal pulp color; (1), discoloration covered less than 10% of total pulp area; (2), discoloration covered 10–20% of total pulp area; (3), discoloration of 20–30% of total pulp area; and (4), discoloration in more than 30% of total pulp area. For seed coats (endocarp) the scores

were: (0), normal seed color; (1) discoloration covered less than 10% of total seed surface; (2) discoloration of 10–20% of total seed surface; (3), discoloration covers 20–30% of total seed surface; and (4) discoloration of more than 30% of the total seed surface.

Preliminary data on taste were gathered by a trained panel of three researchers, who used a scale of 0 (normal taste) and 1 (unacceptable taste). Taste was considered acceptable if two of the panel members deemed it such. Storage life was the time until any of the visible characteristics, or taste, had become unacceptable. A score of two or higher was considered unacceptable for each of the visible parameters.

Means of visible characteristics were based on scores of three samples of 4–5 fruit each (12–15 fruit in total). Statistical differences of the means were calculated using Duncan's multiple range test (DMRT). We describe the results of year 1. The experiment was repeated on a smaller scale the next year. Results were essentially the same as those in the first year.

3. Results and discussion

Mangoes of all six cultivars tested were susceptible to CI. The first symptom of CI was the presence of greyish scald-like spots on the skin. Subsequently a considerable part of the skin became dark brown. The symptoms in mangoes stored at 4 and 8 °C developed more rapidly and were more dramatic than in those stored at 12 °C (Table 1). The intensity of skin discoloration increased after holding at room temperature (Table 1). Mango fruit of the cultivars Kaew, Okrong and Tongdum showed slight pulp discoloration, which occurred considerably later than skin discoloration (Table 2). Pulp discoloration became worse after holding for 5 days at room temperature (Table 2). 'Tongdum' fruit did not show pulp discoloration during storage, but did develop this discoloration after holding at room temperature. 'Nam Dok Mai' and 'Nungklangwun' fruit exhibited no discoloration of the pulp even after 5 days of shelf life (Table 2). Severe skin discoloration was accompanied by uneven pulp softening, and by poor eating quality (results not shown).

The single large seed has a hard coat and a softer inner tissue. CI symptoms were observed in the fibrous part of the flesh, directly around the seed coat,

Table 1
Time (in days) of acceptable skin color of mango fruit stored at 4, 8 and 12 °C

Cultivar	Storage temperature (°C)					
	4		8		12	
	After storage (days)	After 5 days of shelf life	After storage (days)	After 5 days of shelf life	After storage (days)	After 5 days of shelf life
Kaew	10 b	0 b	10 d	0 b	10 d	0 c
Rad	0 d	0 b	15 c	0 b	25 b	15 b
Okrong	20 a	5 a	>30 a	5 a	>30 a	25 a
Tongdum	5 c	0 b	5 e	0 a	15 c	0 c
Nam Dok Mai	5 c	0 b	5 e	0 a	5 e	0 c
Nungklangwun	5 c	0 b	25 b	0 a	25 b	0 c

The criterion for acceptability was a color score less than two. Fruit were evaluated directly (after storage intervals of 5 days), and after another 5 days of shelf life at about 30 °C. If the score was two or higher at the end of the first 5 days of storage, the time to acceptable skin color was taken to be 0. *F*-test based on scores that were analysed by DMRT. In each column a different letter shows statistical difference at $P < 0.05$.

