Changes in Mango Fruit Characteristics during Development and after Harvest

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Key words: sugar、starch、α-amylase

Abstract

The physical and biochemical changes during mango fruit development and after harvest were studied. 'Irwin' and 'Chai' mango (*Mangifera indica* L.) fruits were harvested at 62, 76, 90, 104, 118 and 132 days after full bloom (DAFB). The level of sucrose in flesh increased rapidly from 104 to 132 DAFB. Reducing sugars, comprising mainly of fructose, slightly decreased during fruit ripening. The amount of starch slightly decreased at the same period. α-Amylase activity increased parallel to the increase in fruit weight and rapidly decreased 104 DAFB. The protein content rapidly increased at the onset of ripening 104 DAFB. Fruit harvested at the 118 DAFB were used for postharvest observation. Sucrose was the predominant sugar during fruit ripening postharvest. The level of sucrose increased 4 days after harvest and then remained high. Reducing sugars, comprising mainly of fructose, and the amount of starch decreased slightly during ripening. α-Amylase activity decreased markedly 4 days after harvest. Protein content increased rapidly 2 days after harvest.

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Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical fruits in the world. Mango fruit can be harvested at mature green stage and ripen quite rapidly after harvest. The eating quality of mango, which is a combination of sugar, acid and texture, depends very much on the maturity of the fruit at harvest (Lakshminarayana, 1973, 1975; Subramanyam *et al*., 1975). Mango fruits are usually harvested unripe before the onset of the climacteric but physiologically mature (Lakshminarayana, 1970). Mangoes harvested at the mature and half-mature stages ripen to good quality fruit while immature fruits do not ripen normally (Medlicott *et al*., 1990). It is necessary to define the optimum stage of maturity for harvest to extend shelf-life without affecting fruit quality. The changes in fruit characteristics of 'Irwin' and 'Chai' mangoes during development and after harvest were determined.

Materials and Methods

Plant materials

Experiment 1: Fruits were harvested every 2 weeks from 15 April to 30 June 2004 for 'Chai' cultivar and from 22 April to 7 July 2004 for 'Irwin' cultivar from Horticultural Research Station, College of Agriculture and Natural Resources, National Chung Hsing University in Taichung, Taiwan. Fifteen tagged fruits for each stage were collected at 62, 76, 90, 104, 118, and 132 days after full bloom (DAFB). The peel of both cultivars of the 118 and 132 DAFB reached a color break and 100% color change, respectively. Flesh of the mid-section of each mango were collected and frozen in liquid nitrogen. The samples were maintained at -80ºC until they were used. The experiment was conducted with five replications with three fruits per replication.

Experiment 2: The fruits were harvested on 15 June 2004 for 'Chai' cultivar and on 23 June 2004 for 'Irwin' cultivar at the same place as Experiment 1. Both 'Irwin' and 'Chai' fruits were harvested at 118 DAFB and ripened further in the laboratory at room temperature, and were sampled at 2-day intervals over an 8-day ripening period. Flesh of the mid-section of each fruit were collected and frozen in liquid nitrogen. The samples were maintained at -80ºC until they were used. The experiment was conducted with five replications with three fruits per replication.

Fruit character determination

Prior to analysis, fruits were washed with tab water, rinsed and dried with paper towels. The fruit weight and fruit volume of each mango fruit was determined by using digital balance

(METTLER PJ 400) for 'Chai' cultivar and balance (LARIO) for 'Irwin' cultivar. The fruit length, fruit width, and fruit flesh thickness was measured by vernier caliper (Mahr 16EX). The total soluble solids (TSS) of each fruit was determined by hand refractometer (ATAGO). The titratable acid (TA) content was determined by a juice acid detector (NH-1000 HORIBA). The remaining flesh tissues were sliced and a 10-g sample was dried for 2 days at 70^{o}C, weighed, and percent dry matter content was calculated.

