Cutting and temperature of preservation effect on the physiological activity and quality of fresh cut 'Packham's Triumph' and 'Shinco' pears

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Abstract

The aim of this work was to evaluate the effect of wedge and dice cut format and storage temperature on the physiological activity, firmness and organic acid and sugar content of fresh cut pears (*Pyrus communis* L.) 'Packham's Triumph' and 'Shinco'. The whole fruit was washed, peeled, cut, packed in modified atmosphere and subsequently stored at 5 and 8°C for 8 days. In 'Packham's Triumph' the storage temperature and the cutting format separately showed a significant effect on the physiological activity, which was lower in the wedges stored at 5°C. The cutting format and storage temperature, separately, also showed a significant effect on the firmness, the wedges showed a 12% higher firmness than dices (4.9 kg_{-f}) while wedges and dices of 'Packham's Triumph' pears stored at 5°C were firmer (5.3 kg_{-f}) than those stored at 8°C (5.1 kg_{-f}). The interaction of the cutting format and storage temperature showed a significant effect on organic acid, the content of oxalic and malic acids was higher in wedges stored at 5°C compared with the other cutting format at both storage temperatures at the end of the storage. In 'Shinco', the cutting format and the storage temperature showed a significant effect on the ethylene rate, which was lower in the wedges stored at 5°C than those stored at 8°C. At the end of storage, the content of malic acid was affected by the cut format which was 18% higher in dices in comparison with wedges while the fructose content in dices stored at 5°C was the highest in comparison with the other cutting formats stored either at 5 or 8°C. In summary, the 'Packham's Triumph' and 'Shinco' pears can be minimally processed under wedge and dice cut format, respectively, and they both must be stored at 5°C packed in modified atmosphere in order to preserve their quality.

Keywords: respiration rate, ethylene emission rate, firmness, organic acids, sugars

INTRODUCTION

Fresh-cut products are an important and rapidly expanding food category for the produce industry, food processors, retailers, and food service operators. With the increased interest in fresh-cut products comes the desire of the manufacturer to meet the consumers' demand with safe products that are packaged and distributed to maintain freshness and nutrition with an extend shelf-life, while ensuring a good eating quality (Kader, 2002).

The increase of postharvest loss in quality in the fresh-cut products is caused by the respiration rate (RR), the higher the RR the more perishable the product (Lamikanra, 2002; Escalona and Luchsinger, 2008). The RR increases as a response to the damage caused after cutting in comparison to the whole product (Lamikanra, 2002; Kader, 2002). The fresh-cut processing also increases the ethylene emission rate (ER), which has a direct incidence on the synthesis of enzymes related to ripening and tissue degradation such as the change of color, taste (loss of organic acids and sugars), aroma, texture and functional quality (Kader, 2002; Soliva-Fortuny et al, 2004; Escalona and Luchsinger, 2008).

The mechanical damage experienced by tissues during processing appears a few minutes after cutting, with a maximum manifestation 1 h later. So, to reduce these changes, the fresh-cut products must be stored at temperatures closed to 0°C and their manipulation

must be done around 10°C, preferably at 4°C, and they must be stored at low temperatures (between 0 and 5°C) to avoid the growth of microorganisms which can affect the quality (Kader, 2002; Escalona and Luchsinger, 2008). Therefore, the control of temperature and the reduction of cold storage period are the best methods to reduce the quality loss of fresh-cut products (Thomson et al., 2007).

Studies on fresh-cut pear (Senesi et al., 1999) and apple have shown that cold storage did not affect the taste according to the sugar content (Bett et al., 2001; Rocha et al., 1998). Whole pears are climacteric fruit with a moderate RR and a high ER (Kader, 2002). However, the ER of slightly ripened fresh-cut pears is 2-fold higher than in whole fruit in advanced ripening stage (Soliva-Fortuny et al., 2004). Cantwell (1998) reported that 2 cm pear wedges stored at 2°C showed a RR and ER similar to the whole fruit. In addition, small fresh-cut pieces of pear showed a higher ER than in bigger pieces, which is similar to the rate of the whole fruit (Cantwell and Suslow, 2007).

