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# FRUIT QUALITY AND STORABILITY OF SOME ASIAN PEAR CULTIVARS COLLECTED IN THE GENE BANK OF THE RESEARCH INSTITUTE OF HORTICULTURE, CENTRAL POLAND

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ABSTRACT

The aim of this study was to evaluate the fruit quality of 13 Asian pear cultivars grown in climatic conditions of central Poland. The following cultivars were tested: 'Chojuro', 'Hayatama', 'Hosui', 'Kosui', 'Yuan Huang', 'Nijisseiki', 'Dżin Li', 'Er Shi Shinge', 'Er Jang Li', 'Golden 20th', 'Min Czi Li', 'San Li', and 'Shinseiki'. Pears were harvested in Experimental Orchard of Research Institute of Horticulture in Dąbrowice (near Skierniewice). Fruits were stored for 10 weeks at 0 °C in regular atmospheric conditions. Flesh firmness (FF), total soluble solids (TSS), and titratable acidity (TA) were measured at harvest and after the storage followed with 1 and 7 days of shelf life (SL) at 18 °C. After the storage, the sensory evaluation was also performed. Among the tested cultivars, 'Min Czi Li' and 'San Li' were the most firm (above 45 N) and 'Kosui' was the least firm (below 28 N) at harvest time. High amount of TSS (above 11% in both seasons and harvest dates) was observed in 'Chojuro', 'Hayatama', 'Kosui', 'Yuan Huang', and 'Er Jang Li' pears. Low TSS (not more than 10.6% at harvest) was observed in 'Nijisseiki', 'Dżin Li', and 'Er Shi Shinge' cultivars. The large differences among cultivars were observed in TA. High TA was observed in 'Nijisseiki' (above 0.32% in all terms of analyses) and low TA in 'Hayatama' and 'Kosui' (below 0.14%). All of the evaluated cultivars can be stored for 10 weeks at 0 °C in regular atmosphere without major negative impact on their quality characteristics. Fruits showed a slight (sometimes significant) decrease in FF after storage and a slight or no changes in TSS and TA. In sensory evaluations, 'Chojuro', 'Hayatama', 'Hosui', 'Kosui', 'Yuan Huang', 'Er Jang Li', 'Er Shi Shinge', and 'Shinseiki' (mostly cultivars characterized by high TSS) obtained highest scores for the overall quality (above 5.0 points in 10 points scale).

**Keywords:** flesh firmness, sensory evaluation, PCA, soluble solids, storage, regular atmosphere, titratable acidity

## INTRODUCTION

Asian pears, also known as oriental pears, Chinese pears, Japanese pears, Nashi, apple pear, sand apples, salad pears, have been grown commercially in Asia for centuries. The cultivars were developed from *Pyrus ussuriensis* Maximowicz, *Pyrus serotina* Rehder (*Pyrus pyrifolia* Nakai), *Pyrus bretschneideri* Rehder and other species native to Asia (Crisosto 2004). Recently, in the European countries, there has been an increasing interest in this kind of pears. Trees are characterized by cold hardiness similar to European pears, early and high productivity, and disease resistance. Climate in Poland is suitable for the cultivation of Asian pear (Pitera 2003, 2005; Pitera & Odziemkowski 2004; Sosna 2018). However, these fruits are poorly known and grown on a small scale. Fruits of Asian pears differ from European pears in appearance, taste, and ripening process. Most Asian pear cultivars have a round shape and juicy fruit with firm and crispy texture and can be eaten soon after harvest but also after several months of cold storage (Beutel 1990). Asian pears are considered as dietary and healthy fruit. They have less sugars and starch than European pears

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(Yim & Nam 2016). On an average, Japanese pears provide 42 kcal of food energy per 100 g of fresh fruit. They consist of 88.25% water, 0.50% protein, 0.23% fat, 10.65% carbohydrate, and 3.60% fiber and contain potassium (121 mg), calcium (4 mg), magnesium (8 mg), phosphorus (11 mg), and ascorbic acid (3.8 mg) (USDA 2018). As reported by Lee et al. (2016) and Yim and Nam (2016), they also contain phenolic and flavonoid compounds with strong antioxidant activity. Taking into account the health benefits of fruits and their sweet, refreshing, juicy, crisp flesh and unique flavor, Asian pears can be an interesting product for Polish consumers as a dessert fruit.

Fruits of Asian pears should be stored at 0–5 °C in a high humidity atmosphere (> 90%) because they are susceptible to water loss (Beutel 1990; Asakura et al. 2001; Kader 2003; Crisosto 2004). The skin is very susceptible to abrasion and friction marks; therefore, this delicate fruit requires careful handling during picking and packing. Fruit taste (sugar content) and skin color are the main maturity indices to determine the harvest time. Depending on cultivar, the skin color changes from green to golden brown or to yellowish green (Beutel 1990; Crisosto 2004). Delayed harvest results in increased incidence and severity of physiological disorders during storage – internal browning (Crisosto et al. 1994; Arzani et al. 2009; Yan et al. 2013; Choi et al. 2015).

Little information can be found on the quality of fruits of Asian pears grown in Polish climatic conditions. The aim of this study was to evaluate the fruit quality of 13 Asian pear cultivars (harvested in Experimental Orchard of Research Institute of Horticulture) and to determine the changes in selected quality parameters during their cold storage in regular atmospheric conditions.

