Harvest Time and Postharvest Behavior of Six Japanese Nonastringent Persimmon Cultivars Grown under Mediterranean Conditions

in HortScience

Authors: Ayoub Fathi-Najafabadi[1], Cristina Besada[1], Rebeca Gil[1], and Alejandra Salvador[1]

DOI: https://doi.org/10.21273/HORTSCI15181-20
Page Count: 6
Volume/Issue: Volume 55: Issue 11
Article Category: Research Article
Online Publication Date: 06 Oct 2020

Open access

Get Citation Alerts

Get Permissions

Download PDF

Abstract/Excerpt Full Text PDF Contributor Notes

Abstract

Persimmon cultivation has significantly grown in the Mediterranean Region in recent years. The production concentrates mainly in three astringent cultivars: Kaki Tipo in Italy, Triumph in Israel, and Rojo Brillante in Spain. Therefore, the varietal range expansion is one of the current challenges for persimmon producers in this area. Moreover, the introduction of nonastringent persimmon cultivars is particularly interesting because they can be commercialized immediately after harvest without applying deastringency treatment before commercialization. This study evaluated the harvest period and the postharvest response of six Japanese nonastringent cultivars (Kanshu, Shinshu, Soshu, Suruga, Youhou, Izu). During two seasons, fruit from each cultivar were harvested at two maturity stages. Fruit quality (external color, firmness, and total soluble solids) was evaluated after harvest and after different commercial scenarios (domestic market: 7 days at 20 °C, market to European Union (EU): 5 days at 5 °C plus 5 days at 20 °C, and market to countries with cold-quarantine treatment requirements: 21 days at 0 °C plus 5 days at 20 °C). Cultivars Kanshu, Shinshu, Soshu, and Izu were identified as early cultivars, and Soshu was the earliest one, which reached commercial maturity at the beginning of September. These four cultivars showed good quality after simulating commercialization on domestic and EU markets. Cultivars Suruga and Youhou overlapped the current harvest window, but their low chilling injury sensitiveness is highlighted, so they are of special interest to be cold-stored at the end of the season to be commercialized in overseas markets.

Keywords: Izu; Kanshu; Shinshu; Soshu; Suruga; Youhou

In Europe, persimmon cultivation is located mainly in the Mediterranean Region where it was traditionally a minor crop, but has significantly expanded in the past few decades. In this area, persimmon production takes place chiefly in three countries: Italy, Israel, and Spain. Nowadays in the Mediterranean Region, persimmon production is based mostly on monovarietal cultivation. In Italy, almost 90% of persimmon production is based on 'Kaki Tipo'. In Israel, 'Triumph', under the 'Sharon' trademark, is the main cultivar and consists of 95% of total persimmon production (Yesiloglu et al., 2018). In the past 20 years, Spain's persimmon cultivation has grown the most and more quickly in this area, mainly because of the increased production of cultivar Rojo Brillante in the Valencian Community of Spain (Perucho, 2018).

Centralized production of a single cultivar is one of the main problems that the persimmon industry must face, as this implies a major commercial limitation given harvesting period concentration and the high phytosanitary risk. Therefore, one common objective for growers, marketers, and researchers is to introduce cultivars that allow the varietal range of persimmon to extend with certain success guarantees. It is noteworthy that the main cultivars presently grown in this area are astringent at harvest, which implies that fruit must be submitted to postharvest treatments to remove astringency before commercialization. Accordingly, the introduction of nonastringent cultivars is of special interest to simplify postharvest fruit handling.

In this context, a persimmon breeding program has been developed in Spain at the Instituto Valenciano de Investigaciones Agrarias (IVIA) since 2002 (Martínez-Calvo et al., 2018). Besides plant breeding to obtain new cultivars, a germplasm bank with cultivars from different geographical areas has been created as part of this program to evaluate their response under our Mediterranean agroclimatic conditions. It has been reported that the climate differences between persimmon-growing regions can lead to a wider variation in persimmon fruit maturity and quality at harvest (Soqanloo, 2015; Zanamwe, 2018).

Among the persimmon cultivars under study, a group of Japanese cultivars brought from the National Institute of Fruit Tree Science of Japan (NIFTS) stands out for being nonastringent cultivars and are, therefore, of much potential interest to extend the varietal range in this persimmon-growing area.

One of the main factors of agronomic behavior to condition commercial interest in the different cultivars is harvest time. The introduction of early and late cultivars can prolong the production period with subsequent profits for industry. Currently, the harvesting period of the main persimmon cultivars grown in the Mediterranean Region is mid-October to December. Therefore, the cultivars that reach commercial maturity earlier or later in the season must be considered of special interest for introduction purposes.

The selection of new cultivars involves having to evaluate their postharvest behavior to guarantee quality preservation and to respond to the high quality standards that consumers demand (Kader and Yahia, 2011). It is worth highlighting that persimmon with a soft texture is normally eaten in Asian countries, but is consumed when flesh is still firm in European countries. Thus, fruit firmness is one of the main quality parameters that needs to be preserved during its postharvest life. This may be a challenge as most persimmon cultivars are sensitive to chilling injuries when stored at low temperature. Flesh softening and flesh gelling are the main symptoms of this disorder (Besada and Salvador, 2018; Tessmer et al., 2019). Although a minimum firmness value is not established by current persimmon quality standards, according to previous studies, 20 N is considered the limiting firmness value from which fruit would not be acceptable for commercialization (Besada et al., 2010).