The aim of this work was to evaluate the effect of two cutting formats (dice and wedges) and two storage temperatures (5 and 8°C) on the physiological activity, firmness and organic acid and sugar content of fresh-cut 'Packham's Triumph' and 'Shinco' pears.

MATERIALS AND METHODS

'Packham's Triumph' and 'Shinco' pears (*Pyrus communis* L.) used in this study were provided free of defects by Inversiones Kiwi del Sur Ltda. (Curicó, Chile). The pears were transported to the laboratory of the Center of Postharvest Studies at the School of Agricultural Sciences, University of Chile, where they were stored at 0±1°C until they were processed.

The pears were conditioned at 20°C for 24 h before processing to reach firmness values around 5 kg_{-f}. Processing was performed at a low temperature (5±0.5°C). The whole fruit was washed with cold water at 5°C for 5 min. Then, the pears were peeled, cored, cut with a sharp stainless steel knife into dices or wedges and packaged in 500 mL plastic trays, according to treatment (8 wedges or 12 dices) and then, they were stored at 5 or 8°C for 8 days. At the first, sixth and eighth day of storage, three samples of each treatment were randomly selected and removed from the cold storage room for the analyses of the respiration and ethylene emission rates, firmness and, organic acid and sugar contents.

The analyses of the respiration (RR) and ethylene emission (ER) rates were performed on 0.5-L jars with approximately 110 g or 80 g of pears in wedge or dice cutting format, respectively. The jars were fitted with air-tight lids equipped with a rubber septum. Then, the jars were stored at 5 or 8°C to monitor the respiration rate behavior of fresh-cut pears during 8 days. On the day of analysis, a 10-mL gas sample was taken from the headspace of every jar at the designated sampling time (1-1.5 h). Subsequently, the sample was injected into a gas chromatograph (GC) HP 5890 series II (Hewlett Packard Co., Rockville, Md., USA) fitted with a 2.4 m × 3 mm Hayesep Q column (Supelco, USA) and equipped with a thermal conductivity detector (TCD) for the analyses of RR. The injector and oven temperature were set at 50°C, while the detector was set at 200°C. Helium was used as a carrier gas at 50 psi. RR was expressed in mg CO_2 kg^{-1} h^{-1}. The GC was calibrated every day with a 5% O_2 and 10% CO_2 standard (Indura, Santiago, Chile).

Samples for analysis of the ER were taken with a 1-mL syringe 0.5 h after the jars were tightly closed (Fernández-Trujillo et al., 2005). Then, the sample was injected into a gas chromatograph (GC Agilent Technologies 7820A, GC System, USA) equipped with a FID detector and a 1.2 m × 3.18 mm Porapak QN 80/100 column (Norwalk, Connecticut, USA). The oven, injector and FID temperature were set at 50, 200 and 200°C, respectively. Helium was used as carrier gas at 6 mL min^{-1}. The GC was calibrated daily with a 1.26 ppm standard (Indura, Santiago, Chile). ER was expressed in μL C_2H_4 kg^{-1} h^{-1}.

The firmness of fresh cut pear was determined using a fruit texture analyzer (FTA, FR, Forly, Italy). Compression firmness was measured with 14000 kg_{-f} maximum load and a 7.9-mm-diameter cylindrical probe to a deformation of 10 mm at 30 mm s^{-1}. The peak force was recorded and used to indicate the firmness of the fresh-cut product. Fresh cut pear juice was obtained by homogenizing 100 g of either wedges or dices with a Multiquick/Minipimer

mixer (MR 400 HC Plus, Braun, Spain). The juice was filtered through a four layers of cheesecloth. Three Eppendorf vials containing 1.5 mL of filtered juice were stored at -20°C in a freezer (model FE26, Electrolux, Chile) until their organic acid and sugar composition analyses by high performance liquid chromatography (HPLC). Prior to the analysis by HPLC, the juice samples were centrifuged at 18620 g_n for 15 min at 4°C. Subsequently, the final samples were filtered by SepPack cartridges (Waters, Milford, MA, USA) and Millex filters with PVDF membrane of Ø 13 mm and 0.22 µm Ø pore (Barueri, São Paulo, Brazil).