## MATERIALS AND METHODS

For the experiment, 13 Asian pear cultivars were chosen. Five of them are round with brown-colored skin and eight are round or elongated with green to yellow skin. Among round cultivars with brown skin, 'Chojuro', 'Hayatama', 'Hosui', 'Kosui', and 'Yuan Huang' were analyzed. Among cultivars with green to yellow skin, 'Dżin Li', 'Er Shi Shinge', 'Er Jang Li', 'Golden 20$^{th}$', 'Min Czi Li', 'Nijisseiki', 'San Li' (elongated shape), and 'Shinseiki' were analyzed. Fruits were obtained from the Experimental Orchard of Research Institute of Horticulture located near Skierniewice, in Dąbrowice (51°55′ N and 20°6′ E). Trees of all cultivars were produced on the *Pyrus communis* seedlings and planted at a spacing of 4 × 2.5 m in the spring of 1995. From the first year after planting, drip irrigation was used. The rules concerning pruning and soil management were the same as for commercial orchards. According to this principle, grass were sown in between rows and herbicide was used for weeds control in rows of trees. Every spring, trees were pruned and spindle-bush crowns were formed. In addition, in the period before the harvest, summer pruning was performed.

Fruiting was strictly dependent on cultivar and weather conditions. In some years, a decrease in yield was observed, mainly due to damage caused by spring frosts. For example, in the year 2010 cropping ranged from 12 to 22 kg per tree. Among the best-yielding cultivars were 'Dżin-Li', 'Er-She-Shinge', 'Nijisseiki' and 'Hosui' (21-22 kg per tree). The lowest yield was obtained for 'Min-Czi-Li' and 'Yuan Huang'. The following year, the cropping was much lower due to scant and significantly delayed flowering coupled with a short flowering period. As in the previous season, the lowest yield was recorded for 'Min-Czi-Li' (5 kg per tree).

The storage experiment was conducted during two successive seasons: 2010 and 2011 (the exception was 'Er Jang Li' cultivar, which was tested in 2011 and 2012). Pears were harvested at commercial maturity stage based on skin color and taste, as recommended by Beutel (1990) and Crisosto (2004). For some cultivars or seasons, two harvests were performed (Table 1). The fruits were stored for 10 weeks at 0 °C in regular atmospheric conditions. On removal from storage, the fruits were placed for 1 and 7 days in the air-conditioned room at 18 °C to simulate shelf life (SL). At the next day after harvest and after storage, followed with 1 and 7 days of SL, the following parameters were evaluated: flesh firmness (FF), total soluble solids (TSS), and titratable acidity (TA). The sugar-to-acid ratio was also calculated for pears after harvest. In 2011, the sensory evaluation was performed for fruits after storage.

FF was assessed on two opposite peeled sides of each fruit by penetrometric method using Zwick

Roell Z010 (Germany) instrument, equipped with a plunger of 8-mm diameter. The percentage of TSS was measured in the freshly prepared juice using Atago PR-101 (Japan) electronic refractometer. TA was measured by the titration of fruit juice with 0.1 N NaOH to an endpoint of pH 8.1 using Mettler Toledo DL 21 (Swiss) automatic titrator. Acidity was expressed as equivalent percentage of malic acid.

Sensory analysis was performed by scaling–profiling method. Samples (fruit quarters) were served in covered plastic containers. The following traits were evaluated: fruit aroma, overall aroma quality, hardness, crispness, crunchiness, juiciness, overall texture quality, bitter taste, acidity, sweetness, and the overall quality that was defined as the sensory impression of the balance and harmony of all attributes and their interactions. Each attribute was evaluated on a linear scale (0–100 points) and then transposed to numeric values from 0 to 10 units, where 0 denoted the absence of a given trait or low quality/harmonization, whereas 10 indicated an intensive sensation or high quality/harmonization of evaluated attribute. The expert panel consisted of 10 trained judges recruited from staff of the Research Institute of Horticulture.

For FF, TSS, and TA analyses, three replicates of five fruits each were used. The mean values were compared using one factorial ANOVA. The results of sensory data were calculated as mean of indications of 10 judges for 10 fruits, where 1 person assessed 1 fruit quarter. To illustrate relationships between evaluated attributes of the sensory characteristic (Fig. 2), the data were analyzed by the multivariate principal component analysis (PCA) on standardized mean data. All calculations were performed using the statistical software STATISTICA 9 (StatSoft).

## RESULTS AND DISCUSSION

FF is an important physical property of fruit, which directly affects the eating quality. As reported by Crisosto (2004), in Asian pears, FF of 7–10 lb (31.1–44.5 N) (depending on cultivar) is optimum for eating, and only small changes in firmness occur during storage at 0 °C. Data presented in Table 1 showed that cultivars differed in firmness. 'Min Czi Li' and 'San Li' were characterized by high firmness at harvest time (above 45 N in all seasons and harvest dates), and 'Kosui' had very low firmness (below 28 N). Oraguzie et al. (2010) also reported a similar firmness at harvest time for 'Kosui' pear. In the experiment of Itai and Tanahashi (2008), the FF of 'Gold Nijisseiki' and 'Hosui' was 28.9 and 22.9 N at harvest, respectively, and decreased to about 22 and 7 N after 60 days of cold storage at 5 °C. In our experiments, the cultivars had a much higher FF (Table 1). After 10 weeks of storage in normal atmosphere, a decrease in FF was observed for most of the tested cultivars ('Chojuro', 'Hayatama', 'Hosui', 'Nijisseiki', 'Dżin Li', 'Er Shi Shinge', 'Er Jang Li', 'Min Czi Li', 'San Li', and 'Shinseiki'), but significant differences were recorded only to some harvest dates or seasons (Table 1). No significant changes in FF during storage were observed in 'Kosui', 'Yuan Huang', and 'Golden 20$^{th}$'. For most cultivars, a subsequent decrease in FF occurred after 7 days of SL. It was not observed in 'Yuan Huang', 'Min Czi Li', and 'San Li' pear. Our result was similar to that of Li et al. (2011), who reported FF decrease with the prolonging of the storage period of 'Wonhuwang' pear; however, the tendency and extent differentiated in harvesting time. Other authors also reported a slow decrease in FF during the storage of 'Cuiguan' pear (Chen et al. 2010), 'Early Gold' and 'Shinko' (Zagory 1989), 'Pathernakh' (Mahajan & Dhatt 2004; Mahajan et al. 2010), 'KS'$_9$ and 'KS'$_{13}$ (Arzani et al. 2008), and Yali pear (Chen et al. 2006).

