Environmentally Friendly and Safe Technologies for Quality of Fruits and Vegetables

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The papers contained in this book report some of the peer reviewed Proceedings of the International Conference "Environmentally friendly and safe technologies for quality of fruit and vegetables", but also other papers related with the subject were included. The manuscripts were reviewed by the Editor and Editorial Board, and only those papers judged suitable for publication were accepted. The Editor wish to thank to all the reviewers and authors for their contribution.

Authors are responsible for content and accuracy of their papers.

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SECTION 5. NEW APPROACHES TO ENHANCE SAFETY AND QUALITY OF MINIMALLY PROCESSED FRUITS AND VEGETABLES

32. PHYSIOLOGICAL BASES FOR TEXTURE AND COLOR CHANGES IN FRESH-CUT ‘ROCHA’ PEAR: IMPLICATIONS FOR THE DEVELOPMENT OF PRODUCTS AND PROCESSES

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Abstract

The physiological bases for the effectiveness of technologies used in fresh-cut fruit were examined in an attempt to foster the shift from a market-pull to a science-push innovation model. Respiration rate of fresh-cut ‘Rocha’ pear were measured at various oxygen concentrations. Apparent Km values for oxygen uptake were very close to the fermentation thresholds, indicating that it is physiologically impossible to reduce the respiration rate of fresh-cut pear by more than 50% without inducing fermentation. Based on this information, we hypothesize that optimizing oxygen concentration inside packages is of little or no value in fresh-cut pears. Additionally, additives used to reduce enzymic browning and softening may have pleiotropic effects on quality. It was found that pH significantly affected the rate and intensity of browning of fresh-cut pears. Browning was more intense in pears treated at pH 3.0 and less pronounced at pH 7.0, but the softening rate was lower at the latter pH value. Calcium salts also affected texture and color in a salt-specific manner. Larger color changes were observed with propionate and lactate. Although calcium ascorbate reduced color changes, fruit slices treated with this salt were softer than those treated with calcium propionate, lactate or chloride. Based on the physiological information gathered, we will develop and evaluate an integrated process to maximize the quality of fresh-cut ‘Rocha’ pear throughout the distribution chain.

Keywords: minimally processed, modified atmosphere packaging, pH, *Pyrus communis*, respiration

Introduction

Fresh-cut produce are one of the fastest growing segments of the fresh food market in developed countries, both at retail level and restaurant outlets. The fresh-cut fruit industry is urged to provide products to the growing number of consumers who seek convenience and will not lower their high expectations regarding the intrinsic quality and food safety of fresh-cut fruit. Fruit processing has physiological consequences that impact negatively on the quality of the final fresh-cut product. Loss of cellular compartmentation caused by cutting deeply affects tissue metabolism. Wounding causes an increase in respiration rate, ethylene synthesis and area-to-volume ratio, favors water loss, and destroys structural barriers to the entry of microorganisms (Watada & Qi 1999). Additionally, the metabolic changes induced by cutting can produce undesirable flavor, loss of vitamins, excessive softening and color changes all of which severely reduce shelf life (Wiley 1994). Enzymatic browning and softening are the major limiting factors for fresh-cut pear (Gorny *et al.* 2000), when microbiological stability is secured. Anti-browning additives, often combined with calcium, and modified atmosphere packaging are used to extend shelf-life in fresh-cut pear. A number of studies encompassing packaging films and geometries have assessed O_2 concentration versus produce quality, in order to empirically find the best package (Del Nobile *et al.* 2007; Soliva-Fortuny *et al.* 2007). An alternative approach to the trial-and-error, should data be available, is to deduce optimal packaging geometry and film permeability based on the produce respiration rate (Lakakul *et al.* 1999; Jacxsens *et al.* 2000), as affected by oxygen concentration and temperature.

This research project aims at evaluating the potential of MAP utilization for fresh-cut 'Rocha' pear. The relationship between oxygen concentration and respiration rate was modeled to help design of MAP for fresh-cut pear at temperatures normally found during processing and distribution. The effect of dipping solutions with different pH values and calcium salts in the control of quality loss of pear slices during cold storage has also been studied. The physiological information gathered is useful to develop and evaluate an integrated process to maximize the quality of fresh-cut fruits.

Material & Methods

Plant Material and General Processing

Pears (*Pyrus communis* L. 'Rocha') with a flesh firmness ranging between 38 to 56 N (8-mm probe) were sanitized and hand cut in wedges, without skin removal.

Respiratory Data

The fresh-cut pear wedges (30 to 26 g) were packed in low-density polyethylene (LDPE) (Dow Chemical Company, Midland, MI) pouches that were hermetically sealed using an impulse heat sealer. A range of steady-state O_2 and CO_2 partial pressures was achieved by varying fruit weight (30-260 g), film surface area (450-800 cm^2), and film thickness (27-105 μm) among the pouches. Oxygen and carbon dioxide were measured daily with a gas analyzer. Rates of O_2 uptake and CO_2 production were calculated by mass balance, once steady-state O_2 and CO_2 partial pressures were achieved inside the packages. Three replicates of each combination of film thickness, film area, and fruit mass were stored at 0, 5, 10 and 15 °C.

