Shelf-life of chilled cut orange determined by sensory quality

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The shelf-life of chilled cut orange was evaluated in terms of physical and chemical quality characteristics, microbial contamination and sensorial acceptability. After minimal processing (peeling and cutting), fresh orange was stored in air at 4°C. Evaluations were performed at different times of storage. The respiration rate of the fresh-cut orange was also evaluated. No significant increase was noticed in relation to the whole fruit which means that this was not the factor responsible for an accelerated deterioration of the product. During the first eight days of storage the major quality parameters remain almost unchangeable, except for titratable acidity which decreased around 36% and ascorbic acid content which decreased around 22%. With respect to microbial contamination low temperature determined a considerable shelf-life (15 days). Sensory quality was the parameter which determined the shelf-life of cut orange to five days at 4°C due to flavour changes.

Keywords: minimal processing; peeling; cutting; fresh-cut fruits; orange; chilled; shelf-life; respiration

INTRODUCTION

The current consumer trend is towards fresh, natural, minimally processed convenient foods (Huxsoll *et al.*, 1989; Rosen and Kader, 1989). Minimally processed fruits are products which have these attributes. Besides the safety aspect, acceptability of those products depends mainly upon their organoleptic characteristics: flavour, texture and appearance. Research has previously been carried out to provide the industry with new methods for assuring the quality of these products: Heaton *et al.* (1969) studied the effects of antioxidants on sensory qualities of fresh sliced peaches; Santerre *et al.* (1988) tried to optimize the concentration of sulphide substitutes to preserve the colour of apple slices; Sapers *et al.* (1990) compared different browning inhibitors applied to the cut surface of apple; Powrie *et al.* (1990) suggested the MAP technology as a new method to preserve fruit salad; and Stephan (1990) described a method to preserve a tropical fruit salad by using vitamin C, as a browning inhibitor, in the juice. Nevertheless, little information is available on the shelf-life of chilled cut orange.

Orange provides an important source of ascorbic acid for human nutrition. The juice contains 40–70 mg of ascorbic acid per 100 ml (Reuther *et al.*, 1968). Rushing and Vincent (1962) studied the flavour stability and the microbial population in chilled citrus salads which included orange at different temperatures. They reported a loss of typical fresh flavour even at low storage temperature before a significant increase in microbial count was noticed. Baker and Bruemmer (1989) tested a new approach for commercial sectioning of citrus fruits using pectinase peeling and segmenting. In these experiments low temperature was effective in delaying bacterial but not yeast development. Normal losses of flavour quality of the chilled segments could be reduced by the use of controlled atmosphere packaging.

The fresh cut fruit is believed to behave differently to the whole fruit. Due to wounding and damage to the skin cut fruits are usually more perishable than fresh

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produce (Huxsoll *et al.*, 1989; Rosen and Kader, 1989). When peeled and cut the outside protective layer is removed, exposing the fresh cells, rich in water, sugars and organic acids (Klein, 1987). The leakage of nutrients will promote microbial growth and the damaged tissue also provides a portal of entry for establishing a microbial colony (Fennema, 1985). One might expect an increase of respiration rate in cut fruit (Rosen and Kader, 1989) and the shelf-life of a fruit varies inversely with the respiration rate (Hardenburg *et al.*, 1986).

Temperature is the most important environmental factor in the post-harvest life of fresh fruits because of its dramatic effect on the rates of biological reactions, including respiration (Kader, 1987). For a 10°C rise in temperature, respiration rate is roughly doubled or tripled (Hardenburg *et al.*, 1986). Therefore, control of respiration may be achieved by an adequate temperature management (Jurin and Karel, 1963).

The objective of this study was to determine the shelf-life of chilled cut orange in terms of physical and chemical properties, microbial contamination, and sensorial acceptability in order to detect the limiting quality factor.

MATERIALS AND METHODS

Plant material

The oranges used were a seedless regional variety from Felgueiras, in the north of Portugal. Oranges were harvested on 8 February 1994, all from the same tree. The orange tree was not fertilized and no fungicides were applied throughout the season.

