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Effect of Various Maturity Stages at Harvest on Storability of Persimmon Fruits (*Diospyros kaki* L.)

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ABSTRACT

Fruits of a commercial cultivar of sweet persimmon (*Diospyros kaki* L.) were harvested at four stages of maturity to evaluate the practical maximum postharvest storage during 1998 and 1990. Fruits were harvested at four stages of maturity which corresponded to 6th October, 19th October, 4th November, 29th November in 1998 and 1st October, 15th October and 29th October in 1999, respectively. Fruits were held at 2 ±1°C and 95 % relative humidity for a period of twenty weeks. Fruit firmness, titrable acidity (TA), soluble tannin and vitamin C content significantly decreased with increasing maturity, while pH and soluble solid concentrations (SSC) increased. After storage, fruit harvested at all stages of maturity had higher pH, SSC, weight loss, and breakdown, but lower TA, firmness, vitamin C and soluble tannins as compared with their quality attributes at harvest. The least weight loss (less than 10 percent) during twenty weeks storage occurred in fruits harvested at the early stage of maturity (first harvest), compared to other harvest dates. Fruit firmness, SSC and vitamin C content were also best in the same order for the first harvest. However, at the end of storage period, total soluble tannins were remarkably high in fruit harvested at the early stage of maturity. In contrast, harvesting fruit at early maturity stage (i.e., SSC around 13 % and fruit firmness of 15 kg/cm^2) was found to be the best stage for minimising a postharvest loss and maintaining a marketable persimmon fruit quality product for short term storage.

Keywords*:* Persimmon, harvest date, maturity and storage.

INTRODUCTION

Oriental persimmon (*Diospyros kaki* L.) is popular in many parts of the world for its dessert quality fruit. It is popular in Japan, Asia and South America (Lyon, Senter and Payne, 1995). In Japan, production ranks fifth after mandarin, orange, apples, pears and grapes (Iwata, 1989). In Iran, persimmon is produced as an export crop and so research on fruit quality and storage life is needed to achieve this. Generally, persimmon is classified as a climactric fruit (Wills, McGlasson, Graham and Joyce, 1998). Climactric fruits could be ripe after harvest even if harvesting fruits at early maturity stage and unripe (Ben-Arie and Zutkhi, 1992; Brackmann, Mazaro and Saquet, 1997). Persimmon, unlike other climactric fruit, is not edible at the early maturity stage and has very firm texture with a low sugar and water content (Salunkhe and Desai, 1984). These characteristics give the opportunity to store fruits for lengthy periods with minimum loss, whereas ripe persimmons are very soft and mushy and high in sugar and water and can be easily bruised. The thin peel can be easily damaged or ruptured by rough handling. The reduced sugar content increases steadily during fruit development,

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reaching a maximum as the fruit became ripe (Salunkhe and Desai, 1984). The soluble tannin content at the early stage of maturity of persimmon fruits is very high, which contributes to its remarkable astringency, and then begins to fall during maturation and ripening.

The physiological studies of development and ripening of fruit and postharvest fruit quality were previously investigated in astringent and non-astringent types. Rouhani, Bassiri and Shaybany (1978) reported that fruit firmness, percentage of weight loss, pH Juice, titrable acidity and soluble solids were significantly affected by the stage of maturity. However, they didn't consider the exact stage of maturity at harvest for long term storage. Sugiura, Zheng and Yonemori (1991) in their study of the environmental factors on growth, maturity and ripening of `Hiratanenashi` persimmon, reported that persimmon have a double sigmoidal growth curve and temperature i.e. 22°C has an important role in the growth and ripening. Sargent, Crocker and Zoellner (1993) working on non-astringent persimmon cv. 'Fuyu' have indicated that in fruit harvested at the yellow stage and stored at 0, 5, 10 or 20°C for two weeks, followed by one week at 20°C, nearly all fruit at 5°C showed chilling injur. They recommended storage temperatures for Florida grown 'Fuyu' must be 20°C if rapid ripening is desired. A similar report also given by Lyon, *et al.* (1995) for persimmon cv. 'Fuyu'. However, in most cases, little attempt has been made to quantify optimum maturity stage at harvest for long term storage of persimmon fruits.

