

Changes in Some Quality Criteria During Controlled Atmosphere (CA) Storage of Peaches

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Summary: Intensive research has been implemented on different aspects of the bee pollination of pear in Hungary in the past decade, extending to the following topics: the effect of the opening sequence of the flowers within the inflorescence of pear cultivars on the effectiveness of bee pollination; the nectar production of flowers of pear cultivars; intensity of honeybee visitation and their foraging behaviour at the flowers of pear cultivars; flower constancy of honeybees to pear plantations; competition by weeds in bloom for bee pollination in flowering pear orchards; and some aspects to the bee pollination strategies of pear plantations (the effect of the limitation of bee pollination period on the set and the yield, possible compensation of frost damage of flowers by bee pollination in pear orchards, the optimal size of single cultivar block in pear plantations). The results of these studies are reviewed in this paper and some important aspects that need further studies are outlined.

Introduction

The peaches are normally stored for a maximum of 3-4 weeks under NA conditions without any treatment, whereas this period may be doubled using different treatments and storage methods. As a matter of fact, in a study with peach cultivars Beijing, China and Tuhua, the fruits were kept at 33°, 37° and 41°C for 48 h, and as a result, it was determined that hot treatment at 37°C had positive effect on the fruits. Reductions occurred in titratable acidity contents of the treated fruits, whereas the firmness values remained relatively unchanged, thus the storage periods of the fruits were prolonged via limiting some physical changes (Tao et al. 1997).

In a study on the CA storage of Hale Haven peaches, the fruits were stored at 0°C temperature and 90-95% relative humidity, in 0:21 (control), 5:2, 10:2 and 10:4 atmospheric combinations. It was determined in the study that the quality factors and maturity situations might be preserved between acceptable limits, in case that Hale Haven fruits were held at room conditions for 4 days, in addition to storage for 30 days in 5:2 or 10:2 atmospheric combinations (Eris et al. 1993).

The atmosphere combinations of 5:1 and 5:4 were determined as the most successful treatments at the end of the storage trials with peaches at different atmosphere combinations (5%CO₂:1, 4, 7, 20% O₂). The sugar content of the fruits stored in these combinations was found to be lower, whereas titratable acidity and fruit flesh firmness values were higher. However, it was determined that 5:1

atmosphere combination and 22°C temperature application for 2 days lead to less internal browning, hence better fruit quality (El-Shiekh 1992).

Various researches were carried out with peaches, in order to minimize the postharvest losses caused by the pathogens such as *Monilinia* & *Rhizopus*. With this purpose, the fruits were dipped into Benomyl solution (100 and 500 ppm) at 46° and 51°C for 1.5 and 3.0 minute, and the quality of fruits was preserved along the storage period. Moreover, more successful results with regard to fruit quality were obtained when these treatments were combined with 5:1 atmospheric combination (Wang & Anderson 1985).

CA storage, especially ultra-low O₂, has numerous advantages compared with NA storage. As a matter of fact, the losses in FFF, TA, chlorophyll and sugar were decreased in many fruits and vegetables via this storage method. In this way, the onset of ripening and the retardation of senescence in the fruits were realised more efficiently (Sass 1993, Tian et al. 1996, Henze et al. 1997).

In this study, which was carried out with the aim of improving the limited storability of peach fruits, prolonging their storage period and establishing new applications that could be put into practice, the effects of some treatments on the storage period and fruit quality of peaches were investigated.

Material and methods

"Flavorcrest" and "Red Top" peach cultivars were used in the study, as being suitable for Marmara Region.

The fruits were harvested at firm-ripe stage, close to the harvest maturity.

The initial analyses of the fruits were realised before storage and the fruits other than controls were held at 20 °C for 5 hours, then dipped into the solution containing Benomyl (60 g/100 l) and Captan (300 g/100 l) at 52 °C for 1 minute.

The fruits were left for drying at room conditions, following the removal from fungicide solution, and then precooled by cold air. The fruits to be stored in CA were subjected to low O₂ treatment at 0±0.5°C and 90±5% relative humidity, before transfer to different atmospheric combinations. With this aim, the fruits were held in 0.7% O₂

for 24 hours. Thereafter, they were put into storage (0±0.5°C temperature and 90±5% relative humidity) in different atmospheric combinations [(CO₂%:O₂%) 0:21 (control), 3:3, 5:2 and 10:2].

