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Effective Transport and Storage Condition for Preserving The Quality of 'Jiro' Persimmon in Export Market

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Abstract

This study was carried out to determine the favorable conditions for preserving the quality of 'Jiro' persimmon during overseas transport and subsequent storage. Persimmon were packed using two types of packaging materials: plain cardboard boxes and cardboard boxes with modified atmosphere packaging (MAP) using 40-µm thick low density polyethylene (LDPE) film as an inner packaging material. These fruits were exported to Hong Kong via sea for 7 days using reefer containers at set temperatures of 2°C and 15°C. After delivery, the fruits were stored at 10°C and room temperature for 6 days. The number of softened fruits in each test was counted on the day of delivery and on every second day during storage. The softening of fruit was judged directly by touch and fruits that had even slightly softened were regarded as softened fruits. Simultaneously a laboratory test was conducted under conditions mimicking the transport conditions to determine the effect of MAP on persimmon quality based on the evaluation of headspace O_2 and CO_2 concentration inside the package, fruit skin color, and ion leakage. The number of softened fruit was less at 2°C than at 15°C transportation temperatures on the day of delivery, but during shelf-life conditions at both 10°C and room temperature, the number of softened fruit increased rapidly on the fruit that was transported at 2°C. These results indicate that the selection of an appropriate transportation temperature, considering the chilling sensitivity of 'Jiro' persimmon fruits, is very important to increase the number of marketable fruits, thereby increasing its overseas trade value. Storage at room temperature after transportation prolonged the shelf-life of fruits better than those stored at 10°C. Using MAP was more effective at preventing quality loss of persimmon not only on the delivery day but also on the day after delivery. 'Wase-Jiro', which is an early-ripening type, was more sensitive to chilling than 'Futsu-Jiro', which is a middle-ripening type. Moreover, it was found that high-grade persimmon is more suitable for export.

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1. Introduction

With the progress of food globalization, the amount of agricultural products that are traded internationally has been increasing. At the same time, the distance transported and the duration have also been extending. Particularly in the fresh produce sector, the prevention of quality loss during transportation is a key issue because they are very perishable. Persimmon (*Diospyros kaki* L.) fruit is an important agricultural commodity exported by Japan because it is popular among wealthy people in Southeast Asian countries and it can be sold with a higher price. However, quality can be lost during transport and the shelf life is reduced in store. These are the factors hindering the expansion of the overseas market of Japanese persimmon fruit.

Persimmon 'Jiro' is a specific variety in Aichi Prefecture, Japan that is harvested from the end of October to November. There are two types of subspecies, one is called 'Futsu-Jiro', which is a middle-ripening type and the other is 'Wase-Jiro', which is an early-ripening type and is a bud mutation of 'Futsu-Jiro'. The characteristics of this persimmon are a non-astringent, sweet taste, flat shape, and crunchy flesh. Harvested fruits are gathered at a packinghouse and sorted by size and external quality, which depends on their appearance such as the presence of surface scars, the calyx separation and cracking at the apex. Next, sorted fruits are packed into a cardboard box and then sold to the domestic market as one of the special products from this district. However, the agricultural product market in Japan has reached saturation in recent years. For this reason, farmers plan to expand sales channels to other Asian countries such as Hong Kong. The transportation process usually takes 7 days by sea transportation from harvesting by farmers to devanning by importers in Hong Kong .In some cases it takes longer because of complications at customs or because of the weather. Supplying high quality fruits at the export destination is the first requirement for making 'Jiro' persimmon become a main commodity for export. Therefore, more advanced quality control technology for longer distances and duration is needed.

Persimmon is classified as a climacteric fruit and becomes over-ripe quickly without adequate handling. Since distributors and consumers prefer a firm fruit with a crisp texture, flesh firmness is the most important postharvest quality attribute of persimmon fruit (Park and Lee, 2005). As softening associates with ripening, the control of this physiological process is the key for successful quality maintenance of persimmon fruit. Ripening is regulated by both endogenous and exogenous ethylene. Normally, persimmon fruit produces small amounts of ethylene (Kader, 2002), yet they are very sensitive to ethylene action, which accelerates the ripening process. Generally, storing fresh produce at low temperatures is effective at maintaining the quality because lower temperatures can suppress ethylene production as well as other physiological activities. However, for persimmon fruit, low temperature will lower the quality due to their sensitivity to chilling. Storage at 10ºC or below reduces the quality of the fruit and this is especially pronounced at 5ºC when softening and gelling of flesh, loss of flavor, sweetness, juiciness, off-odors, flesh darkening and mottling, and skin translucence (Mac Rae, 1987; Coslin and Tisdel, 1995) can all occur. For this reason, maintaining the quality of persimmon fruit is very difficult compared to other fresh produce because of their chilling sensitivity.

