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Postharvest Heat Treatments for Enhanced Fruit Quality during Storage of Early Ripening European Pear

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Summary

Fruits of 'Akca', an early ripening European pear (*Pyrus communis* L.) cultivar, were exposed to 38 °C for 24 h, 48 h and 72 h immediately after harvest, and subsequently they were stored at 0±1 °C and 85–90 % RH conditions for one month. During two harvesting seasons, after removing from the storage, they were placed at ambient conditions for determination of the shelf life. Fruit quality analysis, such as free sugars and organic acids, flesh firmness, fruit skin colour, weight loss, fruit taste, and flesh browning were performed at fifteen-day-intervals during the cold storage and at the end of the shelf life after the cold storage. All quality parameters with the exception of flesh browning and weight loss decreased during the storage and the shelf life period. Heat treatments did not affect sugar composition of the fruits. However, fruits heated for 48 h and 72 h had higher organic acid content, and no flesh browning at the end of the shelf life in contrast to controls and heated fruits for 24 h. In addition, the shelf life period of these fruits were prolonged at least five fold. Loss of flesh firmness was retarded especially in 72 h heated fruits.

Key words. European pear fruit – heat treatments – storage – quality

Introduction

The present trend to limit the use of chemicals in agriculture has prompted new approaches for providing alternative methods to keep postharvest quality of horticultural commodities. Postharvest heat treatment is one of the methods that appear promising as a means of reducing fungal decay and improving insect disinfestations and disease control during postharvest storage. Otherwise, this method is highly useful to alleviate physiological disorders and to maintain fruit quality during storage of freshly harvested horticultural crops (Maxie et al. 1974; Kerbel et al. 1985; Klein and Lurie 1992; Lurie and Klein 1992; Klein et al. 1995; Lay-Lee et al. 1997; Lurie 1998; Luna-Guzman et al. 1999).

The onset of climacteric fruit ripening is characterized by an exponential increase in ethylene production, increase in respiration, softening in flesh tissue, changes in fruit colour, flavour and aroma (Abeles 1973). Exposing fruit to high temperatures such as 35–40 °C (Yu et al. 1980; Klein 1989) attenuates some of these processes while enhancing others. There are a lot of researches, which showed, that heat-treated fruit gain more advanced characteristics in some ripening properties and thereby maintain their quality for a longer period during the shelf life at 20 °C compared to non-heated fruit (Liu 1978; Lurie 1998; Paull and Chen 2000). Lurie and Klein (1990) reported that holding of 'Anna' apples, a non-storing early summer cultivar, at 38 °C for 4 days reversibly inhibited protein synthesis, ethylene production, fruit softening and ripening. Maxie et al. (1974) found that exposing of 'Bartlett' pears to 40 °C delayed ripening and ethylene production.

Early ripening pear cultivars that are especially for the fresh market trade tend to overripen quickly. They are subject to internal breakdown and their quality is ephemeral (Bell et al. 1996). 'Akca', which is an early ripening pear cultivar in the summer season (the end of June) is widely cultivated in Turkey. Since fruits of this cultivar have very limited storage life of about one month, it will be very beneficial to prolong the market period of the fruits with suitable postharvest techniques. The present study examines the effects of different heating periods at 38 °C on some quality attributes, the storage and the shelf life of 'Akca' pear fruits.

Material and Methods

Fruit material

This research was carried out on 'Akca' pear (*Pyrus communis* L.) cultivar grafted on Quince A rootstock. Fruits were harvested at the end of June, the commercial harvest time in Ankara.

Heat treatments and storage

The fruits were heated at 38±1 °C and 90–95 % RH conditions for 24 h, 48 h and 72 h after harvesting and they

Table 1. The effects of heat treatments on sugar composition and sorbitol content.