Hot treatment at 20°C was applied to all fruits except controls for 24 hours, in the analytical periods of 15th and 30th day, in addition to the analyses [weight loss (%), firmness of fruit flesh (FFF) (kg), total sugar (g/100 g), titratable acidity (TA) (%), total chlorophyll (mg/100 g) and product decay situation] the fruits were kept in CA storage on the 0, 15th, 30th, 45th and 45+10th days.

The research was established according to Randomized Plots Factorial Experimental Design. The analyses were

Table 1 Changes in weight loss, firmness of fruit flesh and total sugar during the CA storage of peach cvs.

Cv.	Stor. period (day)	Treatments.	Weight loss (%)			Firmness of fruit flesh (kg)			Total sugar (g/100 g)		
			1996	1997	1998	1996	1997	1998	1996	1997	1998
F L	0	0:21	0.00 g	0.00 h	0.00 f	6.25 abc	8.15 ab	9.92 b	5.69 g-k	3.50 hy	5.61 l
		3:3	0.00 g	0.00 h	0.00 f	6.25 abc	8.15 ab	9.92 b	5.69 g-k	3.50 hy	5.61 l
		5:2	0.00 g	0.00 h	0.00 f	6.25 abc	8.15 ab	9.92 b	5.69 g-k	3.50 hy	5.61 l
		10:2	0.00 g	0.00 h	0.00 f	6.25 abc	8.15 ab	9.92 b	5.69 g-k	3.50 hy	5.61 l
A V O R C	15	0:21	5.75 efg	7.34 cde	7.70 a-f	4.42 cde	6.79 cde	4.64 d-l	5.84 g-k	5.60 c-f	7.10 f-l
		3:3	2.39 g	1.87 gh	0.61 def	3.46 d-g	7.96 abc	7.36 b-g	4.98 jk	4.80 e-h	6.36 y-l
		5:2	2.06 g	2.23 gh	0.24 ef	3.20 d-h	8.15 ab	10.19 a	7.93 c-f	2.27 y	5.91 kl
		10:2	1.76 g	2.02 gh	0.31 ef	4.67 bcd	6.79 ab	8.22 b-c	5.91 g-k	4.00 ghy	6.32 y-l
R E S T	30	0:21	11.32 c-f	4.99 ef	11.06 a	4.30 e-f	6.57 def	3.96 g-m	8.59 b-e	7.50 abc	7.97 d-j
		3:3	3.18 fg	0.27 h	1.53 e-f	1.85 f-k	7.25 bcd	4.76 d-k	7.21 e-h	5.50 c-h	7.20 f-l
		5:2	3.31 fg	0.24 h	2.01 b-f	1.63 g-k	7.25 bcd	5.55 d-y	9.23abc	4.50 fgh	6.33 y-l
		10:2	2.88 fg	0.58 h	1.54 e-f	1.81 g-k	6.11d-h	8.15 b-f	9.38abc	4.37 f-l	6.74 h-l
S T	45	0:21	13.01 b-e	10.96 ab	6.03 a-f	2.74 d-j	3.62 kl	1.58 y-n	10.11 ab	8.21 ab	9.70bcd
		3:3	1.62 g	0.96 h	8.13 a-f	0.45 jk	2.94 l	1.00 k-n	9.94 ab	5.83 c-g	8.56 c-h
		5:2	1.07 g	0.64 h	7.93 a-f	1.58 g-k	5.32 g-j	3.17 h-n	4.40 k	5.00 d-h	6.54 y-l
		10:2	2.34 g	1.10 h	6.45 a-f	0.70 yjk	5.17 hyj	2.72 y-n	5.65 h-k	5.27 d-h	7.79 e-k
R E D T O P	0	0:21	0.00 g	0.00 h	0.00 f	7.70 a	9.06 a	8.72 bc	7.84 e-f	6.47 b-f	6.18 jkl
		3:3	0.00 g	0.00 h	0.00 f	7.70 a	9.06 a	8.72 bc	7.84 e-f	6.47 b-f	6.18 jkl
		5:2	0.00 g	0.00 h	0.00 f	7.70 a	9.06 a	8.72 bc	7.84 e-f	6.47 b-f	6.18 jkl
		10:2	0.00 g	0.00 h	0.00 f	7.70 a	9.06 a	8.72 bc	7.84 e-f	6.47 b-f	6.18 jkl
E D T O P	15	0:21	6.20 efg	5.91 ef	5.34 a-f	6.91 ab	7.25 bcd	8.38 bed	7.41 d-g	6.00 c-g	8.02 d-j
		3:3	2.69 fg	1.39 h	0.99 def	2.22 d-k	6.37 d-g	5.78 c-y	5.69 g-k	5.00 d-h	7.28 f-l
		5:2	1.87 g	1.35 h	0.25 ef	3.14 d-l	6.34 d-h	8.15 b-g	6.50 f-j	4.50 fgh	6.83 g-l
		10:2	2.09 g	1.10 h	0.98 def	2.57 d-k	7.85 bc	6.95 b-h	6.76 f-y	4.00 ghy	7.25 f-l
T O P	30	0:21	15.90bcd	4.28 fg	7.11 a-f	3.10 d-l	6.27d-h	4.76 d-l	7.66 e-f	6.30 b-f	8.89 b-f
		3:3	4.53 efg	0.28 h	1.90 b-f	1.29 g-k	5.44 f-y	4.08 f-n	6.93 e-h	5.50 c-h	8.12 d-y
		5:2	3.92 fg	0.21 h	1.84 b-f	1.58 g-k	6.11d-h	4.91 d-k	7.99 e-f	5.00 d-h	7.25 f-l
		10:2	3.29 fg	0.25 h	1.86 b-f	1.99 e-k	7.25 bcd	4.33 e-n	9.91 ab	4.50 fgh	7.66 e-k
T O P	45	0:21	15.28bcd	9.41 abc	9.26 abc	1.13 g-k	6.00 e-h	1.36 j-n	10.30 a	6.71 b-e	10.44 abc
		3:3	4.08 fg	0.58 h	5.24 a-f	0.81 h-k	4.14 jk	1.70 y-n	9.08 a-d	5.68 c-g	8.71 c-g
		5:2	1.29 g	0.84 h	3.73 a-f	0.93 h-k	4.30 yjk	3.44 h-n	10.42 a	5.54 c-h	7.20 e-l
		10:2	1.20 g	0.35 h	4.95 a-f	1.11 g-k	4.76 yjk	1.81 y-n	6.48 f-j	4.73 e-h	7.69 e-k
T O P	45+10	0:21	18.90 abc	9.37 abc	11.08 a	0.45 jk	0.41 m	0.29 n	10.80 ab	7.00bcd	11.60 a
		3:3	26.46 a	8.77 bcd	6.15 a-f	0.45 jk	0.91 m	0.34 n	7.01 e-h	6.21 b-f	9.38 b-e
		5:2	11.27 c-f	6.27 def	5.36 a-f	1.02 g-k	1.20 m	1.11 k-n	6.59 f-j	5.42 c-h	7.87 d-j
		10:2	15.12bcd	6.47 def	5.77 a-f	0.47 jk	1.04 m	0.50 mn	6.96 e-h	6.00 c-g	8.46 d-h