The soluble sugars were determined in 20 µL aliquots of pure juice solution in a Zorbax column (Agilent Technologies, Germany), using acetonitrile/deionized water (resistivity of 18 Ω cm, MilliQ system, Millipore, Milford, MA) in an 80:20 v/v combination as the mobile phase with a flow of 1.5 mL min^{-1} and a refractive index detector (Hitachi, Lachrom L-7200, Tokyo, Japan).

Organic acids in the fresh cut pear juice were analyzed in 20-µL aliquots of pure juice using a Discovery RP Amide C16 column (25 cm × 4.6 mm, 5 µm, Supelco, Bellefonte, PA, USA). The mobile phase (0.3 mL min^{-1}) was a 99:1 v/v combination of deionized water (as described above) and methanol with a 0.1 M phosphate di-hydrogen potassium with H_2PO_4 (pH=3) buffer. Samples were read at 210 nm in a 1200 Series HPLC equipped with a UV-Vis detector (Agilent Technologies, Waldbronn, Germany) for 30 min at 30°C. The reagents used for the mobile phase preparation were of HPLC grade. Organic acid and sugar identification was done by comparison of retention times using authentic compounds (Sigma Chem. Co., Darmstadt, Germany), alone and with spiked sample juice (Obando-Ulloa et al., 2009). The calibration curves for each organic acid and sugar were over the range of 0.14-56.6 mg mL^{-1}, yielding correlation coefficient values greater than 0.97, results were expressed in mg g^{-1} fresh weight, using juice density and fruit juiciness measurements (Obando-Ulloa et al., 2009).

Data were subjected to ANOVA using JMP 8.0 (SAS Institute Inc., Cary, NC, USA) with factorial statistical modeling. In those cases where the interaction of factors were statistically significant, mean values of each treatment were separately compared among treatments within the day of analysis by the Tukey-Kramer contrast analysis test at P=0.05 with the Type-I error $\alpha \leq 0.05$ to determine the effect of cutting format and storage temperature.

RESULTS AND DISCUSSION

Respiration rate (RR)

In the cultivars analyzed in this study, both cutting formats of 'Shinco' pears stored at both temperatures (5 or 8°C) showed statistical significantly effects on the RR only on the 1st day after processing. The RR then declined over the remainder of the experiment. On day 3 and 8 there was an effect of storage temperature at $P<0.001$ and $P<0.05$ respectively (Table 1). In contrast, the storage temperature had a significantly statistical effect on the RR of fresh cut 'Packham's Triumph' pears from the first day after processing until the end of storage period. The RR of these products stored at 8°C was higher than those stored at 5°C (Table 2).

The highest RR values obtained in all treatments after processing could be due to the stress produced by cutting (Beltrán et al., 2005; Beirão-da-Costa et al., 2006). According to Rivera et al. (2005) the RR of papaya subjected to different cutting shapes and different storage temperatures was only affected by storage temperature. After the stress produced by cutting operations, RR decreased and it might be due to the adaptation of tissue to new physical structure conditions (cutting shape) and storage as it has been reported in fresh cut papaya (Rivera et al., 2005) and melon (Silveira, 2009).

The storage temperature effect on the RR of both cultivars could be related to a lower temperature, which may reduce the RR (Schlime, 1995; Silveira, 2009). Rivera et al. (2005) reported that a storage temperature of 5°C reduced the RR of fresh cut papaya in comparison with those stored at 10 and 20°C, but non-significantly statistical effects of cutting shapes on RR were found.