Modified atmosphere packaging (MAP) is a promising way to avoid chilling injury and has succeeded in maintaining the quality during storage and marketing. It has been reported that the packing of persimmon in MAP extends the storage life of fruits (Cia et al, 2006), retards flesh softening and alleviates chilling injury (CI) (Ben-Arie and Zutkhi, 1992). The ability of MAP to prevent or retard postharvest fruit ripening is caused by the reduction of O_2 and elevation CO_2 in the package. Altering the O_2 and CO_2 level around the products reduces respiration rate, and helps in alleviating CI for chilling sensitive crops (Forney and Lipton, 1990).

In the study of postharvest physiology and technology for persimmon fruit, the variety of 'Fuyu' has been mostly used as a target sample, because it is a major persimmon variety throughout the world, and thus, there is a lot of information on it. But the postharvest characteristics are quite different among varieties, for example, the chilling sensitivity between 'Fuyu' and 'Suruga' persimmon are quite different as demonstrated by Coslin and Tisdel (1995). In case of 'Jiro', unfortunately, little information is available on the quality preservation during transport and storage. Moreover, not only laboratory tests but also practical ones are required to provide basic research findings on useful technology. However, published reports that evaluate fruit quality during and after overseas transportation are few in spite of its importance.

In order to determine favorable conditions for preventing quality loss during overseas transportation and prolonging the shelf-life of 'Jiro' persimmon on the day after delivery, the effect of the temperature during transportation and storage, packing style, and fruit grade on the quality of fruits, which are practically exported from Japan to Hong Kong, were investigated. Additionally, several laboratory tests simulating practical transporting conditions were also conducted to determine the effect of packaging on quality and physiological properties of the fruits.

2. Materials and Methods

2.1. Practical transportation test from Japan to Hong Kong

Wase-Jiro' and 'Futsu-Jiro' persimmon harvested from Toyohashi city, Aichi prefecture, Japan were used for the transportation test. 'Wase-Jiro' was harvested on November 7 and 'Futsu-Jiro' was harvested on November 21. 2010. Both varieties were sorted at the same size and divided into three grades, i.e. A, B and C, according to the degree of surface scares, calyx separation and cracking at apex based on the standard of the packing house. For the experiment of 'Wase-Jiro', only the A grade fruits were used and divided into two lots, and then enclosed in a different packaging system. One was packed only in a cardboard box and the other was in MAP using 40-μm thick low-density polyethylene (LDPE) film as an inner packaging material of the cardboard box. The size of the cardboard box was 40 cm (length) × 35 cm (width) × 25 cm (height), and could contain 10 kg of fruits. For the experiment of the 'Futsu-Jiro', only the B grade fruits were packed in MAP and the others were packed only in a cardboard box. On the day after harvesting, the persimmon lots were transported to Nara central wholesale market (Nara prefecture, Japan) by truck, and loaded into reefer containers with a set temperature of 2°C and 15°C, and then transferred to the Port of Kobe (Hyogo Prefecture, Japan). Two days after harvesting, fruits were shipped to Hong Kong and transported by sea for five days. The temperature change during transportation was measured by self-recording thermometer (TR-72, T&D Corporation). On the day of delivery (7 days after harvesting), fruits were unloaded from the containers, and 1,170 fruits of 'Wase-Jiro' persimmon and 1,080 (A grade) and 540 (B and C grade) fruits of 'Futsu-Jiro' for each experimental conditions were checked for firmness. The fruit firmness was examined by directly touching them with hand. Where a fruit exhibited slight softening, this was counted as a softened one even if there was no change in the appearance. Following this, 108 fruits of both varieties for each of the individual experimental conditions were stored in the cold room at 10°C and an air-conditioned room set at 24°C for 6 days. Fruit firmness was also conducted on every second day during storage. The softened fruits were removed from the lots. The incidence of softened fruit was evaluated as a percentage of the number of softened fruits against the total number of fruits used in each experimental condition.

2.2. Laboratory test

2.2.1. Materials and storage conditions

'Fustu-Jiro' persimmon fruits were used in the laboratory test. They were harvested on November 27. 2011 at the same producing region mentioned above. The sample fruits were transported to the laboratory using the parcel delivery service over one day from harvesting. On the day of arrival at the laboratory, the harvested quality was determined through skin color and ion leakage test. Then, 36 fruits were packed only in a cardboard box and in MAP in the same way as for the practical transportation test. Both packages were placed in an environmental control chamber (Cosmopia, Hitachi, Japan), which controlled temperature change accurately based on the program. In this experiment, the temperature in the chamber was set so as to simulate the 2°C transportation condition. After storage, the fruits were transferred to room temperature (24°C) to check the quality of fruit through skin color properties and ion leakage testing.