Sugar analysis

A 0.5 g of fruit flesh tissue was incubated at 70°C in 15 ml 80% ethanol for 45 min, then centrifuged for 15 minutes at 12000 xg. The supernatant was evaporated to 0.5 ml using a vacuum evaporator (VAPOUR-MIX KC-12) at 50ºC. The concentrated sample was diluted with deionized water to 1 ml and then filtered through a 0.45 µm filter (Millex, Millipore). The filtrated sample was diluted 10 times with deionized water. A 20 µl aliquot of filtrated sample was then injected into the HPLC column [Mightysil RP-18 GP 250-4.6 (5 µm)] for analysis by using Hitachi HPLC system equipped with UV Detector L-7400 Model, Hitachi pump L-7100, and Hitachi D-2000 Chromato Integrator.

Starch determination

0.1 g of dry fruit flesh tissue was ground to a powder with a chilled mortar and pestle. 10 ml of deionized water was added and then placing into water bath at 30ºC for 3 hrs. Centrifuge at 13000 xg for 10 min. Pellet was dried at 80ºC for 12 hrs. 2 ml of deionized water was then added and placed in a boiling water bath for 15 min. After cooling, 2 ml of 9.2 N $HClO_4$ was added, followed by 6 ml of deionized water. Centrifuge at 13000 xg for 10 min. The supernatant was kept for further steps. 2 ml of 4.6 N $HClO_4$ was added to the pellet, followed by 8 ml of deionized water. Centrifuge at 13000 xg for 10 min. Pool the supernatant of both steps and adjust into 50 ml with deionized water. 0.1 ml of starch extract was mixed with 1.9 ml of deionized water. Liquid phenol (Phenol: deionized water; 9:1), 0.1 ml, was added, followed by 6 ml of 98% H_2SO_4 immediately. After cooling, the absorbance at 490 nm was determined. Standard curves were prepared by using glucose.

α-Amylase assay

0.5 g of fruit flesh tissue was ground to a powder by using a chilled mortar and pestle with 5 ml of 0.02 M phosphate buffer (pH 6.9). Sample was centrifuged at 20000 xg for 20 min. 0.1 ml of supernatant was mixed with 0.9 ml deionized water and 1 ml of substrate solution [1 g soluble starch was dissolved in 100 ml of 0.02 M phosphate buffer (pH 6.9) which contain 0.0067 M NaCl]. After 5 min then add the DNS reagent 1 ml (400 g Na-K tartrate, 1 g Na_2SO_3, 4 g phenol and 23.6 g 3.5-dinitrosalicylic acid which was soluted into 2 liters with 1% w/v NaOH) followed by placing the tubes in boiling water for 10 min. After cooling, add 5 ml of

deionized water. The absorbance at 540 nm was determined. Standard curves were prepared by using maltose.

Protein determination

0.5 g of fruit flesh tissue was ground to a powder by using a chilled mortar and pestle with 5 ml of 0.02 M phosphate buffer (pH 6.9). Sample was centrifuged at 20000 xg for 20 min. The supernatant was used for further determination.

Protein content was determined by Bradford method (Bradford, 1976). The analysis was carried out by adding 2 ml of protein extract to 5 ml Coomassie blue dye reagent (100 mg of Coomassie brilliant blue G-250 dissolved in 50 ml of 95% ethanol to which 100 ml of 85% phosphoric acid has been added and the whole diluted to 1 L with deionized water). After 5 minutes, the absorbance was measured at 595 nm. Standard curves were prepared by using bovine serum albumin.

Results

Fruit development

The 'Irwin' and 'Chai' fruit fresh weight and fruit volume increased rapidly from 62 to 104 DAFB (Fig. 1). There were little changes in fruit weight and volume after this period. Changes in fruit length, fruit width, and fruit flesh thickness of 'Irwin' and 'Chai' mangoes during development are presented in Fig. 2. During the 60 and the 104 DAFB, there were dramatically increases in these parameters. After the 104 DAFB, they were constant till the final harvest.