made in 2 replicates for each trial, having 3 fruits in each replicate. All data obtained from the trial were evaluated using LSD test at 0.01 level.

Results and discussion

The basic results of the investigations during 3 years are shown in *Table 1* and 2.

According to the gained results the following sensitive and meaning points have been determined. In the study, the weight loss which was 10–12% initially in 0:21 treatment in the two peach cultivars was reduced by 2–3% in CA applications, principally in 5:2 atmospheric combination, at

the end of the CA storage period of 45 days at $0\pm 0.5^{\circ}\text{C}$ temperature and $90\pm 5\%$ relative humidity conditions (*Table 1*). This result is originated from the fact that in the fruits held in low O_2 initially, the water loss was reduced due to low temperature and high humidity and the fruit preserved this level in different atmospheric combinations during the storage period. At the end of 10 days-shelf life, the weight losses increased in all CA treatments, principally in 0:21 treatment due to high temperature and low relative humidity. However, this increase was smaller in CA stored fruits. *Eriss* et al. (1993) also stated that the highest weight loss in CA storage of peaches occurred in 0:21 treatment with 13.24%.

Table 2 Changes in titratable acidity, total chlorophyll I and product decay situation during the CA storage of peach cvs.

Cv.	Stor. period (day)	Treatments.	Titratable acidity (%)			Total chlorophyll I (mg/100 g)			Product decay situation*		
			1996	1997	1998	1996	1997	1998	1996	1997	1998
F L A V O R C R E S T	0	0:21	0.80 a	1.08 bed	0.91 ab	0.92 a	1.17 a	1.09 a	0.00	0.00	0.00
		3:3	0.80 a	1.08 bed	0.91 ab	0.92 a	1.17 a	1.09 a	0.00	0.00	0.00
		5:2	0.80 a	1.08 bed	0.91 ab	0.92 a	1.17 a	1.09 a	0.00	0.00	0.00
		10:2	0.80 a	1.08 bd	0.91 ab	0.92 a	1.17 a	1.09 a	0.00	0.00	0.00
	15	0:21	0.54 a	1.09 bed	0.49 cde	0.50 d	0.57 c	1.04 abc	0.00	1.50	1.00
		3:3	0.52 a	1.06 bed	0.49 cde	0.60 cd	0.59 c	1.03 a-d	0.00	0.00	0.00
		5:2	0.64 a	0.96 bcde	0.62 b-e	0.54 d	0.58 c	1.05 ab	0.00	0.00	0.00
		10:2	0.63 a	0.90 b-f	0.55 cde	0.75 abc	0.58 c	1.06 ab	0.00	0.00	0.00
	30	0:21	0.49 a	0.92 b-f	0.47 cde	0.75 abc	0.56 c	0.89 b-g	3.00	2.50	1.25
