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Shelf-life of fresh-cut pears processed after harvest and storage in controlled atmosphere

UDC: 634.13 : 664.8.035

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Summary

The aim of this work was to investigate the effect of condition of raw material and different agents on shelf-life of fresh-cut pears *Packham's Triumph* variety. Treatments were obtained with pear fruits after harvest and after six months of controlled atmosphere storage. Colour and texture measurements, as well as visual evaluation of untreated and samples treated with different agents, during sixteen days of storage at 4 °C, were carried out. Fresh-cut pear slices were dipped for 2 minutes in water solution of hydrogen peroxide (HP), potassium sorbate (PS), ascorbic acid (AA), calcium ascorbate (CaA), sodium hexametaphosphate (SHMP), calcium chloride (CaC), and combinations of AA with SHMP (2 % AA + 1 % SHMP, 2 % AA + 2 % SHMP, 3 % AA + 1 % SHMP, 3 % AA + 2 % SHMP) and calcium chloride (2 % AA + 0.2 % CaC, 3 % AA + 0.2 % CaC). The shelf-life of fresh-cut pears (prepared from pears after harvest) could be prolonged, depending on treatment, on about 12 to 16 days (the best treatment was 2 % AA + 0.2 % CaC). Shelf-life of samples, prepared from fruit stored in controlled atmosphere for 6 months was approximately 8 days, except for samples treated with 1 % calcium ascorbate (12 days). Addition of calcium (calcium ascorbate) significantly prevented tissue breakdown of samples during storage at 2 °C. Quality of minimally processed fruits depends on fruit (raw material) quality during prolonged storage.

Keywords: pears, colour, texture, shelf-life

Introduction

The beneficial effect of controlled atmosphere storage (CA) for whole fruits has been well documented and is widely employed throughout food industry. CA storage of fruits and vegetables not only increases the shelf-life of these products and maintains good quality but also allows a consistent year-round supply in the marketplace.

Pear is a popular and commercially important fruit served as a fresh-cut item. With CA storage pears can be stored longer while retaining higher quality and reducing losses as compared to storage in a normal atmosphere (Kader, 1992; Ma and Chen, 2003). The effect of such storage of intact fruits on the subsequent shelf-life of the fresh-cut fruit is not well known (McLellan et al., 1990; Gorny et al., 2000; 2002).

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Gorny et al. (2000) determined that, compared to air storage, CA (2 % O_2 + 98 % N_2) storage at -1 °C of whole mature-green pears extended shelf-life of slices by 1 to 2 days. A significant reduction in shelf-life of slices from pears stored at -1 °C in air and CA, compared to slices from freshly harvested pears was observed. Therefore, it seems beneficial to use CA for off-season pears (as opposed to air-stored) to maximize post-cutting life of slices. Browning is a particular problem in fruit with white flesh such as pear. Chemical dips (such as ascorbic acid, calcium salts and other compounds) have been shown to be effective in retarding browning and softening of fruits such as apple, pear, etc. (Piližota and Sapers, 2004; Oms-Oliu et al., 2010).
The aim of this work was to investigate the effect of different agents on shelf-life of fresh-cut pears *Packham's Triumph* variety immediately after harvest and after 6 months of CA storage. Colour and texture measurements, as well as visual evaluation of untreated and samples treated with different agents, during 16 days of storage at 2 °C, were carried out.

Materials and Methods

Packham's Triumph pears were obtained from a commercial orchard in Slavonia County (Croatia). Pear fruit firmness was measured on pared surfaces on opposite sides of fruit using a fruit pressure tester (McCormick, USA) with an 8 mm diameter tip. Pears selected for treatment had flesh firmness within the range of 58 - 75 N.
After harvest, pears were submitted to pre-cooling in air at 1 °C for 2 weeks before applying CA containing of 2 % O_2 and 1 % CO_2 at 2 °C. After 6 months of CA storage pears were kept for 1 week in air at 2 °C. Chemical analyses were obtained with pear fruits after harvest and after 6 months of CA storage. Total dry matter was obtained by vacuum drying previously prepared pear puree, at 70 °C until constant weight was achieved. Soluble solids were determined at 20 °C by means of a refractometer (Carl Zeiss, Germany). The pH was measured by using a pH meter (Mettler Toledo, Switzerland). Total acidity was measured by titration with 0.1 N NaOH, based on malic acid (AOAC, 1980). The titration AOAC method, using 2,6-dichlorophenol indophenol solution, was used to measure ascorbic acid. Reducing and total sugars were determined by Luff-Schoorl method (AOAC, 1980). Pectic compounds were determined by Carré-Haynes method (Carré and Haynes, 1922). Total phenol content was determined using the Folin-Ciocalteu colorimetric method described by Ough and Amerine (Ough and Amerine, 1988). Antioxidant activity was determined by DPPH assay (Arnao et al., 2001).

