Optimal temperature and modified atmosphere for keeping quality of fresh-cut pineapples

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Received 13 October 2005; accepted 18 October 2005

Abstract

The influences of storage temperature and modified O₂ and CO₂ concentrations in the atmosphere on the post-cutting life and quality of fresh-cut pineapple (Ananas comosus) were studied. Temperature was the main factor affecting post-cutting life, which ranged from 4 days at 10 °C to over 14 days at 2.2 and 0 °C. The end of post-cutting life was signaled by a sharp increase in CO₂ production followed by an increase in ethylene production. The main effect of reduced (8 kPa or lower) O₂ levels was better retention of the yellow color of the pulp pieces, as reflected in higher final chroma values, whereas elevated (10 kPa) CO₂ levels led to a reduction in browning (higher L values).

Modified atmosphere packaging allowed conservation of pulp pieces for over 2 weeks at 5 °C or lower without undesirable changes in quality parameters.

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Keywords: Color; Ethylene; Firmness; Respiration

1. Introduction

Pineapple (Ananas comosus L. Merrill) is a non-climacteric tropical fruit that shows moderate to low rates of respiration and ethylene production (Dull et al., 1967). Fresh-cut pineapple products are already found in supermarkets and food service distribution chains, but very few studies have been published regarding the optimal conditions for maintaining quality of these products. O’Connor-Shaw et al. (1994) reported that pineapple cubes stored in polypropylene containers at 4 °C kept their sensory attributes for 7 days, but after 11 days showed brown discoloration, and after 14 days off-odors and softening were apparent. Spoilage is associated with an increase in respiratory activity due to the growth of microbial flora (Iversen et al., 1989). The post-cutting life of pineapple has been reported to be very dependent on temperature, from a few hours at 20 °C to several weeks at 1 °C (O’Hare, 1994). In a preliminary study (Marrero and Kader, 2001), we found that post-cutting life of pineapple pieces ranged from 4 days at 10 °C to over 2 weeks at 0 °C.

The prolonged post-cutting life of fresh-cut pineapple products at such low temperatures is contrary to the susceptibility of whole fruits to chilling. Chilling injury develops when whole fruits are stored at temperatures below 10 °C for extended periods of time. The symptoms include dull shell color when ripe, wilting of crown, water-soaked appearance of pulp, increased susceptibility to decay and internal browning (Paull and Rohrbach, 1985; Paull, 1997). Some of these symptoms appear after the chilled fruits have been removed to non-chilling temperatures, and their incidence can be alleviated using controlled or modified atmospheres (Paull and Rohrbach, 1985; Chitarra and da Silva, 1999).

The objectives of this study were to determine the optimal temperature for conservation of fresh-cut pineapple pieces and to investigate the influence of atmosphere modification on quality maintenance of the product. The suitability of a new pineapple cultivar for minimal processing was also studied.
2. Materials and methods

2.1. Plant material

Unless otherwise stated, experiments were performed using fruit of the Smooth Cayenne selection no. 3620 (‘SC3620’) cultivar. Fruit were received from Hawaii via air freight and stored at 10 °C until processed. For some experiments, fruit of ‘Premium Select’, a new commercial cultivar, were also obtained from Costa Rica and similarly handled. Fruit with a shell color corresponding to stages 2 and 3 of the Dole pineapple color chart (between 25 and 50% shell color change) were peeled, cored and the pulp cut into 1-cm-thick wedges (about 8 g each), dipped in a 100 µL L⁻¹ sodium hypochlorite solution for 2 min, and blotted dry. For some experiments, peel and core tissues were similarly cut into pieces and treated with hypochlorite. In all experiments, three replicates of at least 10 pulp pieces each were used per treatment.

2.2. Storage conditions

For controlled atmosphere (CA) experiments, 1-L glass jars, each containing about 300 g of pulp wedges, were continuously flushed with a humidified flow of air or the desired gas mixture. Flow rates were adjusted so that CO₂ concentrations were measured using an infrared gas analyzer. Gas samples were taken from the outlet tubes of the jars or cups. The detection of off-odors and off-flavors was also recorded.

After an initial increase due to wounding, respiration rates 1 and 2 days after cutting at 10 °C were almost twice as high in peel pieces as in pulp and core pieces (Fig. 1). Whole fruit showed an intermediate respiration rate between those of peel and pulp pieces. Five days after cutting all pieces showed a much elevated CO₂ production rate and signs of microbial spoilage.

Temperature had a significant effect on respiration and post-cutting life. The end of post-cutting life was indicated by a marked increase in respiration followed by visual signs of microbial spoilage. This stage was reached after 4 days at 10 °C, 8 days at 5.5 °C, 12 days at 5 °C and more than 15 days at 2.2 and 0 °C (Fig. 2).

