

Influence of harvest date and storage conditions on the content of chlorophyll pigments in pear peels

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ABSTRACT

During each season, pears were harvested on three dates at four-day intervals. The fruit was stored for 150 days in temperatures of 0-0.5°C in common cold storage (NA – normal atmosphere) and also in controlled atmospheres (CA) of different gaseous content: 0.8% CO₂ + 2% O₂, 2% CO₂ + 2% O₂ and 3% CO₂ + 3% O₂. After removing the pears from storage they were additionally stored for seven days in a temperature of 17°C – simulated shelf life. The content of chlorophyll pigments (chlorophyll a + b) was determined after each harvest date, storage time and simulated shelf life. Based on the results, I concluded that the a + b chlorophyll content in the peel of both pear cultivars significantly decreased along with the subsequent harvest date. In addition, the storage conditions had a significant influence on the studied factor. Compared to the normal atmosphere, the controlled atmosphere conditions were more efficient in slowing the yellowing of the fruit due to reduced chlorophyll degradation. The atmosphere consisting of 3% CO₂ + 3% O₂ or 2% CO₂ + 2% O₂ was more favourable for the higher content of chlorophyll a + b in the peel of 'Conference' pears than 0.8% CO₂ + 2% O₂. In the case of 'Concorde' pears, the influence of particular compositions of CA on the content of chlorophyll a + b changed over the years.

Key words: colour, controlled atmosphere, fruits, normal atmosphere, shelf life

INTRODUCTION

During the pre-harvest ripening on trees and post-harvest ripening in cold storage, there are some significant changes of peel colour, resulting from the degradation of existing pigments and the synthesis of the new ones (Górecki 1994). The chlorophyll content changes over the period of fruit development. It increases, starting at cell division, and after reaching of the maximum value (70-90 days after fertilisation) decreases until harvest (Schulz 1996). According to Zelles (1967), the maximum content of chlorophyll pigments in pears

occurs at harvest. Colour can be adequately used to evaluate fruit maturation (Voss 1992). The fruit peel colour change rate depends on climatic conditions and storage conditions (Drake 1994). Storing in a controlled atmosphere (CA) causes significantly slower degradation of chlorophyll than storing in common cold storage (Herregods 1995, Ben and Błaszczyk 2002). According to Galvis-Sanchez et al. (2003) and Ma and Chen (2003), pears stored in a low-oxygen atmosphere retain a greener peel than fruit from a common cold storage.

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The aim of the study was to determine the influence of harvesting conducted on three different dates and different storage conditions on the content of chlorophyll pigments present in the peel of 'Conference' and 'Concorde' pears.

MATERIAL AND METHODS

The study was conducted in the years 2008-2010. The subjects of the study were pears from the Experimental Orchard of the Department of Pomology and Apiculture of the Agricultural University in Garlica Murowana (Poland). During each season the pears were harvested on three dates, in four-day intervals. The first harvest of the 'Conference' pear cultivar was performed 132 days after full flowering, and 135 days for the 'Concorde' cultivar. The pears were stored for 150 days in temperatures of 0-0.5°C in a common cold storage (NA – normal atmosphere) and in a controlled atmosphere (CA), of different gas contents: 0.8% CO₂ + 2% O₂, 2% CO₂ + 2% O₂ and 3% CO₂ + 3% O₂. After the pears were removed from storage, they were matured for seven days in a temperature of 17°C (simulated shelf life). The contents of chlorophyll pigments (chlorophyll a + b) were determined after each harvest, after storage time and after simulated shelf life. Analyses were performed in three replications for each combination. A repetition consisted of five fruits. In order to do this, a hand crank drill was used to cut 20 rings of peel, 1 cm² each. The samples were pulped in mortar with 80% acetone, magnesium carbonate and ceramic sand. After filtration of the solution, the samples were supplemented with 80% acetone to a volume of 25 cm³ and kept for 30 minutes in the dark in order to stabilise the pigments. The absorbance of the colour solution was measured with a Helios Alfa spectrometer, with 663 nm for chlorophyll 'a' and 645 nm for chlorophyll 'b'

(Lichtenthaler 1987). The results in µg cm⁻² of peel were presented for chlorophyll 'a' and chlorophyll 'b' (a + b). Data were subjected to analysis of variance. The assessment of the significance of experimental factors was performed on the basis of the F-Fisher-Snedecor test. To compare means, the Tuckey test was applied with the significance level $p = 0.05$.