Year	Treatment	Analysis time			
		0. day	15. day	30. day	End of the shelf life after storage
		Sucrose content (g 100 ml^{-1})			
First	Control	1.4 ± 0.6**	0.9 ± 0.0 a*	0.6 ± 0.1 a	1.9 ± 0.4**
	24 h	0.6 ± 0.2	0.5 ± 0.1 c	0.3 ± 0.1 c	0.9 ± 0.1
	48 h	0.8 ± 0.1	0.7 ± 0.0 b	0.5 ± 0.1 b	1.4 ± 0.1
	72 h	0.6 ± 0.4	0.6 ± 0.0 b	0.3 ± 0.1 c	1.6 ± 0.5
	LSD		0.1	0.1	
Second	Control	0.9 ± 0.1**	1.0 ± 0.1**	0.5 ± 0.1**	0.3 ± 0.1 b
	24 h	1.6 ± 0.2	1.2 ± 0.1	0.3 ± 0.1	0.5 ± 0.1 b
	48 h	1.6 ± 0.1	1.1 ± 0.2	0.3 ± 0.1	2.0 ± 0.2 a
	72 h	1.3 ± 0.5	0.9 ± 0.1	0.4 ± 0.1	1.8 ± 0.1 a
	LSD				0.4 0.4
		Glucose content (g 100 ml^{-1})			
First	Control	1.6 ± 0.1**	1.8 ± 0.0 b	2.2 ± 0.1 a	1.8 ± 0.4**
	24 h	2.2 ± 0.1	1.6 ± 0.0 b	1.4 ± 0.1 d	2.0 ± 0.3
	48 h	2.3 ± 0.2	2.4 ± 0.0 a	1.9 ± 0.1 c	2.6 ± 0.1
	72 h	2.2 ± 0.5	2.3 ± 0.1 a	1.6 ± 0.1 b	2.5 ± 0.3
	LSD		0.3	0.2	
Second	Control	1.8 ± 0.1**	1.8 ± 0.1 b	1.5 ± 0.1**	0.3 ± 0.1 c
	24 h	2.0 ± 0.2	1.4 ± 0.1 b	1.2 ± 0.1	1.4 ± 0.1 b
	48 h	3.0 ± 0.1	2.5 ± 0.3 a	1.5 ± 0.1	2.0 ± 0.2 a
	72 h	1.7 ± 0.6	1.7 ± 0.1 b	1.2 ± 0.2	2.2 ± 0.3 a
	LSD		0.5		0.6
		Fructose content (g 100 ml^{-1})			
First	Control	5.1 ± 0.4**	7.0 ± 0.0**	7.8 ± 0.1 a	6.3 ± 0.2 bc
	24 h	6.2 ± 0.0	7.3 ± 0.0	6.5 ± 0.1 d	5.9 ± 0.6 a
	48 h	6.0 ± 0.2	6.9 ± 0.4	6.7 ± 0.1 c	7.5 ± 0.1 ab
	72 h	6.1 ± 1.2	7.5 ± 0.1	6.9 ± 0.1 b	7.7 ± 0.2 a
	LSD			0.2	1.2
Second	Control	5.2 ± 0.4**	6.1 ± 0.5**	6.4 ± 0.1**	4.8 ± 0.8**
	24 h	5.4 ± 0.3	6.6 ± 0.1	6.3 ± 0.5	5.6 ± 0.1
	48 h	5.5 ± 0.1	6.6 ± 0.4	7.2 ± 0.5	6.3 ± 0.4
	72 h	4.8 ± 1.2	6.4 ± 0.7	7.1 ± 0.2	6.3 ± 0.2
		Sorbitol content (g 100 ml^{-1})			
First	Control	3.3 ± 0.4 a	2.4 ± 0.2**	2.0 ± 0.1**	1.4 ± 0.3 b
	24 h	3.1 ± 0.3 a	2.7 ± 0.2	1.9 ± 0.1	1.5 ± 0.1 b
	48 h	3.2 ± 0.1 a	2.2 ± 0.1	1.9 ± 0.1	1.7 ± 0.1 b
	72 h	2.1 ± 0.3 b	2.3 ± 0.1	1.7 ± 0.1	2.3 ± 0.1 a
	LSD	0.5			0.6
Second	Control	4.2 ± 0.2 a	4.3 ± 0.2**	2.5 ± 0.4**	0.7 ± 0.1 b
	24 h	3.8 ± 0.3 a	4.3 ± 0.4	2.8 ± 0.2	1.0 ± 0.2 b
	48 h	3.5 ± 0.2 ab	3.7 ± 0.4	3.4 ± 0.2	2.6 ± 0.2 a
	72 h	2.6 ± 0.4 b	3.2 ± 0.2	3.6 ± 0.2	2.6 ± 0.1 a
	LSD	1.0			0.5