Sugars and organic acids are one of the most important components of fruit taste and quality. As reported by Crisosto (2004), the soluble solids content for Asian pears should be 11–14% depending on cultivar. High amount of TSS was observed for 'Chojuro', 'Hayatama', 'Kosui', 'Yuan Huang', and 'Er Jang Li'. These cultivars reached above 11% at harvest in both seasons and harvest dates. In the experiment of Sosna (2018), the extract of 'Chojuro', 'Kosui', 'Hosui', and 'Nijisseiki' had above 11% of TSS. For 'Chojuro' cultivar, the TSS level of 11.3% was also reported by Kopera et al. (2005). In our experiment, 'Nijisseiki', 'Dżin Li', and 'Er Shi Shinge' cultivars had low TSS (not more than 10.6% at harvest). In the experiments of Kopera et al. (2005) and Sosna (2018), 'Shinseiki' pear was characterized by 10.2 and 10.3% of TSS (respectively), which, in our experiment, reached values from 10.4 to 12.0%, depending on the harvest date and season (Table 2).

Table 1. Flesh firmness (N) of Asian pears at harvest and after storage for 10 weeks in regular atmosphere (means and standard deviations)

| Cultivar | Date of harvest | At harvest | After 1 day of shelf life | After 7 days of shelf life |
|---|---|---|---|---|
| 'Chojuro' | 21.09.2010 | 35.3 ± 2.60 b | 33.9 ±2.16 ab | 32.0 ± 2.83 a |
| | 29.08.2011 | 47.7 ± 6.96 b | 39.9 ± 4.75 a | 36.7 ± 4.99 a |
| | 19.09.2011 | 40.5 ± 7.07 b | 36.4 ± 5.78 b | 28.4 ± 4.32 a |
| 'Hayatama' | 08.09.2010 | 30.8 ± 3,87 b | 30.6 ± 3.03 b | 22.2 ± 4.23 a |
| | 23.08.2011 | 38.9 ± 6.61 c | 27.7 ± 4.91 b | 21.2 ± 4.40 a |
| | 29.08.2011 | 36.3 ± 4.27 c | 28.0 ± 4.00 b | 21.4 ± 4.10 a |
| 'Hosui' | 08.09.2010 | 40.2 ± 2.62 a | 41.9 ± 4.92 a | 40.5 ± 3.52 a |
| | 21.09.2010 | 40.0 ± 5.22 a | 41.2 ± 3.37 a | 40.0 ± 4.14 a |
| | 12.09.2011 | 39.2 ± 4.93 b | 32.8 ± 4.23 a | 32.0 ± 3.87 a |
| | 19.09.2011 | 37.5 ± 4.81 c | 33.1 ± 5.01 b | 27.7 ± 5.32 a |
| 'Kosui' | 08.09.2010 | 27.7 ± 4.35 b | 25.7 ± 3.51 b | 21.4 ± 1.62 a |
| | 29.08.2011 | 23.3 ± 2.03 b | 21.7 ± 2.65 b | 17.1 ± 3.23 a |
| | 05.09.2011 | 22.3 ± 2.37 b | 20.4 ± 2.43 b | 16.7 ± 1.88 a |
| 'Yuan Huang' | 09.09.2010 | 35.0 ± 4.31 b | 33.4 ± 3.20 ab | 31.1 ± 2.93 a |
| | 20.09.2010 | 33.8 ± 4.46 a | 32.3 ± 5.02 a | 29.8 ± 4.24 a |
| | 29.08.2011 | 39.0 ± 4.43 b | 34.4 ± 4.09 ab | 32.3 ± 4.87 a |
| 'Dżin Li' | 20.09.2010 | 24.3 ± 3.29 b | 22.2 ± 4.49 ab | 16.8 ± 2.84 a |
| | 05.09.2011 | 36.8 ± 3.75 c | 31.0 ± 7.09 b | 22.2 ± 2.84 a |
| 'Er Shi Shinge' | 09.09.2010 | 35.3 ± 3.06 a | 37.6 ± 2.43 b | 34.9 ± 4.63 a |
| | 05.09.2011 | 36.6 ± 4.58 c | 29.6 ± 2.89 b | 24.7 ± 2.80 a |
| 'Er Jang Li' | 05.09.2011 | 39.5 ± 6.59 c | 29.6 ± 5.82 b | 18.8 ± 2.91 a |
| | 12.09.2011 | 27.3 ± 2.43 b | 25.5 ± 2.51 b | 18.6 ± 1.97 a |
| | 30.08.2012 | 43.6 ± 6.30 c | 32.7 ± 3.27 b | 22.7 ± 3.69 a |
| | 04.09.2012 | 40.5 ± 3.59 c | 32.5 ± 3.82 b | 21.2 ± 2.73 a |
| 'Golden 20$^{th}$' | 20.09.2010 | 29.9 ± 2.38 a | 30.7 ± 3.25 a | 28.6 ± 3.45 a |
| | 05.09.2011 | 31.1 ± 3.10 b | 29.3 ± 4.64 b | 25.0 ± 3.53 a |
| 'Min Czi Li' | 20.09.2010 | 51.1 ± 7.40 a | 50.3 ± 5.23 a | 46.3 ± 6.08 a |
| | 12.09.2011 | 49.4 ± 4.88 b | 40.4 ± 3.92 a | 41.1 ± 4.19 a |
| | 22.09.2011 | 46.1 ± 3.50 b | 40.2 ± 3.79 a | 40.6 ± 4.43 ab |
| 'Nijisseiki' | 08.09.2010 | 39.8 ± 3.65 a | 39.6 ± 4.48 a | 39.5 ± 4.01 a |
| | 21.09.2010 | 41.4 ± 5.28 b | 35.5 ± 4.34 a | 34.7 ± 4.40 a |
| | 29.08.2011 | 47.2 ± 5.40 c | 41.3 ± 4.54 b | 36.2 ± 5.11 a |
| | 12.09.2011 | 39.4 ± 5.35 a | 38.3 ± 5.51 a | 37.5 ± 6.37 a |
| 'San Li' | 04.10.2010 | 45.9 ± 4.14 b | 38.0 ± 3.09 a | 36.4 ± 3.87 a |
| | 22.09.2011 | 51.5 ± 3.41 b | 47.0 ± 3.02 a | 45.5 ± 3.63 a |
| | 04.10.2011 | 46.8 ± 3.06 a | 44.8 ± 2.91 a | 43.5 ± 3.20 a |
| 'Shinseiki' | 08.09.2010 | 42.7 ± 4.97 a | 43.8 ± 1.82 a | 42.5 ± 3.23 a |
| | 20.09.2010 | 40.1 ± 3.49 b | 37.1 ± 3.60 b | 31.0 ± 3.33 a |
| | 09.09.2011 | 42.2 ± 6.27 b | 33.6 ± 3.85 a | 31.4 ± 3.24 a |
| | 19.09.2011 | 41.7 ± 5.31 b | 34.1 ± 5.26 a | 32.6 ± 6.14 a |