'Irwin' and 'Chai' mangoes showed high levels of water content in the fruit flesh of the 62 DAFB with a value of 89.1% and 88.8%, respectively (Fig. 3). It gradually decreased during the latter stage of fruit development, while dry matter percentage increased from 10.9% to 15.9% and 11.20% to 15.60% from the 62 to the 132 DAFB in 'Irwin' and 'Chai' mangoes, respectively.

Biochemical changes in fruit flesh during development

The TSS in fruit flesh increased as maturity advanced in 'Irwin' and 'Chai' mangoes (Fig. 4), particularly in the last stage of fruit development. TSS increased from 8.1 ^{o}Brix to 12.9 ^{o}Brix and 8.5 ^{o}Brix to 13.7 ^{o}Brix from the 62 to the 132 DAFB in 'Irwin' and 'Chai' mangoes, respectively. The percentage of TA decreased rapidly as maturity advanced in 'Irwin' and 'Chai' mangoes (Fig. 4). TA decreased from 0.8% to 0.3% and 1.1% to 0.32% in 'Irwin' and 'Chai' mangoes, respectively during the same period.

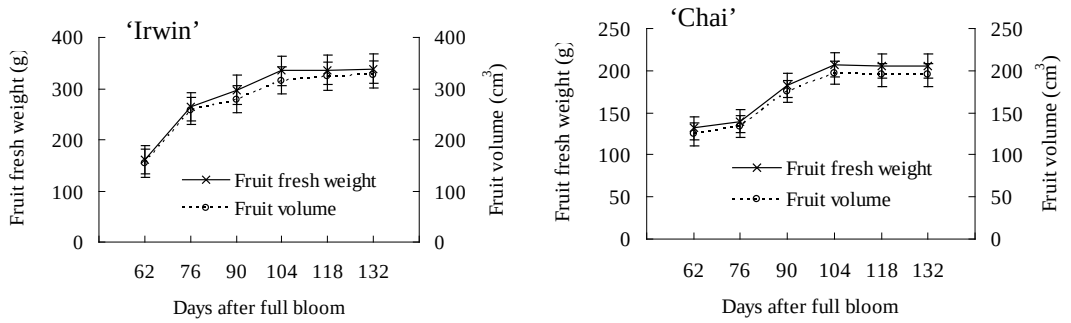

Fig. 1. Changes in fruit fresh weight and fruit volume in 'Irwin' and 'Chai' mangoes during development.

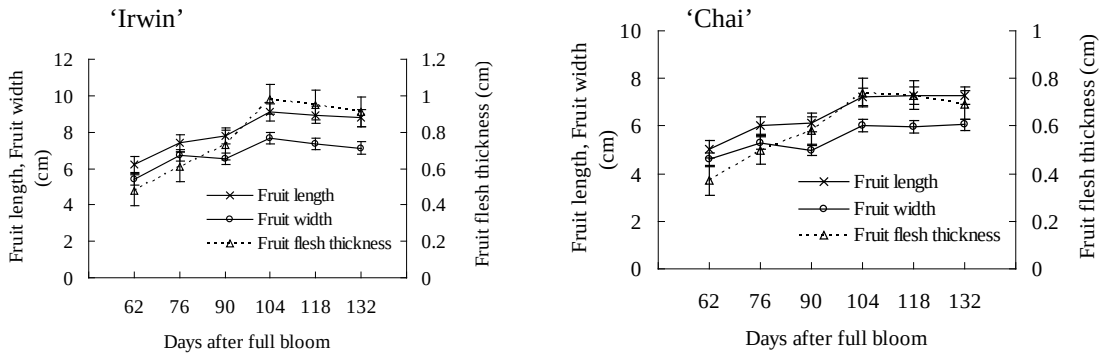

Fig. 2. Changes in fruit length, fruit width and fruit flesh thickness in 'Irwin' and 'Chai' mangoes during development.