2.2.2. Measurement of O_2 and CO_2 concentration in MAP

The concentration of O_2 and CO_2 in MAP were determined by gas chromatography.0.2 ml of the headspace gas in the packages was taken directly using a micro syringe and injected into a gas chromatograph (GC-14, Shimadzu, Japan) equipped with a thermal conductivity detector (TCD). Molecular sieve 5A and Porapak Q column were used for separation of O_2, N_2 and CO_2. Helium gas was used as a carrier. The gas chromatogram was analyzed with an integrator (C-R7A plus, Shimadzu, Japan) based on standard curves produced by standard gas. The results were expressed in percentage of total gas volume.

2.2.3. Skin color

Skin color was measured after five days from starting test assuming the day of delivery in Hong Kong. Minolta chromameter (CR-13, Minolta, Japan) was used to get parameter L^*, a^* and b^*. Three readings were made at different locations (peduncle, apex, and equator) on the fruit. The results expressed as $L*$ value correspond to lightness, whereas chroma and hue angle (h°) conform to intensity and actual color calculating from $[(a*)^2+ (b*)^2]^{1/2}$ and arc-tan $b*/a*$, respectively (McGuire, 1992).

2.2.4. Ion leakage

Ion leakage was assessed at the same time as measuring skin color and followed by an additional 6 day at 24 °C (room temperature) by the methods described by Saltveit (2002) with some modifications. Pericarp discs (11-mm diameter) were excised with stainless steel cork borer and trimmed of locular and epidermal tissue to produce 4-mm thick discs. The discs were washed in deionized water three times for about one minute each time, blotted dry and three discs were placed in plastic Petri dishes. Three pericarp discs were put into 50-ml centrifuge tubes with 20-ml 0.2 M mannitol and shaken at a 100-strokes/min using water bath incubator (Model BT-31, Yamato Scientific, Japan). Conductivity was measured using a conductivity meter (ES-51, Horiba, Ltd., Kyoto, Japan) 0.5 h after adding the mannitol. The tubes were then capped, frozen, thawed and weighed. The contents were incubated for 10 min in a 50-ml flask, allowed to cool at room temperature and transferred back to plastic tubes. Deionised water was added to make initial weight and the total conductivity was measured after an additional 0.5 h of shaking. The individual conductivity reading was divided by the total conductivity and multiplied with 100 to convert the readings to the percentage of total conductivity.

2.2.5. Statistical analyses

The results obtained from laboratory tests were completely randomized with five replications. Five persimmon fruits were taken from each type of package to compare fruit quality in cardboard boxes and MAP through skin color properties and ion leakage tests. Statistical significance was determined by submitting the mean values to analysis of variance and was subsequently compared using Tukey's test at the 5% probability level performed by R software (version 2.15.2 for Windows, R Foundation).

3. Results

3.1. Practical transportation test from Japan to Hong Kong

3.1.1. Percentage of softened fruits on the day of delivery

Table1 shows the incidence of softened fruits on the day of delivery after transporting 'Jiro' persimmon fruits from Japan to Hong Kong by using different packages and temperatures. For both tested subspecies of persimmon, the fruits transported at 2°C by using cardboard boxes had a lower rate of softening than those transported at 15°C. For fruits packaged using MAP, the softening was entirely prevented at 2°C, and only a few of them were softened at 15°C. The difference of subspaces also had an effect on the number of softened persimmon at delivery day. In similar packaging and grade, 'Wase-Jiro' had less instances of softening compared with 'Futsu-Jiro' when fruits were transported at 2°C. When fruits were transported at15°C, the softening in 'Wase-Jiro' was higher than in 'Futsu-Jiro'. The number of softened fruits differed among the fruit grades with instances of softening of the C-grade persimmon increasing3.9 fold at 2°C and 5.8 fold at 15°Ccomparedwith A-grade persimmon when they were packed in the cardboard.

Table 1. Effect of packaging style, transportation temperature and grade of fruit on softening incidence of different subspecies of 'Jiro' persimmons on the day of delivery in Hong Kong.