*Letters show differences among treatments at p≤0.05 error level, **: not significant

were subsequently transferred to the cold storage at 0±1 °C and 85–90 % RH. Controls were stored without heating. To determine the poststorage shelf life, fruits were kept at 20 °C after the end of the cold storage for one month. The end of the shelf life was determined based on the sensory evaluation, appearance of the fruits and flesh firmness values.

Fruit quality analysis

The effect of the heat treatments on fruit quality was investigated in 10 fruits with three replicates. Fruit quality analyses were done at 0, 15th and 30th day of the cold storage period and at the end of the shelf life after cold storage for two harvesting seasons.

Analysis of sugars was isocratically performed on fruit juices extracted from ten fruits for each replication. Fruit juices, filtered by 0.2 μm Millipore filters, were injected to high pressure liquid chromatograph (Bio Rad, Model 2800) connected with a refractive index detector (Bio Rad, Model 1755). Aminex column (Bio Rad, HPX-87C) and double deionise ultra pure water (pH= 6–7) were used to separate individual sugars and sorbitol. Column temperature and mobile phase flow rate were 85 °C at 0.6 ml min^{-1}, respectively (Anonymous 1995).

After eliminating phenolic compounds by filtering of the fruit juice through C_{18} cartridge (Waters Sep Pak WAT 051910), organic acids were isocratically determined with high pressure liquid chromatograph fitted with aminex column (Bio Rad, HPX-87H) at 35 °C and UV/Vis detector (Bio Rad, UV 1806). The concentration of 0.008 N H_2SO_4 was used as the mobile phase at 0.6 ml min^{-1} flow rate (Anonymous 1995). The amounts of the different sugar and organic acids were individually calculated based on standards.

Fruit flesh firmness was measured with an Effegi penetrometer with a 7.8 mm plunger. Measurements were done at two different sites on the equatorial regions of the fruits. The fruit flesh firmness was read in kg and then converted to Newton (N) (Blankenship et al. 1997).

Fruit skin colour was determined at three different sides on the equatorial regions of the fruits with a Minolta CR-200 Chromo Meter (Minolta Camera Co., Osaka, Japan) in CIE L* a* b* system and then converted to hue angle values (McGuire 1992).

Weight loss was calculated considering the initial weight of the fruits. Ten panellists evaluated the taste of the fruits based on 1 (very bad) and 5 (very good) points for sweetness, firmness and aroma (Zerbini et al. 1993). Flesh browning was graded between 0 (non-browned) to 10 (completely browned) by observation after cutting of the fruits longitudinally.

Experimental design and statistical analysis

The statistical design of this research was a completely randomised experimental design and data were analysed by means of one-way ANOVA in Minitab statistical software (MINITAB Inc. 814-238-3280 WS 112102553) at P=0.05 error level based on the differences among treatments in each analysis time. Significant differences were determined by Duncan Multiple Range test ($p \leq 0.05$) in MSTAT-C statistical software and marked with letters.

Results and Discussion

Sucrose, glucose, fructose and sorbitol composition

Sucrose content in the fruits generally tended to decrease during cold storage period for both years (Table 1). However, the effect of heat treatments on sucrose content was dissimilar for both years. Significant differences among the heat-treated fruits were observed at the 15th and 30th day of the cold storage in the first year but the changes were observed at the end of the shelf life after the cold storage in the second year ($p \leq 0.05$). In the first year, the control fruits had significantly higher sucrose content at the day 15 (0.9 g 100 ml^{-1}) and 30 (0.6 g 100 ml^{-1}) during the cold storage compared to the heated fruits. The heat treatments for 48 h and 72 h caused higher sucrose content of 2.0 g 100 ml^{-1} and 1.8 g 100 ml^{-1} at the end of the shelf life in the second year, respectively (Table 1).

