CHANGES IN FRUIT QUALITY IN PEARS DURING CA STORAGE

Anna Wawrzyńczak, Krzysztof P. Rutkowski and Dorota E. Kruczyńska

Research Institute of Pomology and Floriculture
Pomologiczna 18, 96-100 Skierniewice, POLAND
e-mail: awawrzyn@insad.pl; krutkow@insad.pl; dkruczyn@insad.pl

(Received March 6, 2006/Accepted March 25, 2006)

A B S T R A C T

In 2003/2004 and 2004/2005, fruit quality parameters were evaluated in six late-ripening pear cultivars at harvest time, after CA storage, and after simulated shelf life. The cultivars used in this study were: 'Alexander Lukas', 'Amfora', 'Delbuena', 'Delmoip', 'Erica', and 'Nojabrska'. After harvest, the pears were stored for seven months at –0.5ºC in an atmosphere containing 2% O_2 and 0.8% CO_2. After they were removed from storage, the pears were kept for four days at 18ºC to simulate shelf life. The following quality parameters were recorded: flesh firmness, total soluble solids content (TSS), titratable acidity (TA), and the TSS/TA ratio. Starch index at harvest time was also recorded. All of the cultivars tested retained a high level of internal quality after CA storage and after four days of shelf life at 18ºC. Flesh firmness, total soluble solids content, titratable acidity and the TSS/TA ratio varied greatly among the cultivars tested at harvest time, after CA storage, and after shelf life. There were no significant differences in soluble solids at harvest and after storage. In general, changes in flesh firmness, TA and TSS/TA ratio after CA storage were greatest in 'Delbuena' and least in 'Amfora'.

Key words: controlled atmosphere, cultivars, firmness, fruit quality, pears, soluble solids, storage, titratable acidity

INTRODUCTION

Storage in a controlled atmosphere (CA) is a very effective way to extend storage life and lengthen the marketing period of many different fruits.

For pears, the recommended atmosphere for CA storage contains 2.0 to 2.5% oxygen and 0.8 to 1.0% carbon dioxide (Childers, 1973; Hardenburg et al., 1986).

Pears are very sensitive to storage temperature. Rapid cooling after harvest is essential for successful long-term storage (Bower et al., 2003; Ma et

al., 2000). The optimum temperature for pear storage is between -0.5°C and -1.5°C (Hardenburg et al., 1986; Mitchell, 1992).

It is also very important to pick the pears at the right stage of ripeness to ensure high fruit quality and long storage life (Bower et al., 2003; Hardenburg et al., 1986; Ma et al., 2000).

In pears, storage life and quality retention also depend on the cultivar, growing season, and production region (Childers, 1973; Hardenburg et al., 1986; Smock, 1979).

With CA storage, pears can be stored longer while retaining higher quality and reducing losses as compared to storage in a normal atmosphere (Chen and Mellenthin, 1982; Ma and Chen, 2003).

The optimum conditions for CA storage delay ripening and senescence in many fruits. The low concentration of O_2 and the high concentration of CO_2 reduce respiration and ethylene production and retard changes in color, firmness, flavour and nutritional quality. Exposing fresh fruits to CA storage conditions slows down the loss of chlorophyll, the biosynthesis of carotenoids and anthocyanins, and the biosynthesis and oxidation of phenolic compounds. CA storage also inhibits enzymes which degrade the cell wall, reduces losses in acidity, reduces the conversion of starch to sugar, and slows down the biosynthesis of volatile compounds responsible for aroma (Kader, 2003).

In Poland, interest in pear cultivation has increased considerably over the past few years. One of the main late-ripening pear cultivars in Poland is 'Alexander Lukas'. However, little is known about how to apply CA storage to 'Alexander Lukas' and other cultivars grown in Poland.

The aim of this study was to evaluate some fruit quality parameters in six late-ripening pear cultivars at harvest, after CA storage, and after simulated shelf life. The fruit quality parameters studied were: flesh firmness, soluble solids content (TSS), titratable acidity (TA), and the TSS/TA ratio.