To evaluate the postharvest behavior of fruit, it is important to consider the different commercialization scenarios. The persimmon fruit produced in Mediterranean countries are usually commercialized in three different ways: a) sending fruit directly to domestic market at ambient temperature; b) transporting fruit to EU countries in refrigerated trucks at 5 °C; c) shipping fruit to overseas countries, like the United States, for which quarantine treatment is needed and fruit must be keep at low temperature (0 to 1 °C) for at least 21 d. The third scenario is that in which chilling injury and fruit firmness reduction are more likely to happen.

In this context, the objective of this study was to determine the harvest period and postharvest behavior under the Mediterranean agroclimatic conditions of six nonastringent Japanese persimmon cultivars belonging to the IVIA germplasm bank to select which ones are suitable for extending this region's varietal range.

Materials and Methods

Plant material, fruit harvest, and storage.

The cultivars that this study evaluated were Kanshu, Shinshu, Soshu, Suruga, Youhou, and Izu. They were all released by the NIFTS-Japan (Table 1) and were introduced into the IVIA germplasm bank in 2014 thanks to an agreement reached between the IVIA and NIFTS. They were cultivated following the habitual agronomic practices in an experimental germplasm bank orchard located in L'Alcúdia, Valencia, Spain (lat. 39°11′18.7″N, long. 0°32′06.2″W) at an altitude of 42 m above sea level. This area has a Mediterranean climate characterized by 3 to 5 months of summer drought (June–September). The distribution of rainfall is among autumn, winter, and spring, with the highest rainfall during the autumn.

Table 1.
Genetic origin and year of release of the studied persimmon cultivars.

Cultivar name	Genetic origin	Yr of release	References
Kanshu	Shinshu × 18-4 (Fuyu × Okitsu-16) (Oku-gosho × Hana-gosho)	2002	Tetsumura et al., 2008; Yamada et al., 2006
Shinshu	Okitsu-20 (Fukuro-Gosho × Hana-Gosho) × Okitsu-1 (Oku-gosho × Oku-gosho)	1991	Tetsumura et al., 2008; Yamada and Sato, 2003
Soshu	Izu × 109-27 (Okitsu-2 × Okitsu-17)	2000	Tetsumura et al., 2008
Suruga	Hana-gosho × Oku-gosho	1959	Tetsumura et al., 2008; Yamada et al., 2012
Youhou	Fuyu × Jiro	1990	Tetsumura et al., 2008; Yamada and Sato, 2003
Izu	Fuyu × Okitsu-1	1970	Yamada and Sato, 2003

The study was carried out during two seasons (2017–18) with fruit from at least three trees of each cultivar. The average annual rainfall was between 450 and 550 mm, and the mean annual temperature was 18 °C in both studied years. Two harvests took place during the first season. Changes in skin coloration have been reported to be linked with the main physicochemical changes during persimmon maturation (Salvador et al., 2007; Veberic et al., 2010), and skin color is habitually used as the maturity index for harvesting. In this study, the first harvest of each cultivar was carried out when fruit displayed a homogeneous orange to orange-red color, with no visible green background, according to Besada and Salvador (2018). The second harvest took place some 15 to 20 d later. Depending on the results obtained for the first season per cultivar, one or two harvests were organized during the second season to corroborate the previous results or to acquire new information.

On each harvest date, and depending on fruit availability, 80 to 100 fruits were collected and immediately transported to IVIA's Postharvest Laboratory Technology Center. Fruit were carefully evaluated to avoid selecting those with external damage. They were separated into four lots of 20 fruits. One lot was used to characterize maturity stage and fruit quality at harvest. The fruit from the other lots were placed in plastic trays and submitted to the conditions related to the following commercialization scenarios: 1) fruit stored for 7 d at 20 °C to simulate commercialization on domestic market (D); 2) fruit stored for 5 d at 5 °C, plus 5 d at 20 °C, to simulate transport to EU countries, plus shelf life (EU); 3) fruit stored for 21 d at 0 °C, plus 5 d at 20 °C, to simulate shipping to countries with quarantine treatment (e.g., the United States), plus shelf life (United States). Quarantine treatment requirements for U.S. exportation are 14 d at 1.1 °C or lower temperature. Fruit was kept for 21 d at the storage chamber at 0 °C to include in this commercial scenario the habitual delay before shipment, which usually lasts 5 to 6 d.

It is important to clarify that, due to the limited number of available fruit, only those scenarios during some harvests that gave the most consistent results were tested.

Fruit assessments.

Color, firmness, and total soluble solids (TSS) were determined after each harvest and after simulated commercialization scenarios. External skin color was determined by a Minolta colorimeter (Model CR-300; Ramsey, NY). Hunter parameters (L, a, b) were measured and the results were expressed as a color index: CI = 1000a/Lb, according to Salvador et al. (2007). Fruit firmness was established in a Texturometer Instron Universal Machine model 4301 (Instron Corp., Canton, MA) using an 8-mm-diameter plunger and breaking the flesh in each fruit on 180° sides after removing peel. To determine TSS, fruit were peeled and placed in an electric juice extractor (model 753; Moulinex, Barcelona, Spain) and the obtained juice was filtered through cheesecloth. The TSS juice was measured over three replicates by a digital refractometer (model PR-1; Atago, Tokyo, Japan) and expressed as percent fresh weight (%FW).