Fresh-cut processing

Pears were held at room temperature for ca 1 hr before fresh-cut processing. The pears were sanitized by immersion for 2 minutes in 1000 mg/L Cl_2 solution (total Cl_2 calculated from level of added sodium hypochlorite, adjusted to pH 6.5

with citric acid) and rinsed with tap water before fresh-cut processing. Cutting of pears were performed manually with a knives, into 8 wedges. To minimize browning during sample preparation, the wedges from individual pears were immersed in browning inhibitor solution immediately after cutting, removed with a plastic colander, and pooled until sufficient wedges were accumulated according to the experimental design (each sample containing the wedges from 5 pears). Pear wedges were gently dried by rolling on four layers of absorbent tissue to remove excess liquid from the surface.
Fresh-cut pear wedges were dipped for 2 minutes in water solution of hydrogen peroxide (HP), calcium chloride (CaC), ascorbic acid (AA, Kemika, Croatia), calcium ascorbate (CaA), potassium sorbate (PS, Merck, Germany), sodium hexametaphosphate (SHMP, Fluka, Switzerland), and combinations of AA with SHMP (2 % AA + 1 % SHMP, 2 % AA + 2 % SHMP, 3 % AA + 1 % SHMP, 3 % AA + 2 % SHMP) and CaC (2 % AA + 0.2 % CaC, 3 % AA + 0.2 % CaC). Immediately following treatment (or dipping in water) and dewatering, sets of 8 wedges were stored in plastic bags. Samples were stored at 2 °C for up to 16 days.
The colour of pear wedges was evaluated with a Minolta CR-300 tristimulus chromameter (Minolta Camera Co., Japan) using the standard white reflector plate. Results were expressed as L*, a*, and b*, C* and h° values immediately after treatments (0 time), and during storage on day 1, 4, 8, 12 and 16 using the averaging mode with 30 replications. Total colour difference (ΔE) from the control sample (untreated and water treated sample), was used to describe the colour change, immediately after treatment and during storage, by the following equation:

$$\Delta E = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}.$$

Visual observations of sample appearance (colour, visible structural integrity and general visual appeal) were made by three of the investigators at day 1, 4, 8, 12 and 16.
Firmness of fresh-cut pear wedges was measured on 0, 1, 4, 8, 12 and 16 day using a texture analyser (TA.XT 2, Stable Micro Systems, UK) fitted with a 2 mm diameter probe. The penetration depth was 5 mm and the cross-head speed was 1.5 mm s^{-1}. Ten pieces per replicate were performed for texture measurements.

Results and Discussion

In Table 1, composition parameters and pH of *Packham's Triumph* pear are given. Analyses were performed immediately after harvest and after 6 months of CA storage. Fresh pears had slightly lower values of total dry matter, soluble solids and sugars. Total acidity, content of ascorbic acid and total phenolics, pectic compounds and antioxidant activity of fresh pears was higher compared to pears from CA storage, especially content of ascorbic acid. Results of composition parameters are in accordance with the investigations of other authors (Moya-León et al., 2006).

Table 1. Composition parameters and pH of *Packham's Triumph* pear after harvest and after 6 months of CA storage

Parameter	After harvest	After CA storage
Total dry matter (%)	18.91	20.27
Soluble solids (%)	16.30	18.30
pH	4.04	4.40
Total acidity (%)	0.22	0.17
Ascorbic acid (mg/100 g)	36.36	0.41
Total phenol content (g/L)	1.11	1.06
Pectic compounds (%)	0.82	0.73
Total sugars (%)	10.47	12.30
Reducing sugars (%)	10.00	11.47
Antioxidant activity (mgGAE/100 g)	18.49	5.14