This study was conduced to find the optimum stage of maturity at harvest for long term storage of persimmon fruit and to provide a better understanding of how harvesting fruit at various levels of maturity may affect storage life.

MATERIALS AND METHODS

Fruit Material

Seven-year old trees of sweet persimmon (*Diospyros kaki.* L.) cv. Natanzy (a local landrace) were used for the experiment from a local orchard in Natanz, central Iran. Fruits were harvested at the various stages of maturity on 6th October, 19th October, 4th November, 29th November 1998 and 1st October, 15th October and 29th October 1999. Fruits were harvested from the all sides of the tree, leaving the stem end and a short length of stem attached to the fruit. The sample material was handled carefully after the harvest packed in cardboard boxes to minimise mechanical damage, arrived at the laboratory generally within 24 h of harvest. Fruits were selected for uniformity of size and colour and free of disease and defects. A six sample of 20 fruits was used for each harvest date and storage time. Each treatment had three replications (3×6 samples per treatment). Samples were weighed and placed into unwaxed ventilated cardboard boxes and stored in a cold store at a constant temperature of 2+1°C. Relative humidity was controlled at between 90- 95 %. Fruit quality and performance at each harvest date (before storage) were measured on 10 additional fruit. Fruit characteristics and the stage of maturity for each year and harvest date are given in Table 1.

Physical Determination

Flesh firmness and fruit water loss were evaluated on 15 fruits per treatment at 4-week intervals over the 20 week storage periods. The rate of fruit water loss was calculated as a percentage weight loss from the fruit, with respect to the initial fruit weight. Individual fruit weight was determined on 15 fruit per treatment over the storage period. Flesh firmness was measured immediately before and during the storage period for each harvest date after measuring fruit water loss. Two firmness measurements were taken at opposite points around the equator of the fruit using an Effegi penetrometer with an 11 mm diameter head and the level were expressed in Kg/cm^2.

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Table 1. Fruit quality attributes of persimmon fruit at harvest (before cold storage).

Harvesting Date	Fruit chracteristics						
	Maturity stage	Fruit firmness (kg/cm)	pH	SSC (%)	Organic acid mg/100cc	Vitamin C mg/100cc	Taninns mg/100g
1998							
1st harvest (6 October)	Breaker	15.8	5.33	12.8	750.4	24.25	17.14
2nd harvest (19 October)	Turning	11	20.3	20.3	394.8	19.68	14.19
3rd harvest (4 November)	Yellow	9.5	21.6	21.6	372.4	18.57	11.6
4th harvest (29 November)	Orange (Ripe)	1.2	21.6	21.6	271.6	8.97	5.3
1999							
1st harvest (1 October)	Mature green	19.7	4.7	8.4	890	25.5	16.5
2nd harvest (15 October)	Breaker	14.5	5.78	13	560	20.1	14
3rd harvest (29th October)	turning	9.2	5.9	21	269	19.1	10.8
LSD (P<0.05)		1.8	0.33	0.6	6.5	3.5	2.9

Chemical Analysis

Initially, and for every sampling period, five individual fruits per treatment were randomly sampled. The fruits were chopped into small pieces, put in an electric juice extractor (Model: EFS 103 AEG, Germany) and extracted. The juice from individual fruit was pooled, filtered through chess-cloth and used for chemical analysis. pH was evaluated immediately with a glass electrode pH meter (Model K620, Consort, Belgium). Soluble solid concentrations (SSC) were calculated from refractive indexes using a hand refractometer requiring a drop of undiluted juice (Model K-0032, Cosmo, Japan) and expressed in percentages. Titrable acidity was also calculated from the titrated volume of standard 0.1 N NaOH to pH 8.1 and expressed as mg of malic acid per 100 cc of juice (AOAC, 1980). Soluble tannins were determined for sweet persimmon according to Woolf, *et al*. *(*1997). Ascorbic acids (Vitamin C) were determined also using 2, 6 Dichlrophenol indophenols for the titration of juice and presented as mg/100 cc of fruit extract (AOAC, 1980). All chemical analysis was run in duplicate on the same samples.