Table 1. Respiration rate of fresh cut 'Shinco' pears cut in dices and wedges and stored for 8 days at 5 or 8°C.

	Shelf-life (d)		
	0	3	8
Cut shape (CS)			
Wedges	18.6	13.8	10.5
Dices	25.0	14.2	11.4
Storage temperature (ST)			
5°C	19.5	16.9 a	12.2 a
8°C	24.1	10.9 b	9.7 b
Interaction (CS×ST)			
Wedges 5°C	18.9	17.4	11.9
Wedges 8°C	18.2	10.2	9.1
Dices 5°C	20.0	16.6	12.5
Dices 8°C	30.1	11.8	10.4
Significance level			
CS	**	NS	NS
ST	*	**	*
CS*ST	**	NS	NS

Means (*n*=3) not connected vertically by the same letter are significantly statistical different.

Table 2. Respiration rate of fresh cut 'Packham's Triumph' pears cut in dices and wedges and stored for 8 days at 5 or 8°C.

	Shelf-life (d)			
	1	3	6	8
Cut format (CS)				
Wedges	7.2	10.1	14.8	14.8
Dices	7.9	12.8	16.6	17.8
Storage temperature (ST)				
5°C	6.5 a	8.5 a	12.3 a	12.2 a
8°C	8.6 b	14.4 b	19.2 b	20.5 b
Interaction (CS×ST)				
Wedges 5°C	5.7	6.6	10.2	10.2
Wedges 8°C	8.7	13.5	19.4	19.4
Dices 5°C	7.4	10.3	14.3	14.1
Dices 8°C	8.5	15.2	18.9	21.5
Significance level				
CS	NS	**	NS	**
ST	**	***	***	***
CS*ST	NS	NS	NS	NS

Means (*n*=3) not connected vertically by the same letter are significantly statistical different.

Ethylene emission rate (ER)

One day after processing 'Shinco' pear dices showed an ER 77% higher than wedges, independent of the storage temperature. At the end of the shelf-life, dices stored at 8°C showed the highest ER of all treatments (Table 3). On the other hand, the storage temperature had a significant effect on days 3 and 6 on the ER of the fresh cut 'Packham's Triumph' pears independently of the cutting shape. At the end of shelf-life, the fresh cut pears stored at 8°C showed the highest rates of all treatments (Table 4). 'Shinco' pears had low ER, while 'Packham's Triumph' pears had a relatively high ER (Kader, 2002).

Table 3. Ethylene emission rate behavior of fresh cut 'Shinco' pears cut in dices and wedges and stored for 8 days at 5 or 8°C.

	Storage time (d)			
	1	3	6	8
Cut shape (CS)				
Wedges	0.4 b	0.4	0.6 b	0.8
Dices	0.7a	0.9	1.4 a	2.4
Storage temperature (ST)				
5°C	0.5 b	0.5	0.8	0.7
8°C	0.6a	0.9	1.1	2.5
Interaction (CS×ST)				
Wedges 5°C	0.3	0.4 b	0.6	0.4 b
Wedges 8°C	0.4	0.5 b	0.6	1.2 b
Dices 5°C	0.6	0.6 b	1.1	0.9 b
Dices 8°C	0.7	1.3 a	1.6	3.8 a
Significance level				
CS	****	****	***	***
ST	*	***	NS	***
CS*ST	NS	**	NS	**

Means (*n*=3) not connected vertically by the same letter are significantly statistical different.

Table 4. Ethylene emission rate behavior of fresh cut Packham's Triumph pears cut in dices and wedges and stored for 8 days at 5 or 8 °C.