Colour assesment

Colour was recorded using CIE L*a*b* uniform colour space, where L* indicates lightness, a* indicates chromacity on a green (-) to red (+) axis, b* chromacity on a blue (-) to yellow (+) axis, and using L*C*h° colour scale (C* - chroma, intensity of colour, h° - hue angle, actual colour). Sapers and Douglas (1987) reported that enzymatic browning at the cut surfaces of apples could be monitored by measuring changes in reflectance L* and a* values, and that b* values seemed to be unrelated to the extent of browning, which is in agreement with our results.
Since L* is a measure of the colour in the light-dark axis, decreased values indicated that the samples turned darker (data not shown). Fig. 1 and 2 showed that a* parameter tended to increase during storage of both type of fresh-cut pears (fresh-cut pears after harvest, and fresh-cut pears stored for 6 months in CA before preparation of samples). Initial samples (0 day) showed negative a* values in all samples (the smallest values were -4.00 and -3.48 for the samples treated with 2 % and 3 % AA, respectively). After 8 days of storage, a* value increased in all samples and the highest increase was observed in a control samples (around 4.20).
The rate of lightness decrease may be divided into two periods. In the first period, lasting until the 4^{th} day of storage of fresh-cut pears, processed immediately after harvest, the browning (decrease in L* and h° values, and increase of a* value) increased sharply, which could be attributed to the consumption of substrates by polyphenoloxidase (PPO). In the case of pears processed after 6 months of CA storage, sharp decrease in L* and h° values, and increase of a* value was recorded after 1^{st} day of storage. In the second period browning was much slower. The second period for fresh-cut pears, processed immediately after harvest, was observed between 4^{th} and 8^{th} day of storage, and for fresh-cut pears processed after CA storage, between 1^{st} and 4^{th} day of storage.

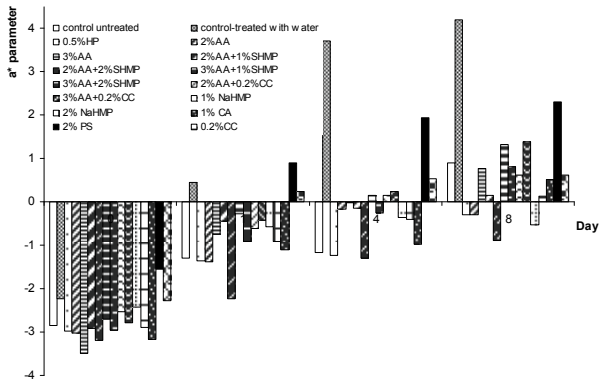

Fig. 1. Effect of different agents and formulations on a* parameter of colour of *Packham's Triumph* pear wedges during 8 day storage at 2 °C (processed after harvest)

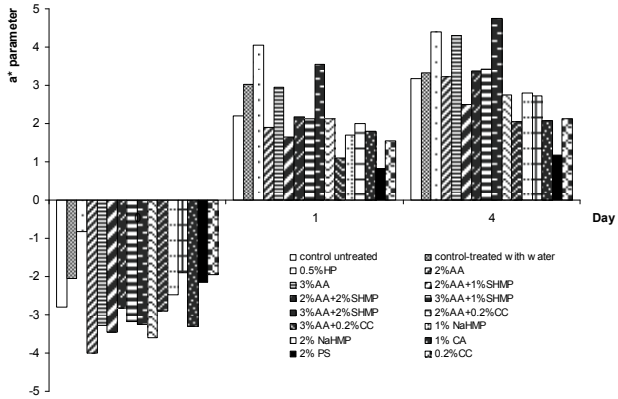

Fig. 2. Effect of different agents and formulations on a* parameter of colour of *Packham's Triumph* pear wedges during 4 day storage at 2 °C (processed after CA storage)

One of the best parameters for describing the colour variation is the colour difference (ΔE). Table 2 shows the variation of this parameter depending on treatment, during storage of fresh-cut samples at 2 °C.

Δ Ec_u-colour difference was calculated from L*, a* and b* values of sample for the same day in comparison to control sample (untreated) and Δ Ec_w-colour difference was calculated according to control sample (treated with water).

The smallest total colour change (ΔE) had samples treated with 2 % AA + 0.2 % CaC, samples treated with 3 % AA + 2 % SHMP, samples treated with 1 % CaA, etc. Nevertheless, ΔE value was very close to 1 in many cases, which imply almost non-perceptible changes in fresh-cut samples.