Subspeices	Packaging style	Transportation Temperatures (°C)	Fruit grade	% of softening
'Wase-Jiro'	Cardboard	2	A	0.6
		15	A	4.4
	MAP	2	A	0
		15	A	0.2
'Futsu-Jiro'	Cardboard	2	A	0.9
			C	3.5
		15	A	3.2
			C	18.7
	MAP	2	B	0.6
		15	B	1.7

n=1080 (A grade fruits), *n* = 540 (B and C grade fruits)

3.1.2. Percentage of softened fruit during storage after delivery

Fig.1 shows percentage of fruit softening of 'Wase-Jiro' subspecies during storage condition at 10°C after transporting at 2°C and 15°C. The number of softened fruits increased with increasing the storage period in all conditions examined, especially, on the fruits transported at 2°C. Similar results were observed in 'Futsu-Jiro' where the number of softened fruits was also higher on fruits transported at 2°C compared with fruit transported at 15°C (data not shown). These results contrasted with results on the day of delivery, where the persimmons transported at 2°C had fewer softened fruits than those transported at 15°C as mentioned previously in section 3.1.1.

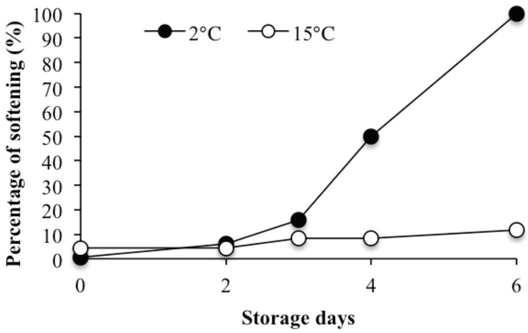

Figure 1. Percentage of fruit softening of 'Wase-Jiro' persimmon during storage condition at 10°C after transporting at 2°C and 15°C in plain cardboard boxes.

The number of softened fruits increased dramatically after 3 days of storage for fruits stored at 10°C compared to those stored at room temperature. (Fig. 2). Similar results were demonstrated in 'Futsu-Jiro' persimmon, wherethe number of softened fruits was also higher than fruits stored at 10°C after transportation(data not shown).

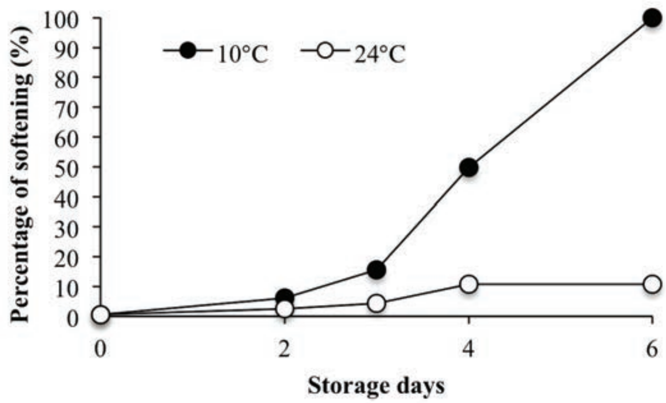

Figure 2. Percentage of softened fruit of ‘Wase-Jiro’ persimmon during storage condition at 10°C and room temperature after transporting at 2°C in plain cardboard boxes.

Use of MAP during transportation process maintained the quality of persimmon in subsequent shelf-life by retarding the rate of fruit softening. MAP was more effective suppressing the softened fruit when fruits were transported at 2°C(Fig.3), but a slight difference in softening between cardboard and MAP was shown on the fruit transported at 15°C (data not shown). In our results, packaged persimmon in MAP gave the best results for maintaining soft fruit not only on the delivery day, but also during shelf-life conditions for both varieties of persimmon.

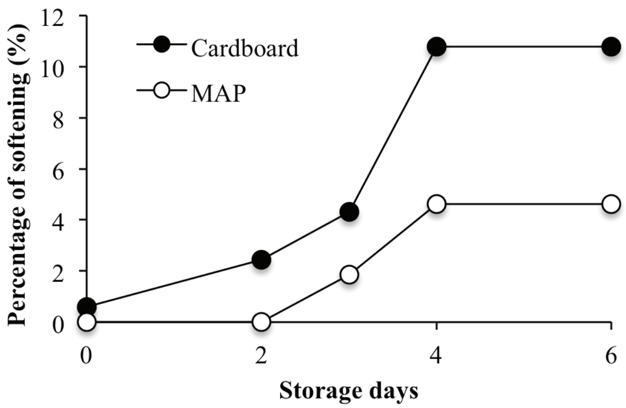

Figure 3. Percentage of softened fruit of ‘Wase-Jiro’ persimmon packaged in cardboard and MAP during storage condition at room temperature after transporting at 2°C.

