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Effect of cutting and storage temperature on Packham's Triumph pears (*Pyrus communis* L.)

Efecto del corte y temperatura de almacenamiento sobre peras (*Pyrus communis* L.) Packham's Triumph

Javier M. Obando Ulloa¹, Alejandra Oyarzún², Alejandra Machuca², Luis Luchsinger^{2,3}, Álvaro Peña-Neira⁴, Víctor H. Escalona^{2,3*}

¹ Technology Institute of Costa Rica, Agro Business School and Doctorate Programme on Natural Science for Development. P.O. Box. 223-21001 Ciudad Quesada, Alajuela, Costa Rica. ² University of Chile. Faculty of Agronomy Science, Center of Postharvest Studies (CEPOC). Ave. Santa Rosa No. 11315, P.O. Box 882 08 08, La Pintana, Santiago, Chile. ³ University of Chile. Faculty of Agronomy Science, Department of Plant Production. Ave. Santa Rosa No. 11315, P.O. Box 882 08 08, La Pintana, Santiago, Chile. ⁴ University of Chile. Faculty of Agronomy Science, Department of Agroindustry and Enology. Ave. Santa Rosa No. 11315, P.O. Box 882 08 08, La Pintana, Santiago, Chile. *Corresponding author: vescalona@uchile.cl

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Abstract

For the minimally processed (MP) fruit, the cutting type and temperature are the main factors in order to maintain good quality and appearance. The objective of this work was to evaluate the effects of cutting type and storage on the metabolic activity, color, firmness, aroma profile and, organic acid and sugar content of MP pears (*Pyrus communis* L. cv. Packham's Triumph). Whole fruits were washed, peeled and cut in wedges or dice. Then, the pieces were packaged in plastic containers and stored 8 days at 5 or 8 °C. The cutting type and storage temperature had an important effect on the physiological parameters, color, firmness and organic acid and sugar content. However, the aroma volatile content was reduced independently of the cutting type and the storage temperature. Therefore, the pear cultivar Packham's Triumph should be cut in wedges and stored 8 d at 5° C to maintain an optimum global quality.

Key words: Aroma, browning, firmness, organic acids, sugar.

Resumen

En los frutos mínimamente procesados en fresco (MPF) el tipo de corte y la temperatura son factores por considerar para mantener una calidad y apariencia adecuada. El objetivo de este trabajo fue evaluar los efectos del corte y la temperatura de conservación sobre la actividad metabólica, color, firmeza, perfil aromático y concentración de ácidos orgánicos y azúcares de peras (*Pyrus communis* L. cv. Packham's Triumph). Los frutos enteros fueron lavados, pelados, cortados en cascos o cubos, envasados en tarrinas y posteriormente almacenados 8 d a 5 o 8 °C. El tipo de corte y la temperatura tuvieron un efecto significativo sobre los parámetros fisiológicos, color, firmeza y en el contenido de ácidos orgánicos y azúcares. Sin embargo, el contenido de compuestos aromáticos volátiles se redujo independientemente del tipo de corte y las temperaturas de conservación. Por tanto, esta variedad de peras Packham's Triumph deben ser procesadas en cascos y deben almacenarse a 5° C para mantener una calidad general óptima durante 8 días.

Palabras claves: Ácidos orgánicos, aroma, azúcar, firmeza, pardeamiento.

Introduction

The minimally processed (MP) fruit suffer important modifications of their quality, due to cutting process accelerates their respiration and ethylene emission rates and activates their metabolism rate, which drastically reduces their shelf life. In addition, cutting causes the breakdown of cell compartments which releases enzymes and substrates generating the browning development of secondary metabolites and unwanted reactions that degrade color, firmness, aroma, flavor and nutritional value (Cantwell & Suslow, 2007; Escalona & Luchsinger, 2008).