Combinations of 2 % AA or 3 % AA and also, 1 % CaA applied as a dip successfully reduced pear wedge surface browning, extending the shelf-life of product. Treatments with browning inhibitor formulations containing SHMP were more effective than treatments without SHMP in suppressing darkening during storage of fresh-cut pears.
Pears treated with combination of 2 % AA + 0.2 % CaC, and 2 % PS solution showed the best results in visual colour evaluation (data not shown).

Table 2. Total colour difference (ΔE) of untreated and treated fresh-cut pears during 8 day storage at 2 °C

Treatment	Day	ΔEc_u		ΔEc_w	
		After harvest	After CA	After harvest	After CA
control untreated	0	-	-	3.75	4.82
	1	-	-	6.03	9.84
	4	-	-	12.35	7.73
	8		-	10.42	-
control-treated with water	0	3.75	4.82	-	-
	1	6.03	10.20	-	-
	4	12.35	8.03	-	-
	8	10.42	-	-	-
0.5 % HP	0	2.05	7.40	1.83	3.74
	1	2.09	10.75	7.87	2.31
	4	5.00	9.14	14.95	1.72
	8	3.77	-	12.94	-
2 % AA	0	0.90	1.86	3.30	6.47
	1	1.81	5.88	7.77	5.23
	4	3.16	6.62	12.52	2.19
	8	4.39	-	14.25	-
3 % AA	0	3.50	1.53	3.25	6.31
	1	2.11	6.69	4.01	4.05
	4	3.68	9.40	9.42	1.90
	8	4.88	-	6.06	-
2 % AA + 1 % SHMP	0	1.68	1.30	4.06	5.71
	1	2.84	3.65	3.55	6.43
	4	1.63	5.85	10.99	2.27
	8	0.57	-	10.76	-
2 % AA+2 % SHMP	0	2.09	2.49	3.27	6.83
	1	1.93	4.13	7.79	5.74
	4	4.75	6.65	14.82	1.56
	8	4.51	-	14.26	-
3 % AA + 1 % SHMP	0	2.12	2.85	3.01	7.60
	1	2.52	3.58	4.00	7.25
	4	2.68	4.17	10.12	4.75
	8	2.17	-	8.28	-

Treatment	Day	Δ Ec_u		Δ Ec_w	
		After harvest	After CA	After harvest	After CA
3 % AA + 2 % SHMP	0	0.38	1.33	3.41	6.11
	1	0.56	7.88	6.29	3.59
	4	2.84	9.87	12.15	2.72
	8	1.51	-	9.22	-
2 % AA + 0.2 % CaC	0	1.25	2.14	4.26	6.73
	1	2.05	3.45	4.00	6.56
	4	2.54	3.32	11.42	4.79
	8	1.01	-	9.87	-
3 % AA + 0.2 % CaC	0	1.85	3.52	3.79	7.60
	1	1.81	2.04	4.64	8.89
	4	4.00	2.09	9.87	6.82
	8	2.83	-	8.36	-
1 % SHMP	0	4.33	2.59	2.92	3.13
	1	1.28	2.64	4.83	7.34
	4	3.29	4.34	12.04	4.34
	8	3.78	-	13.52	-
2 % SHMP	0	15.89	2.80	3.90	2.20
	1	22.02	3.93	3.08	6.11
	4	20.78	7.97	11.78	3.55
	8	22.82	-	10.47	-
1 % CaA	0	1.38	2.45	2.68	7.26
	1	1.31	2.34	6.65	8.56
	4	5.45	2.05	13.90	8.39
	8	3.43	-	12.26	-
2 % PS	0	6.75	1.57	3.61	5.34
	1	6.32	2.39	0.70	9.28
	4	6.84	2.61	5.76	7.36
	8	4.93	-	5.73	-
0.2 %CaC	0	4.71	1.58	2.85	5.73
	1	3.45	2.23	2.71	8.16
	4	3.93	2.37	9.90	7.38
	8	1.89	-	11.01	-

Δ Ec_u-colour difference was calculated from L*, a* and b* values of sample for the same day in comparison to control sample (untreated)
Δ Ec_w-colour difference was calculated according to control sample (treated with water)