* Means followed by the same letter in the lines do not differ significantly at $p \leq 0.05$ according to Tukey's test

Table 2. Total soluble solids (%) of Asian pears at harvest and after storage for 10 weeks in regular atmosphere (means and standard deviations)

| Cultivar | Date of harvest | At harvest | After 1 day of shelf life | After 7 days of shelf life |
|---|---|---|---|---|
| 'Chojuro' | 21.09.2010 | 11.7 ± 0.40 a | 12.1 ± 0.37 a | 12.1 ± 0.49 a |
| | 29.08.2011 | 11.9 ± 0.52 a | 11.8 ± 0.60 a | 12.3 ± 0.41 a |
| | 19.09.2011 | 12.2 ± 0.82 a | 13.0 ± 0.70 a | 13.2 ± 0.67 a |
| 'Hayatama' | 08.09.2010 | 12.4 ± 0.74 a | 12.1 ± 0.64 a | 12.2 ± 1.00 a |
| | 23.08.2011 | 11.5 ± 1.09 a | 12.6 ± 1.38 a | 13.1 ± 1.27 a |
| | 29.08.2011 | 11.1 ± 0.40 a | 11.8 ± 1.03 b | 12.1 ± 0.69 b |
| 'Hosui' | 08.09.2010 | 10.1 ± 0.27 a | 10.0 ± 0.37 a | 10.7 ± 0.36 b |
| | 21.09.2010 | 10.2 ± 0.45 a | 10.5 ± 0.30 ab | 10.7 ± 0.38 b |
| | 12.09.2011 | 12.7 ± 0.72 a | 12.8 ± 0.72 a | 12.5 ± 0.50 a |
| | 19.09.2011 | 12.1 ± 0.75 a | 12.5 ± 0.78 a | 12.8 ± 0.44 a |
| 'Kosui' | 08.09.2010 | 11.8 ± 0.51 a | 11.7 ± 0.56 a | 11.8 ± 0.39 a |
| | 29.08.2011 | 12.7 ±0.83 a | 12.1 ± 0.61 a | 11.9 ± 0.61 a |
| | 05.09.2011 | 13.3 ± 1.26 a | 12.2 ± 1.00 a | 11.6 ± 0.63 a |
| 'Yuan Huang' | 09.09.2010 | 11.9 ± 0.84 a | 11.8 ± 0.55 a | 12.3 ± 0.39 a |
| | 20.09.2010 | 11.4 ± 0.34 a | 11.2 ± 0.37 a | 11.7 ± 0.63 a |
| | 29.08.2011 | 13.4 ± 0.77 a | 13.9 ± 0.82 a | 14.2 ± 0.63 a |
| 'Dżin Li' | 20.09.2010 | 9.2 ± 0.25 a | 9.2 ± 0.46 a | 8.7 ± 0.46 a |
| | 05.09.2011 | 9.2 ± 0.29 a | 9.2 ± 0.19 a | 9.4 ± 0.30 a |
| 'Er Shi Shinge' | 09.09.2010 | 9.2 ± 0.25 a | 9.1 ± 0.37 a | 9.2 ± 0.43 a |
| | 05.09.2011 | 10.6 ± 0.75 a | 11.1 ± 0.81 a | 11.4 ± 0.79 a |
| 'Er Jang Li' | 05.09.2011 | 12.0 ± 1.21 a | 13.5 ± 0.91 b | 13.5 ± 1.57 b |
| | 12.09.2011 | 13.3 ± 0.85 a | 12.7 ± 1.08 a | 12.9 ± 1.13 a |
| | 30.08.2012 | 12.1 ±0.27 a | 13.1 ± 0.53 b | 13.4 ± 0.47 b |
| | 04.09.2012 | 11.7 ± 0.23 a | 12.7 ± 0.31 b | 12.6 ± 0.35 b |
| 'Golden 20$^{th}$' | 20.09.2010 | 10.0 ± 0.56 a | 9.5 ± 0.37 a | 9.5 ± 0.56 a |
| | 05.09.2011 | 11.3 ± 0.64 a | 12.2 ± 0.50 b | 12.2 ± 0.53 b |
| 'Min Czi Li' | 20.09.2010 | 11.0 ± 0.78 a | 11.6 ± 0.57 a | 11.6 ± 0.47 a |
| | 12.09.2011 | 10.2 ± 0.33 a | 11.5 ± 0.49 b | 11.3 ± 0.33 b |
| | 22.09.2011 | 9.9 ± 0.51 a | 10.7 ± 0.40 b | 10.9 ± 0.44 b |
| 'Nijisseiki' | 08.09.2010 | 10.5 ± 0.58 a | 10.1 ± 0.53 a | 10.0 ± 0.30 a |
| | 21.09.2010 | 9.1 ± 0.62 a | 9.6 ± 0.44 ab | 10.2 ± 0.52 b |
| | 29.08.2011 | 10.0 ± 0.75 a | 10.7 ± 1.13 a | 10.9 ± 0.67 a |
| | 12.09.2011 | 9.7 ± 0.60 a | 9.6 ± 0.58 a | 9.1 ± 0.49 a |
| 'San Li' | 04.10.2010 | 11.4 ± 0.24 a | 11.2 ± 0.64 a | 11.3 ± 0.50 a |
| | 22.09.2011 | 10.7 ± 0.48 a | 11.1 ± 0.42 b | 11.1 ± 0.41 b |
| | 04.10.2011 | 11.4 ± 0.49 a | 11.6 ± 0.40 a | 11.6 ± 0.61 a |
| 'Shinseiki' | 08.09.2010 | 10.4 ± 0.33 a | 10.2 ±0.30 a | 10.7 ± 0.27 a |
| | 20.09.2010 | 12.0 ± 0.30 ab | 11.4 ± 0.37 a | 12.1 ± 0.54 b |
| | 09.09.2011 | 11.3 ± 0.55 a | 12.1 ± 0.46 b | 12.3 ± 0.33 b |
| | 19.09.2011 | 11.2 ± 0.53 a | 11.8 ± 0.71 ab | 12.3 ± 0.49 b |

* For explanation see table 1

Table 3. Titratable acidity (%) of Asian pears at harvest and after storage for 10 weeks in regular atmosphere (means and standard deviations)