Table 2
Time (in days) of acceptable pulp color in mango fruit stored at 4, 8 and 12 °C

Cultivar	Storage temperature (°C)					
	4		8		12	
	After storage (days)	After 5 days of shelf life	After storage (days)	After 5 days of shelf life	After storage (days)	After 5 days of shelf life
Kaew	25 b	15 c	>30 a	>30 a	>30	>30
Rad	>30 a	20 b	>30 a	20 b	>30	>30
Okrong	>30 a	>30 a	>30 a	5 c	>30	>30
Tongdum	25 b	20 b	25 b	20 b	>30	>30
Nam Dok Mai	>30 a	>30 a	>30 a	>30 a	>30	>30
Nungklangwun	>30 a	>30 a	>30 a	>30 a	>30	>30

The criterion for acceptability was a color score less than two. Fruit were evaluated directly (after storage intervals of 5 days), and after another 5 days of shelf life at about 30 °C. *F*-test based on scores that were analysed by DMRT. In each column a different letter shows statistical difference at $P < 0.05$.

the seed coat (endocarp) itself, and the soft tissue of the seed. The fibrous part of the flesh and the seed coat showed a discoloration ranging from greyish to brownish. Since the color changes in these two tissues were similar we took them together. Table 3 shows the time to a color score 2–3.

Although seed discoloration occurred early, we did not include it in our final score for acceptable fruit. Most consumers in distant markets, for which low temperature storage will be most necessary, will discard the seed. After storage at 4–12 °C, the seed tissue inside the endocarp became brittle and the seeds no longer germinated. This was observed in all cultivars tested. These CI symptoms developed following discoloration of the skin, after a period that was similar to endocarp discoloration. Loss of ability of

Table 3
Time (in days) to discoloration score 2 of the innermost fibrous part of the flesh and the outer seed coat (endocarp) of mango fruit stored at 4, 8 and 12 °C

Cultivar	Storage temperature (°C)		
	4	8	12
Kaew	0	0 c	0 d
Rad	0	0 c	0 d
Okrong	0	5 b	>30 a
Tongdum	0	0 c	5 c
Nam Dok Mai	0	0 c	0 d
Nungklangwun	0	10 a	10 b

Fruit were evaluated directly after storage intervals of 5 days. If the score was two or higher at the end of the first 5 days of storage, the time to discoloration was taken to be zero. *F*-test based on scores that were analysed by DMRT. In each column a different letter shows statistical difference at $P < 0.05$.

seeds to germinate occurred earlier and in more fruit when the storage temperature was lower (results not shown). Some mangoes, such as cultivar ‘Kaew’, are propagated commercially mainly from seed. The fruit of this cultivar (and some other cultivars not presently studied) are consumed or processed locally, and the seeds are collected and planted. In some cultivars that are consumed locally, absence of seed germination is therefore an unwanted side effect of low temperature storage. Nonetheless, seed germination is not important for acceptability in most distant markets. The CI symptoms in endocarp and seeds have not previously been described.

The limiting factor for storage life was skin discoloration. Table 1, therefore, shows the time during which the fruit can be stored, at various temperatures. Among the cultivars tested, ‘Okrong’ mangoes were least and ‘Nam Dok Mai’ most sensitive to CI, based on skin discoloration during storage. The maximum storage life of the various cultivars, tested at 12 °C, varied between 0 and more than 30 days (Table 1). Storage at lower temperature induced more CI and therefore reduced the duration of storage (Table 1). When visible skin injury during shelf life were taken as a criterion, none of the cultivars except ‘Rad’ and ‘Okrong’ could be stored for more than 5 days. According to this criterion, the maximum storage life at 12 °C of ‘Rad’ was 15 days, and ‘Okrong’ fruit could even be stored for 25 days (Table 1). In this study we evaluated the shelf life of fruit at about 30 °C for 5 days following storage. The shelf life is presumably longer if the fruit were held at lower temperature, for example, in temperate countries.

Our results showed the development of peel discoloration following cool storage and a period of 30 °C limits the storage life (at 12 °C) of most mango cultivars tested to only a few days. This means that they can only be transported to distant markets by air. However, we think it may be possible to export ‘Rad’ by surface transport lasting up to 2 weeks, and ‘Okrong’ even lasting up to 3 weeks. We propose that the tolerance of these two cultivars may be useful in breeding

and selection of improved cultivars with reduced sensitivity to chilling.

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