Respiration rate (R_{O_2}) was described as a function of O_2 partial pressure (pO_2) by a Michaelis-Menten model, as suggested by Lee *et al.* (1991).

Respiratory quotients (RQ) and ethanol as function of steady-state oxygen partial pressure were used to determine the lower limit for aerobic respiration (Joles *et al.* 1994). The sudden increase in RQ or headspace ethanol concentration occurring when pO_2 dropped below a certain level is termed 'fermentation threshold'.

pH Treatments

Pear slices were dipped for 1 min in a cold buffer solution (200 mM sodium phosphate and 100 mM citric acid) at pH 3.0, 5.0 and 7.0, packed in clamshells with normal atmosphere and stored at 4 °C. Six replicated packages for each dipping solution were analyzed at 0, 3, 6, 10 and 13 days (d), for color, firmness, soluble solid content, pH, titratable acidity and *mesophilic* and *psychrophilic* bacterial count.

Calcium Treatments

Fresh-cut pears were dipped in calcium solutions buffered at pH 3 and pH 7, placed in covered trays and stored at 5 °C. Four calcium salts – ascorbate, chloride, lactate and propionate – were dissolved in two buffer solutions with pH 3.0 (100 mM citric acid-100 mM sodium citrate and 100 mM citric acid-200 mM sodium phosphate), and two buffers with pH 7.0 (100 mM Mops-NaOH and 100 mM Tris-100 mM HCl) to give a final concentration of 250 mM (1% Ca^{2+}) of calcium. The experiment was conducted in a randomized complete block design with 30 pear slices per treatment. The two buffer solutions with the same pH were considered as replicates. Data were subjected to two-way analysis of variance, considering pH and calcium salt as factors.

Quality Determinations During Storage Period

Color was measured in the CIE L* C* h color space with a Konica-Minolta CR-400 chromameter (Japan) with a D65 illuminant. Metric hue difference, $\Delta H^* = \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 - (\Delta C^*)^2}$, where a* and b* are the Cartesian color coordinates and C* is chroma, was used to express changes in color between day 0 and day 6. Firmness was determined using a texture analyzer (TA-XT2 Plus, Texture Technologies, UK) equipped with a flat plate. Microbiological assessment was attained by enumeration of total plate count of mesophilic and psychrophilic microorganisms (ISO 4833:1991). Soluble solids content (digital refractometer Palette PR-32, Atago, Japan), pH (pH meter Ion 510 Series, Oakton, USA) and titratable acidity (titrator Digitrate, Jencons, UK) were determined in pear juice.

Results & Discussion

Respiration and Modified Atmosphere Packaging

The oxygen uptake rate increased with $pO_{2\ pkg}$ in a manner consistent with saturation kinetics (Fig 1). Michaelis-Menten model was able to explain more than 93% of the total variability of the data and accurately predicted the experimental results (RMSE<0.06). Respiration rates of fresh-cut 'Rocha' pear, as expressed as CO_2 production were similar to the range of value reported for other fresh-cut pear varieties at 0 or 10 °C (Gorny *et al.* 2000). The respiratory quotient (RQ) for aerobic respiration of fresh-cut 'Rocha' pear stored at various temperatures ranged between 1.2 and 1.4 (Table 1), consistent with the usage of organic acids as major respiratory substrates (Fonseca *et al.* 2002). 'Fermentation threshold' ranged between 0.4 and 2.9 kPa (Table 1). At elevated temperatures fermentation occurred at higher pO_2 (Lakakul *et al.* 1999), as observed for 5 up to 15 °C (Table 1).

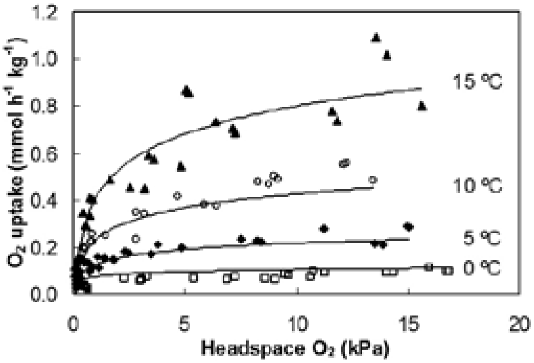

Fig 1. Effect of steady-state O_2 partial pressure and storage temperature on the rate of O_2 uptake of 'Rocha' pear slices in sealed LDPE packages at 0 (□), 5 (♦), 10 (○) and 15 °C (▲) fitted with a Michaelis-Menten model.

Table 1. Estimated respiratory parameters for fresh-cut 'Rocha' pear stored at four temperatures.