RESULTS AND DISCUSSION

The chlorophyll a + b contents in the peels of both pear cultivars under study depended on the harvest date (Tab. 1). In each year of the study, the peel chlorophyll a + b contents significantly decreased with the harvest date delay. Eccher Zerbini et al. (1996), Elgar et al. (1997) and Ramalho et al. (2008) also observed some significant changes of pear peel colour when harvested on different dates.

The influence of harvest time on the contents of chlorophyll a + b in the peel of pears (analysed average for storage conditions) was found to be significant after storage and after simulated shelf life (Tab. 1). In both cases and during all seasons under study, a gradual decrease of this index was observed for the delayed harvest time. The only exception to this rule were 'Concorde' pears from the first season of study, coming from the second and third harvest date – after simulated shelf life, the chlorophyll a + b contents in their peels were similar.

After taking into consideration the influence of storage conditions on the contents of chlorophyll a + b – average for the harvest time – some significant differences were observed between the particular average results, both directly after storage, and after simulated shelf life (Tab. 2). In both cases and all study seasons, the subject index always had the lowest value in pears stored in common cold storage. Higher contents of chlorophyll a + b in the peel of 'Conference' pears

Table 1. Chlorophyll a + b content on the skin (µg cm⁻²) of pears as affected by harvest date

Cultivar	Sampling time	Harvest date in 2008			Harvest date in 2009		
		I	II	III	I	II	III
Conference	At harvest	24.4 c*	21.3 b	19.6 a	27.5 c	26.2 b	23.8 a
	After 150-day storage	6.1 c	5.0 b	4.3 a	11.8 c	10.1 b	9.2 a
	After 150-day storage and 7-day shelf life	4.0 c	3.6 b	2.9 a	9.7 c	8.2 b	6.8 a
Concorde	At harvest	31.4 c	28.8 b	26.4 a	30.8 c	26.4 b	22.9 a
	After 150-day storage	9.3 c	8.3 b	7.6 a	17.6 c	14.9 b	14.1 a
	After 150-day storage and 7-day shelf life	7.9 b	7.2 a	6.8 a	14.1 c	12.8 b	12.1 a

*Means followed by the same letter within row, for each year, do not differ significantly at $p = 0.05$

Table 2. Chlorophyll a + b content on the skin ($\mu\text{g cm}^{-2}$) of pears as affected by storage conditions

Cultivar	Storage condition	2008/2009		2009/2010	
		After 150-day storage	After 150-day storage and 7-day shelf life	After 150-day storage	After 150-day storage and 7-day shelf life
Conference	Normal atmosphere	3.3 a*	2.3 a	6.0 a	4.0 a
	0.8% CO ₂ +2% O ₂	4.5 b	3.5 b	10.8 b	9.0 b
	2% CO ₂ +2% O ₂	5.9 c	4.1 c	13.2 d	10.7 c
	3% CO ₂ +3% O ₂	6.8 d	4.1 c	11.5 c	9.3 b
Concorde	Normal atmosphere	6.8 a	6.0 a	11.7 a	10.0 a
	0.8% CO ₂ +2% O ₂	8.5 b	7.3 b	16.9 c	14.0 bc
	2% CO ₂ +2% O ₂	9.0 c	7.7 b	16.4 b	14.4 c
	3% CO ₂ +3% O ₂	9.4 c	8.2 c	17.1 c	13.6 b

*Means followed by the same letter column, for each analysed date and storage season, do not differ significantly at $p = 0.05$

Table 3. Chlorophyll a + b content on the skin ($\mu\text{g cm}^{-2}$) of 'Conference' pears directly after storage as affected by harvest date and storage conditions