Firmness

The large decrease in L* value for most samples was the result of browning and tissue breakdown, which produced a dark and uneven water-logged appearance that may have been due to use of some slightly overripe pears for treatments (especially for pears stored in CA). Changes in fruit flesh firmness during storage at 2 °C are shown in Fig. 3 and 4.
Treatment with CaA and addition of 0.2 % CaC to browning inhibitor formulations containing AA prevented a loss of fresh-cut firmness in comparison to treatment formulations without CaC addition. Calcium salts effect

on cell wall structure and membrane permeability. It interacts with pectin to form a cross-linked polymer network that increases mechanical strength, thus delaying senescence and controlling physiological disorders in fruit.

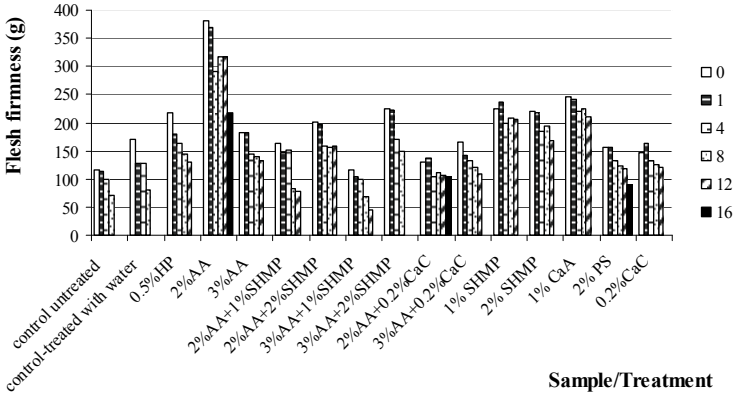

Fig. 3. Effect of treatments on flesh firmness of fresh-cut pears during 16 days storage at 2 °C (processed after harvest)

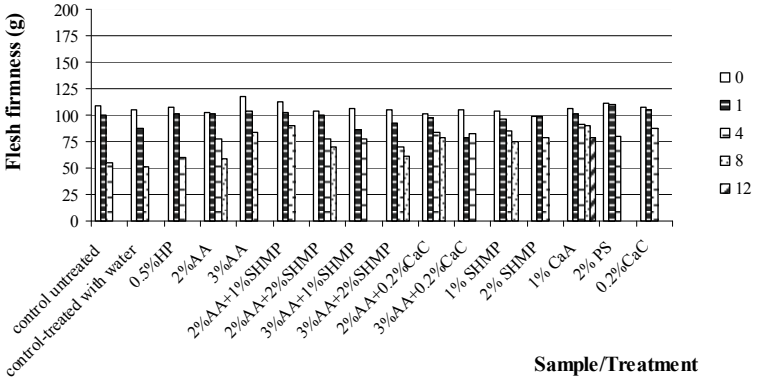

Fig. 4. Effect of treatments on flesh firmness of fresh-cut pears during 12 day storage at 2 °C (processed after CA storage)

The lowest loss of firmness in both types of fresh-cut pears was obtained in samples treated with 0.2 % CaC, combination of 2 % AA + 0.2 % CaC, as well as samples treated with 1 % CaA. The highest loss of firmness in both types of fresh-cut pears was recorded in samples treated with water.

Conclusions

Darkening of fresh-cut pears during storage, manifested in decrease in L* value and h° value, and increase in a* value, resulted from enzymatic browning and

tissue breakdown. Our results showed the effectiveness of ascorbic acid (AA) and calcium chloride (CaC) to preserve minimally processed pears from quality losses. Calcium ascorbate (CaA) treatment and addition of 0.2 % CaC to browning inhibitor formulations containing ascorbic acid prevented a loss of fresh-cut pears firmness in comparison to treatment formulations without CaC addition. The shelf-life of fresh-cut pears (prepared from pears after harvest) could be prolonged, depending on treatment, on about 12 to 16 days (the best treatment was 2 % AA + 0.2 % CaC). Shelf-life of samples, prepared from fruit stored in controlled atmosphere for 6 months was approximately 8 days, except for samples treated with 1 % CaA which was 12 days. Further investigations are required in order to determine the effects of fruit ripeness, variety, storage conditions, and to improve other processing conditions such as packaging methods.

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