Experimental Design

Fruits were arranged in a completely randomised design with three replications for each treatment. Each replicate consisted of 15 fruit for physical analysis and 5 for chemical analysis. Data were analysed using Statgraph and Quatro-5 computing systems and mean differences were separated using least square difference (LSD) at the P<0.05 level.

RESULTS

Generally, flesh firmness was higher when persimmon fruits were harvested at the early stage of maturity (Table 1). Change in fruit firmness during 20 weeks, storage at 2°C are shown in Figure 1. During storage, the firmness of persimmon fruit from the first harvest, and the second and third harvesting times declined considerably as the fruit be-

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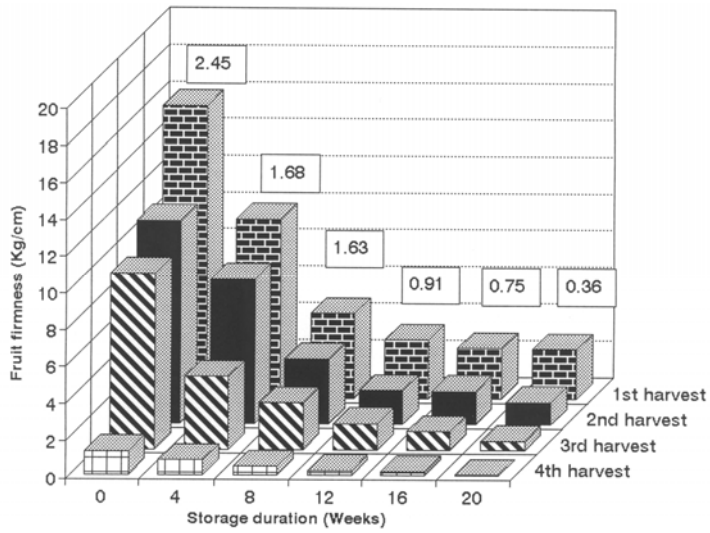

Figure 1. Change in flesh firmness of persimmon fruit as affected by the harvesting date during 20 weeks storase at 2±1°C for 1998 experiment. The figures in the boxes represent LSD at p<0.05.

came matured. For the fourth harvest, those fruit stored at 2°C, showed significant changing firmness due to soft (ripe) fruit at the start of storage. Storage of fruit from the first harvest (breaker) for 20 weeks at 2 °C resulted in good quality and marketability due to firm fruits. At the end of storage (20 weeks), flesh firmness from the first harvest was significantly higher than other harvest dates and it was approximately two times greater than the fourth harvest (Figure 1).

At the time of cold storage, a significant difference (P<0.05) in soluble solid concentrations (SSC) was observed between harvest dates (Table 1 and Figure 2). From the results obtained here, it seems that soluble

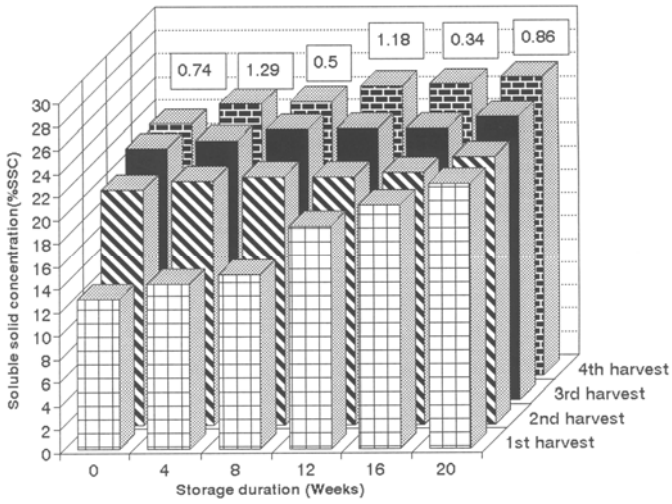

Figure 2. Change in total soluble solids (SSC) in persimmon as affected by the harvesting date during 20 weeks storage at 2±1°C for 1998 experiment. The figures in the boxes represent LSD at p<0.05.