Glucose content of the fruits showed fluctuations in all analysis times for both years (Table 1). In the first year, the highest glucose content was determined as 2.4 g 100 ml^{-1} and 2.3 g 100 ml^{-1} in 48 h and 72 h heated fruits at the 15th day of the cold storage, and as 2.2 g 100 ml^{-1} in controls at the 30th day of the cold storage ($p \leq 0.05$). The fruits heated for 48 h and 72 h had higher glucose content as 2.6 g 100 ml^{-1} and 2.5 g 100 ml^{-1} at the end of the shelf life in the first year. But these values were not significantly different from the others. In the second year, the highest glucose content was determined in 48 h heated fruits as 2.5 g 100 ml^{-1} at the 15th day of the cold storage ($p \leq 0.05$). In addition, 48 h and 72 h heated fruits had considerably higher glucose content at the end of the shelf life ($p \leq 0.05$) (Table 1).

Fructose content of the 'Akca' pear fruits showed unstable changes during storage period and at the end of the shelf life (Table 1). But differences in fructose amount among treatments were significant only for the last two analysis times in the first year ($p \leq 0.05$). For both years, the fruits heated for 48 h and 72 h had higher fructose content at the end of the shelf life.

Significant differences for the sorbitol content, were attractive for the beginning of the cold storage and the end of the shelf life in both years ($p \leq 0.05$) (Table 1). At the beginning of the cold storage, 72 h heat treatment stimulated decline in sorbitol content and fruits heated for 72 h had lower sorbitol amount of 2.1 g 100 ml^{-1} in the first year and 2.6 g 100 ml^{-1} in the second year ($p \leq 0.05$). However, at the end of the shelf life, this fruits had higher sorbitol content than the others in both years ($p \leq 0.05$).

In pome fruits, carbohydrates are transported to developing fruits as sorbitol, which is converted mainly to fructose and starch with some glucose and sucrose (Berüter 1985). In the later stages of fruit growth and ripening, starch hydrolysis usually begins and free sugars increase (Berüter 1985; Knee et al. 1989). By the progressing of ripening, sucrose is slowly hydrolysed to form more glucose and fructose. This might be an evidence for the fluctuations in the individual sugars during the cold storage in the current study. We could not observe significant effects of heat treatments on free sugars in 'Akca' pear fruits however heat treatments of 48 h and 72 h seem to delay loss of free sugars during shelf life. But Klein et al. (1990) reported that neutral sugar residues were similar in both heated and con-

Table 2. The effects of heat treatments on organic acid content.