MATERIAL AND METHODS

The pear cultivars used in this study were: 'Alexander Lukas', 'Amfora', 'Delbuena', 'Delmoip', 'Erica', and 'Nojabrska'. Pears were collected at the experimental orchard of the Research Institute of Pomology and Floriculture, near Skierniewice, Poland. Trials were conducted for two successive seasons: 2003/2004 and 2004/2005.

Harvest date was based on flesh firmness, soluble solids content, and starch index. The harvest dates and starch indices for each cultivar are presented in Table 1.

Pears were stored for seven months at –0.5ºC in a controlled atmosphere containing 2% O_2 and 0.8% CO_2. After they were removed from storage, the pears were kept for four days at 18ºC to simulate shelf-life.

Pears of each cultivar were analyzed three times in each season: at harvest time, at the end of the storage period, and after four days of shelf-life.

Table 1. Harvest dates and starch indices

Cultivar	Season 2003/2004		Season 2004/2005	
	harvest date	starch index (scale 1-10)	harvest date	starch index (scale 1-10)
Alexander Lukas	Sept. 17	5.9	Sept. 20	7.5
Amfora	Sept. 17	5.2	Oct. 6	9.4
Delbuena	Sept. 10	1.0	Sept. 20	1.0
Delmoip	Sept. 10	6.4	Sept. 27	6.7
Erica	Sept. 17	6.7	Oct. 6	10.0
Nojabrska	Sept. 22	9.8	Oct. 4	10.0

The following quality parameters were recorded: flesh firmness, total soluble solids content (TSS), titratable acidity (TA), and the TSS/TA ratio. Starch index at harvest time was also recorded.

Flesh firmness was measured on pared surfaces on opposite sides of each fruit using an EPT-1R penetrometer with a 8-mm diameter tip.

Total soluble solids content was measured in freshly prepared juice using an Atago PR-101 electronic refractometer.

Titratable acidity was measured by titrating freshly prepared juice with 0.1 N NaOH to an endpoint of pH 8.1 using a Mettler Toledo DL21 automatic titrator. Results were recorded as the equivalent percentage of malic acid.

Starch index was determined using the standard iodine test and scored on a scale from 1 to 10, where 1 equals black and 10 equals white.

Three replicates of five fruits each were used for each analysis.

Data were statistically elaborated separately for each season using analysis of variance, followed by means separation using Duncan's multiple-range t-test at $P \leq 0.05$.

RESULTS AND DISCUSSION

In 2003/2004, flesh firmness at harvest time was highest in 'Delbuena' and lowest in 'Erica'. After seven months of CA storage, firmness decreased in all cultivars except 'Amfora'. After four days of shelf life, firmness was lowest in 'Delbuena' and 'Delmoip'. The loss of firmness during the storage period was highest in 'Delbuena' in both 2003/2004 and 2004/2005 (Tab. 2).

In 2004/2005, flesh firmness at harvest time was highest in 'Delbuena' and 'Delmoip' and lowest in 'Erica' and 'Nojabrska'. After seven months of CA storage, flesh firmness decreased in all cultivars except 'Amfora', 'Delmoip' and 'Nojabrska'. After four days of shelf life, firmness was lowest in 'Delbuena' and 'Erica' (Tab. 2).

Table 2. Flesh firmness (N) of pears at harvest, after CA storage and shelf life

Cultivar	At harvest	After storage	After shelf life
Season 2003/2004			
Alexander Lukas	56.29 gh*	43.84 c	39.72 b
Amfora	63.26 i	61.10 i	43.35 c
Delbuena	67.96 j	54.53 fg	35.60 a
Delmoip	61.98 i	48.15 de	35.80 a
Erica	51.78 ef	46.29 cd	36.29 ab
Nojabrska	59.72 hi	49.04 de	45.90 cd
Season 2004/2005			
Alexander Lukas	62.27 h	50.60 fg	41.38 cd
Amfora	61.29 h	60.02 h	49.23 efg
Delbuena	72.67 i	53.74 g	33.05 a
Delmoip	71.00 i	69.04 i	48.94 efg
Erica	50.60 fg	44.62 de	35.30 ab
Nojabrska	51.88 fg	46.88 ef	39.52 bc

*Means followed by the same letter do not differ significantly at $P \leq 0.05$ in Duncan's multiple range test (separately for each season)

After seven months of CA storage, flesh firmness in all cultivars was still high enough to prevent mechanical damage. The lowest flesh firmness recorded after seven months of CA storage was 43.8 N for 'Alexander Lukas' in 2003/2004. The lowest firmness recorded after four days of shelf life was 33.0 N for 'Delbuena' in 2004/2005 (Tab. 2).