Therefore, it is essential that the processing of MP products must be carried out below 10°C (preferably at 4°C). In addition, the final products must be preserved between 0 and 5°C to decrease metabolism, inhibit enzyme activity, prevent microorganism growth and maintain safety (Escalona & Luchsinger, 2008). Studies on MP pears and apples, demonstrate that cool storage does not affect the taste related to the sugars concentration sugars, even though the chemical composition changes during postharvest storage due to the loss of total solids, carbohydrates, amino acids, proteins and vitamins, loss of turgor and dehydration of the tissues, eventually reaching cell death (Escalona & Luchsinger, 2008; Gómez, Artés-Fernández, Aguayo, Escalona & Artés, 2007). Adaro (2010), recommends temperatures between -1 and -0.5°C for the preservation of whole pears, avoiding temperatures between -2.2 and -1.7°C to prevent chilling injury.

The acceptability of whole and MP pears, decreases due to changes in texture, mainly firmness, which is the most important quality parameter (Guerra & Casquero, 2005). Firmness loss of MP fruit is mainly limited to areas close to the cutting surface, characterized by a rapid browning, which also affects the visual quality (Artés, Gómez & Artés-Hernández, 2007).

Another factor that affects the acceptability of MP fruit is the decrease in the content of organic acids and sugars, which are used as energy sources. The variations in the organic acid content is generally minimal. On the other hand, it has been found that the level of sugars (mainly fructose and glucose) decreases over time, because fructose is converted into glucose. In order to avoid this situation, MP fruit should be preserved in modified atmospheres (high concentrations of CO₂ and O₂) at low temperatures, as reported by Gómez *et al.* (2007).

The acceptability of MP fruit is also related to taste and aroma. According to taste, soluble solids increase during the first few days after processing and in the following days remain more

or less constant (Guerra & Casquero, 2005). On the other hand, aroma is generally comprised by the concentration and odor threshold from a mixture of aroma volatile compounds, mainly esters, alcohols, aldehydes and ketones (Obando-Ulloa, Moreno, García-Mas, Nicolai, Lammertyn, Monforte & Fernández-Trujillo, 2008). These compounds tend to either become into others or even to disappear as fruit approaches senescence (Obando-Ulloa, Nicolai, Lammertyn, Bueso, Monforte & Fernández-Trujillo, 2009b). Therefore, the control of storage temperature plays an important role for the preservation of these quality attributes (Maulén, Obando, Barraza, Machuca, Peña, Luchsinger & Escalona, 2012).

Given these concerns, it is considered that with a decreasing temperature, better quality is maintained in the wedges with comparison to dice of Packham's Triumph pears. Therefore, the aim of this research was to evaluate the respiration and ethylene production rates, color, firmness, malic acid and sugar content and, the aroma profile of Packham's Triumph pears minimally processed under two cutting types (wedges and dice) and stored 8 d at 5 or 8°C.

Material and methods

Plant material

The pears cv. Packham's Triumph used in this study were harvested in a commercial orchard belonged to the company Kiwi South, located in Curicó (Region VII, Chile). The fruit were transported at room temperature to the laboratory of the Postharvest Studies Center (CEPOC, University of Chile), where they were stored 2 months at 0 ± 1°C until processing.

Minimally processing (MP) of pears

The whole pears were conditioned at 20°C until they reached firmness close to 5 kg. Around 4 to 5 kg of fruit per treatment were used for processing. All operations were conducted in a disinfected cold room at 5 ± 0.5°C in order to reduce the stress produced to fruit during processing. Minimally processing (MP) started by washing the fruit with tap water at 5°C for 3 min to eliminate any foreign material. Then, pears were peeled, cored and cut with a sharp stainless steel knife into wedges and dice. Around 8 wedges and 12 dice (aprox. 2 cm³) were obtained from each fruit. Subsequently, the pieces were washed 3 min with tap water at 5°C and they were drained 3 min on a stainless steel rack. Finally, 8 wedges (approx. 90 to 110 g) or 12 dice (approx. 60 to 80 g) were packaged into plastic containers with cover and stored 8 d at 5 and 8°C.

Quality analysis of MP Packham's Triumph pears

The respiration (RR) and ethylene production (ER) rates were monitored at 5 and 8°C using the static method. Both physiological activities were monitored on 8 wedges and 12 dice placed in air tight containers. The experimental procedure and sample analysis through gas chromatography (GC) for RR and ER, were conducted according to Obando-Ulloa, Mery-Kraemer, Cáceres-Mella, Machuca, Peña-Neira & Escalona (2014) and, Yoplac, Char, Hinojosa, Obando & Escalona (2013), respectively.