Year	Treatment	Analysis time			
		0. day	15. day	30. day	End of the shelf life after storage
		Citric acid content (mg 100 ml^{-1})			
First	Control	51.5 ± 2.9 a*	1.2 ± 0.2 b	0.1 ± 0.1 c	0.0 **
	24 h	20.4 ± 9.3 b	0.5 ± 0.2 b	0.0 c	0.0
	48 h	13.0 ± 2.9 b	8.1 ± 0.3 a	3.0 ± 0.4 b	0.8 ± 0.8
	72 h	9.7 ± 4.4 b	8.3 ± 1.0 a	3.9 ± 0.4 a	0.4 ± 0.4
	LSD	10.5	1.7	0.9	
Second	Control	37.9 ± 3.3 a	1.6 ± 0.4 b	0.0 b	0.0**
	24 h	24.3 ± 6.4 b	0.7 ± 0.2 b	0.0 b	0.0
	48 h	8.8 ± 0.9 c	8.2 ± 0.8 a	3.7 ± 0.5 a	0.4 ± 0.4
	72 h	8.0 ± 0.8 c	8.8 ± 1.1 a	3.9 ± 1.2 a	0.0
	LSD	11.8	2.2	2.0	
		Malic acid content (mg 100 ml^{-1})			
First	Control	293.5 ± 11.8 a	138.1 ± 12.6 b	84.3 ± 6.5 b	24.8 ± 5.9 c
	24 h	237.2 ± 9.0 b	126.9 ± 3.2 b	46.8 ± 0.7 c	16.6 ± 1.9 c
	48 h	223.2 ± 5.7 b	191.9 ± 2.2 a	112.3 ± 7.1 a	67.4 ± 2.2 a
	72 h	232.7 ± 6.4 b	179.3 ± 8.6 a	104.1 ± 6.6 a	50.3 ± 3.3 b
	LSD	27.9	25.7	19.0	12.1
Second	Control	263.7 ± 4.6 a	137.2 ± 13.0 b	76.4 ± 7.7 b	13.2 ± 0.9 b
	24 h	177.6 ± 2.8 c	113.1 ± 10.1 b	60.3 ± 8.0 b	8.3 ± 0.4 b
	48 h	216.2 ± 3.8 b	200.3 ± 2.5 a	136.6 ± 6.0 a	53.1 ± 6.0 a
	72 h	214.9 ± 5.5 b	193.1 ± 2.7 a	117.6 ± 15.3 a	49.2 ± 4.9 a
	LSD	13.9	27.5	32.3	12.7
		Succunic acid content (mg 100 ml^{-1})			
First	Control	149.2 ± 1.8 a	97.4 ± 1.2**	34.8 ± 3.4 b	0.0
	24 h	110.8 ± 6.6 b	93.0 ± 1.9	25.1 ± 1.8 c	0.0
	48 h	124.4 ± 4.3 b	81.7 ± 1.9	50.7 ± 2.1 a	0.0
	72 h	126.4 ± 6.1 b	85.0 ± 9.3	42.3 ± 2.1 b	0.0
	LSD	16.4		7.9 7.9	
Second	Control	145.7 ± 8.8 a	99.1 ± 1.8**	34.7 ± 4.5**	0.0 b
	24 h	113.3 ± 3.6 b	95.8 ± 1.6	31.0 ± 5.7	0.0 b
	48 h	129.4 ± 4.8 ab	85.5 ± 13.5	51.0 ± 2.9	13.3 ± 2.1 a
	72 h	135.8 ± 5.2 a	76.2 ± 8.0	35.9 ± 5.1	10.3 ± 1.6 a
	LSD	19.5			4.2

*Letters show differences among treatments at p≤0.05 error level, **: not significant

trol fruits of 'Golden Delicious' apple. There are some data on heat treatments. They caused sweeter fruits in apples (Klein and Lurie 1992; Lurie and Nussinovitch 1996) and in pears (Spotts and Chen 1987) but they did not affect soluble solid concentration in apples (Liu 1978; Porrit and Lidster 1978; Klein and Lurie 1990).

Organic acid composition

In this study, the amount of individual organic acids in the fruits declined in all treatments during cold storage for both years (Table 2). Since organic acids are major substrates used in respiration, either titratable acidity or individual organic acids tend to decrease during the ripening of a pear fruit having climacteric respiratory pattern (Drake and Eisele 1999; Ma and Chen 2003). Lurie and Klein (1990) reported that there might be a connection between enhanced respiration and decrease in acidity in apples. In this study, the respiration rate was not measured. But the lower organic acid level in heated fruits than the controls at the beginning of the cold storage (p≤0.05) might be due to of the increase in respira-

Table 3. The effects of heat treatments on other quality parameters.