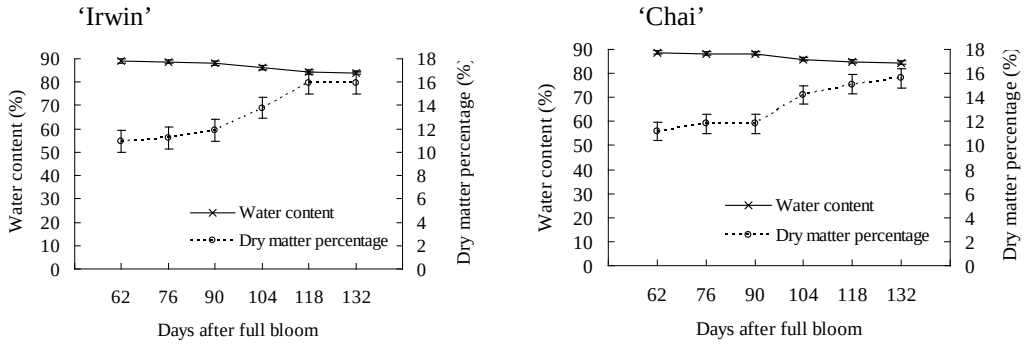

Fig. 3. Changes in water content and dry matter percentage in the fruit flesh of 'Irwin' and 'Chai' mangoes during development.

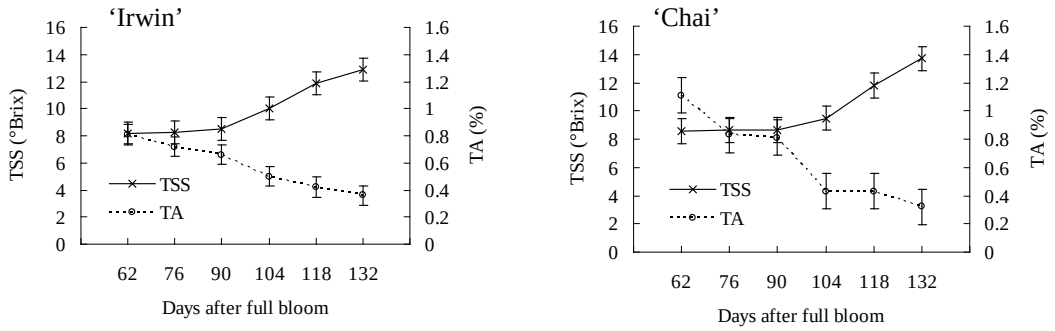

Fig. 4. Changes in total soluble solids and titratable acid in the fruit flesh of 'Irwin' and 'Chai' mangoes during development.

The amount of starch in the flesh of 'Irwin' and 'Chai' mangoes was low at 62 DAFB and it reached the highest content at the 104 DAFB and then rapidly declined till harvest. From the 104 to the 132 DAFB, the starch content decreased from 7.7% to 5.84% and 9.01% to 5.13% on a dry weight basis in 'Irwin' and 'Chai' mangoes respectively. The α-amylase activity was low at the 62 DAFB and reach the maxima at the 104 DAFB (Fig. 5). When starch started to degrade after the 104 DAFB, the α-amylase also showed a dropping in activity.

The protein content in 'Irwin' mango fruit flesh increased gradually from the 62 to 104 DAFB, followed by a rapid increase till the final harvest (Fig. 6). In 'Chai' mango, the changes in protein content showed the similar trend to 'Irwin' mango. It increased from 0.109 to 0.276 μ mole maltose g^{-1} FW from the 62 to the 132 DAFB.

The major soluble sugar during the unripe period in flesh of 'Irwin' and 'Chai' mangoes was fructose (Fig. 7). The level of its content increased from 2.83% FW to 3.34 % FW and 3.16 to 3.93% FW from the 62 to the 132 DAFB in 'Irwin' and 'Chai' mangoes, respectively. Glucose content was lowest among sugar composition and kept relatively constant throughout ripening. Sucrose content increased with ripening in both cultivars and was the predominant sugar during the late ripening period. It increased from 2.10 % FW to 5.41% FW and 2.22% FW to 5.97% FW from the 62 to the 132 DAFB in 'Irwin' and 'Chai' mangoes, respectively.