The colour and firmness changes in fresh cut pear were measured in triplicate on all pieces of each plastic container, according to Obando-Ulloa *et al.* (2014).

Malic acid and sugar contents were analyzed by high performance liquid chromatography (HPLC) according to Obando-Ulloa, Eduardo, Monforte and Fernández-Trujillo (2009a) and Yoplac *et al.* (2013), respectively. The aroma identification of volatile compounds was performed through gas chromatography and mass spectrometry (GC-MS) according to Maulén *et al.* (2012).

Two plastic containers were randomly chosen per treatment and analysis day for the sensory evaluation of taste, sourness, sweetness and bitterness, respectively. This analysis was performed with an in-house trained sensory panel of 12 judges in concordance to Obando-Ulloa *et al.* (2014).

Statistical analysis

Data were submitted to ANOVA using JMP v8.0 for Windows (SAS Institute Inc., NC, U.S.A., 2011). If significant differences at $P < 0.05$ were identified, data were analyzed as a 2-factor linear model using JMP v8.0 for Windows with cutting type (CT) and storage temperature (Te) as factors.

Results

Respiration rate (RR)

After 1 d of storage, both cutting types stored at 8°C showed a RR 24% higher ($p < 0.01$) than those cutting types stored at 5°C ($8.5 \text{ mg CO}_2 \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$). This behavior was shown until the end of storage (day 8, Figure 1). Specifically, dice showed a RR 16 % higher ($P < 0.01$) in comparison to wedges ($14.8 \text{ mg CO}_2 \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$) at the end of their shelf life (data not shown) (Figure 1).

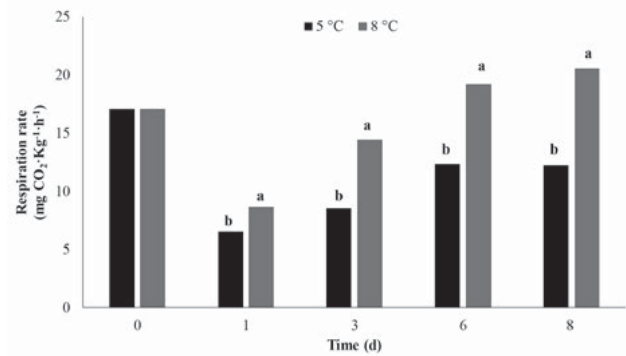


Figure 1. Evolution of the respiration rate ($\text{mg CO}_2 \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$) of Packham's Triumph pears submitted to two cutting types (wedges and dice) stored 8 d at 5 or 8°C. Means not connected by same letter are significantly different ($P < 0.001$).

Ethylene production rate (ER)

After 3 and 6 d of storage, the wedges and dice stored at 8°C showed an ER 37% and 53%, respectively higher in comparison to the same cutting types stored at 5°C (11.1 and $11.7 \text{ mg C}_2\text{H}_4 \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$, respectively). At the end of storage, dice stored at 8°C showed higher ER ($29.4 \text{ mg C}_2\text{H}_4 \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$) in comparison to the cutting types stored at 5 and 8°C (Figure 2).

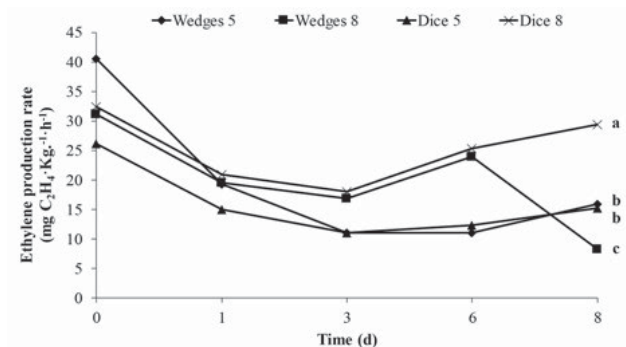


Figure 2. Evolution of the ethylene emission rate of wedges and dice of Packham's Triumph pears stored 8 d at 5 or 8°C. Means not connected by same letter are significantly different among treatments ($P < 0.001$).