Treatment and storage conditions

The oranges were harvested and transported in open wooden boxes from Felgueiras to the laboratory in Porto within approximately 1 h, at around 10°C. The experiment was started the next morning. The oranges (around 25 whole oranges, 5 kg) were initially washed in chlorinated water (0.75% of active chlorine for 5 min) to reduce surface contamination (Wardowski and Brown, 1991). Oranges were peeled and slices were cut in half and then randomly selected for different experiments. Three replicate samples of 150 orange sections ($\approx$ 100 g) were used. The samples were stored in closed plastic boxes in air at 4°C. Quality was evaluated in terms of the cut orange quality attributes listed below, at regular intervals for 13 days. Preliminary experiments were performed to determine whether the closed boxes would create a modified atmosphere. The variation of CO_2 and O_2 concentrations from normal air inside the boxes was less than 1% after 13 days of storage. It was therefore assumed that the amount of CO_2 generated inside the boxes as well as the small decrease in O_2 content would have little effect on the fruit. The moisture loss was less than 0.1%.

Physical properties

Colour assessment

One measurement was made on each of 10 sections of orange for each replicate. The cut fruit surface colour intensity was measured with a hand-held tristimulus reflectance colorimeter (Minolta CR-300, Minolta Corp., Ramsey, New Jersey, USA). Colour was recorded using the (CIE-Lab), where L^* indicates lightness, a^* indicates chromaticity on a green (−) to red (+) axis, and b^* chromaticity on a blue (−) to yellow (+) axis. Numerical values of a^* and b^* were converted into hue angle ($H = \tan^{-1} b^*/a^*$) and chroma (chroma $= (a^{*2} + b^{*2})^{1/2}$) (Hunter, 1967).

Chemical properties

Titratable acidity

Oranges were ground-up, and 20–30 g was diluted in 250 ml of recently boiled water. Potentiometric titration was performed with a pH combined electrode Ingold U402-57/120 and a Crison MicropH 2002 (Crison Instruments, S.A., Barcelona, Spain) potentiometer. 25 ml of the prepared juice was titrated with 0.1N NaOH beyond pH 8.1, and data was interpolated corresponding to pH 8.1. Three replicate samples were analysed and the results were calculated as percent of citric acid/100 g orange.

pH

One measurement was performed on each of 10 orange sections for each replicate. The pH of the fruit was determined using a Crison MicropH 2002 potentiometer and a xerolyt electrode Ingold Lot 406-MG-DXK-57/25, calibrated at pH 4.0 and pH 7.0.

Nutritional properties

Ascorbic acid

Approximately 30 g of crushed orange was mixed with an equal amount of metaphosphoric acid (6%) then diluted in metaphosphoric acid (3%) and filtered. A filtered sample of 5–10 ml was titrated with 2,6-dichlorophenolindophenol until persistent pink colour was observed. Three replicates were performed and the results expressed as mg ascorbic acid/100 g orange.

Soluble solids

The soluble solids content was determined individually for each of the replicates with a hand-held sugar refractometer model Atago-ATCI. Results are expressed as degree brix.

Sugars

Sucrose, D-glucose and D-fructose were determined using HPLC (Spectra Physics SP 8800), using NH_2 column, 5μ/Spherisorb – Biochrom). A 10 μl sample of crushed orange diluted in 50 ml of deionised water filtered and degased, was injected at a flow rate of 2.0

ml/min using 80% acetonitrile + 20% water as eluent and a column temperature of 40°C. The components were detected with a refractive index detector HP 1047 (Hewlett Packard). The peaks were quantified by external calibration.

Respiration rate

Approximately 55 g of cut orange was placed in a sealed glass jar (500 ml) and stored at either 4°C or room temperature (≈19°C) in triplicate. The same procedure was followed for whole oranges. Estimation of CO_2 production was performed from a closed system. Gas concentrations in the jars were measured periodically by injection of 0.6 ml of the head space of the jar in a Shimadzu GC-14A with thermal conductivity detector. For a known weight of orange in a known free space volume, the respiration rate (*RR*, weight of CO_2 evolved per kg fresh weight of the commodity per hour) was calculated. The respiratory quotient (*RQ*) was also calculated. The *RQ* is defined as the ratio of CO_2 evolved to the O_2 used (measured in moles). Values of Q_{10} (van't Hoff's rule) (Hardenburg *et al.*, 1986) were calculated with the average values of respiration rate of whole and fresh-cut orange using the following formula:

$$Q_{10} = \left[\frac{RR_{CO_2}\,(19°C)}{RR_{CO_2}\,(4°C)} \right]^{10/19-4}$$

Microbiological analysis

Initial washing of the whole orange with chlorinated water was performed to remove surface contamination. Peeling and cutting was carried out aseptically. Slices were placed on sterile Petri dishes and incubated at 4°C and 25°C. On each day of storage, cut orange was blended in Ringer solution for two minutes in a Seward Stomacher, serial diluted and plated using spread plate technique. Three culture media were used throughout the study. All were prepared and sterilized according to the manufacturers instructions. Potato dextrose agar (Lab M, Lab 98) for moulds, Wort agar (Lab M, LAB 38) for yeasts and Nutrient agar (Lab M, LAB 8) for bacteria. Duplicate plates were inoculated for each dilution and incubated at 4 and 25°C. For samples stored at 4°C the Newbauer chamber was used to give a total cell count.

Sensorial analysis

Potential sensory panelists were first screened for their ability to recognize basic tastes, determine the intensity of basic tastes, recognize odours and to give texture ratings (Stevens and Albright, 1980). Fifteen panelists were selected. The panelists were male and female graduate students with an age range of 24–34 years.

Triangular test

The samples in clear plastic boxes at room temperature (≈ 20°C) were presented randomly to panelists. Tasting was done in a sensory testing room with individual booths and controlled lighting (white). The collected results were analysed using a Chi-square test.

RESULTS AND DISCUSSION

Physical properties

Colour

No significant changes were observed with time on fresh-cut orange stored at 4°C. L^* values varied between 49.43 and 51.90 (± 2.00). Hue values varied between 35.14 and 37.35 (± 2.30), and chroma values varied between 88.04 and 89.46 (± 1.00) (*Figure 1*). These results agree with those previously reported for different orange products such as unpasteurized orange juice and canned orange by Wenzel and Huggart (1969). This may be explained by a low enzyme activity at the pH value of the cut orange under study (pH 3.9). The optimum pH for polyphenoloxidase activity is higher, around pH 4.5 (Wesch-Ebeling and Montgomery, 1990). Zemel *et al.* (1990) found that polyphenoloxidase (PPO) activity in apples was progressively inactivated at lower pH values; PPO was inactivated by 34%, 63% and 98% of the initial activity after 20 min at adjusted values of 2.5, 2.25 and 2.00, respectively.

Chemical properties

Titratable acidity

Titratable acidity as % citric acid decreased from 0.46% to 0.29% in 13 days of storage at 4°C (≈37% decrease) (*Figure 2*). Citric acid is the characteristic organic acid of orange, it accounts for most of the pulp acidity and its content generally decreases during storage. Ortiz *et al.* (1987) found that titratable acidity decreased gradually with maturation from 30 g/l to 7 g/l for whole oranges.

pH

The pH, unlike titratable acidity, did not change significantly during 10 days of storage at 4°C (3.87±0.07) (*Figure 3*). Sinclair and Jolliffe (1960) also observed that pH and titratable acidity were not directly related in samples of 'Valencia' orange juice. This is probably due to the effect of the buffer capacity of the fruit tissue, and it is a positive aspect since a small variation in pH might imply a negative effect in flavour (Chitarra and Chitarra, 1990).

Nutritional properties

Ascorbic acid

Ascorbic acid content decreased from 45.7 to 30.35 mg/100 g of orange during 13 days of storage at 4°C