Biochemical changes in fruit after harvest

TSS gradually increased throughout the ripening period postharvest and reached 14.8 °Brix and 16.1 °Brix 8 days after harvest in 'Irwin' and 'Chai' mangoes, respectively (Fig. 8). In contrast, TA was high at the start of the ripening period and decreased gradually during the subsequent 8 days (Fig. 8). Its value went down to lower than 0.32 % in both cultivars at the last day of storage.

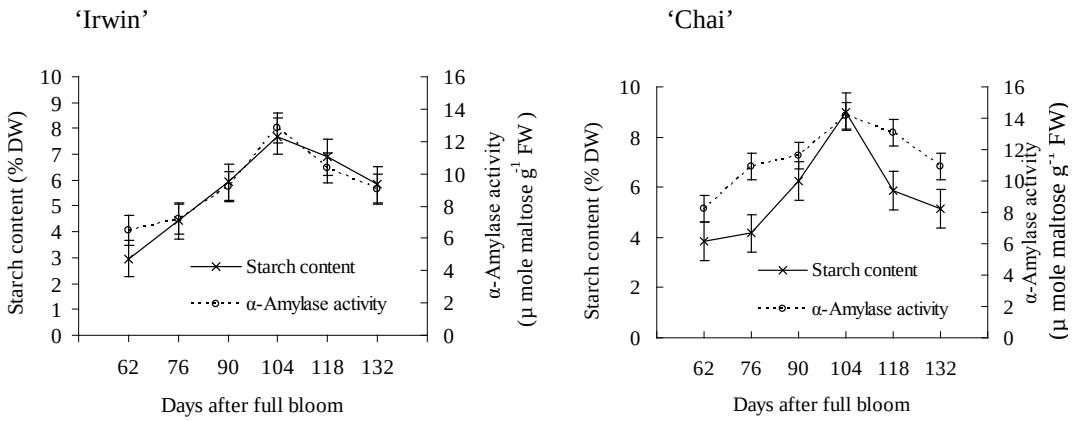

Fig. 5. Changes in starch and α-amylase activity in the flesh of 'Irwin' and 'Chai' mangoes during development.

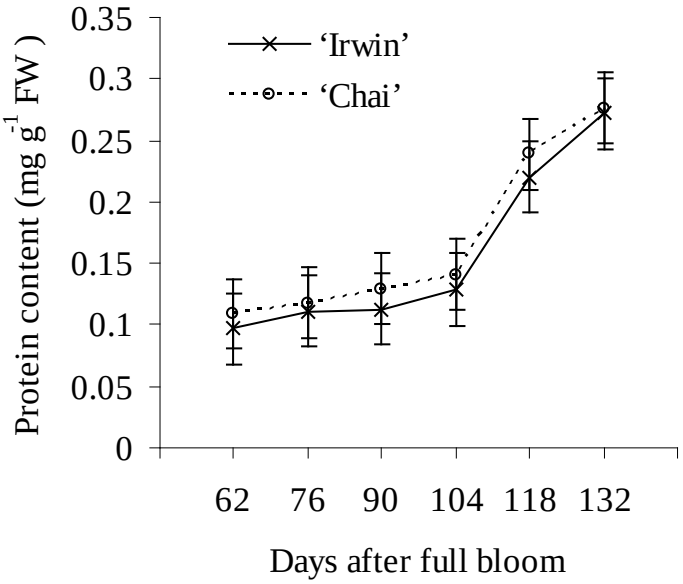

Fig. 6. Changes in protein content in the fruit flesh of 'Irwin' and 'Chai' mangoes during development.