		3:3	0.42 a	0.84 b-f	0.47 cde	0.53 d	0.67 bc	0.97 a-e	1.00	1.50	1.00
		5:2	0.50 a	0.63 b-f	0.55 cde	0.64 cd	0.60 e	1.03 a-d	2.00	1.50	1.00
		10:2	0.57 a	0.77 b-f	0.49 cde	0.53 d	0.67 bc	1.02 a-d	2.00	3.00	1.33
45	0:21	0.30 a	0.84 b-f	0.44 cde	0.53 d	0.56 c	0.64 j-m	4.25	2.67	2.67	
	3:3	0.38 a	0.78 b-f	0.44 cde	0.50 d	0.56 c	0.92 a-g	3.50	3.80	1.83	
	5:2	0.43 a	0.60 b-f	0.51 cde	0.60 cd	0.61 e	0.96 a-f	2.33	3.50	1.50	
	10:2	0.52 a	0.75 b-f	0.46 cde	0.50 d	0.61 e	0.97 a-e	2.33	2.33	2.33	
45+10	0:21	0.21 a	0.30 c-f	0.40 e	0.50 d	0.50 c	0.46 mn	4.67	4.67	4.17	
	3:3	0.31 a	0.40 c-f	0.40 e	0.50 d	0.50 c	0.74 g-k	4.67	4.50	3.66	
	5:2	0.25 a	0.50 b-f	0.55 cde	0.53 d	0.56 c	0.76 g-k	3.33	3.33	2.33	
	10:2	0.42 a	0.35 c-f	0.42 de	0.50 d	0.50 c	0.67 y-l	4.67	4.50	2.33	
R E D T O P	0	0:21	0.87 a	1.28 b	0.95 a	0.83 ab	1.03 ab	0.97 a-e	0.00	0.00	0.00
		3:3	0.87 a	1.28 b	0.95 a	0.83 ab	1.03 ab	0.97 a-e	0.00	0.00	0.00
		5:2	0.87 a	1.28 b	0.95 a	0.83 ab	1.03 ab	0.97 a-e	0.00	0.00	0.00
		10:2	0.87 a	1.28 b	0.95 a	0.83 ab	1.03 ab	0.97 a-e	0.00	0.00	0.00
	15	0:21	0.85 a	1.04 bed	0.71 a-e	0.50 d	0.53 c	0.99 a-e	0.00	1.50	0.00
		3:3	0.54 a	1.50 a	0.75 abc	0.67 bcd	0.71 bc	0.97 a-e	0.00	1.00	0.00
		5:2	0.68 a	1.15 bc	0.73 a-d	0.50 d	0.75 bc	1.00 a-e	0.00	0.00	0.00
		10:2	0.77 a	1.10 bcd	0.74 abc	0.61 cd	0.65 bc	1.00 a-e	0.00	0.00	0.00
	30	0:21	0.45 a	1.05 bed	0.64 a-e	0.54 d	0.52 c	0.78 f-j	3.25	3.50	1.25
		3:3	0.41 a	0.81 b-f	0.69 a-e	0.53 d	0.74 bc	0.86 c-h	1.25	1.00	1.00
		5:2	0.52 a	0.94 b-f	0.70 a-e	0.58 cd	0.75 bc	0.92 a-g	2.00	1.80	1.50
		10:2	0.61 a	0.99 b-e	0.68 a-e	0.50 d	0.60 e	0.91 a-g	2.00	2.00	1.25
45	0:21	0.40 a	0.84 b-f	0.55 cde	0.60 cd	0.53 c	0.50 lmn	4.33	3.67	2.00	
	3:3	0.36 a	0.75 b-f	0.59 cde	0.50 d	0.64 c	0.85 d-y	2.75	3.00	1.50	
	5:2	0.45 a	0.63 b-f	0.63 b-e	0.54 d	0.50 e	0.85 d-y	1.33	2.00	1.00	
	10:2	0.48 a	0.52 b-f	0.59 cde	0.50 d	0.67 bc	0.83 e-y	2.33	3.33	2.16	
45+10	0:21	0.27 a	0.10 f	0.45 cde	0.50 d	0.50 c	0.38 n	4.67	4.33	4.00	
	3:3	0.30 a	0.23 def	0.50 cde	0.50 d	0.50 c	0.54 lmn	4.33	3.50	2.83	
	5:2	0.35 a	0.35 c-f	0.57 cde	0.55 d	0.58 c	0.68 h-l	2.00	2.00	1.66	
	10:2	0.32 a	0.15 ef	0.52 cde	0.50 d	0.58 c	0.58 klm	3.50	3.17	2.16	