| Cultivar | Date of harvest | At harvest | After 1 day of shelf life | After 7 days of shelf life |
|---|---|---|---|---|
| 'Chojuro' | 21.09.2010 | 0.193 ± 0.005 b | 0.169 ± 0.005 a | 0.173 ± 0.007 a |
| | 29.08.2011 | 0.210 ± 0.009 a | 0.197 ± 0.017 a | 0.192 ± 0.005 a |
| | 19.09.2011 | 0.189 ± 0.004 a | 0.169 ± 0.010 a | 0.174 ± 0.011 a |
| 'Hayatama' | 08.09.2010 | 0.113 ± 0.007 a | 0.114 ± 0.002 a | 0.109 ± 0.001 a |
| | 23.08.2011 | 0.132 ± 0.010 a | 0.124 ± 0.009 a | 0.130 ± 0.002 a |
| | 29.08.2011 | 0.120 ± 0.007 a | 0.117 ± 0.006 a | 0.121 ± 0.006 a |
| 'Hosui' | 08.09.2010 | 0.162 ± 0.008 b | 0.147 ± 0.005 ab | 0.140 ± 0.002 a |
| | 21.09.2010 | 0.166 ± 0.002 b | 0.141 ± 0.007 a | 0.135 ± 0.004 a |
| | 12.09.2011 | 0.179 ± 0.006 a | 0.172 ± 0.012 a | 0.160 ± 0.006 a |
| | 19.09.2011 | 0.186 ± 0.015 b | 0.153 ± 0.013 ab | 0.150 ± 0.005 a |
| 'Kosui' | 08.09.2010 | 0.108 ± 0.005 a | 0.102 ± 0.002 a | 0.114 ± 0.005 a |
| | 29.08.2011 | 0.114 ± 0.001 a | 0.136 ±.0.008 b | 0.131 ± 0.004 b |
| | 05.09.2011 | 0.125 ± 0.012 a | 0.123 ± 0.006 a | 0.124 ± 0.009 a |
| 'Yuan Huang' | 09.09.2010 | 0.211 ± 0.010 a | 0.201 ± 0.017 a | 0.195 ± 0.005 a |
| | 20.09.2010 | 0.193 ± 0.007 a | 0.179 ± 0.015 a | 0.171 ± 0.013 a |
| | 29.08.2011 | 0.230 ± 0.015 ab | 0.239 ± 0.011 b | 0.190 ± 0.013 a |
| 'Dżin Li' | 20.09.2010 | 0.262 ± 0.011 b | 0.253 ± 0.008 b | 0.214 ± 0.008 a |
| | 05.09.2011 | 0.334 ± 0.009 a | 0.331 ± 0.029 a | 0.349 ± 0.026 a |
| 'Er Shi Shinge' | 09.09.2010 | 0.271 ± 0.007 a | 0.266 ± 0.012 a | 0.275 ± 0.011 a |
| | 05.09.2011 | 0.299 ± 0.008 a | 0.304 ± 0.010 a | 0.301 ± 0.024 a |
| 'Er Jang Li' | 05.09.2011 | 0,309 ± 0.009 a | 0.298 ± 0.008 a | 0.287 ± 0.003 a |
| | 12.09.2011 | 0.313 ± 0.016 a | 0.278 ± 0.007 a | 0.286 ± 0.028 a |
| | 30.08.2012 | 0.282 ± 0.011 a | 0.281 ± 0.019 a | 0.286 ± 0.016 a |
| | 04.09.2012 | 0.248 ± 0.005 a | 0.239 ± 0.015 a | 0.246 ± 0.009 a |
| 'Golden 20$^{th}$' | 20.09.2010 | 0.287 ± 0.010 b | 0.268 ± 0.007 ab | 0.250 ± 0.005 a |
| | 05.09.2011 | 0.345 ± 0.012 a | 0.349 ± 0.025 a | 0.337 ± 0.019 a |
| 'Min Czi Li' | 20.09.2010 | 0.317 ± 0.029 a | 0.284 ± 0.025 a | 0.308 ± 0.008 a |
| | 12.09.2011 | 0.248 ± 0.025 a | 0.251 ± 0.017 a | 0.260 ± 0.019 a |