The effect of subspecies on fruit softening was also studied throughout the storage time for all test conditions. Changes in fruit softening of ‘Jiro’ persimmon at two harvest dates on different transporting temperatures are shown in Fig. 4. From our results, during storage conditions, ‘Wase-Jiro’ had a higher rate of softening compared with ‘Futsu-Jiro’ when they were transported at 2°C, conversely, ‘Futsu-Jiro’ exhibited a higher value in softening when they were transported at 15°C. These results contrast with the results of softened fruits on the day of delivery.

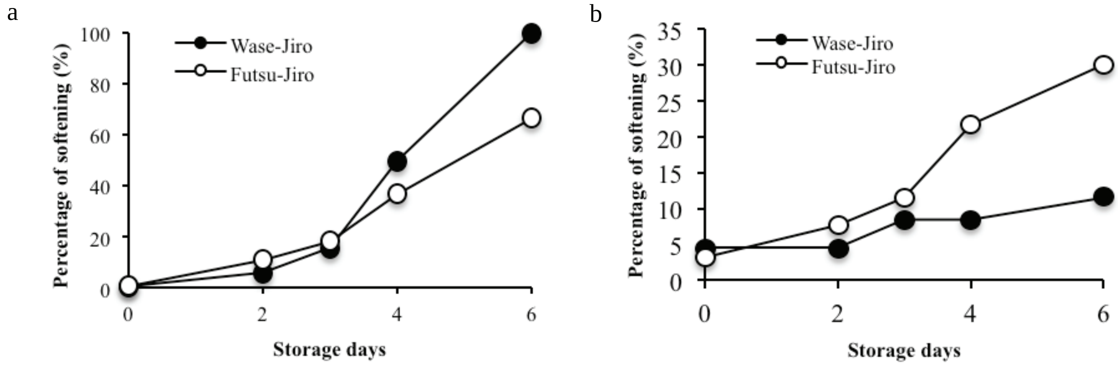

Fig.4. Percentage of softening fruit of two subspecies 'Jiro' persimmon, early ('Wase-Jiro') or late ('Futsu-Jiro') during storage condition at 10°C. Fruits transported at 2°C (a) and 15°C (b) and packaged in cardboard.

3.2. Laboratory test

3.2.1. O_2 and CO_2 concentration change in MAP during transportation

The change gas concentration in MAP is shown in Fig.5. The data in this figure were obtained in the laboratory test simulating the transporting temperature condition set at 2 °C from Japan to Hong Kong. From our results, O_2 concentration decreased gradually with elapsed time at the beginning of three days and after that steady at the concentration of 6.63 %, whereas CO_2 concentration increased slowly and relative constant at 5.41 % after two days of transportation.

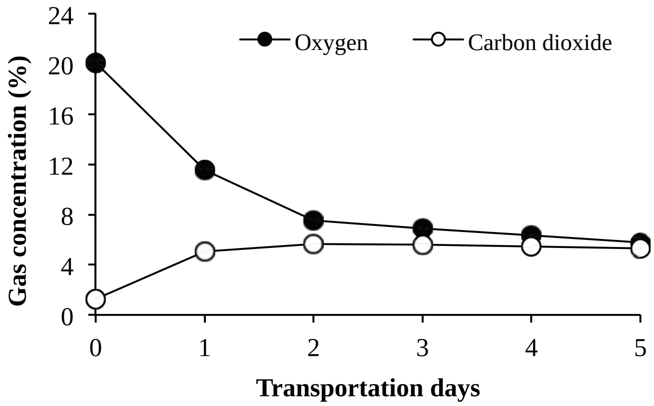

Fig.5 O_2 and CO_2 concentration change in the headspace of 40-µm LDPE film during transportation process at 2°C.

3.2.2. Skin color

Fig.6 shows the skin color properties of 'Jiro' persimmon packaged in cardboard and MAP during transportation at 2°C for 5 days and followed at room temperature for 6 days. These results were obtained from a laboratory test simulating the transport condition set temperature of 2°C. Color change in persimmon fruit decreased during the transportation process in both packages, however, significant difference in lightness, chroma and hue-angel did not show among them on the day of delivery. Nevertheless, the skin color properties were higher in the fruits packed in MAP than those in cardboard boxes. When fruits were transferred to storage condition at room temperature, the skin color properties such as lightness, chroma and hue-angel decreased gradually in both of packages, however, significant difference was not found between them.