Year	Treatment	Analysis time			
		0. day	15. day	30. day	End of the shelf life after storage
		Flesh firmness (Newton)			
First	Control	39.5 ± 1.1 a*	30.1 ± 1.0 a	0.0 b	0.0 b
	24 h	35.9 ± 0.6 a	10.8 ± 2.0 d	0.0 b	0.0 b
	48 h	36.2 ± 1.7 a	17.0 ± 0.7 c	0.0 b	0.0 b
	72 h	30.0 ± 3.2 b	21.5 ± 0.6 b	11.1 ± 1.2 a	6.4 ± 1.2 a
	LSD	3.5 3.5	3.8 3.8	1.9	2.0
Second	Control	40.1 ± 2.0 a	30.7 ± 2.6 **	0.0 b	0.0 b
	24 h	34.9 ± 1.7 b	30.4 ± 1.5	0.0 b	0.0 b
	48 h	33.9 ± 0.9 b	32.6 ± 0.3	0.0 b	0.0 b
	72 h	33.3 ± 0.6 b	31.3 ± 0.6	21.5 ± 2.0 a	10.8 ± 1.5 a
	LSD	4.6		3.2	2.4
		Fruit colour (hue, °)			
First	Control	110.3 ± 0.5**	108.4 ± 0.5**	99.7 ± 0.7**	96.1 ± 1.1 c
	24 h	110.1 ± 0.2	106.2 ± 1.1	99.6 ± 1.4	98.7 ± 0.1 b
	48 h	110.3 ± 0.4	108.2 ± 0.5	93.3 ± 1.9	100.0 ± 0.1 ab
	72 h	109.0 ± 2.9	109.0 ± 0.2	95.7 ± 2.5	101.2 ± 0.6 a
	LSD				2.1 2.1
Second	Control	109.5 ± 0.6**	105.8 ± 2.2**	99.1 ± 0.5 b	96.9 ± 0.7 c
	24 h	110.2 ± 0.8	105.2 ± 0.9	98.8 ± 0.3 b	98.6 ± 0.2 b
	48 h	110.9 ± 0.5	107.4 ± 0.3	103.8 ± 0.7 a	101.8 ± 0.7 a
	72 h	111.4 ± 0.3	107.2 ± 0.5	104.4 ± 0.3 a	102.3 ± 0.4 a
	LSD			1.5	1.7
		Weight loss (%)			
First	Control	–	0.3 ± 0.1 a	1.1 ± 0.1 a	1.4 ± 0.1 a
	24 h	–	0.3 ± 0.1 a	1.1 ± 0.1 a	1.3 ± 0.1 a
	48 h	–	0.1 ± 0.1 b	0.5 ± 0.1 b	0.6 ± 0.1 b
	72 h	–	0.1 ± 0.1 b	0.4 ± 0.1 b	0.5 ± 0.1 b
	LSD		0.8	0.6	0.5
Second	Control	–	0.3 ± 0.1**	1.2 ± 0.0 a	1.4 ± 0.1 a
	24 h	–	0.2 ± 0.1	0.6 ± 0.1 a	1.0 ± 0.1 b
	48 h	–	0.1 ± 0.1	0.2 ± 0.1 b	0.4 ± 0.1 c
	72 h	–	0.1 ± 0.1	0.3 ± 0.1 b	0.5 ± 0.1 c
	LSD			0.7	0.6

*Letters show differences among treatments at p≤0.05 error level, **: not significant

tion during the heat treatments. Similar results have been found for the apples that had acceleration in the respiration rate for the first or second day with temperatures of 35–40 °C (Lurie and Klein 1990, 1991). However, this effect was irreversible. The respiration was lower and acidity was higher in the heated fruits when transferred to the ambient temperatures after heat treatments (Klein and Lurie 1990). In the current study, the fruits heated for 48 h and 72 h had higher citric and malic acid levels at the end of the storage period and after the shelf life than the others in both years (p≤0.05). The lower organic acid contents in the fruits heated for 24 h (p≤0.05) might be an indicator of insufficiency of the heating period and also of the stimulating effect of this period on ripening. Generally, fruits heated for 48 h had higher organic acid content than the others with the exception of succinic acid content only in the first year (p≤0.05). Previous studies showed that the effect of the heat treatments on titratable acidity based on temperature and duration (Paull and Chen 2000) and that the heat treatments caused lower acidity content (Liu 1978; Spotts and Chen 1987; Lurie and Nussinovitch 1996).