Colour

According to the color parameters of both cutting types of Packham's Triumph pears, wedges showed lightness values (L) 2% higher than dice after 1 d of storage. This trend continued until the end of storage (day 8). On the other hand, dice showed the highest values of chroma (92.4) after 1 d of storage. However, both cutting types stored at 8°C had achieved a higher chroma values (22.0) in comparison to those cutting types stored at 5°C on day 6. At the end of storage, dice

showed a chroma value 9% higher than wedges (24.9). According to hue (Hab) parameter, wedges showed a Hab value 2% higher than dice (90.2) after 1 d of storage and this behavior continued until the end of storage (Table 1).

Table 1. Evolution of the color parameters of wedges and dice of Packham's Triumph pears stored 8 d at 5 or 8°C.

Color parameter	Time (d)			
	1	3	6	8
Lightness (L)				
Wedges	75.2 a ²	74.8	74.6 a	73.9 a
Dice	73.6 b	75.7	71.8 b	71.1 b
Chroma (C)				
Wedges	92.4 a	20.2	20.8 b	24.9 b
Dice	90.2 b	20.2	23.8 a	27.4 a
Hue (Hab)				
Wedges	92.4 a	91.2 b	89.3	98.7 a
Dice	90.2 b	92.6 a	86.9	95.1 b
Significance level				
Lightness (L)	***	**	****	****
Chroma (C)	****	NS	****	****
Hue (Hab)	***	***	***	***

²Means not connected by same letter within columns are significantly different at P<0.05 for each factor. NS, *, **, ***: Non significative or significative at P<0.05, 0.01, 0.001, respectively.

Firmness

After 1 d of storage, the firmness of wedges was 10% higher than dice (5.02 kg_f, P<0.001). This trend continued until the end of storage (data not shown).

Malic acid content

Dice stored at 8°C showed the highest malic acid content (0.0014 mg·g_{PF}⁻¹) in comparison to the other cutting types after 1 d of storage, either at 5 or 8 °C (P<0.01). This trend continued until the end of storage (data not shown).

Sugar content

The dice stored at 8°C showed the highest fructose content (0.0244 mg·g_{PF}⁻¹) in comparison to other cutting types after 1 d of storage either at 5 or 8 °C. At the end of storage (day 8), the dice and wedges stored at 8 and 5°C, respectively, showed the highest fructose content (0.0433 and 0.0434 mg·g_{PF}⁻¹, respectively) in comparison to the other cutting types stored at both temperatures (Table 2).

Table 2. Fructose content (mg·g_{PF}⁻¹) of wedges and dice of Packham's Triumph pears stored 8 d at 5 or 8 °C.

	Time (d)				
	0	1	3	6	8
Cutting type (CT)					
Wedges	0.0277	0.0156	0.0103	0.0170 b ²	0.0417
Dice	0.0242	0.0192	0.0150	0.0355 a	0.0424
Temperature (Te)					
5°C	0.0271	0.0165	0.0200	0.0188 b	0.0425
8°C	0.0248	0.0183	0.0153	0.0337 a	0.0417
Interaction (CT×Te)					
Wedges 5°C	0.0338	0.0190 b	0.0254	0.0072	0.0434 a
Wedges 8°C	0.0216	0.0122 c	0.0152	0.0267	0.0400 c
Dice 5°C	0.0204	0.0140 c	0.0146	0.0304	0.0416 b
Dice 8°C	0.0280	0.0244 a	0.0153	0.0407	0.0433 a
Significance level					
TC	NS	****	NS	*	NS
Te	NS	**	NS	*	NS
TC×Te	NS	****	NS	NS	**

²Means not connected by same letter within columns are significantly different at P<0.05 for each factor. NS, *, **, ***: Non significative or significative at P<0.05, 0.01, 0.001, respectively.

In addition, the dice stored at 8°C showed the highest glucose content (0.0115 mg·g_{PF}⁻¹) after 1 d of storage, in comparison to the other cutting types stored at both temperatures. However, at the end of storage (day 8), the wedges stored at 5°C achieved the highest glucose content (0.0180 mg·g_{PF}⁻¹) in comparison to the other cutting types stored at 5 and 8°C (Table 3).

Table 3. Glucose content (mg·g_{PF}⁻¹) of wedges and dice of Packham's Triumph pears stored 8 d at 5 or 8°C.