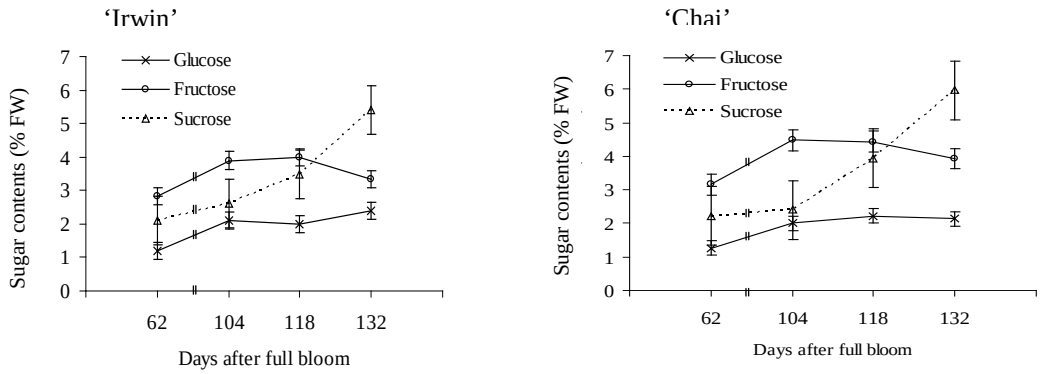

Fig. 7. Changes in glucose, fructose and sucrose contents in the flesh of 'Irwin' and 'Chai' mangoes during development.

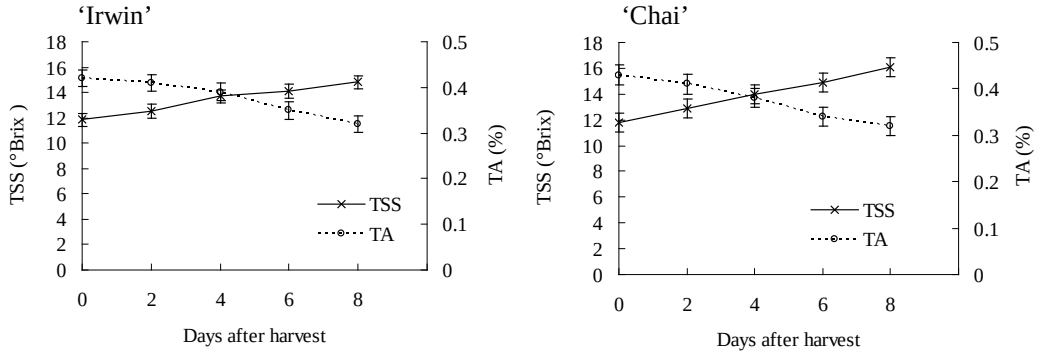

Fig. 8. Changes in total soluble solids and titratable acid in the fruit flesh of 'Irwin' and 'Chai' mangoes after harvest.

Starch content in 'Irwin' and 'Chai' mangoes showed a gradual decrease during storage from 6.90% to 5.34% and 5.85% DW to 4.69% DW, respectively, during the 8 days of storage (Fig. 9). At the same time, α-amylase activity was found to decrease after the 4th day of ripening to 7.98 and 9.84 μ mole maltose g^{-1} FW in 'Irwin' and 'Chai' mangoes, respectively, at the 8th day after harvest (Fig. 9).

The protein content in 'Irwin' and 'Chai' mangoes decreased in the first 2 days of ripening, followed by a rapid increase and reached 0.30 mg g^{-1} FW and 0.31 mg g^{-1} FW, respectively, at the 8th day after harvest (Fig. 10).

The predominant soluble sugar at the 8th day of storage of 'Irwin' and 'Chai' mangoes was sucrose (Fig. 11); 3.53% FW and 3.85% FW, respectively. The percentage of fructose went

down after the 4th after harvest to 2.58% FW and 2.96% FW at the 8th day after harvest in 'Irwin' and 'Chai' mangoes, respectively. At the same period, the percentage of glucose was lowest among sugar composition and kept relatively constant over the 8-day ripening period.