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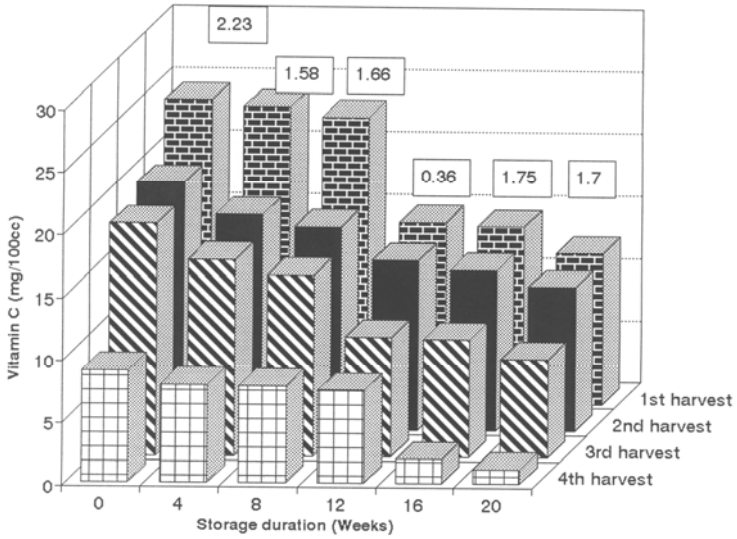

Figure 3. Change in vitamin C content of persimmon fruits as affected by the harvesting date during 20 weeks storage at 2±1°C for 1998 experiment. The figures in the boxes represent LSD at p <0.05.

solid contents were highly affected by maturity levels. With the maturity index, the light red fruits (fourth harvest) had a 22% SSC that was significantly higher than those of other maturity stages. Generally, the increase in soluble solid content during storage at 2°C was similar for all fruits (Figure 2), except for the first harvest date, when the SSC of fruits was slightly lower than that of other harvest dates.

Ascorbic acid content in all harvest dates prior to storage is given in Table 1. The values for ascorbic acid (vitamin C) gradually decreased, as fruit became mature. The maximum content was obtained in fruit harvested earlier (first harvest) and it was *ca*. four times greater than fruit harvested fully ripe (fourth harvest). Change in ascorbic acid content also, during refrigeration are shown in Figure 3. The results obtained point out that the ascorbic acid content of all harvested persimmon significantly decreased during storage and reached a minimum at the end of 20 weeks storage at 2°C. The final level of ascorbic acid at the end of storage periods (20 weeks) in fruits harvested at the breaker stage (first harvest) was significantly ($p<0.05$) higher than persimmons harvested in late October and November (Figure 3).

Physiological weight loss in persimmon based on water loss from the fruit (not disease infection and rotting) was also studied. The rate of weight loss in storage for each stage of maturity was determined from changes in sample weight, after 4, 8, 12, 16 and 20 weeks of storage. Weight loss in all treatments during storage at 2°C and 95 percent relative humidity over 20 weeks is shown in Figure 4. Generally, weight loss varied between the treatments. With increasing storage periods, a notable increase in weight loss was found in all treatments. The fourth harvest had the highest total weight loss at all times during storage, while persimmon harvested at early maturity (first harvest) had the lowest weight loss (less than 10 %) compared with the other treatments that lost more than 10 % of their weight at the end of 20 weeks storage and became unmarketable (Figure 4).