	Shelf-life (d)		
	1	6	8
Cut shape (CS)			
Wedges	19.4	17.5	12.1
Dices	17.9	18.8	22.3
Storage temperature (ST)			
5°C	17.2	11.7 b	15.6
8°C	20.2	24.7 a	18.9
Interaction (CS×ST)			
Wedges 5°C	19.3	11.0	15.9 b
Wedges 8°C	19.5	23.9	8.3 c
Dices 5°C	15.0	12.3	15.2 b
Dices 8°C	20.9	25.4	29.4 a
Significance level			
CS	****	NS	NS
ST	*	**	****
CS*ST	NS	NS	NS

Means (*n*=5) not connected vertically by the same letter are significantly statistical different.

The differences between both cultivars in their ER are not consistent with Gorny et al. (2000), who compared the ER of four cultivars of fresh cut pears and they did not find statistically significant differences among cultivars. However, they found a statistically significant effect of storage temperature on the ER of all evaluated cultivars, with a mean increase by around 77% when the temperature increased from 0 to 10°C. This behavior agrees with findings of Saavedra de Aguila et al. (2006). On the other hand, Bai et al. (2009) reported that a low storage temperature had no effect on ER of fresh cut 'Anjou' pears.

Organic acid and sugar content

In this work, five different organic acids (quinic, oxalic, malic, citric and succinic) were identified in the juice of fresh cut 'Shinco' and 'Packham's Triumph' pears. However, only malic and oxalic acids were found in higher content either in the whole or fresh-cut fruit. After processing, 'Shinco' pear dices stored at 5°C showed the lowest oxalic acid content, while wedges stored at 8°C showed the highest content. At the end of the shelf-life, the highest content was reported by dices stored at 5°C (Figure 1A). On the other hand, dices stored either at 5 or 8°C showed lower malic acid content compared to wedges stored at the same conditions, 1 day after processing. However, the dice cutting format at both storage temperatures had the highest content at the end of shelf-life (Figure 2A).

'Packham's Triumph' pears cut in dices and wedges, stored at 5 and 8°C, showed the highest oxalic acid content after processing (day 0), while the lowest content was shown by the wedge cutting format stored at 5°C. However, this treatment had the highest content at the end of shelf-life (Figure 1B). In addition, the wedge cutting format stored at 5°C also showed the highest malic acid content compared to the other treatments, either 1 d after processing or at the end of shelf-life (Figure 2B), while the same cut format stored at 8°C had the lowest content.

After processing, 'Shinco' dices stored at 5°C showed the lowest content of fructose compared with the other treatments, while this content was higher in the dices stored at 8°C. However, at the end of the shelf-life, this cutting format at both storage conditions showed a high content of fructose, but dices at 5°C had the highest values (Figure 3A). In contrast, 'Packham's Triumph' wedges and dices stored at 5 and 8°C, respectively showed the highest content either after processing (day 0) or at the end of the shelf-life (Figure 3B).

According to these results, the cutting format influences the preservation of quality of fresh-cut fruit depending on the cultivar, as it has been reported in fresh-cut Galia melon (Silveira et al., 2007). In this work, it seems that dices are the best cutting format to process 'Shinco' pears, while 'Packham's Triumph' pears can be cut either in dice or wedge formats in order to preserve the organic acid and sugar content.

Firmness

Fresh-cut 'Shinco' pears showed a firmness value around 2.8 kg_{-f} along the shelf life period ($P>0.05$), but no significantly statistical differences were found among treatments (data not shown).On the other hand, the cutting format had a statistically significant effect on the firmness of MP 'Packham's Triumph' pears along the shelf-life period with a range around 4.7-5.6 kg_{-f}, among which wedges showed the highest values (5.6 kg_{-f} approx., data not shown).

Flesh firmness is a very important physical property of fruit tissue, as it directly affects the eating quality and texture (Chen et al., 2006). As it was found, during the shelf-life of both cultivars, the firmness is maintained to a certain degree, which is not common in other fruits, as it was also reported by Chen et al. (2006) in 'Yali' pear. In addition, Gorny et al. (2000) reported differences among firmness of fresh-cut pear cultivars along shelf-life.