Statistical analysis.

Data were subjected to an analysis of variance based on two factors (harvest time × commercialization scenarios) during each season. The mean values of the evaluated parameters were compared by the least significant difference test ($P < 0.05$) using the StatgraphicsPlus 5.1 software application (Manugistics Inc., Rockville, MD).

Results and Discussion

After performing an exhaustive review of the existing literature, we noted that very little information had been published about the behavior of the herein studied cultivars in other countries. For each cultivar, we now go on to report the main fruit characteristics at harvest and the postharvest response determined under Mediterranean conditions, together with the limited information previously reported in other countries, which corresponds mainly to Japanese conditions.

'Kanshu'.

'Kanshu' persimmon is flattened to oblong with irregular rounded to square cross section (Fig. 1A). In Japan, the average fruit weight is ≈230 to 244 g (Yakushiji and Nakatsuka, 2007; Yamada et al., 2006), higher than in Spain where it is close to 120 to 170 g (average data recorded for the past 3 years of production in germplasm bank). In Japan, this fruit cultivar is harvested late in October with TSS close to 18% with medium flesh firmness and excellent eating quality (Yakushiji and Nakatsuka, 2007).

Fig. 1.
Persimmon fruit of (**A**) 'Kanshu', (**B**) 'Shinshu', (**C**) 'Soshu', (**D**) 'Suruga', (**E**) 'Youhou', and (**F**) 'Izu'. Photo courtesy of Plant Production Department (IVIA).

Citation: HortScience horts 55, 11; 10.21273/HORTSCI15181-20

In our study, the first harvest was carried out on 18 Sept. (S1-H1) when fruit showed an orange coloration (CI close to +9), high flesh firmness ≈72 N, and a TSS value of 16.9% (Table 2). After 2 weeks on trees, external color and firmness had not significantly changed, but TSS had increased to above 18.2% (S1-H2). During the second season, two harvests were organized later in the season to evaluate if harvest period could be prolonged. Fruit were harvested on 28 Oct. (S2-H1) and 8 Nov. (S2-H2), when they were bright red in color, with CI close to +28 and +32, and had a high TSS content from 20% to 21% during the first and the second harvest, respectively. Nevertheless, on both dates, fruit had low firmness values close to 19 N.

Table 2.
Color index (CI), firmness, and total soluble solids (TSS) determined in persimmon cultivar Kanshu on different harvest dates (H) during two consecutive seasons (S1-S2) and after stimulating distinct commercialization scenarios: D (domestic market commercialization: 7 d at 20 °C), EU (transport to European Union: 5 d at 5 °C plus 5 d at 20 °C), and USA (shipping to overseas markets: 21 d at 0 °C plus 5 d at 20 °C).

Season	Harvest	Analysis	CI (1000a/Lb)	Firmness (N)	TSS (%FW)
S1	(H1) 18 Sept.	Harvest	8.7 a[z]	72.6 d	16.9 a
		D	11.7 ab	65.8 cd	21.4 c
		EU	10.5 ab	54.4 b	19.9 bc
		USA	17.8 c	6.5 a	20.1 bc
	(H2) 1 Oct.	Harvest	9.0 a	64.9 cd	18.2 a
		D	11.9 ab	62.1 c	18.4 ab
		EU	13.5 b	54.1 b	17.6 a
		USA	20.3 c	5.0 a	20.9 c
S2	(H1) 28 Oct.	Harvest	27.9 a	19.6 b	19.6 a
		D	31.7 ab	17.0 b	19.9 a
		EU	ND	ND	ND
		USA	33.0 bc	4.5 a	21.3 ab
	(H2) 8 Nov.	Harvest	31.7 ab	19.1 b	20.7 a
		D	35.4 bc	15.0 b	23.7 b
		EU	ND	ND	ND
		USA	35.3 c	5.0 a	21.6 ab

[z]For each evaluated parameter and season (S) different letters among scenarios (Harvest, D, EU, and USA) indicate statistical differences $P < 0.05$ (least significant difference test).
FW = fresh weight; ND = not determined.

According to the data obtained from the different harvests, 'Kanshu' reached commercial maturity earlier and had a slightly lower TSS content under Mediterranean than under Japanese conditions. Its harvest period was earlier than the cultivars currently cultivated on the Mediterranean coast. Fruit maturation evolution was relatively slow in the second half of September, but significantly advanced in October.

Regarding postharvest behavior, in Japan it is reported that fruit are suitable for consumption for 15 d at ambient temperature (Yamada et al., 2006). During the first season in the present study, fruit firmness decreased, which was greater with longer storage duration. Although the firmness values remained high after domestic and EU commercialization scenarios, they drastically dropped to noncommercial values, close to 5 to 6 N, after the U.S. conditions simulation, which indicates this cultivar's high susceptibility to manifest chilling injury at low temperature. In parallel to firmness loss, both color and TSS increased. In the second season, when fruit were harvested with firmness close to 20 N, the fruit softening during the postharvest period was a limiting factor even for commercialization on the domestic market. Sensitivity to low temperatures was corroborated during this season.