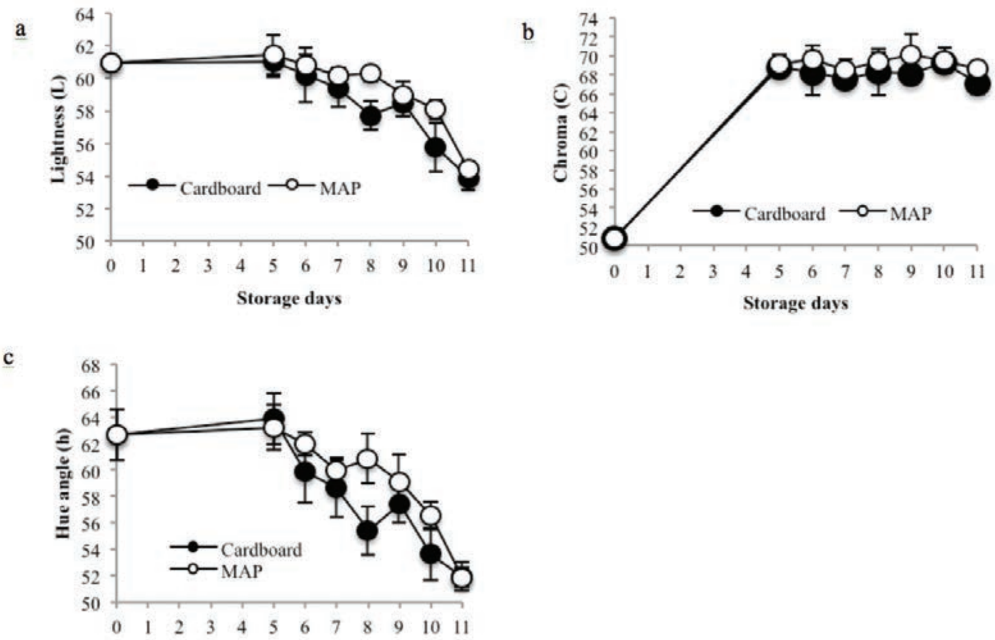

Figure 6. Skin color change of ‘Wase-Jiro’ persimmon fruit during transportation at 2°C for 5 days followed by room temperature for 6 days. Vertical lines represent standard error (n = 5).

3.2.3. Ion leakage

Fig. 7 shows percentage ion leakage of ‘Wase-Jiro’ persimmon during transportation and following to storage conditions at room temperature for 6 days. Significant difference of ion leakage was not found between cardboard and MAP on the day of delivery, however, when ion leakage observed to storage condition at room temperature, rapid increase in ion leakage was shown in cardboard persimmon after 6 day of storage, while in MAP persimmon was suppressed up to day 10, after that, the percentage of leakage increased sharply as well as in cardboard persimmon.

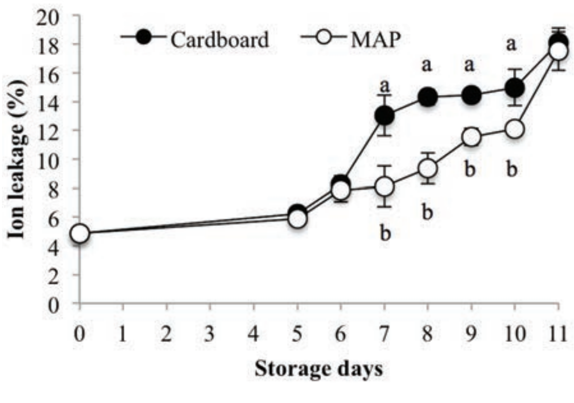

Figure 7. Ion leakage of ‘Wase-Jiro’ persimmon tissue in cardboard and MAP during transportation at 2°C and followed at room temperature for 6 days. Vertical bars represent the standard deviation of the mean. Values with different letters for each day were significantly different at $P<0.05$.

4. Discussion

4.1. Effect of transporting and storage temperature on fruit softening

As a climacteric type of fruit, persimmon is sensitive to ethylene action, which accelerates softening and reduces shelf life and marketability (Takata, 1983; Krammes et al., 2005; Park and Lee, 2005). Storage at low temperatures is the main postharvest tool to control physiological processes such as respiration and ripening, and it can also prevent spoilage of perishable produce in general. However, since some fresh produce originating in tropical or subtropical regions are chilling sensitive, low temperature below 10 ˚C can lower their quality. For this reason, exposure to low temperature has a counter effect in the quality management of such produce. The important thing in this study is that persimmon fruit is a kind of chilling produce. From our results, transportation at 2˚C suppressed the incidence of softened fruits at delivery comparing with transportation at 15^{o}C. Low temperature suppresses metabolic process on fresh horticultural commodities, conversely, the rate of these reactions generally increase with increasing temperature. Arnal and Del Río (2004) reported that storage of persimmon at 1°C maintained the firmness up to 20 day than those stored at 8° and 15°C. Transported at 2°C reduced the respiration rate and ethylene production coincident with ripening process during transportation, while these reaction increased when the fruits were transported at 15°C.