	Time (d)				
	0	1	3	6	8
Cutting type (CT)					
Wedges	0.0085	0.0076	0.0077	0.0063 b ²	0.0164
Dice	0.0108	0.0084	0.0063	0.0139 a	0.0163
Temperature (Te)					
5°C	0.0080	0.0073	0.0083	0.0067 b	0.0172
8°C	0.0113	0.0088	0.0057	0.0135 a	0.0155
Interaction (CT×Te)					
Wedges 5°C	0.0055	0.0093 b	0.0101	0.0019	0.0180 a
Wedges 8°C	0.0115	0.0060 c	0.0053	0.0107	0.0147 c
Dice 5°C	0.0106	0.0054 c	0.0065	0.0115	0.0164 b
Dice 8°C	0.0110	0.0115 a	0.0061	0.0162	0.0162 b
Significance level					
TC	NS	NS	NS	**	NS
Te	NS	NS	NS	*	***
TC×Te	NS	**	NS	NS	***

²Means not connected by same letter within columns are significantly different at P<0.05 for each factor. NS, *, **, ***: Non significative or significative at P<0.05, 0.01, 0.001, respectively.

According to the sucrose content, the dice stored at 8°C achieved the highest content after 1 and 6 d of storage (0.0038 and 0.0044 mg·g_{PF}⁻¹, respectively) in comparison to other cutting types stored either at 5 or 8°C (P<0.001 and P<0.01, respectively). At the end of storage, the sucrose content in all cutting types ranged from 0.0055 to 0.0079 mg·g_{PF}⁻¹ with no significantly statistical differences (data not shown).

Aroma volatile compounds

Around 125 aroma volatile compounds were identified in the headspace of the wedges and dice of Packham's Triumph pears. However, only 5 compounds (3 esters, 1 alcohol y 1 aldehyde) were in common in the whole and MP fruit (Table 4).

Table 4. Aroma volatile compounds identified in the headspace of whole and MP Packham's Triumph pears.

Compound	CAS Number	RT (min)	KI calc.	Odor and flavor descriptors
Butanol	71-36-3	2.2	437	Odor : fusel oil sweet balsam whiskey Flavor : banana fusel
Butyl acetate	123-86-4	5.6	837	Odor : ethereal solvent fruity banana Flavor : sweet, ripe banana, tutti frutti, tropical and candy-like with green nuances
Ethyl acetate	141-78-6	1.8	610	Odor : ethereal fruity sweet weedy green Flavor : ethereal, fruity, sweet, with a grape and cherry nuance
Propyl acetate	109-60-4	2.9	737	Odor : solvent celery fruity fusel raspberry pear Flavor : estry, fruity, ethereal, tutti-frutti, banana and honey
Pentanal	110-62-3	2.6	686	Odor : fermented breadly fruity nutty berry Flavor : winey, fermented, breadly, cocoa chocolate notes

RT: retention time; KI: Kovats index

The relative content of these compounds decreased in the wedges stored either at 5 or 8 °C and in the dice stored at 5°C. Instead, butyl acetate and propyl acetate were not identified in the dice stored at 8 °C. Among all the compounds identified, pentanal was the only compound which did not show a reduction of its relative content (Figure 3).

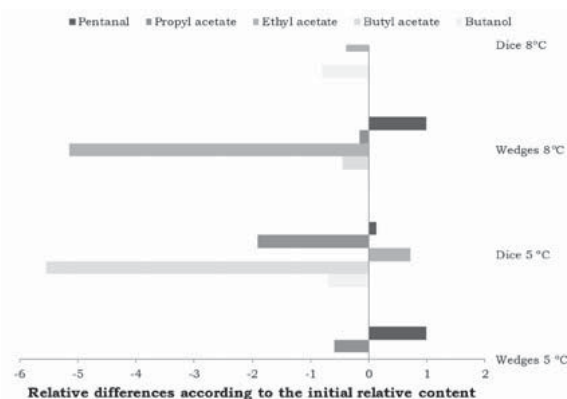


Figure 3. Changes in the relative content of the aroma volatile compounds identified in the headspace of wedges and dice of Packham's Triumph pears stored 8 d at 5 or 8°C.