Temperature (°C)	R_{O2}^{max} (mmol kg^{-1} h^{-1})	$K_{m,O2}$ (kPa)	RQ	Fermentation threshold (kPa)	Safe working atmosphere (kPa)
0	0.108	0.52	1.4	2.9	None
5	0.224	0.73	1.3	0.4	0.33
10	0.464	1.02	1.2	0.7	0.32
15	0.961	1.43	1.3	0.7	0.73

Respiratory behavior as function of oxygen concentration provides a basis to deduce the potential benefits of using MAP technologies. Low oxygen atmospheres could be useful if a sizeable reduction in respiration rate (e.g. 50%) can be reached without the induction of fermentation (Beaudry 2000). In cases where K_{m,O_2} (apparent K_m - is the $pO_{2\ pkg}$ at half of maximal value of R_{O_2}, kPa) is much higher than fermentation threshold, a reduction in pO_2 slows down metabolic activities without an increase in the RQ and fermentative compounds. The range of pO_2 between K_{m,O_2} and fermentation threshold is termed 'safe working atmosphere' (Beaudry 2000). Fresh-cut 'Rocha' pear had narrow (0.3 to 0.7 kPa) safe working atmospheres at the temperatures tested (Table 1). Low oxygen atmospheres did not offer any reduction in metabolic activity without the danger of inducing anaerobiosis, especially between 0 and 10 ºC, temperatures normally found during storage and marketing. Gorny (2001) also reported a poor efficacy of modified atmosphere for fresh-cut pear at 0-5 ºC.

Given this physiological behavior, the potential for reducing respiration of fresh-cut via MAP is limited. Efforts in packaging design should, therefore, to directed at avoiding microbial contamination and dehydration, and allow aerobic respiration.

Effect of pH

Color of fresh-cut pear slices was significantly affected by pH of the dipping solutions throughout the storage period (Fig 2a, Table 2). Acidic additives (e.g. ascorbate, citrate) are frequently used during processing of fresh-cut fruit to limit microbial growth. However, dipping in an acidic solution increases pear browning (Sapers & Miller 1998). Enzymatic browning is mediated by polyphenoloxidase (PPO) and optimal pH values for pear PPO are cultivar dependent. Catalytic properties of 'Rocha' pear PPO are yet to be thoroughly characterized but low enzymatic activity at pH 7 is expected, as observed with PPO of 'Bosc' and 'Red' cultivars (Siddiq *et al.* 1994).

A significant effect of pH on firmness was also observed. Higher softening rates were observed at acidic pH, especially during the first 6 to 9 d at 4 ºC (Fig 2b). Similar results observed by Pinheiro & Almeida (2008) in tomato were attributed to enhanced pectin disassembly at lower pH.

Microbial count increased over storage and pears dipped with pH 7.0 solution presented higher counts, although below 10^6 cfu g^{-1} after 10 d in storage (data not shown).

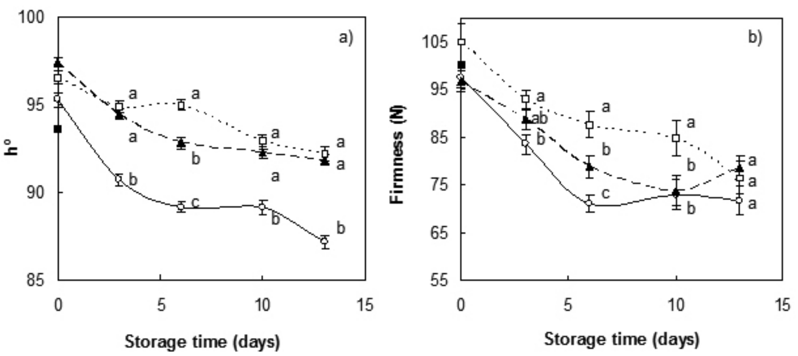

Fig 2. Hue angle (a) and firmness (b) values of fresh-cut pear slices untreated (■) or treated with a solution at pH 3 (○); 5 (▲) or 7 (□), during storage at 4 ºC. Points are average of 36 replicates; bars are standard error.Values followed by the same letter are not significantly different.

Effect of Calcium

Ascorbate was the calcium formulation less effective in maintaining firmness but preserved initial color (Table 2). An interaction between the effects of pH and calcium in color and firmness was observed, as previously reported by Pinheiro & Almeida (2008) for tomato. While color of slices treated with calcium ascorbate or calcium chloride did not differ with solution pH, calcium lactate and calcium propionate clearly promoted browning when dissolved in solutions at pH 3 when compared with solutions at pH 7 (data not shown).

Table 2. Effect of calcium salt and buffer pH on firmness and color of fresh cut pear stored 6 days at 5 °C. Values are means (n=120 for calcium; n= 300 for pH) ± SE. Values followed by the same letter are not significantly different.

	Firmness variation (%)	Color variation (ΔH^*)
Calcium		
Buffer	133.2 ± 3.7^{a}	2.50 ± 0.10^{c}
Ascorbate	93.4 ± 3.3^{d}	0.42 ± 0.03^{e}
Chloride	120.0 ± 3.1^{b}	1.69 ± 0.08^{d}
Lactate	117.5 ± 3.3^{b}	3.26 ± 0.14^{a}
Propionate	106.5 ± 3.6^{c}	3.02 ± 0.23^{b}
pH		
3.0	100.8 ± 2.1^{b}	3.00 ± 0.12^{a}
7.0	127.9 ± 2.2^{a}	1.35 ± 0.06^{b}
Significance (P)		
Calcium	<0.001	<0.001
pH	<0.001	<0.001
pH*Calcium	<0.001	<0.001

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