So the optimum harvest time for this cultivar would be from mid-September to early October, when fruit external color is appealing, its firmness is high, and TSS contents come close to 17% to 18%. If fruit are harvested later, firmness loss would be a major limitation for posterior commercialization. Moreover, the drastic drop in firmness of this fruit cultivar after being exposed to 0 °C indicates that this cultivar is susceptible to manifest chilling injury symptoms.

'Shinshu'.

'Shinshu' persimmon is oval with irregular rounded cross section (Fig. 1B). The fruit weight is ≈240 to 250 g (data from Japan) (Yakushiji and Nakatsuka, 2007; Yamada and Sato, 2003). Similar fruit weight has been recorded here in Spain (data recorded for the past 3 years of production in germplasm bank). In Japan, 'Shinshu' persimmons are harvested in late October with TSS content at ≈17%, and with soft flesh firmness and high eating quality (Yakushiji and Nakatsuka, 2007; Yamada and Sato, 2003).

Under Mediterranean conditions, the fruits of this cultivar displayed external yellowish-orange tones (CI close to +7) at the beginning of October, when TSS content was 18.5% and fruit had high firmness values close to 65 N (S1-H1) (Table 3). Only 2 weeks later, on 15 Oct. (S1-H2), fruit ripening has rapidly advanced, with color increase accompanied by marked firmness loss. For this reason, fruit were collected during the second season on 11 Oct. when it was in an intermediate maturity stage between both stages evaluated during the previous season. Therefore, fruit maturation under Mediterranean conditions happened earlier and the TSS value was relatively higher than in Japan. Our results also revealed that the maturation of these cultivars happened 2 weeks earlier than that of the cultivars currently cultivated in Spain and Italy.

Table 3.
Color index (CI), firmness, and total soluble solids (TSS) determined in persimmon cultivar Shinshu on different harvest dates (H) during two consecutive seasons (S1-S2) and after stimulating distinct commercialization scenarios: D (domestic market commercialization: 7 d at 20 °C), EU (transport to European Union: 5 d at 5 °C plus 5 d at 20 °C), and USA (shipping to overseas markets: 21 d at 0 °C plus 5 d at 20 °C).

Season	Harvest	Analysis	CI (1000a/Lb)	Firmness (N)	TSS (%FW)
S1	(H1) 1 Oct.	Harvest	7.2 a[z]	64.8 f	18.5 a
		D	9.7 b	39.5 e	18.2 a
		EU	10.2 b	31.8 d	18.5 a
		USA	11.6 b	4.4 a	19.4 b
	(H2) 15 Oct.	Harvest	11.9 b	36.6 de	19.6 bc
		D	17.1 c	25.0 c	20.2 cd
		EU	18.1 c	11.3 b	20.7 cd
		USA	22.5 d	0.8 a	23.4 d
S2	(H1) 11 Oct.	Harvest	12.6 a	42.3 c	20.4 a
		D	18.6 b	24.7 b	23.1 b
		EU	ND	ND	ND
		USA	21.8 b	0.0 a	23.4 b

[z]For each evaluated parameter and season (S) different letters among scenarios (Harvest, D, EU, and USA) indicate statistical differences $P < 0.05$ (least significant difference test).
FW = fresh weight; ND = not determined.

In Japan, the average shelf life of this cultivar lasts ≈8 d at ambient temperature (Yamada and Sato, 2003). Producing fruit in greenhouses is recommended due to excessive softening when exposed to rain or wetness (Yamada et al., 2012). Although significant softening occurred after 7 d at 20 °C (domestic market) in the present study, fruit quality was suitable for commercialization irrespectively of harvest date. Under the EU conditions, only the fruit harvested with high firmness (S1-H1) still had commercial values; however, all fruit displayed drastic softening after the U.S. commercialization. This finding indicates that this cultivar is very sensitive to chilling injury when exposed to 0 °C, which was observed for the two evaluated seasons.

According to our results, this cultivar should be harvested at the beginning of October to ensure that fruit firmness at harvest is high enough to be commercialized on domestic and European markets. This fruit should not be sent to overseas markets because of its high susceptibility to manifest chilling injury.

'Soshu'.

'Soshu' persimmon is flattened with irregular rounded cross section (Fig. 1C). The average fruit weight is ≈250 g (data from Japan) (Yakushiji and Nakatsuka, 2007; Yamada et al., 2012). In Spain the data recorded so far indicates a fruit weight between 170 and 250 g (average data recorded for the past 3 years of production in the germplasm bank). In Japan, 'Soshu' fruit are harvested from late September to early October, with TSS close to 15%, medium flesh firmness, and moderate sweetness (Yakushiji and Nakatsuka, 2007; Yamada et al., 2012).

In this study, 'Soshu' already displayed adequate external coloration, CI close to +10, a TSS content of ≈15% and firmness values of 48.4 N on 5 Sept. (S1-H1) (Table 4). After 2 weeks (S1-H2), fruit external color had increased (CI close to +18) and firmness values had lowered to ≈42 N. No significant changes in TSS were observed between these two harvests. During the second season, the fruit harvested on 12 Sept. had CI close to +12, a firmness value of 39.3 N, and TSS content of 16%, which allowed us to corroborate harvest time.