After transportation, the number of softened fruits increased at both storage temperatures (10°C and 24°C), especially on fruit transported at 2°C, the increase of softened fruits was higher compared with fruits transported at 15°C. This result was in contrast to the results observed on the day of delivery. These facts indicate that CI occurred at the internal level of the fruit during the period of the transportation at 2°C, after that, the severity increased when the fruit was transferred to warm temperatures. Arnal and Del Río (2004) conducted research with 'Rojo Brillante' persimmon and reported drastic flesh softening in persimmon as the manifestation of CI occurs when fruit is removed from low temperatures to shelf-life conditions. The firmness loss at 15°C is a natural change associated with ripening, whereas this process is accelerated by increasing temperature.

Room temperature is more effective for storing persimmon fruits after transportation. Storage of persimmon fruits at room temperature suppressed the increase of fruit softening and prolonged the storage period of fruit. Conversely, rapid increases in fruit softening were observed for fruits stored at 10°C.. Although usually CI symptoms appear after removing fruit from low to higher temperatures, CI manifestation also occurs after long time storage at low temperatures. These results are in contrast with temperatures recommended by Kader (2002), where temperature 10°C or below 15°C is ideal temperature for transit and storage of chilling sensitive commodities. The results suggest that, in the export 'Jiro' persimmon to overseas market, transportation temperatures affect quality of persimmon after transportation. Transport at 2°C prevent quality loss of fruit at delivery comparing at 15°C, but during storage period the losses increased, conversely, at 15°C transportation temperature is suppressed. In the export market of persimmon, a transportation temperature of 2°C is favorable for importers, however, the distributors and customers also play an important role in the expansion of the persimmon market. Therefore, in order to expand marketing of 'Jiro' persimmon to the overseas market, and make this fruits become a main commodity export in Japan, the persimmon of 'Jiro' should be transported at 15°C to maintain the quality for consumers. In addition, to prolong the shelf-life after transportation, the persimmon should be stored at room temperature.

4.2. Effect of packaging on fruit softening

MAP with 40-µm thick LDPE film was effective in limiting softened fruits compared with cardboard boxes. It suppressed the increasing of fruit softened for all test conditions, not only on the delivery day but also after the fruits were transferred to storage conditions. Low O_2 and high CO_2 created inside MAP inhibited respiration rate resulting in a decrease of the number of fruit softened. From the results of laboratory tests, the steady state gas composition in the headspace of the package has been established to 6.63% O_2 and 5.41% CO_2. These compositions were consistent relatively with the optimum atmosphere for persimmon fruit that has been shown as 3-5% O_2 and 5-8% CO_2 (Kader, 2002). Moreover, during period of storage (10°C and room temperature), the persimmon that were transported using MAP at both transportation temperatures (2°C and 15°C) had lower numbers softening than those transported using cardboard only. In particular for fruits transported at 2°C, MAP effectively reduced the softening better than that of cardboard, while at 15°C, the softening was slightly different between cardboard and MAP. In this study, there is a different effect of MAP in reducing the number of softened fruits between two transportation temperatures. For fruits that transported at 2°C, the lower of softening in MAP due to MAP suppressed the development of CI, which induced ethylene production in persimmon fruits. Use of MAP affected the activity of ethylene synthesis, because low O_2 that formed inside of the package inhibited the ACC oxidase activity resulting in reducing of ethylene production. Meanwhile, on the fruits that were transported at 15°C, MAP delayed the normal ripening process of fruits, where the rate of deterioration was slower than CI. Besides low O_2 that formed inside the package, high humidity was also created in MAP. It also plays a role in reducing ethylene production which slows the ripening process. Nakano et al, (2002) reported that persimmon stored in high humidity conditions at non-chilling temperatures neither produced detectable levels of ethylene nor softened rapidly.