| | 22.09.2011 | 0.207 ± 0.010 a | 0.243 ± 0.008 b | 0.258 ± 0.008 b |
| 'Nijisseiki' | 08.09.2010 | 0.371 ± 0.006 b | 0.336 ± 0.009 a | 0.358 ± 0.008 ab |
| | 21.09.2010 | 0.336 ± 0.011 a | 0.312 ± 0.010 a | 0.335 ± 0.001 a |
| | 29.08.2011 | 0.386 ± 0.010 a | 0.389 ± 0.025 a | 0.370 ± 0.006 a |
| | 12.09.2011 | 0.321 ± 0.002 a | 0.274 ± 0.007 a | 0.308 ± 0.033 a |
| 'San Li' | 04.10.2010 | 0.271 ± 0.018 b | 0.235 ± 0.009 ab | 0.223 ± 0.008 a |
| | 22.09.2011 | 0.222 ± 0.007 a | 0.200 ± 0.018 a | 0.199 ± 0.021 a |
| | 04.10.2011 | 0.216 ± 0.013 a | 0.181 ± 0.014 a | 0.199 ± 0.007 a |
| 'Shinseiki' | 08.09.2010 | 0.177 ± 0.007 b | 0.144 ± 0.005 a | 0.142 ± 0.002 a |
| | 20.09.2010 | 0.166 ± 0.008 a | 0.144 ± 0.006 a | 0.147 ± 0.010 a |
| | 09.09.2011 | 0.177 ± 0.006 a | 0.167 ± 0.007 a | 0.160 ± 0.009 a |
| | 19.09.2011 | 0.165 ± 0.005 a | 0.163 ± 0.011 a | 0.164 ± 0.006 a |

* For explanation see table 1

Table 4. Overall sensory quality (10 points scale) of Asian pears after storage (means and standard deviations)

| Cultivar | Date of harvest | After 1 day of shelf life | After 7 days of shelf life |
|---|---|---|---|
| 'Chojuro' | 29.08.2011 | 4.2 ± 1.05 | 4.0 ± 1.38 |
| | 19.09.2011 | 5.8 ± 1.65 | 6.1 ± 1.28 |
| 'Hayatama' | 23.08.2011 | 4.9 ± 1.59 | 4.3 ± 1.80 |
| | 29.08.2011 | 5.2 ± 1.15 | 5.5 ± 1.23 |
| 'Hosui' | 12.09.2011 | 5.5 ± 1.14 | 5.1 ± 1.33 |
| | 19.09.2011 | 5.4 ± 1.15 | 5.6 ± 1.00 |
| 'Kosui' | 29.08.2011 | 6.5 ± 1.47 | 6.4 ± 1.39 |
| | 05.09.2011 | 6.2 ± 1.85 | 5.6 ± 1.64 |
| 'Yuan Huang' | 29.08.2011 | 6.0 ± 0.67 | 5.8 ± 1.26 |
| 'Dżin Li' | 05.09.2011 | 4.6 ± 1.09 | 2.5 ± 1.03 |
| 'Er Shi Shinge' | 05.09.2011 | 5.2 ± 1.27 | 5.1 ± 1.30 |
| 'Er Jang Li' | 05.09.2011 | 5.5 ± 1.43 | 5.8 ± 1.43 |
| | 12.09.2011 | 6.3 ± 1.38 | 5.8 ± 1.36 |
| 'Golden 20$^{th}$' | 05.09.2011 | 4.8 ± 1.37 | 4.7 ± 1.41 |
| 'Min Czi Li' | 12.09.2011 | 4.8 ± 0.55 | 4.2 ± 1.14 |
| | 22.09.2011 | 4.9 ± 0.94 | 4.8 ± 1.09 |
| 'Nijisseiki' | 29.08.2011 | 4.2 ± 1.44 | 4.3 ± 1.27 |
| | 12.09.2011 | 3.5 ± 0.89 | 3.0 ± 1.47 |
| 'San Li' | 22.09.2011 | 3.4 ± 0.89 | 3.6 ± 1.43 |
| | 04.10.2011 | 4.6 ± 1.15 | 4.5 ± 1.26 |
| 'Shinseiki' | 09.09.2011 | 4.7 ± 1.20 | 4.9 ± 0.82 |
| | 19.09.2011 | 5.9 ± 0.91 | 5.4 ± 1.07 |