Table 4.
Color index (CI), firmness, and total soluble solids (TSS) determined in persimmon cultivar Soshu on different harvest dates (H) during two consecutive seasons (S1-S2) and after stimulating distinct commercialization scenarios: D (domestic market commercialization: 7 d at 20 °C), EU (transport to European Union: 5 d at 5 °C plus 5 d at 20 °C), and USA (shipping to overseas markets: 21 d at 0 °C plus 5 d at 20 °C).

Season	Harvest	Analysis	CI (1000a/Lb)	Firmness (N)	TSS (%FW)
S1	(H1) 5 Sept.	Harvest	10.1 a[z]	48.4 d	14.9 ab
		D	11.1 a	22.5 c	14.3 a
		EU	21.5 b	15.8 bc	15.4 b
		USA	18.5 b	8.0 a	16.1 b
	(H2) 20 Sept.	Harvest	18.2 b	42.5 d	15.6 b
		D	29.8 c	13.0 b	17.7 c
		EU	ND	ND	ND
		USA	37.1 d	0.0 a	15.4 b
S2	(H1) 12 Sept.	Harvest	12.4 a	39.3 c	16.0 b
		D	18.9 b	13.5 b	13.9 a
		EU	ND	ND	ND
		USA	23.0 b	0.0 a	15.5 ab

[z]For each evaluated parameter and season (S) different letters among scenarios (Harvest, D, EU, and USA) indicate statistical differences $P < 0.05$ (least significant difference test).
FW = fresh weight; ND = not determined.

In Japan, a semishort shelf life is reported for this cultivar (Yamada et al., 2012). Accordingly, fruit softening was considerable during our postharvest period, even after simulating domestic market commercialization. The fruit harvested with the most firmness (48 N at S1-H1) presented values exceeding 22 N after 7 d at 20 °C (N). However, when it was harvested with firmness values close to 42 N (S1-H2), firmness values were 13 N, which would be below the acceptability limit. Although commercialization to the EU was simulated only during the first harvest (S1-H1), major firmness loss was detected. During both seasons, fruit underwent drastic softening with values below 10 N after the U.S. commercialization, which indicates this cultivar's high sensitivity to manifest this disorder at low temperature.

According to our results, the optimal harvest time for this cultivar would be the beginning of September, which is, therefore, earlier than in Japan, and also much earlier than the cultivars currently cultivated in the Mediterranean Region. The shelf life of this fruit would shorten if it were harvested later because this cultivar is prone to postharvest firmness loss.

'Suruga'.

'Suruga' persimmon is flattened with square cross section (Fig. 1D). The average fruit weight is close to 182 g (data from Australia and from the germplasm bank of Spain) (Collins et al., 1995). In Japan, 'Suruga' is a late cultivar. Fruit are harvested from early to mid-November, but can be left on trees without softening until late November (Yamada and Sato, 2003). In California, harvest time goes from November to early December, and TSS is more than 20% (Miller and Crocker, 1994).

In our study, the first harvest was carried out on 8 Nov. when external coloration was bright red (CI close to 20), the TTS content went above 16% and firmness values were high, ≈59 N (Table 5). Twenty days later (S1-H2), no significant changes in external coloration and firmness were observed, but TSS significantly increased to values close to 18%. During the second season (S2), harvest date and fruit characteristics were confirmed.

Table 5.
Color index (CI), firmness, and total soluble solids (TSS) determined in persimmon cultivar Suruga on different harvest dates (H) during two consecutive seasons (S1-S2) and after stimulating distinct commercialization scenarios: D (domestic market commercialization: 7 d at 20 °C), EU (transport to European Union: 5 d at 5 °C plus 5 d at 20 °C), and USA (shipping to overseas markets: 21 d at 0 °C plus 5 d at 20 °C).

Season	Harvest	Analysis	CI (1000a/Lb)	Firmness (N)	TSS (%FW)
S1	(H1) 8 Nov.	Harvest	19.6 a[z]	58.9 c	16.2 a
		D	22.1 ab	41.9 b	16.7 ab
		EU	31.9 c	24.1 a	16.9 ab
		USA	32.6 b	20.1 a	17.4 b
	(H2) 28 Nov.	Harvest	21.2 ab	47.2 bc	17.8 b
		D	ND	ND	ND
		EU	30.9 c	43.6 bc	17.3 ab
		USA	34.8 c	21.8 a	17.5 ab
S2	(H1) 8 Nov.	Harvest	12.2 a	53.8 b	14.9 a
		D	ND	ND	ND
		EU	ND	ND	ND
		USA	15.9 b	34.6 a	17.3 b

[z]For each evaluated parameter and season (S) different letters among scenarios (Harvest, D, EU, and USA) indicate statistical differences $P < 0.05$ (least significant difference test).
FW = fresh weight; ND = not determined.