Decay in fruits is another limitation of storing of persimmon for lengthy periods. Results obtained here showed that advanced maturity of fruit promotes decay during storage (Figure 5). The number of infected

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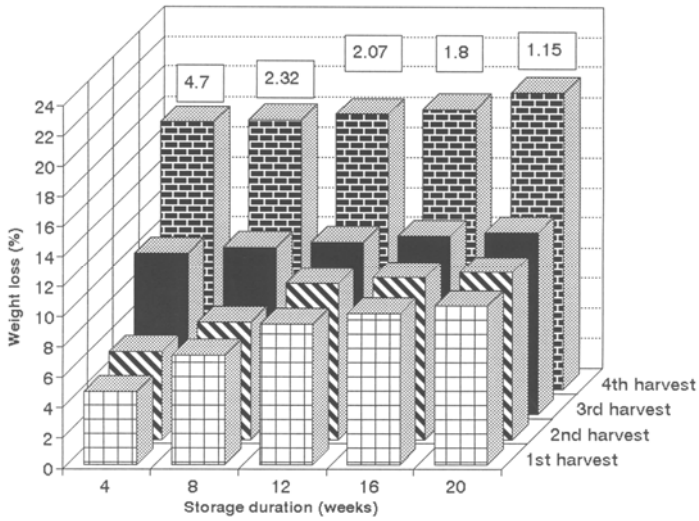

Figure 4. Percentage of weight loss (based on fresh weight) for different harvest dates in persimmon fruits during 20 weeks storage at 2±1 [°C for 1998 experiment. The figures in the boxes represent LSD at p<0.05.

fruits increased with the duration of storage. The fourth harvest always showed a significantly (p<0.05) higher percentage of decay than other harvest dates. As expected, fruits stored at an early stage of maturity (first harvest) suffered less. At the end of the storage period, the lowest level of decay was found in fruit harvested at breaker stage (first harvest). Decay greatly affects the appearance and marketability of persimmons and therefore must be considered in evaluating the storage potential of persimmon fruits.

At harvesting, persimmon had a pH of ranged from 5.33 for the first harvest to 6.12 for fruit harvested at a mature and ripe stage (Table 2). For all treatments, pH increased during storage and at the end of the cold

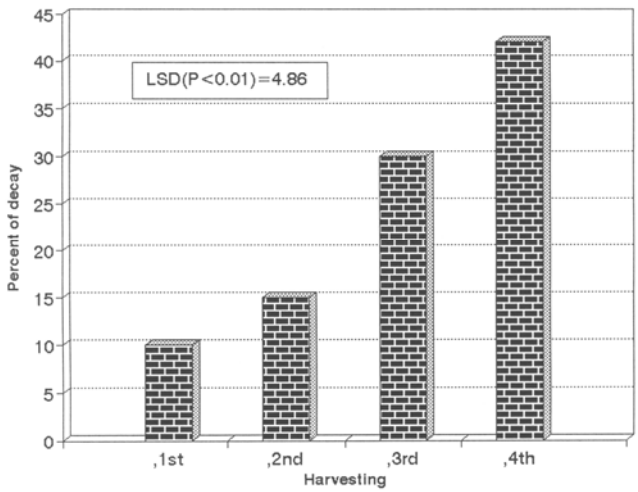

Figure 5. Effect of harvest date on percentage of decay (Rotting) in persimmon fruit over a 20 weeks storage period for the 1998 experiment.

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Table 2 Effects of harvest date and storage period on pH, malic acid and soluble tannins of persimmon fruits in the first year experiment (1998).