Table 3. Total soluble solids [%] in pears at harvest, after CA storage and shelf life

Cultivar	At harvest	After storage	After shelf life
Season 2003/2004			
Alexander Lukas	12.80 ab*	13.28 abc	13.17 ab
Amfora	14.40 cd	15.40 d	14.87 d
Delbuena	13.07 ab	13.40 bc	13.57 bc
Delmoip	12.07 a	12.90 ab	12.90 ab
Erica	12.10 a	12.70 ab	13.07 ab
Nojabrska	13.72 bc	13.47 bc	12.87 ab
Season 2004/2005			
Alexander Lukas	13.47 efgh	14.10 gh	12.63 bcde
Amfora	13.63 efgh	14.53 h	13.37 defg
Delbuena	12.93 bcdef	13.73 efgh	13.87 fgh
Delmoip	13.17 cdefg	13.20 cdefg	13.27 cdefg
Erica	11.23 a	11.93 ab	12.30 abcd
Nojabrska	12.87 bcdef	12.20 abc	11.97 ab

*For explanation, see Table 2

The highest TSS content recorded was 15.4 for 'Amfora' after CA storage in 2003/2004 (Tab. 3).

In 2004/2005, the cultivar with the lowest TSS content at harvest time was 'Erica'. The cultivars with the lowest TSS content after seven months of CA storage and after four days of shelf life were 'Erica' and 'Nojabrska' (Tab. 3).

There were no significant differences between TSS content at harvest, after storage and after shelf life. This agrees well with an earlier study in which TSS content in pears at the end of six months of refrigerated air storage was the same as it was at harvest time (Błaszczyk and Łysiak, 2001). TSS content in pears also did not change during storage and ripening in other studies as well (Elgar et al., 1997; Ma and Chen, 2003). In one study, though, TSS content increased slightly after eight months of storage (Chen and Mellenthin, 1982). In our study, there was also a slight, but statistically insignificant increase in TSS during CA storage both in 2003/2004 and 2004/2005. This increase may be due to starch degradation, especially in 'Delbuena', which had a starch index of 1 at harvest time. The only cultivar to show a slight, but statistically insignificant decrease in TSS content was 'Nojabrska', which had a starch index of 10 at harvest time. It is difficult to predict the TSS content after the storage period because it also depends on transpiration and respiration, which use carbohydrates as a source of energy.

Table 4. Titratable acidity [% of malic acid] in pears at harvest, after CA storage and shelf life

Cultivar	At harvest	After storage	After shelf life
Season 2003/2004			
Alexander Lukas	0.389 i*	0.214 cd	0.209 bcd
Amfora	0.212 bcd	0.183 abc	0.174 ab
Delbuena	0.418 i	0.181 abc	0.182 abc
Delmoip	0.354 h	0.247 def	0.230 def
Erica	0.313 g	0.264 f	0.224 de
Nojabrska	0.260 ef	0.147 a	0.147 a
Season 2004/2005			
Alexander Lukas	0.486 f	0.290 bcd	0.276 bc
Amfora	0.168 a	0.197 a	0.167 a
Delbuena	0.578 g	0.340 e	0.278 bc
Delmoip	0.547 g	0.304 cde	0.306 de
Erica	0.326 de	0.281 bc	0.273 bc
Nojabrska	0.256 b	0.198 a	0.171 a

*For explanation , see Table 2

In 2003, TA at harvest time was highest in 'Delbuena' and 'Alexander Lukas', and lowest in 'Amfora' (Tab. 4). There was also a significant decrease in TA after storage, especially in 'Delbuena', 'Alexander Lucas', 'Nojabrska', and 'Delmoip'. The only cultivar in which there was no

significant difference between acidity at harvest time and after storage was 'Amfora'.