Table 4. The effects of heat treatments on taste and flesh browning

Year	Treatment	Analysis time			
		0. day	15. day	30. day	End of the shelf life after storage
		Taste (1–5 points)			
First	Control	5.0 ± 0.00 a*	3.9 ± 0.1 a	3.1 ± 0.1 bc	2.8 ± 0.1 b
	24 h	4.3 ± 0.04 b	3.6 ± 0.1 b	3.7 ± 0.3 c	2.7 ± 0.1 b
	48 h	4.6 ± 0.01 b	4.0 ± 0.1 a	3.8 ± 0.1 a	3.3 ± 0.1 a
	72 h	3.4 ± 0.03 c	3.8 ± 0.1 a	3.4 ± 0.1 b	3.5 ± 0.1 a
	LSD	0.3	0.7	0.9	0.7
Second	Control	5.0 ± 0.0 a	3.8 ± 0.1**	1.7 ± 0.1 ab	0.7 ± 0.1 b
	24 h	4.1 ± 0.1 b	3.7 ± 0.0	0.8 ± 0.1 b	0.4 ± 0.1 b
	48 h	4.0 ± 0.1 b	3.9 ± 0.1	3.5 ± 0.1 a	3.5 ± 0.1 a
	72 h	4.1 ± 0.1 b	3.8 ± 0.1	3.5 ± 0.1 a	3.5 ± 0.1 a
	LSD	0.6		0.9	1.1
		Flesh browning (0–10 points)			
First	Control	0.0	0.0	0.0	8.0 ± 0.0 a
	24 h	0.0	0.0	0.0	7.0 ± 0.0 b
	48 h	0.0	0.0	0.0	0.0 c
	72 h	0.0	0.0	0.0	0.0 c
	LSD	0.0	0.0		1.0
Second	Control	0.0	0.0	5.0 ± 0.0 a	9.0 ± 0.0 a
	24 h	0.0	0.0	4.0 ± 0.0 b	9.0 ± 0.0 a
	48 h	0.0	0.0	0.0 c	0.0 b
	72 h	0.0	0.0	0.0 c	0.0 b
	LSD			1.0	1.0

*Letters show differences among treatments at p≤0.05 error level, **: not significant

Other quality parameters

Flesh firmness of the 'Akca' pear fruits rapidly decreased during the storage period (Table 3). It is well known that the flesh firmness declines during ripening of the pear fruit (Elgar et al. 1997) as a result of increase in soluble pectin fraction (Murayama et al. 2002). At the beginning of the cold storage, controls were firmer but at the end of the cold storage and the end of the shelf life, the fruits heated for 72 h were significantly firmer than the others in both years (p≤0.05) (Table 3). Similar results have been reported in pear (Maxie et al. 1974; Spotts and Chen 1987) and also in apple (Porritt and Lidster 1978; Klein and Lurie 1990; Klein et al. 1990; Sams et al. 1993; Conway et al. 1994; Lurie and Nussinovitch 1996). The main reason is the inhibition of cell wall hydrolytic enzyme synthesis such as polygalacturonase (Yoshida et al. 1984; Lazan et al. 1989) and α- and β-galactosidase (Sozzi et al. 1996), by the heat treatments at 38 or 40 °C.

Fruit colour values declined during the storage period. The values were between 110.26 to 108.95 ° and 111.39 to 109.52 ° in the first and the second year, respectively (Table 3). Reduction in hue values shows the changing in fruit colour from green to yellow, in the other terms, the chlorophyll degradation in the fruit skin (McGuire 1992). In this study, heat treatments for 48 h and 72 h had positive effects to retard chlorophyll loss and caused more greenish fruits especially at the end of the storage and the shelf life period (p≤0.05). The positive effects of heat treatments on skin colour were also observed in pears after 7th day of the shelf life in the study of Downs et al. (1989).

Weight loss gradually increased during the cold storage period and the shelf life after the cold storage in all fruits for both years (Table 3). The highest value of the weight loss was determined in the controls as 1.4 %for both years, respectively. The fruits heated for 48 h and 72 h were more resistant to the weight loss (p≤0.05). This might be due to alteration in lipid metabolism and subsequently water permeability of the skin by the heat treatments (Roy et al. 1994; Whitaker et al. 1997).