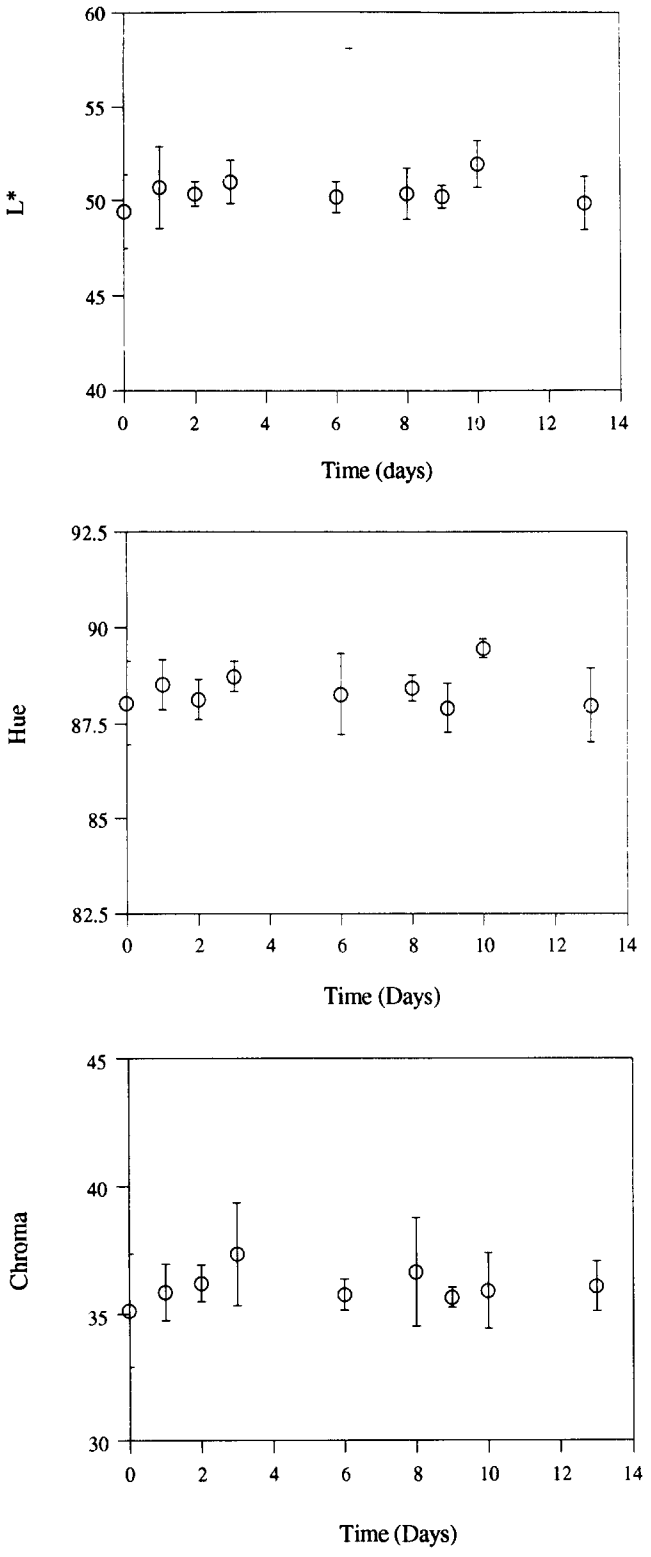

Figure 1 Colour parameters of cut orange during storage at 4°C

(≈36% decrease) (*Figure 4*). Similar results have been reported for maturing orange juice (Nagy, 1980) and with storage time (Fellers, 1988). Since no enzyme inactivation was attempted the ascorbic acid degradation was probably due to specific enzymes (cytochrome oxidase, ascorbic acid oxidase and peroxidase). Simultaneously, there was the possibility that non-enzymatic reactions of degradation of ascorbic acid occurred in the presence of oxygen (Nagy, 1980).