After simulating different commercialization scenarios, the firmness values lowered. Nevertheless, the values after the domestic commercialization, and even after the EU simulation, were still high. It was noteworthy that fruit maintained their commercial firmness values after the U.S. market simulation, which reveals low sensitivity to manifest disorders associated with low temperatures. Collins and Tisdell (1995) reported that 'Suruga' fruits cultivated in Australia did not suffer chilling injury at 0 °C for up to 56 d, plus a 7-day shelf life. Fruit characteristics and postharvest behavior, mainly low chilling injury susceptibility, were corroborated during the second season.

In the Mediterranean Region, the 'Suruga' harvest could be carried out from the beginning to the end of November to achieve adequate firmness at harvest and after different commercial scenarios. Thus, the harvesting period in this area coincides with the harvest time in Japan. This cultivar is highlighted by showing low susceptibility to chilling injury and preserving firmness after the U.S. commercialization scenario, as reported in other studies.

'Youhou'.

'Youhou' persimmon is flattened with irregular rounded cross section (Fig. 1E). In Japan, the average fruit weight is ≈240 to 280 g (Yamada and Sato, 2003; Yamada et al., 2012). Data recorded so far indicate that fruit in Spain is smaller, with weight values ≈130 to 200 g (average data recorded for the past 3 years of production in germplasm bank). In Japan, the fruit of this cultivar are harvested at the beginning of November with TSS content of 15% to 17%, firm flesh firmness, and excellent taste (Yamada and Sato, 2003; Yamane et al., 1991).

Under our Mediterranean conditions, 'Youhou' fruits were harvested on 16 Oct. (S1-H1) with external coloration close to +9, a very high firmness value (83.2 N), and a TSS content near 17% (Table 6). Similar TSS values were shown after 15 d, although color had significantly increased (CI = 17.3) and firmness had slightly decreased (72.2 N). For the first season, the firmness values at harvest were very high. Thus, during the second season, fruit were harvested later on 8 Nov. and 27 Nov. to investigate the maturity process on trees. At both harvests, fruit had high firmness values above 48 N, and their external color values lay between +18 and +25. Therefore, the maturation process on the trees of this cultivar was slow, which led to a long harvest period lasting from mid-October to the end of November.

Table 6.
Color index (CI), firmness, and total soluble solids (TSS) determined in persimmon cultivar Youhou on different harvest dates (H) during two consecutive seasons (S1-S2) and after stimulating distinct commercialization scenarios: D (domestic market commercialization: 7 d at 20 °C), EU (transport to European Union: 5 d at 5 °C plus 5 d at 20 °C), and USA (shipping to overseas markets: 21 d at 0 °C plus 5 d at 20 °C).

Season	Harvest	Analysis	CI (1000a/Lb)	Firmness (N)	TSS (%FW)
S1	(H1) 16 Oct.	Harvest	9.3 a[z]	83.2 d	16.9 a
		D	ND	ND	ND
		EU	ND	ND	ND
		USA	19.2 b	23.0 a	17.2 a
	(H2) 31 Oct.	Harvest	17.3 b	72.2 c	17.4 a
		D	ND	ND	ND
		EU	ND	ND	ND
		USA	27.5 c	30.5 b	18.7 a
S2	(H1) 8 Nov.	Harvest	18.5 a	55.1 c	16.3 a
		D	18.9 ab	52.1 c	16.5 ab
		EU	21.9 bc	49.2 c	17.6 b
		USA	29.3 c	37.7 b	17.6 b
	(H2) 27 Nov.	Harvest	25.5 c	48.5 c	16.9 ab
		D	ND	ND	ND
		EU	33.3 d	30.1 a	17.5 b
		USA	35.2 d	20.1 a	17.2 ab

[z]For each evaluated parameter and season (S) different letters among scenarios (Harvest, D, EU, and USA) indicate statistical differences $P < 0.05$ (least significant difference test).
FW = fresh weight; ND = not determined.

Regarding postharvest behavior, this cultivar in Japan has been reported to be stored for ≈2 weeks at ambient temperature (Yamane et al., 1991). As trees had very few fruits during our first season, a decision was made to perform only the U.S. marketing simulation. Although the postharvest firmness values lowered, fruit maintained commercial values close to 23 N and 30 N during the first and the second harvests, respectively. So these results revealed low chilling susceptibility, which was corroborated during the second season. In China, Li et al. (2018) observed that the chilling injury symptoms of 'Youhou' fruits stored for 21 d at 1 °C, plus 5 d at 25 °C, were only very slight, which agrees with our results. Fruit also responded well after the domestic commercialization and EU simulations herein studied during the second season.

'Youhou' had a long harvest period, from mid-October to late November, and fruits maintained commercial firmness after simulating the different marketing scenarios. They presented little sensitivity to low temperature.

'Izu'.

'Izu' persimmon is flattened to oblong with irregular rounded to square cross section (Fig. 1F). The average fruit weight is ≈230 to 240 g in Japan (Yamada et al., 2012; Sato and Yamada, 2003). Data recorded so far in Spain indicate a similar fruit weight ≈180 to 200 g (average data recorded for the past 3 years of production in the germplasm bank). In California and Japan, the fruit of this cultivar are harvested from late September to mid-October and, therefore, this cultivar is known as an early cultivar in both areas (Miller and Crocker, 1994; Yamada et al., 2012). In Japan, harvested fruit have a TSS content of 15%, medium flesh firmness, and a delicious taste.