For some cultivars ('Hayatama', 'Hosui', 'Nijisseiki', 'Er Jang Li', 'Golden 20$^{th}$', 'Min Czi Li', 'San Li', and 'Shinseiki'), there was a slight increase in TSS after storage (1 or 7 days of SL), but significant only for some seasons or harvest dates (Table 2). For 'Chojuro', 'Kosui', 'Yuan Huang', 'Dżin Li', and 'Er Shi Shinge' fruits, no significant differences in TSS after storage were observed. No change in soluble solids content over time of 6 months storage was also observed by Zagory (1989) for 'Early Gold' and 'Shinko' pears and by Goliáš et al. (2016) for 'Zaosuli' stored for 40 days. Itai and Tanahashi (2008) reported that in 'Gold Nijisseiki' and 'Hosui', total sugar content was maintained during storage; however, cold storage led to an accumulation of hexoses and a decrease in sucrose. An increase in TSS throughout 3 months storage was observed by Kopera et al. (2005) in 'Shinseiki', 'Hosui', and 'Chojuro' cultivars. On the other hand, Chen et al. (2010) reported a decrease in TSS after storage of 'Cuiguan' pear for 60 days at 0 °C. In 'Pathernakh', the TSS increased for up to 45–60 days and thereafter declined (Mahajan & Dhatt 2004; Mahajan et al. 2010). Chen et al. (2006) also described a similar pattern of Yali pear TSS change throughout 5 months of storage, and the results of Arzani et al. (2008) confirm this finding for 'KS'$_9$ and 'KS'$_{13}$ Asian pears. As reported by Li et al. (2011) for 'Wonhuwang' pear stored for 250 days, TSS showed a tendency of continuous increase or initial increase then decrease depending on harvest time. The increase in TSS during storage may be due to hydrolysis of starch into sugars (Garriz et al. 2008) and transpiration processes (Kopera et al. 2005). On complete hydrolysis of starch no further increase in sugars occurs.

Large difference in TA among cultivars was observed (Table 3). High TA was observed in 'Nijisseiki' (above 0.32% in all harvest dates) and low TA in 'Hayatama' and 'Kosui' (below 0.14%). Low TA (0.09%) for 'Kosui' pear was also reported by Jurick et al. (2015). After storage (1 and 7 days of SL), no significant decrease in TA was observed for 'Hayatama', 'Kosui', 'Yuan Huang', 'Er Shi Shinge', 'Er Jang Li', and 'Min Czi Li' pears. In the season 2011, 'Kosui' (first harvest) and 'Min Czi Li' (second harvest) had a little, but statistically significant, higher TA after storage (1 and 7 days of SL)

compared to harvest time. It could be due to intensive transpiration of fruits during 10 weeks of storage. No or a slight decrease (in some cases significant) in TA was observed for the other cultivars ('Chojuro', 'Hosui', 'Nijisseiki', 'Dżin Li', 'Golden 20th', 'San Li', and 'Shinseiki'). There have been numerous studies showing decreasing level of TA during storage. The reduction in TA during storage was described for 'Cuiguan' (Chen et al. 2010), 'Early Gold' and 'Shinko' (Zagory et al. 1989), 'Shinseiki', 'Hosui', 'Chojuro' (Kopera et al. 2005), and 'Pathernakh' (Mahajan & Dhatt 2004; Mahajan et al. 2010). The decrease in acidity during storage may be due to utilization of organic acids in the respiration process.

In Japanese pear, fruit storage potential depends on cultivar (Beutel 1990) and is closely related to the maximum level of ethylene production. As reported by Itai et al. (1999) and Kitamura et al. (1981), cultivars 'Kosui' and 'Chojuro' exhibit a rapid increase in ethylene production and have a low storage potential, whereas cultivar 'Nijisseiki' evolves non-detectable levels of ethylene while maintaining fruit quality for longer time. Our results (data for ethylene not shown) confirmed these findings, because they showed no significant or a little changes in FF, TSS, and TA in 'Nijisseiki' after 10 weeks of storage (1 or 7 days of SL), and a significant decrease in FF in 'Chojuro' and 'Kosui' (Tables 1–3).

Large difference among cultivars was observed for sugar-to-acid ratio (Fig. 1). A very high ratio of sugars to acids was observed in 'Hayatama' and 'Kosui' (belonging to the round shaped fruits with brown skin). A low sugar-to-acid ratio was observed especially in 'Nijisseiki', as well as 'Dżin Li', 'Er Shi Shinge', and 'Golden 20th' (round with green to yellow skin).