In 2004, TA at harvest time was highest in 'Delbuena' and 'Delmoip', and lowest in 'Amfora'. In 'Nojabrska', TA was low, especially after storage and shelf life in both 2003/2004 and 2004/2005.

In previous studies, TA in pears decreased during storage (Błaszczyk and Łysiak, 2001; Chen and Mellenthin, 1982; Ma and Chen, 2003). In our study, TA decreased in all cultivars except for 'Amfora'. In 'Amphora', there were no significant changes in flesh firmness, TSS content or TA over the seven months of storage, which means that this cultivar has a low rate of metabolism under CA storage conditions. There was also only a slight drop in TA during storage in 'Erica', which lost only 15.6% of its initial TA in 2003/2004, and 13.8% in 2004/2005. This agrees well with a previous study in which 'Erica' was kept in refrigerated air storage (Błaszczyk and Łysiak, 2001).

The TSS/TA ratio at harvest time was highest in 'Amfora'. In 2003/2004, the TSS/TA ratio increase during storage in all of the cultivars tested. After seven moths of CA storage, the TSS/TA ratio was highest in 'Nojabrska' and 'Amfora'. In 2004/2005, the TSS/TA ratio was highest in 'Amfora', which had essentially the same TSS/TA ratio at harvest time and after seven months of CA storage (Tab. 5).

Table 5. TSS/acid ratio in pears at harvest, after CA storage and shelf life

Cultivar	At harvest	After storage	After shelf life
Season 2003/2004			
Alexander Lukas	32.87 a*	62.00 cdef	63.25 def
Amfora	68.07 ef	86.70 gh	86.54 gh
Delbuena	31.37 a	73.95 fg	75.18 fg
Delmoip	34.07 a	52.45 cd	56.67 cde
Erica	38.65 ab	48.14 bc	58.34 cde
Nojabrska	52.76 cd	91.91 h	88.09 gh
Season 2004/2005			
Alexander Lukas	27.71 ab	48.76 de	45.81 de
Amfora	81.07 h	75.47 gh	80.19 h
Delbuena	22.49 a	40.55 cd	50.30 e
Delmoip	24.10 a	43.46 de	43.28 de
Erica	34.48 bc	42.46 cde	45.18 de
Nojabrska	50.34 e	61.88 f	70.95 g

* For explanation, see Table 2

The growing season had a large effect on flesh firmness, TSS content, TA, and the TSS/TA ratio in the cultivars tested (Tab. 2 to 5). In 2004/2005, TA was much higher in 'Delbuena', 'Delmoip' and 'Alexander Lukas' than in 2003/2004, even though the starch indices were about the same in 2003/2004 and 2004/2005.

CONCLUSIONS

'Alexander Lukas', 'Amfora', 'Delbuena', 'Delmoip', 'Erica', and 'Nojabrska' could successfully be stored for seven months at –0.5ºC in a controlled atmosphere containing 2% O_2 and 0.8% CO_2. At the end of the storage period, no physiological disorders were found. All of the cultivars tested retained a high level of internal quality after CA storage and after four days of shelf life at 18ºC. Flesh firmness, total soluble solids content, titratable acidity and TSS/TA ratio varied greatly among the cultivars tested at harvest, after CA storage, and after shelf life. In general, changes in quality parameters after CA storage were greatest in 'Delbuena' and least in 'Amfora'.

REFERENCES

Błaszczyk J., Łysiak G. 2001. Storage properties of Czech pear cultivars 'Erica' and 'Dicolor'. J. FRUIT ORNAM. PLANT RES. 9/1-4: 71-76.

Bower J.H., Biasi W.V., Mitcham E.J. 2003. Effect of ethylene in the storage environment on quality of 'Bartlett pears'. POSTHARVEST BIOL. TECHNOL. 28: 371-379.

Chen P.M., Mellenthin W.M. 1982. Storage behavior of 'd'Anjou' pears in low oxygen and air. In: D.G. Richardson, M. Meheriuk (eds), Controlled Atmosphere for Storage and Transport of Perishable Agricultural Commodities, Timber Press, Beaverton, OR, USA, pp. 139-148.