Sensory analysis

Along the shelf-life period of fresh cut 'Shinco' pears, the taste scored higher than fair by judges, while the sweetness was graded as fair and the sourness and bitterness was not perceived by judges, but non-significantly statistical differences were found among treatments along the shelf-life period (data not shown).

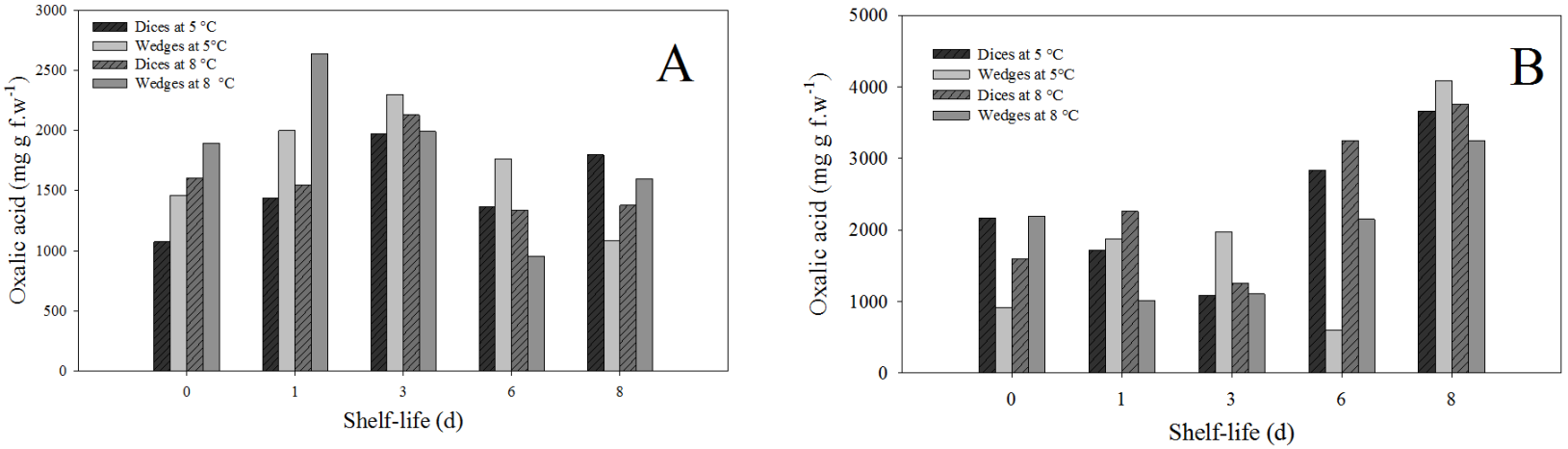

Figure 1. Oxalic acid content behavior of fresh cut 'Shinco' (A) and 'Packham's Triumph' (B) pears cut in dices and wedges and stored at 5 or 8°C for 8 days.