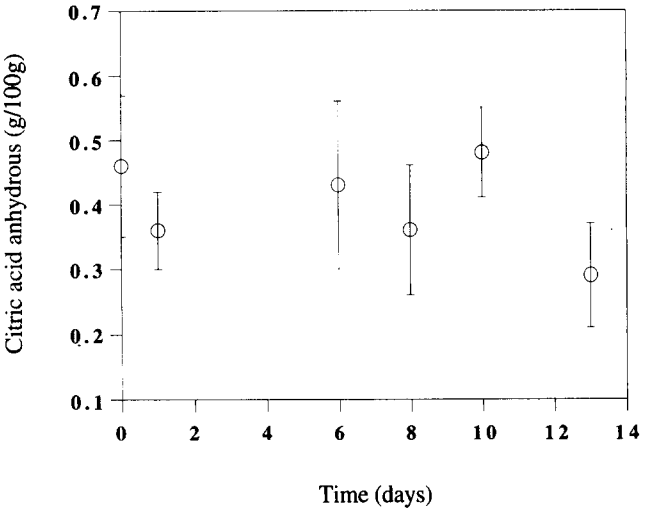

Figure 2 Citric acid content of cut orange during storage at 4°C

Soluble solids, sugars and respiration rate

Glucose and fructose contents followed similar trends during storage. Between the first and fourth day of storage sucrose was converted into reducing sugars: glucose and fructose (*Figure 5*). This drop in sucrose content might also be explained by the fact that this early period (after peeling and cutting) would be characterized by an intensive respiration during which this sugar would be rapidly used as substrate in the metabolic process. However, the results of respiration rate of cut orange at 4°C were not much higher than for the whole fruit (*Table 1*). The increase of sucrose at the fifth day might be due to metabolism of the cell wall polysaccharides producing sugars (Fennema, 1985). However, at the eleventh day the cell wall polysaccharides might not be sufficient to make up sugars consumption in respiration and sugars content decreased again. Nevertheless, those changes were not noticed on the soluble solids content, probably due to a low sensitivity of the method used. Soluble solid content was similar throughout 13 days of storage at 4°C (9.82±0.68) (*Figure 6*).

The *RQ* varied from 0.6 to 1.3 (*Table 1*). These values were similar to those reported in the literature

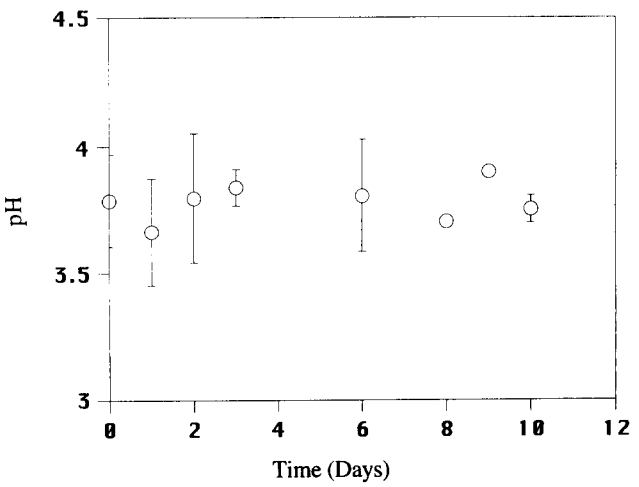

Figure 3 pH value of cut orange during storage at 4°C

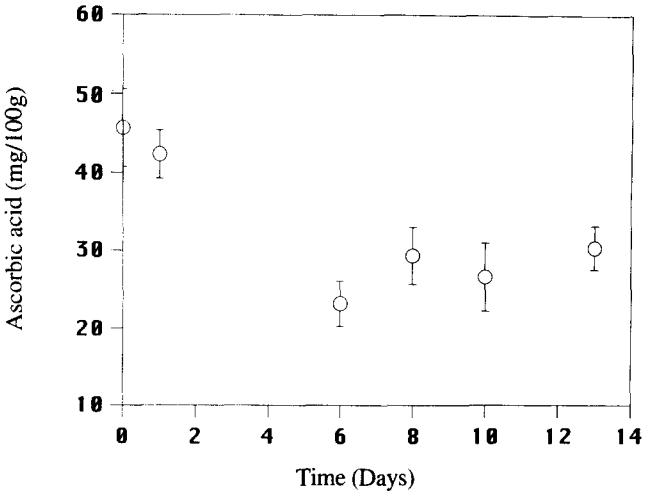

Figure 4 Ascorbic acid content of cut orange during storage at 4°C

(Hardenburg *et al.*, 1986). The Q_{10} was 3.20 for whole orange and 3.12 for fresh-cut orange. Whole orange respires about 3.20 times faster at 19°C than at 4°C, and the fresh-cut orange respires about 3.12 times faster at 19°C than at 4°C.

Microbiological and sensorial analysis

Colonies were visible on slices of orange after 48 hours at 25°C and 384 hours at 4°C. At 25°C the effect of low pH may not be enough to restrict microbiological development in orange resulting in a shelf-life of only 2 days. At 4°C the effects of low pH together with low temperature carry out a 'hurdle' effect to extend the shelf-life of fresh-cut orange to 15 days.