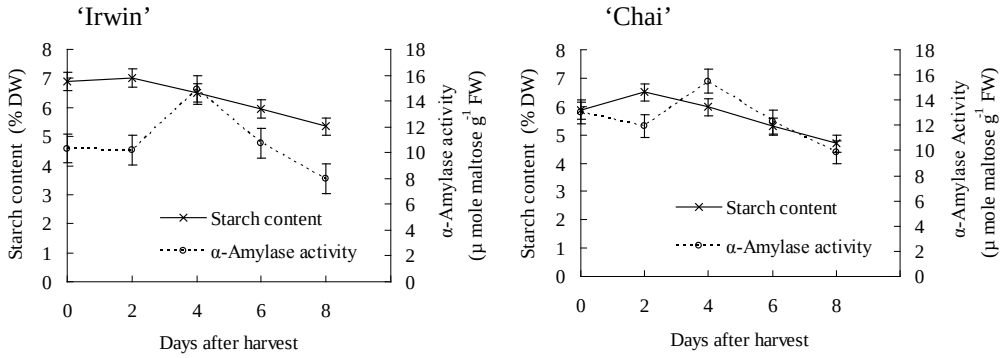

Fig. 9. Changes in starch and α-amylase activity in the fruit flesh of 'Irwin' and 'Chai' mangoes after harvest.

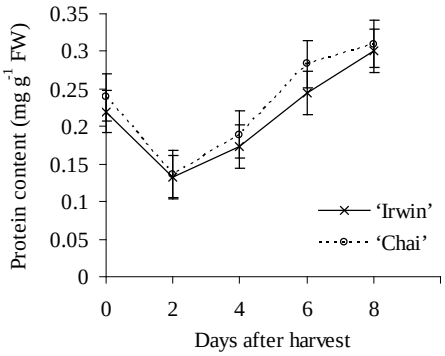

Fig. 10. Changes in protein content in the fruit flesh of 'Irwin' and 'Chai' mangoes after harvest.

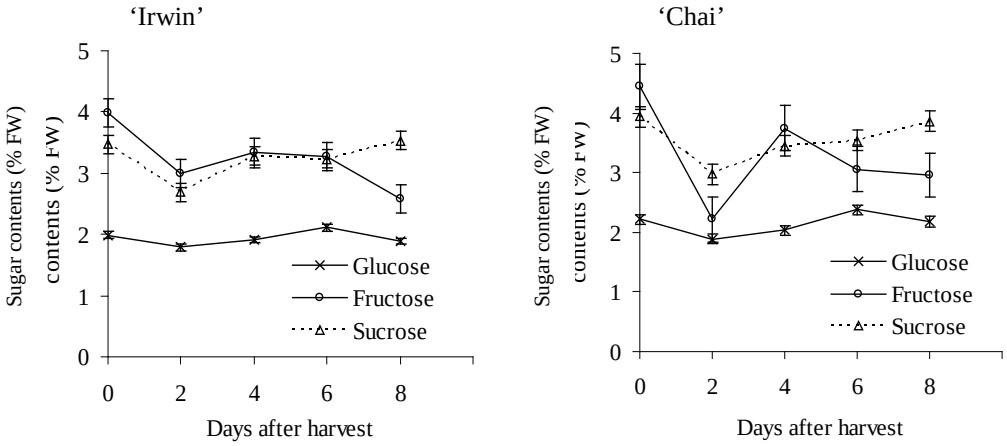

Fig. 11. Changes in glucose, fructose and sucrose contents in the fruit flesh of 'Irwin' and 'Chai' mangoes after harvest.