Childers N.F. 1973. Pear and quince culture. In: Modern Fruit Science, Horticultural. Somerset Press, Inc., Sommersville, New Jersey, Fifth Edition, pp. 181-205.

Elgar H.J., Watkins C.B., Murray S.H., Gunson F.A. 1997. Quality of 'Buerre Bosc' and 'Doyenne du Comice' pears in relation to harvest date and storage period. POSTHARVEST BIOL. TECHNOL. 10: 29-37.

Hardenburg R.E., Watada A.E., Wang C.Y. 1986. The commercial storage of fruits, vegetables, and florist and nursery stocks. U.S. Department of Agriculture, AGRIC. HANDBOOK 66: 47-48.

Kader A.A. 2003. Physiology of CA treated produce. ACTA HORT. 600: 349-354

Ma S.S., Chen P.M. 2003. Storage disorder and ripening behavior of ,Doyenne du Comice' pears in relation to storage conditions. POSTHARVEST BIOL. TECHNOL. 28: 281-294.

Ma S.S., Chen P.M., Mielke E.A. 2000. Storage life and ripening behaviour of 'Cascade' pears as influenced by harvest maturity and storage temperature. J. AM. POM. SOC. 54: 138-147

Mitchell G.F. 1992: Postharvest handling systems: temperate zone tree fruits (pome fruits and stone fruits) In: A.A. Kader (ed.), Postharvest Technology of Horticultural Crops., University of California, Davis, pp. 215-221

Smock R.M. 1979. Controlled atmosphere storage of fruits. HORT. REV. 1: 301-336

ZMIANY WYBRANYCH PARAMETRÓW JAKOŚCIOWYCH GRUSZEK PO PRZECHOWYWANIU W KONTROLOWANEJ ATMOSFERZE

Anna Wawrzyńczak, Krzysztof P. Rutkowski
i Dorota E. Kruczyńska

S T R E S Z C Z E N I E

Badano wpływ przechowywania późno dojrzewających odmian gruszek w warunkach kontrolowanej atmosfery na wybrane parametry wewnętrznej jakości owoców. Doświadczenia przeprowadzono w dwóch następujących po sobie sezonach przechowalniczych (2003/2004 i 2004/2005). Do badań wybrano sześć odmian: 'Lukasówka', 'Amfora', 'Delbuena', 'Delmoip', 'Erika' i 'Nojabrska'. Gruszki przechowywano przez 7 miesięcy w temperaturze –0.5ºC w warunkach kontrolowanej atmosfery (2% O_2 + 0.8% CO_2). Po wyjęciu z chłodni owoce umieszczono na cztery dni w pomieszczeniu o temperaturze 18ºC. Pomiary jędrności miąższu, zawartości ekstraktu i kwasowości oraz stosunku ekstraktu do kwasowości wykonywano bezpośrednio po zbiorze, po wyjęciu z chłodni i po okresie dojrzewania owoców. W czasie zbiorów wyznaczono również indeks skrobiowy. Owoce wszystkich badanych odmian zachowały dobrą jakość po przechowywaniu w kontrolowanej atmosferze i po dodatkowych czterech dniach w temperaturze 18ºC. Gruszki poszczególnych odmian różniły się między sobą jędrnością, zawartością ekstraktu, kwasowością i stosunkiem ekstraktu do kwasowości zarówno podczas zbioru, jak i po przechowywaniu. Nie obserwowano istotnych różnic w zawartości ekstraktu w owocach bezpośrednio po zbiorze i po przechowywaniu. Zmiany pozostałych parametrów jakościowych (jędrności miąższu, kwasowości i stosunku ekstraktu do kwasowości) po przechowywaniu w kontrolowanej atmosferze były największe u gruszek odmiany 'Delbuena', a najmniejsze u owoców 'Amfora'.

Słowa kluczowe: kontrolowana atmosfera, odmiany, jędrność, jakość owoców, gruszki, zawartość ekstraktu, przechowywanie, kwasowość miareczkowa