Storage season	Harvest date	Storage conditions			
		0.8% CO ₂ +2% O ₂	2% CO ₂ +2% O ₂	3% CO ₂ +3% O ₂	NA
2008/2009	I	5.4 b B*	6.7 c B	8.5 d B	3.7 a B
	II	4.3 a A	5.9 b B	6.0 b A	3.6 a B
	III	3.9 a A	5.1 c A	5.8 c A	2.5 a A
2009/2010	I	11.5 b B	16.1 d B	12.9 c C	6.5 a B
	II	11.0 b B	12.0 c A	11.2 b B	6.2 a B
	III	9.7 b A	11.4 c A	10.3 b A	5.4 a A

*Means followed by the same small letter within row and capital letter within column, for each storage season, do not differ significantly at $p = 0.05$; NA - Normal atmosphere

stored in CA were observed in the case of 3% CO₂ + 3% O₂ or 2% CO₂ + 2% O₂, but not in 0.8% CO₂ + 2% O₂. In the case of the 'Concorde' cultivar, the influence of particular CA combinations on the value of the described index presented some changes in particular years. It should be emphasised that the pears of both cultivars harvested in 2009 contained significantly more chlorophyll a + b in the skin than the pears of these cultivars harvested one year earlier. Such regularity was not observed at harvest only for 'Concorde' pears.

The harvest time had a significant influence on the contents of chlorophyll a + b in the peels of 'Conference' and 'Concorde' pears, together with storage conditions, but only directly after storage. 'Conference' pears harvested on the first harvest date had a significantly higher chlorophyll a + b content than fruit harvested on the third harvest date (Tab. 3). On the other hand, the lowest value of this feature was observed in pears stored in common cold storage, independent of the harvest date and study season. And similarly, the lowest value of chlorophyll a + b was observed in the peels of pears that were stored in CA 0.8% CO₂ + 2% O₂ during the first study season, and harvested on the second and third harvest date. Among the

evaluated gaseous content of CA, usually the highest contents of chlorophyll a + b in the first study season were observed in cases of fruit coming from the atmosphere consisting of 3% CO₂ + 3% O₂ or 2% CO₂ + 2% O₂, whereas during the next study season the highest value of the subject feature was observed in pears stored in CA 2% CO₂ + 2% O₂.

In the case of 'Concorde' pears, the common influence of harvest time and storage conditions on the contents of chlorophyll a + b in the peel was expressed by the fact that the value of the subject index usually decreased along with the harvest delay, regardless of the storage conditions, or by the fact that pears harvested on the earliest date had higher chlorophyll contents than those harvested on the third harvest date (Tab. 4). On the other hand, higher chlorophyll a + b content was observed in the peels of pears stored in CA than those stored in common cold storage.

During the pear ripening time, the basic colour of the peel changes from green to yellow, which is the result of chlorophyll degradation, and due to its diminishing contents some other pigments appear (Ramalho et al. 2008). Previous studies have confirmed these changes, although they are difficult to be visually determined. The rate of

Table 4. Chlorophyll a + b content on the skin ($\mu\text{g cm}^{-2}$) of 'Concorde' pears directly after storage as affected by harvest date and storage conditions

Storage season	Harvest date	Storage conditions ($\text{CO}_2:\text{O}_2$)			
		0.8:2	2:2	3:3	NA
2008/2009	I	9.6 b B*	10.1 c C	10.2 c B	7.3 a B
	II	8.2 b A	8.8 bc B	9.1 c A	7.2 a B
	III	7.6 b A	8.0 b A	8.9 c A	6.0 a A
2009/2010	I	18.8 c C	17.2 b C	19.8 d B	14.3 a C
	II	16.5 b B	16.4 b B	16.0 b A	10.8 a B
	III	15.4 b A	15.4 b A	15.5 b A	5.4 a A