Panelists were able to identify the refrigerated orange samples after 5 days storage (*Table 2*). Previously, flavour changes were detected by sensorial panels in citrus products such as juices (Lund *et al.*, 1981; Moshonas and Shaw, 1989; Nagy, 1980; Braddock *et al.*, 1991). Those changes have been identified as being the results of the combined increase of potential off-flavours components and loss of desirable oil components (Fellers, 1988). A similar conclusion was also reported by Rushing and Vincent (1962) who reported detectable differences between fresh and refrigerated samples. This observation was attributed to the loss of a 'flavour characteristic' of fresh citrus fruits during storage. These results show that it is not the microbial population by itself that results in spoilage, at least when appropriate temperatures are employed, but rather some factor in the fruit itself together with

Table 1 Respiration rate (*RR*) and respiratory quotient (*RQ*) of fresh-cut orange and whole orange at 4°C and 19°C

Orange	Temperature (°C)	*RR* ($\frac{mg\ CO_2}{kg \times h}$)	*RQ* ($\frac{mol\ CO_2}{mol\ O_2}$)
Whole	4	4.41±0.77	0.56 to 0.87
	Room (≈19)	25.3 ±3.79	0.83 to 1.12
Fresh-cut	4	6.28±1.22	0.95 to 1.33
	Room (≈19)	34.7 ±1.16	1.11 to 1.14

Table 2 Effects of storage at 4°C on sensorial perception of cut orange

Storage time (days)	Triangular test result
0	No significant differences between samples
2	No significant differences between samples
5	Significant differences between samples
7	No significant differences between samples
10	Significant differences between samples

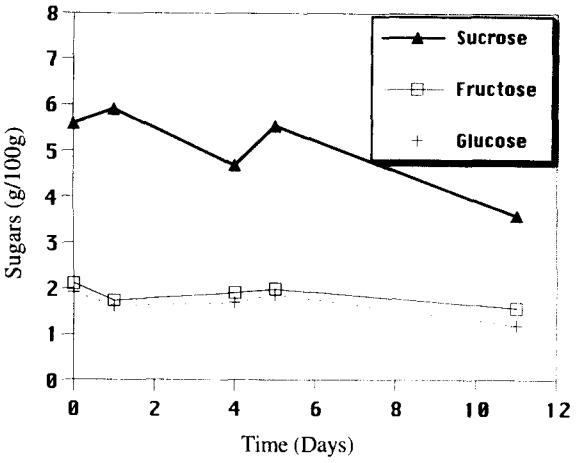

Figure 5 Sucrose, glucose and fructose content of cut orange during storage at 4°C

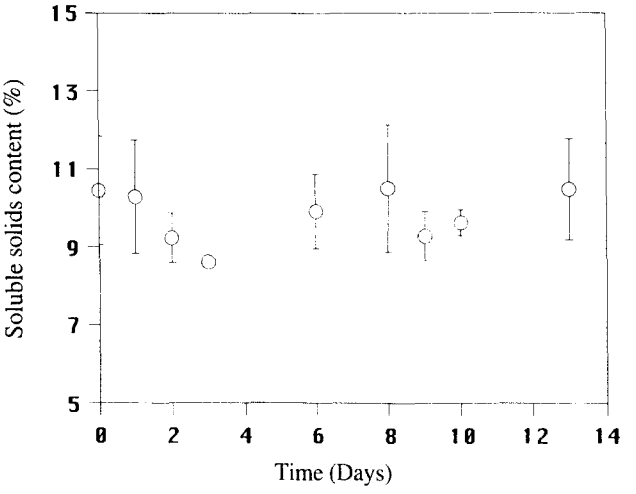

Figure 6 Soluble solids content of cut orange during storage at 4°C

factors acquired during processing that may mediate the spoilage. Since cut orange contains its normal fruit enzymes it is likely that they are involved.

CONCLUSION

In general, orange chemical composition and cellular structure seem to enable a stable metabolic behaviour. Physical and chemical properties, and microbial contamination were not the quality parameters determining the shelf-life of cut orange. Respiration rate does not accelerate the deterioration of the cut orange in

relation to the whole fruit. The shelf-life was limited to 5 days at 4°C by sensory analysis, showing that the problem of extending shelf-life is mainly due to flavour stabilization. Based on these results, we suggest storage in a non-oxidative atmosphere by using controlled/modified atmosphere technologies, in order to control oxidation reactions. Associated to this a chemical treatment with ascorbic acid might be used to make up losses during storage.

Further research is required in the extension of the shelf-life of fresh-cut fruits in order to provide the possibility of creating new products and allowing the expansion of ready-to-eat fruit into different sectors of the market.

ACKNOWLEDGMENTS

This research work was funded by a JNICT and a PEDIP scholarships. The authors gratefully acknowledge the collaboration of Estação Regional de Vitivinicultura e Fruticultura – Quinta de Sergude – Felgueiras.

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