Discussion

The rapid increase in dry matter in 'Irwin' and 'Chai' mango fruit flesh during the 90 and the 118 DAFB found in the present study indicated a strong sink strength in the mature and ripening fruit. After the fruit had reached its full size, later harvested fruit will have higher fruit weight, TSS, and total soluble sugars (Fuchs *et al*., 1980; Tandon and Kalra, 1983) due to continual accumulation of dry matter. The protein content in 'Irwin' and 'Chai' mangoes increased about 3-fold during the 62 and the 132 DAFB which is corresponding to the work of Castrillo *et al*. (1992) in 'Haden' mango.

One of the important point for commercial cultivation of mango is at what stage the fruit should be harvested to achieve optimum fruit quality. There are suggestions using fruit morphology as a non-destructive index for harvesting mango (Krishnamurthy and Subramanyam, 1970; Subramanyam *et al*., 1975). Morphological observations showed that as the fruit developing to the 90th day of age, the shape of the fruit gradually changed from flat to round, as a result of gradual increase in fruit width. Such morphological change had also been reported in both 'Julie' and 'Pairi' mangoes (Krishnamurthy and Subramanyam, 1970).

'Irwin' and 'Chai' mango fruits harvested 104 DAFB onwards were more or less similar in the ripe stage with regard to their chemical composition to the fruits harvested from 118 DAFB. It had also been noticed that susceptibility of the fruits to diseases became greater when it reached the 132 DAFB.

When the ‘Irwin’ and ‘Chai’ mango fruits of the 118 DAFB ripened at room temperature, an increase in TSS and protein content and a decrease in starch, α-amylase activity and titratable acid were observed. However, some other constituents exhibited a rise or fall for a few days and then the trend was reversed. Similar results were recorded by Fuchs *et al*. (1980) in ‘Haden’ mango and Kalra and Tandon (1983) in ‘Dashehari’ mango. An increase in TSS and a decrease in acidity might improve flavour. In addition, an increase in protein content may indicate that additional enzymes were being synthesized to accelerate changes during ripening. In mango, the protein content could increase several time during ripening (Castrillo *et al*., 1992). The decline in reducing sugars during later stages of storage might be due to their high rate of consumption for respiration and for other energy-consuming ripening processes of the fruit. Similar observations have been reported on ‘Dashehari’ mango (Kalra and Tandon, 1983) which reducing sugars increased up to the day 6 and then decreased until the fruits were in a senescent condition. During ‘Irwin’ and ‘Chai’ mango ripening, the starch was being hydrolyzed and at the same time α-amylase activity was changing. It appeared that during the first 4 days after harvest α-amylase activity increased to initiate starch hydrolysis. However, as the fruit ripened further, when only traces of starch can be detected, α-amylase activity was also substantially reduced which corresponding to the result of Kalra and Tandon (1983) that there was a boost in α-amylase activity with a concomitant loss of starch content in the pulp during storage, but after 6 days, enzyme activity declined and the starch concentration was reduced to a negligible level. Others have also reported a starch breakdown during ripening in ‘Alphonso’ and ‘Carabao’ mangoes (Morga *et al*., 1979).

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芒果果實特性於發育期間及採收後之變化

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關鍵字：糖、澱粉、α-澱粉水解酵素

摘要：本研究調查芒果果實發育期間及採收後物理的及生化的變化。分別於滿花後 62、76、90、104、118 及 132 天採收`愛文´及`柴檨´芒果果實，結果發現：果肉內蔗糖含量於滿花後第 104 天至 132 天快速增加，而果糖含量在果實成熟期間稍微下降，同期間，果肉內的澱粉含量亦稍微下降。α-Amylase 活性隨著果重的增加而上升，但在滿花後 104 天之後迅速下降。另於滿花後第 118 天採收果實，觀察其採收後後熟之變化。芒果果肉採後後熟期間主要的醣類為蔗糖，其含量於採收後第 4 天開始增加，此後則維持高含量。澱粉含量在同一期間些微下降，採收後 4 天 α-澱粉水解酵素活性明顯下降，而蛋白質含量在採後 2 天快速增加。

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