Under our Mediterranean conditions, 'Izu' fruit reached the homogeneous orange color (CI = +12.1) on 8 Oct., when the firmness value was 39.2 N and TSS content came close to 17.5% (S1-H1) (Table 7). The second harvest was carried out 15 d later (S1-H2). At this time, fruit showed more intense coloration (CI = +19.1), but no significant changes in firmness and TTS content values were detected.

Table 7.
Color index (CI), firmness, and total soluble solids (TSS) determined in persimmon cultivar Izu on different harvest dates (H) during two consecutive seasons (S1-S2) and after stimulating distinct commercialization scenarios: D (domestic market commercialization: 7 d at 20 °C), EU (transport to European Union: 5 d at 5 °C plus 5 d at 20 °C), and USA (shipping to overseas markets: 21 d at 0 °C plus 5 d at 20 °C).

Season	Harvest	Analysis	CI (1000a/Lb)	Firmness (N)	TSS (%FW)
S1	(H1) 8 Oct.	Harvest	12.1 a[z]	39.2 d	17.5 a
		D	ND	ND	ND
		EU	13.5 a	22.4 b	17.6 a
		USA	15.8 b	2.7 a	18.1 b
	(H2) 31 Oct.	Harvest	19.1 c	35.5 cd	17.2 a
		D	21.2 c	30.6 c	17.3 ab
		EU	19.1 c	20.3 b	17.4 a
		USA	28.1 d	0 a	18.2 b
S2	(H1) 16 Oct.	Harvest	11.10 a	37.8 c	17.35 a
		D	12.9 ab	35.9 c	17.0 a
		EU	15.1 b	27.1 b	17.0 a
		USA	21.2 c	9.1 a	18.3 b

[z]For each evaluated parameter and season (S) different letters among scenarios (Harvest, D, EU, and USA) indicate statistical differences $P < 0.05$ (least significant difference test).
FW = fresh weight; ND = not determined.

In Japan, a short shelf life has been reported for this cultivar (Yamada, 2005). In this study, the postharvest analysis revealed that during domestic commercialization, fruit still had firmness values close to those at harvest. Softening became more marked after the EU simulation, which could compromise fruit quality when it reaches consumers. The firmness value drastically lowered after the U.S. simulation, which indicates that this cultivar is very sensitive to chilling injury.

During the second season, in which fruit was harvested on 16 Oct., the previous results about characteristics at harvest and postharvest behavior were corroborated.

According to the results, the harvest period for 'Izu' under Mediterranean conditions would be from early to late October, which coincides with the harvest dates reported in California and Japan. Although fruit firmness was not very high at harvest, its commercial values remained after simulating the domestic and EU commercializations. However, it was sensitive to low temperatures.

Conclusion

In the present work, the harvest window of the six studied cultivars grown under Mediterranean conditions differed for most of them from that reported for Japanese conditions. This was true of 'Kanshu' and 'Shinshu', which are harvested late in October in Japan, whereas their harvest time was earlier when grown in Spain, from mid-September to early October for 'Kanshu', and in the first half of September for 'Shinshu'. Likewise, 'Soshu' is harvested from the end of September in Japan, but its optimum harvest time was early September in the Mediterranean Region. However, cultivars Suruga, Youhou, and Izu had the same harvest period in both Spain and Japan. It is noteworthy that the optimal harvest time herein established fell in line with the criterion that fruit displayed homogeneous color and high firmness at harvest, and firmness was maintained after the main commercial scenarios because it is one of the most important quality parameters. This differs in other production areas, where persimmon is consumed as soft fruit.

Nowadays the harvest window of persimmon in the Mediterranean Region goes from mid-October to December. In this study, cultivars Kanshu, Shinshu, Izu, and Soshu showed earlier commercial maturity, and Soshu stood out as the earliest cultivar because it can be harvested at the beginning of September. However, it is worth mentioning that all these cultivars were susceptible to manifest chilling injury when stored at low temperature. Therefore, fruit should not be destined to long-distance markets. In the particular case of 'Soshu', its postharvest fast softening compromises its fruit quality when it arrives in the EU. Hence, this fruit cultivar should be destined only to domestic market.

Cultivars Suruga and Youhou overlapped the harvesting window of the cultivars already cultivated in countries like Spain, Italy, or Israel, but both can be highlighted for their low susceptibility to manifest chilling injury when stored at low temperature. Nowadays, the persimmons cultivars grown in the Mediterranean Region are normally submitted to 1-MPC treatment before being transported to the EU and overseas markets to avoid excessive fruit softening. Thus, 'Suruga' and 'Youhou' could be good alternatives for the industry to be sent to overseas markets with quarantine treatments and no previous postharvest treatment.

The information herein provided is also useful for persimmon breeders. The cultivars that offer early maturation and those not sensitive to chilling injury could be used as plant material for future crossings in breeding programs.