In sensory evaluations, Asian pears did not receive high scores for overall quality (not more than 6.5 points in 10 point scale) (Table 4). Among the tested cultivars, 'Chojuro' (second harvest), 'Hayatama' (second harvest), 'Hosui', 'Kosui', 'Yuan Huang', 'Er Shi Shinge', 'Er Jang Li', and 'Shinseiki' (second harvest) obtained highest scores after 1 day and also after 7 days of SL. Lowest scores after 1 day of SL were received by 'Nijisseiki' and 'San Li' for both harvest dates, 'Chojuro' (first harvest), and 'Dżin Li' (one harvest).

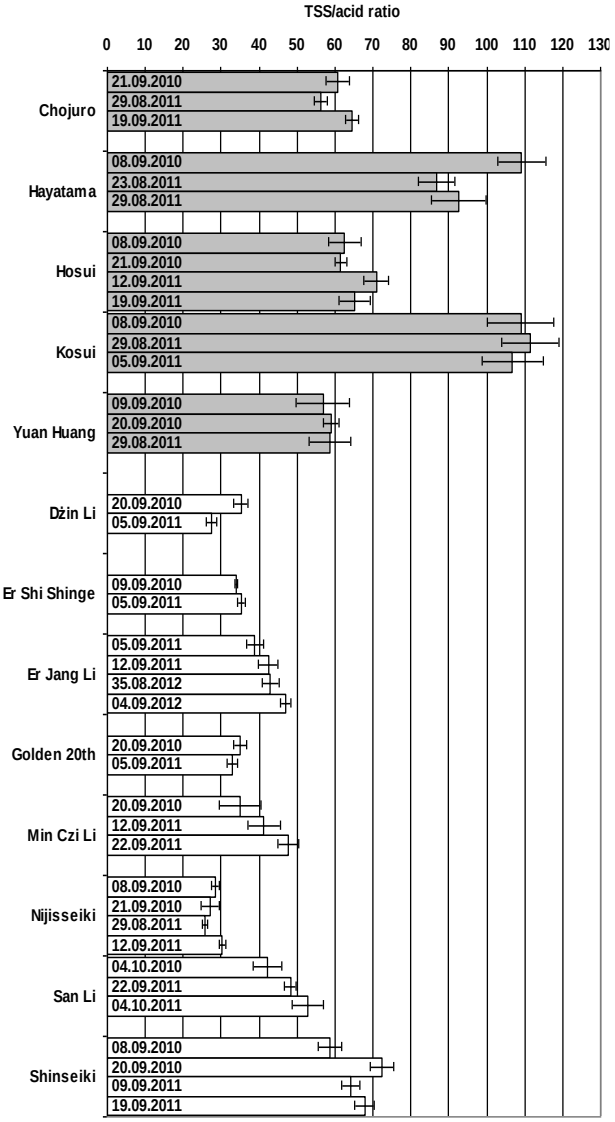


Fig. 1. TSS-to-acid ratio in Asian pears at harvest (means and standard deviations). Dark bars indicate round-shaped cultivars with brown skin.

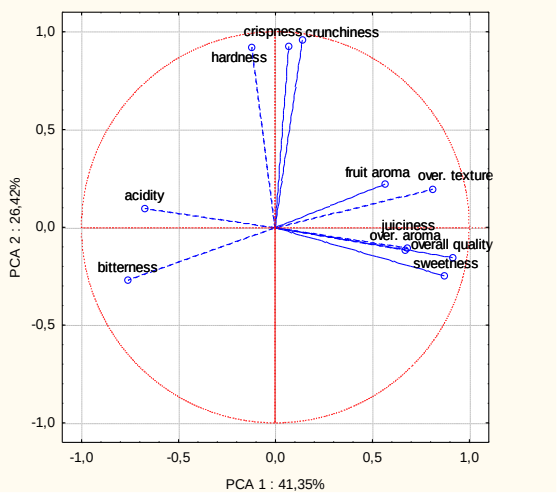


Fig. 2. PCA projection of evaluated attributes of the sensory characteristic of Asian pears

After 7 days of SL, low scores were also observed for 'Nijisseiki' (second harvest), 'Dżin Li', and 'San Li' (first harvest). PCA projection of evaluated attributes of sensory characteristic (Fig. 2) shows that overall quality was positively correlated mainly with sweetness, as well as with juiciness and aroma, and negatively correlated with acidity and bitterness. It explains the high sensory quality of cultivars characterized by high TSS and the low sensory quality of cultivars with high TA. Walsh et al. (2016) also observed that among the five Asian pear cultivars tested, fruits with a high-soluble solids content were judged to be superior.

## CONCLUSIONS

The results of our studies showed that tested cultivars of Asian pears differ in firmness, total soluble solids, acidity, sugar-to-acid ratio, and sensory evaluation. All of the evaluated cultivars can be stored up to 10 weeks at 0 °C in regular atmosphere without major negative impact on their quality characteristics. In sensory evaluation, cultivars characterized by high TSS were higher appreciated than others. High amount of TSS (in all dates of analyses) was observed in 'Chojuro', 'Hayatama', 'Kosui', 'Yuan Huang' and 'Er Jang Li'. Low TSS was observed in 'Nijisseiki', 'Dżin Li', and 'Er Shi Shinge'. Among the pears that obtained the highest scores in the sensory evaluation were all round-shaped cultivars with brown skin ('Chojuro', 'Hayatama', 'Hosui', 'Kosui', 'Yuan Huang'), and three cultivars with green to yellow skin ('Er Jang Li', 'Er Shi Shinge', and 'Shinseiki').

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