*Explanations: see Table 3

changes depended on the harvest date and storage conditions both after pears were stored in cold storage and after total storage time and an additional seven days in simulated shelf life conditions. The greatest changes were observed in pears harvested at the latest date and stored in a normal atmosphere. The slowest chlorophyll degradation was usually observed in pears harvested on the first harvest date and stored in CA combinations. Both pear cultivars stored under CA conditions retained a green skin colour, unlike the pears held in cold storage. The green colour of the skin is associated with not over-ripened fruits. Yellowing of the pears from CA was observed only during the shelf life period. The results obtained confirm the opinions of many researchers, that green colour is better maintained by pears stored in controlled atmospheres than by those stored in common cold storage (Garcia and Streif 1993, Bertolini and Casadei 2000, Ben and Błaszczuk 2002, Galvis-Sanchez et al. 2003, Moggia et al. 2005). In the case of 'Conference' pears, we observed that chlorophyll degradation is more rapid in the peels of fruit stored in an atmosphere with 0.8% CO_2 when compared with an atmosphere of higher concentration of carbon dioxide (2 and 3%). So it is likely that the fruit turning yellow due to chlorophyll degradation is significantly influenced by the content of carbon dioxide and its concentration in the atmosphere. The favourable influence of CO_2 concentration in the atmosphere on increasing the retention of green colour in pears up to 3-5% has been reported by Drake (1994), Lopez et al. (2001) and Eccher Zerbini et al. (2002).

CONCLUSIONS

1. The influence of harvest time on the chlorophyll content in the peel of pears is shown by its gradual decrease during subsequent harvest dates.

2. The atmosphere consisting of 3% CO_2 + 3% O_2 or 2% CO_2 + 2% O_2 was more favourable for a higher content of chlorophyll a + b in the peel of 'Conference' pears than 0.8% CO_2 + 2% O_2 . In the case of 'Concorde' pears, the influence of particular compositions of CA on the content of chlorophyll a + b changed over the years.

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z Sadu Doświadczalnego Katedry Sadownictwa i Pszczelnictwa w Garlicy Murowanej. W każdym sezonie gruszki zbierano w trzech terminach, w odstępach 4-dniowych pomiędzy każdym. Owoce przechowywano przez 150 dni w temperaturze 0-0,5°C w chłodni zwykłej (NA – normalna atmosfera) jak również w warunkach kontrolowanej atmosfery (KA) o różnym składzie gazowym tj. 0,8% CO₂ i 2% O₂, 2% CO₂ i 2% O₂ oraz 3% CO₂ i 3% O₂. Po wyjęciu gruszek z chłodni przechowywano je jeszcze dodatkowo przez 7 dni w temperaturze 17°C – okres symulowanego obrotu. Zawartość barwników chlorofilowych (chlorofil a + b) oznaczono po każdym terminie zbioru, po okresie przechowywania oraz po symulowanym obrocie. Na podstawie uzyskanych wyników wykazano, że zawartość chlorofilu a + b w skórce gruszek obu badanych odmian zmniejszała się istotnie wraz z opóźnieniem terminu zbioru. Wyraźny był również wpływ warunków przechowywania na wartość badanego wskaźnika. Warunki kontrolowanej atmosfery w porównaniu z warunkami atmosfery normalnej skuteczniej spowalniały żółknięcie owoców wynikające z bardziej ograniczonego rozkładu chlorofilu. Wyższej zawartości chlorofilu a + b w skórce gruszek odmiany 'Konferencja' bardziej sprzyjała atmosfera zawierająca 3% CO₂ i 3% O₂ lub 2% CO₂ i 2% O₂ niż 0,8% CO₂ i 2% O₂. W przypadku odmiany 'Concorde' wpływ poszczególnych składów KA na zawartość chlorofilu a + b wykazywał pewną zmienność między latami.

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WPLYW TERMINU ZBIORU I WARUNKÓW PRZECHOWYWANIA NA ZAWARTOŚĆ BARWNIKÓW CHLOROFILOWYCH W SKÓRCIE GRUSZEK

Streszczenie: Badania prowadzono w latach 2008-2010. Materiałem były gruszki pochodzące