Literature Cited

Besada, C. & Salvador, A. 2018 Postharvest biology and technology of persimmon. In: S. Mir, M. Shah, and M. Mir (eds.). Postharvest biology and technology of temperate fruits. Springer, Cham

Besada, C., Jackman, R.C., Olsson, S. & Woolf, A.B. 2010 Response of 'Fuyu' persimmons to ethylene exposure before and during storage *Postharvest Biol. Technol.* 57 2 1766 1771

Collins, R.J., George, A.P. & Nissen, R.J. 1995 Extending the marketing season of non-astringent persimmons grown in sub-tropical Australia *Acta Hort.* 409 75 84

Collins, R.J. & Tisdell, J.S. 1995 The influence of storage time and temperature on chilling injury in Fuyu and Suruga persimmon (*Diospyros kaki* L.) grown in subtropical Australia *Postharvest Biol. Technol.* 6 1-2 1766 1771

Kader, A. & Yahia, E. 2011 Postharvest biology of tropical and subtropical fruits, p. 79–111. In: E.M. Yahia (ed.). Postharvest biology and technology of tropical and subtropical fruits. Woodhead Publishing, Cambridge, UK

Li, J., Han, Y., Hu, M., Jin, M. & Rao, J. 2018 Oxalic acid and 1-methylcyclopropene alleviate chilling injury of 'Youhou' sweet persimmon during cold storage *Postharvest Biol. Technol.* 137 134 141

Martínez-Calvo, J., Climent, J., Naval, M.M. & Badenes, M.L. 2018 The I.V.I.A. germplasm collection of persimmon (*Diospyros kaki* Thunb.) *Acta Hort.* 1195 55 60

Miller, E.P. & Crocker, T.E. 1994 Oriental persimmons in Florida. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. This document is SP 101:1–16

Perucho, R. 2018 Evolution of production of the 'Rojo Brillante' cultivar in Spain and its impact on markets *Acta Hort.* 1195 1 8

Salvador, A., Arnal, L., Besada, C., Larrea, V., Quiles, A. & Perez-Munuera, I. 2007 Physiological and structural changes during ripening and deastringency treatment of persimmon fruit cv. 'Rojo Brillante' *Postharvest Biol. Technol.* 46 2 1766 1771

Sato, A. & Yamada, M. 2003 Leading persimmon cultivars for commercial production and breeding targets in Japan *Acta Hort.* 601 25 30

Soqanloo, S.S. 2015 Effect of different regional climates on persimmon quality. J. Civ. Eng. Environ. Sci. 1(1):008-012

Tessmer, M.A., Appezzato-da-Glória, B. & Kluge, R.A. 2019 Evaluation of storage temperatures to astringency 'Giombo' persimmon: Storage at 1 °C combined with 1-MCP is recommended to alleviate chilling injury *Scientia Hort.* 257 108675

Tetsumura, T., Giordani, E. & Tao, R. 2008 Persimmon (kaki), p. 235–257. In: C. Kole and T.C. Hall (eds.). Compendium of transgenic crop plants: transgenic tropical and subtropical fruits and nuts. Blackwell Publishing, Oxford

Veberic, R., Jurhar, J., Mikulic-Petkovsek, M., Stampar, F. & Schmitzer, V. 2010 Comparative study of primary and secondary metabolites in 11 cultivars of persimmon fruit (*Diospyros kaki* L.) *Food Chem.* 119 477 483

Yakushiji, H. & Nakatsuka, A. 2007 Recent persimmon research in Japan *Jpn. J. Plant Sci.* 1 42 62

Yamada, M. & Sato, A. 2003 Persimmon cultivars released in the 1990s by the national institute of fruit tree science in Japan *Acta Hort.* 601 19 23

Yamada, M. 2005 Persimmon genetic resources and breeding in japan *Acta Hort.* 685 55 64

Yamada, M., Sato, A., Yamane, H., Yoshinaga, K., Hirakawa, N., Iwanami, H., Ozawa, T., Kakutani, M., Mitani, N., Yoshioka, M. & Nakajima, I. 2006 New Japanese persimmon cultivar 'Kanshu' *Bul. Natl. Inst. Fruit Tree Sci.* 5 95 106

Yamada, M., Giordani, E. & Yonemori, K. 2012 Persimmon. In: M. Badenes and D. Byrne (eds.). Fruit breeding. Handbook of plant breeding, vol 8. Springer, Boston, MA

Yamane, H., Kurihara, A., Nagata, K., Yamada, M., Kishi, T., Yoshinaga, K., Matsumoto, R., Kanato, K., Sumi, T., Hirabayashi, T., Ozawa, T., Hirose, K., Yamamoto, M. & Kakutani, M. 1991 New Japanese persimmon cultivar 'Youhou' *Bul. Fruit Tree Res. Sta.* 20 49 61

Yesiloglu, T., Cimen, B., Incesu, M. & Yilmaz, B. 2018 Genetic diversity and breeding of persimmon, p. 21–46. In: J. Soneji and M. Nageswara-Rao (eds.). Breeding and health benefits of fruit and nut crops. IntechOpen

Zanamwe, P. 2018 Effects of production area and harvest maturity on post-harvest quality of South African 'Triumph' persimmon fruit (*Diospyros kaki*) *Afr. J. Hort. Sci.* 13 31 42

Terms of Use Permissions For Advertisers Privacy Policy Contact Us

© 2019-2020 American Society for Horticultural Science

Follow us on:

Powered by: Sheridan PubFactory