Negative values indicate the decrease according to the relative content identified in the whole fruit.

Sensory evaluation

The sourness of wedges and dice was scored with a mean value between 1 and 2.7 along storage, which can be interpreted as low. On the other hand, the sweetness was considered as moderate, due to it was scored with a mean value between 6 and 9.6, while taste was graded as high (mean value between 7.6 and 10.9). These results did not show significantly statistical differences among treatments during storage either at 5 and 8°C (data not shown).

Discussion

The respiration and ethylene production rates are an expression of the fruit deterioration due to an increasing content which makes which makes the products more perishable (Escalona & Luchsinger, 2008; Chassagne, Poirier, Devaux, Fonseca, Lahaye, Pigorini, Girault, Marin & Guillon, 2009). The respiration rate increases not only by temperature, but also by the damage provoked to the product either during processing or storage due to the surface area exposed to the atmosphere (Cantwell & Suslow, 2007; Escalona & Luchsinger, 2008), as it was observed in the dice stored at 8 °C, whose respiration rate was higher than the respiration rate shown by the wedges.

In addition, the respiration rates of MPF products increases due to processing damage compared to intact products (Cantwell & Suslow, 2007). This aspect was reflected in the results obtained, where dice cutting type with a greater degree of damage due to processing and, stored at 8°C exhibited the highest respiratory rates compared to wedges. Even though, it has been reported that pears cut into pieces of 2 cm and kept at 2°C, showed respiration and ethylene production rates

similar to the whole fruit (Cantwell & Suslow, 2007).

The effect of cutting was also evidenced by the color change of the MP Packham's Triumph pears. The change in lightness, chroma and hue was due to the breakdown of cell compartments, which have allowed the interaction of the enzyme polyphenoloxidase with the phenolic compounds causing the browning of cut surfaces (Toivonen & Brummell, 2008). The change in the color parameters was more noticeable in the dice, due to their greater exposed surface (Escalona & Luchsinger, 2008). Similarly, this cutting type had a softer and less crispy and juicy firmness (Artés, Gómez & Artés-Hernández, 2007). Smith, Stanley & Baker (1987), states that the change in texture is due to the hydrolysis of the cell wall components. In addition, these changes are extended as temperature and storage time increase. So, the control of the storage temperature is one of the most important techniques to reduce post-harvest losses (Franck, Lammertyn, Verboven, Ho, Verlinden & Nicolai, 2007).

Conversely, a decreasing in the content of organic acids, evidences their function as substrates for the respiration process (Obando-Ulloa *et al.*, 2009). On the other hand, an increasing in the sugar content observed in the MP Packham's Triumph pears is due to the starch hydrolysis and dehydration provoked by respiration and cold storage (Obando-Ulloa *et al.*, 2009a). According to the analysis of the sugar content, fructose is the sugar with a higher proportion, followed by glucose and sucrose, as it has also been reported in whole "Yali" pears (Chenyan, Feng Xiao & Hu, 2006).

The definition of aroma profile is the balance of all compounds emitted from the headspace. This profile is based on the presence of each of these compounds in most of the samples tested (Obando-Ulloa *et al.*, 2008). The esters have been identified with high relative levels in other cultivars of pears (*Pyrus communis* L.) (Chen *et al.*, 2006), pineapple (*Ananas comosus* L.) Merr.) (Chang-Bin, Sheng-Huiyu-Ge, Ling-Ling, Wen-Xiu and Guang-Ming, 2011), melon (*Cucumis melo* L.) (Obando-Ulloa *et al.*, 2008) and watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) (Beaulieu & Lea, 2006). These compounds are degraded to other products or disappear as the product reaches the end of its shelf life (Mehinagic, Royer, Symoneaux, Jourjon & Prost, 2006; Obando-Ulloa *et al.*, 2009b).

Conclusion

This study evaluated the effects of cutting type and storage temperature on Packham's

Triumph pears, which have implications in the evolution of physiological parameters, due to an increasing cutting level and storage temperature are correlated with the respiration and ethylene production rates. Given these concerns, the content of aroma volatile compounds decreased regardless the cutting type and storage temperature. Therefore, Packham's Triumph pears should be cut in wedges and stored at 5°C to maintain optimum quality for at least 8 days.

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