Though fruit taste decreased during the storage and the shelf life period in all fruits for both years. But the heat treatments of 48 h and 72 h offered much sweeter and the most preferable fruits at the end of the shelf life (p≤0.05) (Table 4).

The effect of heat treatments on flesh browning was dissimilar based on the years. As seen in Table 4 and Fig. 1, the flesh browning firstly occurred in the controls and in fruits heated for 24 h at the end of the shelf life in

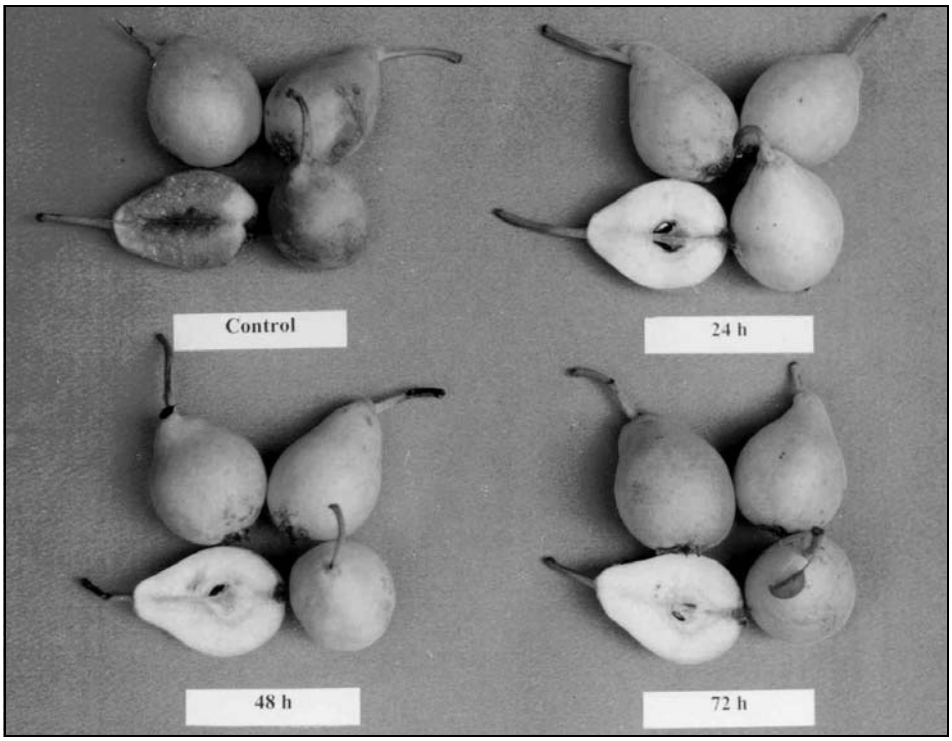


Fig. 1. The general appearance of the fruits at the end of the shelf life after cold storage.

the first year and at the end of the storage in the second year. The inhibitory effects of the heat treatments especially for 48 h and 72 h on flesh browning were observed. Similarly, heat treatment for 72 h caused the longest shelf life after cold storage of one month with 5.7 and 6.0 days, in the first and the second year, respectively. It was followed by the heat treatment for 48 h (4.7 and 5.3 days), control (2.7 and 2.3 days) and at last heat treatment for 24 h (1.3 and 1.0 days).

As a result of this study, the beneficial effects of heat treatments at 38 °C for 48 h and 72 h on the fruit quality were determined. The storage and also the shelf life period of the fruits of the early ripening pear cultivar 'Akca' were prolonged at least five fold with these treatments in comparison to the controls and 24 h heat-treated fruits. In addition, flesh browning was completely prevented. Our results suggest that the heat treatments at 38 °C for 48 h and 72 h will help to maintain fruit quality by retarding the ripening as well as the loss of firmness and flesh browning during ripening, to keep quality attributes such as organic acids, colour and fruit taste which are also important for commercial practice.

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