Fruit quality	Harvesting	Storage duration (weeks at 2 C)					
		0	4	8	12	16	20
pH	1st harvest	5.33	5.61	5.64	5.64	5.69	5.57
	2nd harvest	5.52	5.73	5.76	5.79	5.88	5.96
	3rd harvest	5.63	5.73	5.79	6.11	6.12	6.14
	4th harvest	6.12	6.12	6.13	6.16	6.39	6.40
	LSD (p<0.05)	0.46	0.35	0.28	0.32	0.41	0.39
Malic acid (mg/100 cc)	1st harvest	750.4	408.8	338.8	331.24	331.24	326.2
	2nd harvest	34.8	341.6	316.4	190.4	190.4	180.0
	3rd harvest	372.4	322	257.6	176.4	176.4	128.8
	4th harvest	271.6	254.8	232.4	156.8	156.8	106.4
	LSD (p<0.05)	53.99	112.14	18.05	15.43	15.43	11.57
Taninns (mg/100cc)	1st harvest	17.14	16.5	16.1	10.06	10.06	8.34
	2nd harvest	14.9	13.5	11.42	7.06	7.06	6.16
	3rd harvest	11.6	11.42	10.7	6.6	6.6	2.8
	4th harvest	5.3	5.75	4.36	2.94	2.94	1.54
	LSD (p<0.05)	2.77	0.78	1.41	1.35	1.35	0.95

storage there was a significant difference ($p<0.05$) in pH in fruit between first and fourth harvests. However, after 20 weeks storage period, there were no significant differences in pH in the second and third harvest compared to fruit harvested at a ripe stage (fourth harvest).

The later the harvest date, the lower the malic acid levels measured in persimmons at harvest (Tables 1 and 2). Ripe fruits consistently exhibited lower malic acid concentrations than unripe mature fruit. These differences were significant ($p<0.05$) at the first and last harvest. During storage, there was a gradual decrease in malic acid content with time for all harvests (Table 2). After 20 weeks cold storage, the first harvest had *ca* three times more malic acid than fruit harvest at ripe stage (fourth harvest).

Astringency is a major quality problem in persimmon. An immature or mature but unripe fruit is markedly astringent due to water-soluble tannins present in fruit flesh (Table 2). At the time of storage a significant difference in soluble tannin was observed between harvest dates ($P<0.05$). The soluble tannin content of fruit harvested earlier (first harvest) was *ca.* 3 times greater than that of fruit harvested at a ripe stage. The reduction of astringency (soluble tannin) during cold storage was observed for all harvest dates. The final level of soluble tannin at the end of storage in fruit harvested at the breaker stage (first harvest) was significantly ($p<0.05$) higher than persimmon harvested at a ripe stage.

In the second year experiment (1999), all physical and chemical properties of fruits harvested at the same stage of maturity were almost the same as for 1998 (Table 1). The effect of maturity at harvest on change in physico-chemical characteristics of fruits during cold storage also, showed the same results as the 1998 experiment (Table 3). Again, fruits harvested with flesh firmness around 15 Kg/cm^2 and SSC 13 % at the breaker stage showed minimum losses during storing compared to other harvest dates.

The results of the second year experiment indicate that some physical and chemical properties of fruit were nearly the same as for 1998. At the same stage of maturity, seasonal variations in pH, organic acid and soluble tannins levels occurred, but SSC and firmness of fruit flesh were nearly the same (Table 1). Fruits harvested at the mature

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Table 3. Effects of harvest date and storage period on change in physico-chemical characteristics of persimmon fruits in the second year experiment (1999).

Fruit quality	Harvesting	Storage periods (weeks) 0	4	8	12	16	20
Fruit firmness (kg/cm)	1 Oct. [a]	19.7	11	-	-	-	-
	15 Oct.	14.5	9.5	5.2	3.5	2.5	2.1
	29 Oct.	9.2	5.8	2	1.7	1.5	0.9
SSC (%)	1 Oct.	8.4	9	-	-	-	-
	15 Oct.	13	14.1	16	17.8	19	21
	29 Oct.	21	21.5	21.8	21.9	22	22
Vitamin C (mg/100g/fw)	1 Oct.	19	17	-	-	-	-
	15 Oct.	20.1	18	14.5	13	12.8	12.5
	29 Oct.	19.1	17.5	13	11	11	10.8
Soluble tnnin (mg/100cc)	1 Oct.	16.5	14	-	-	-	-
	15 Oct.	14	11.5	9	8.5	7	6.8
	29 Oct.	10.8	8.5	6	3.4	3.1	2.8
pH	1 Oct.	4.37	4.8	-	-	-	-
	15 Oct.	5.78	5.7	5.3	5.21	5.3	5.4
	29 Oct.	5.9	5.92	6.1	6.11	6.13	6.12
Malic acid (mg/100cc)	1 Oct.	890	882	-	-	-	-
	15 Oct.	560	532	510	490	467	454
	29 Oct.	269	250	234	189	178	170