*) 0:(0 mm), 1:(0–4 mm), 2:(5–10 mm), 3:(11–17 mm), 4:(18–25 mm), 5:(>25 mm).

It was determined that deductions occurred in the firmness values of peach fruits, in relation to the prolonging storage and shelf life periods, and the greatest reduction was in 0:21 application, again (*Table 1*). Despite the softening in CA stored fruits of both cultivars, especially becoming more marked after shelf life, higher FFF values were determined in 5:2 treatment, compared with 0:21 treatment. *Ke et al.* (1991) reported that 5:1 atmospheric combination retarded softening in peach fruits, the greatest softening was determined in control according to the result of their research.

The total sugar content of peach fruits were determined to increase continuously during 45 days CA storage and 10 days shelf life periods. This increase which was observed in total sugar contents of these fruits having minute quantities of starch mainly resulted from the conversion of polysaccharides in the cell walls to sugar. In our study, the increases in the total sugar values of the peach fruits were limited through their CA storage, thus their ripening was delayed (*Table 1*). These changes occurred in the total sugar contents of peaches during their CA storage and these were similar to the results of the studies conducted by *Erit et al.* (1993) and *El-Shiekh* (1992).

Certain reductions were observed in the TA values of peaches due to their CA storage. According to the experimental results, 0:21 treatment was determined to have the lowest and 5:2 application was determined to have the highest TA values (*Table 2*). This situation is parallel to the changes occurred in TA values during CA storage of peaches, determined by *Ke et al.* (1991) and *El-Shiekh* (1992).

Reductions occurred in the total chlorophyll contents of peaches stored in CA at $0\pm 0.5^{\circ}\text{C}$ and $90\pm 5\%$ relative humidity and in different atmospheric combinations, parallel to ripening. These reductions were especially more visible in 0:21 treatment after the shelf life. Contrarily, the fruits stored in atmospheric combinations with high CO_2 levels had the total chlorophyll contents closest to the initial values (*Table 2*). *Nanos and Mitchell* (1991) reported that the atmosphere combination consisting of 5–15% CO_2 and 1–5% O_2 retarded the chlorophyll loss.

The decay ratios of fruits increased more slowly in CA stored peach cvs. "Flavorcrest" and "Red Top", compared with 0:21 treatment. A marked superiority was obtained with respect to quality criteria such as decay in CA treatments, compared with control fruits. This may be originated from hot fungicide solution and hot treatments applied to fruits. This effect became more pronounced with the involvement of different atmospheric combinations (*Table 2*). Similar

results to our study were obtained with respect to product decay ratios of fruits in numerous studies on CA storage of peaches. Disorders in terms of internal browning, wooliness and fruit flesh reddening were determined especially in 0:21 treatments, at the end of storage and shelf life, in the studies on CA storage of peaches (*Ke et al.* 1991, *El-Shiekh* 1992).

As a result, the limited storage period of peaches may be prolonged through different applications, retaining the quality. As a matter of fact, the storage period of peaches which is maximum 3–4 weeks under NA conditions may be doubled in CA conditions. Moreover, changes in the quality criteria of peach cultivars stored in CA could be kept between certain limits through combining the above treatments with CA conditions. In this way, both "Flavorcrest" and "Red Top" peach cultivars could keep their quality during 10 days shelf life in addition to 45 days storage period.

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