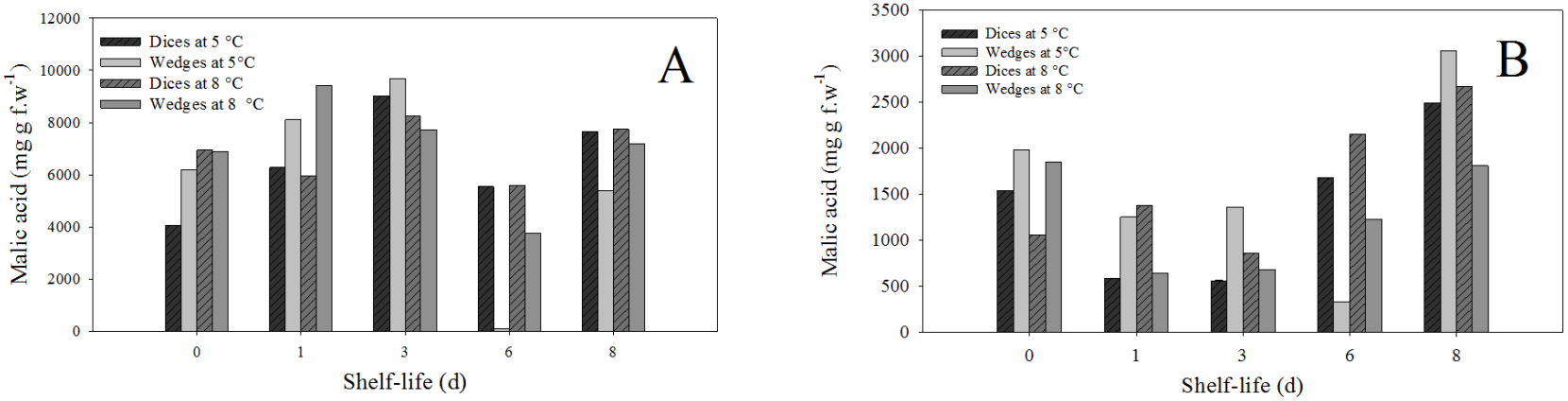

Figure 2. Malic acid content behavior of fresh cut 'Shinco' (A) and 'Packham's Triumph' (B) pears cut in dices and wedges and stored at 5 or 8°C for 8 days.

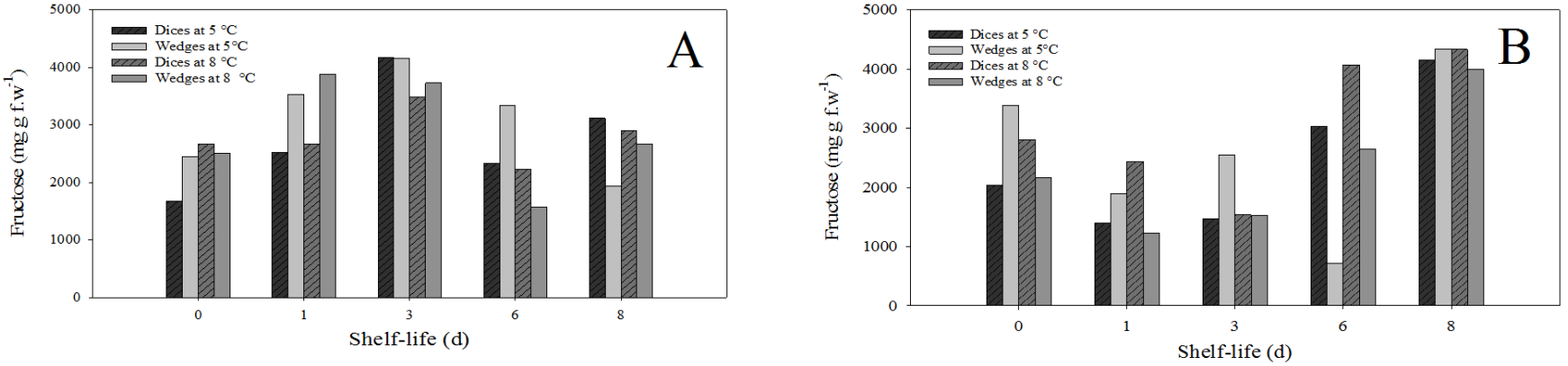

Figure 3. Fructose content behavior of fresh cut 'Shinco' (A) and 'Packham's Triumph' (B) pears cut in dices and wedges and stored at 5 or 8°C for 8 days.

CONCLUSION

The cutting format has an influence on the physiological behavior of fresh-cut 'Shinco' and 'Packham's Triumph' pears. This effect can be reduced by the management of storage temperature. 'Shinco' should be cut in dices and 'Packham's Triumph' in dices or wedges in order to preserve the organic acid and sugar content. However, the cutting format does not have an effect either on the firmness or sensorial quality of fresh-cut 'Shinco' and 'Packham's Triumph' pears.

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