[a] Fruits harvested at mature green stage were damaged after 4 weeks storing at 2°C

green stage were firmer with less in pH, SSC and vitamin C and rich in soluble tannins and titrable acidity compared to the other stages of maturity (Table 1). Change in the physico-chemical characteristics of fruits during cold storage also showed the same pattern and are shown in Table 3. Fruits harvested at mature green had chilling injury after four weeks storage at 2 ±1 °C and, as a result of shrinking and rotting, became unmarketable. Fruits harvested at breaker had minimum loss during storage compared to other harvest dates (Table 3).

DISCUSSION

These results demonstrated that stage of maturity (harvest date) and length of time in cold storage significantly affect quality and storability of persimmon fruit. Some factors, such as SSC and pH, improved with increased maturity (Figure 2 and Table 2). Similar improvements with increased maturity for SSC and pH, have been reported previously by Barbera, *et al.* (1992) for prickly pear Artes, Conesa, Hernandez and Gil (1999) for tomato, Rouhani *et al.* (1975), Klein (1987), Sargent *et al.* (1993), Lyon *et al.* (1995) and Seymour, Taylor and Tucker (1996) for persimmon and Diaze Perez, *et al.* (2000) for sapota mamey. For other factors, such as firmness or post harvest rot incidence, quality decreased with increasing maturity. The optimum stage of maturity for post harvest storage of persimmons will depend on the relative importance of each of these factors plus additional factors such as acidity levels, vitamin C and soluble tannins contents, and sensory quality which are not presented here, such as appearance and flavour.

Harvest date also affects the optimum stage of maturity for post harvest storage. For example, the percentage of weight loss during storage will increase with increasing

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maturity at the time of cold treatments (Figure 4). On the other hand, increased rotting with late harvest as the result of soft fruits and a decrease in damage with harvesting fruit at the preclimatric stage have been reported by Seymour *et al.* (1996) and Wills *et. al.* (1998). The percentage of increases in weight loss between ripe fruit and mature but not ripe fruit was much more significant during storage and at the end. Since firmness declined during the season at all stages of maturity (Table 1 and Figure 1), harvesting at an early stage of maturity (breaker) rather than late maturity improved firmness without greatly reducing fruit quality at the end of cold treatments. These differences may be related to the level of free water content, which was higher in ripe fruit than unripe ones. Decline in firmness may due to polgalacturonase activity that causes changes in composition of pectic substances in the soluble fraction (Taira *et al.,* 1987 and Seymour, *et al.,* 1996). The breakdown of pectic substances in the middle lamellae and cell wall is a critical factor in fruit ripening and results in the loss of cell wall integrity (Tzoutzoukou and Bouranis, 1997).

The differences in soluble tannin levels at the time of cold storage were significant between harvest dates (Table 2). During maturation and fruit ripening in the persimmon, the level of astringency (due to soluble tannin) eventually decrease giving fruit an excellent flavor. The decrease in soluble tannin is due to polymerisation of the existing tannins forming larger, water-soluble molecules no longer capable of reacting with the taste receptions in the mouth (Kays, 1991). However, the level of soluble tannins at the end of storage in fruits harvested earlier was remarkably high (Table 2). This means fruits need further astringency removal by exposing the fruit to a high carbon dioxide atmosphere or ethanol solution (Taira *et al* 1987 and Seymour *et al.* 1996).