Furthermore, the gas composition created in the inside of MAP during transportation affected the persimmon color at delivery and subsequent storage. Although significant difference in skin color was not found between cardboard and MAP, however, persimmon packaged in MAP had a higher value in skin color properties compared with fruit packaged in cardboard. Color change has been used as a maturity index in many fruits. In the ripening process of persimmon, the color changes from yellow to orange-red indicated by increasing in chroma and decreasing in hue-angle. Also, there is a loss of their luminosity in terms of lightness. However, under chilling condition, the term ‘browning’ is usually used to designate various discoloration disorders, and decrease in chroma also could be indicative of CI (Cia et al, 2006). Besides, the most severe injury in persimmon is also typified by skin browning at the calyx end. From the skin color results, the higher lightness shown in MAP represents that browning of the persimmons during transportation was delayed, on other hand, the lower one shown in cardboard indicates loss of luminosity resulting in skin darkening, and it could be attributed to skin browning of the fruit surface (Cocci et al, 2006). Use of MAP significantly affected color intensity in terms of chroma. Higher in chroma value of MAP persimmon is characteristic of more advanced stages of fruit ripening, while lower in cardboard associates with development of CI. Hue angle value was also lower in cardboard persimmon indicates that skin color was more orange compared with MAP persimmon.

Moreover, the percent of ion leakage increased significantly during the transportation process, but on the delivery day, significant difference was not found between cardboard and MAP. According to Sharom et al, (2004), drastic increase in electrolyte leakage observed after transfer to higher temperature. However, the difference in ion leakage between two packages was observed after fruits transferred to room temperature. The lower level of ion leakage value in MAP persimmon is a good indication that MAP has suppressed development of CI during period transport at 2°C. Ion leakage has been used as an indicator of damage to the plasma membrane. Increase of ion leakage in cardboard persimmon is an evidence of membrane deterioration, in contrast in MAP; it increases persimmon tolerance to chilling stress. This study shows that use of 40-μm of LDPE film as an inner packaging material, maintains the quality of persimmon during transportation and storage period, because MA that created inside the packages control the respiration rate and also decrease the intensity of catabolic activity and degradation process (Laughed, 1987).

4.3. Effect of harvest date and fruit’s grade on fruit softening

Japanese persimmon is usually harvested in October and November and either marketed immediately or stored. Development of CI in persimmon during storage varied with season and harvest time. In our result, the fruit that were harvested late in the season were more resistant to chilling stress compared with those harvested in the early part of the season. This result is consistent to New Zealand persimmon (MacRae, 1987), where the fruit harvested late in the season had less CI than those harvested early, but this results contrasts to California persimmon. Salvador et al, (2006) also reported that the firmness loss was faster in fruit harvest earlier. The differences in sensitivity CI between two harvest dates of ‘Jiro’ persimmon may be influenced by climate conditions on fruit development. The difference of environment temperature between early and late harvested affects the fruit development, therefore, early harvests were more sensitive to low temperatures, presenting the highest incidence to CI symptoms compared with late harvest, but it was resistant to non-chilling temperature compared with late harvest.

In addition, both subspecies of ‘Jiro’ persimmon (early and late) were sorted at the same size and divided into three grades, i.e. A, B and C, based on the degree of surface scares, calyx separation and cracking around apex. In our results, the softening of fruit differed among low-grade and high-grade at delivery. The higher number of softened fruit at C-grade persimmon was caused by calyx separation, surface scares and cracking at apex that contained in this grade. These injuries increased biosynthesis of ethylene and thus accelerated the ripening process. Hydo (1983) reported that the wound fruit produced a large amount of ethylene because of rapid increasing of 1-Aminocyclopropane-l-carboxylate (ACC) synthase activities resulting in accumulation of ACC to a greater extent. ACC is a precursor in ethylene, which ACC oxidase catalyzes the oxidation of ACC to ethylene. Therefore, in exporting of 'Jiro' persimmon, only the A-grade fruits, which did not have any injuries on their appearance, should be shipped to the oversea market.

5. Conclusion

'Jiro' persimmon fruit is a sensitive product and susceptible to chilling temperature. Improving the shelf-life of persimmon is aimed at expanding its market to the overseas market. There are many factors that affect the distribution of 'Jiro' persimmon such as harvested date, grade of fruit, transportation and storage temperatures, and packaging treatment. Selection of an appropriate transportation temperature and storage with considering the chilling sensitivity of 'Jiro' persimmons increases the number of marketable of fruits, thereby increasing its overseas trade value. In this study, transportation temperature of 2°C suppressed the quality deterioration of persimmon at delivery, while at 15°C prolonged the shelf-life of fruit. Stored at room temperature preserved quality after transportation compared with stored at 10°C. MAP inhibited chilling injury symptoms in fruit transported at 2°C and retarded the ripening at 15°C. Moreover, it was found that early harvested ('Wase-Jiro') fruit more sensitivity to low temperature compared with the late harvested ('Futsu-Jiro') one, conversely, late harvest was sensitive to non-chilling temperature (15°C), and also found that high-grade persimmons whose did not have the injuries is suitable for exporting market.

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