Chemical analysis of fruit and vegetable composition is used primarily to estimate consumption quality. Vitamins are hidden attributes that affect consumer perception. The most commonly measured nutrient in fruits and vegetables is ascorbic acid (vitamin C). Despite the importance of this compound, little is known about the rates of degradation of that during post harvest handling. The changes in vitamin C in persimmon fruits related to different harvesting periods and during storage are shown in Figure 3. Ascorbic acid levels were high for first harvest compared to other harvesting times, but gradually declined with the increase in storage periods. The final values of ascorbic acid were very low after 20 weeks, storage for fruits harvested ripe. This finding is in agreement with previously work on cashew apples by Chempakam (1983), Taira *et al.* (1987) for persimmons, Nagar (1993) for Kinnow fruits and Saltveit (1999) for tomato. The destruction of ascorbic acid is associated with activity of ascorbic acid oxidise, which is high in ripe fruits (Chempakam, 1983). Therefore, for improved nutrient quality during the storage of persimmons, fruit must be harvested at an early stage of maturity.

The results obtained from two growing seasons have shown that both flesh firmness and soluble solid concentrations (SSC) are more reliable indices for judging stage of fruit maturity at harvest and were not much affected by growing season

In summary, ripening of persimmon fruit was associated with a softening of the flesh, an increase in soluble solid content and pH and a decrease in soluble tannins and acidity. Considering the changes of the different physical and biochemical parameters, fruit can be harvested, to give a high quality product for storage, when the soluble solid concentrations reach a value of around 13% Brix and the fruit firmness remains *ca.* 15 Kg/cm^2. This stage can be recognised by the early change in peel colour.

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تأثير مراحل مختلف بلوغ در برداشت بر عمر نگهداري ميوه خرمالو (*Diospyros kaki* L.) در انبار

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چكيده

به منظور بررسي اثر مراحل مختلف بلوغ در برداشت بر عمر نگهداري ميوه خرمالو در انبار, پژوهش‌هاي طي سالهاي ۱۹۹۸ و ۱۹۹۹ انجام پذيرفت. ميوه خرمالو طي مراحل مختلف بلوغ در تاريخ‌هاي ۶ اكتبر, ۱۹ اكتبر, ۴ نوامبر و ۲۹ نوامبر ۱۹۹۸ و اول اكتبر, ۱۵ اكتبر و ۲۹ اكتبر در سال ۱۹۹۹ برداشت گرديد. ميوه‌ها در دماي ۱ ± ۲ درجه سانتيگراد و رطوبت نسبي ۹۵% براي مدت ۲۰ هفته نگهداري شدند. سفتي ميوه, ميزان اسيد قابل سنجش, تانن‌هاي محلول و ويتامين C بطور معني‌داري با پيشرفت بلوغ, كاهش و PH , مواد جامد محلول (SSC) روند افزايش نشان داد. در طول مدت نگهداري در انبار, PH , SSC , درصد پوسيدگي و كاهش وزن در تمام مراحل برداشت, افزايش ولي اسيد قابل سنجش, سفتي ميوه, ويتامين C و تانن‌هاي محلول, روند كاهش داشت. كمترين كاهش وزن پس از ۲۰ هفته نگهداري, در ميوه‌هاي اولين تاريخ برداشت در مقايسه با ديگر تاريخ‌هاي برداشت مشاهده شد. همچنين, ساير شاخص‌هاي كيفيت ميوه از قبيل سفتي ميوه, SSC و ميزان ويتامين C در ميوه‌هايي كه در مراحل اوليه بلوغ برداشت شده بودند (۱۶ اكتبر) در مقايسه با ديگر تاريخ‌هاي برداشت برتري داشت. ولي در پايان دوره نگهداري در انبار, ميزان تانن محلول در ميوه‌هاي حاصل از اولين تاريخ برداشت بطور قابل توجهي بيشتر بود. بطور خلاصه به نظر مي‌رسد برداشت ميوه خرمالو در مراحل اوليه بلوغ (SSC حدود ۱۳% و سفتي ميوه حدود ۱۵ kg/cm^2) بهترين مرحله برداشت به منظور كاهش ضايعات و افزايش عمر نگهداري و كيفيت ميوه خرمالو است.

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