Wounding induced a permanent increase in ethylene production at 10 °C and a temporary one at 7.5 °C (Fig. 2). At this
temperature, as well as at 5°C, a peak in ethylene production was apparent after increased respiration rates were detected. At 0 and 2.2°C no ethylene production was detected with the experimental method used.

Over time there was a tendency toward diminishing values of luminosity (L), chroma and hue angle (Fig. 3), but at the lower temperatures (0 and 2.2°C) these changes were not statistically significant (P > 0.05). No translucency (water-soaked areas) or browning symptoms that could be associated with chilling injury were detected at any temperature.

The volume of juice that leaked from the pieces increased linearly with time, but temperature had no detectable effect on it (Fig. 4). There were no differences in total soluble solids, acidity or texture of the pieces among the different temperatures (data not shown).

3.3. Effects of atmosphere modification

Reducing the oxygen concentration led to diminished respiration rates, but did not delay the onset of fermentation as revealed by a significant increase in CO₂ production (Fig. 5).

Increased (10%) CO₂ levels combined with low (8% or lower) O₂ concentrations led to higher final values of luminosity (L) and acidity of pulp wedges, whereas reduced O₂, with or without increased CO₂, improved the retention of
color, as measured by the chroma values, compared to wedges kept under humidified air for 15 days at 5 °C (Fig. 6). There were no significant changes in soluble solids, pH or hue angle values, nor in the volume of juice leaked from the pieces (data not shown).

3.4. Comparison of the suitability of the ‘SC3620’ and ‘Premium Select’ cultivars for minimal processing

The cultivar ‘Premium Select’ had a significantly higher soluble solids content as well as higher acidity and pH than ‘SC3620’ (Table 1). The contents of β-carotene and total ascorbic acid of this cultivar were about two and three times higher, respectively, than those of ‘SC3620’.

Pulp color of ‘Premium Select’ is a more intense, brighter yellow than ‘SC3620’, as it is reflected in a significantly higher value of chroma and a lower hue angle. Respiration and ethylene production rates of pulp pieces at 10 °C under humidified air were significantly higher for ‘Premium Select’.

When pulp pieces of the two cultivars were stored at 5 °C under humidified air for 2 weeks, those of the ‘Premium Select’ retained their luminosity (L) better than ‘SC3620’, so the final difference in color among the two cultivars was even more prominent than at the beginning (Fig. 7). Neither cultivar showed a significant change in soluble solids, pH, acidity or firmness during storage. In terms of the volume of juice leaked, after 15 days of storage ‘Premium Select’ pieces leaked about one third the volume of that from ‘SC3620’ (Fig. 8).
Table 1

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>SC3620</th>
<th>Premium Select</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical significance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSS (%)</td>
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<td>14.7 *</td>
</tr>
<tr>
<td>Acidity (mM H⁺)</td>
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<td>123 *</td>
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<tr>
<td>pH</td>
<td>3.35</td>
<td>3.41 *</td>
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<tr>
<td>Total ascorbic acid (mg kg⁻¹)</td>
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<td>789 ***</td>
</tr>
<tr>
<td>β-carotene (µg kg⁻¹)</td>
<td>350</td>
<td>670 ***</td>
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<tr>
<td>Flesh color</td>
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<td></td>
</tr>
<tr>
<td>L value</td>
<td>75</td>
<td>74 NS</td>
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<tr>
<td>Hue angle</td>
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<td>98 **</td>
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<tr>
<td>Chroma</td>
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<td>40</td>
</tr>
<tr>
<td>Respiration rate (nmol CO₂ kg⁻¹ s⁻¹)</td>
<td>63.2</td>
<td>88.0 NS</td>
</tr>
<tr>
<td>Ethylene production (pmol kg⁻¹ s⁻¹)</td>
<td>1.69</td>
<td>3.63 **</td>
</tr>
</tbody>
</table>

NS: not significant.

* P < 0.05.
** P < 0.01.
*** P < 0.001

Fig. 7. Change in chroma of ‘SC3620’ and ‘Premium Select’ pineapple pulp pieces kept for 14 days under a continuous flow of humidified air at 5 °C. Data presented are the averages of three replicates. Vertical lines represent the S.D.

Fig. 8. Volume of juice leaked from ‘SC3620’ and ‘Premium Select’ pineapple pulp pieces kept for 14 days under a continuous flow of humidified air at 5 °C. Data presented are the averages of three replicates. Vertical lines represent the S.D.

Fig. 9. Changes in O₂ and CO₂ concentrations inside MA containers of ‘Premium Select’ pineapple pulp pieces stored for 14 days at 0° or 5° C. Data presented are the averages of three replicates. Vertical lines represent the S.D.

3.5. Modified atmosphere packaging of ‘Premium Select’ cultivar

The use of modified atmosphere packaging for pulp pieces of ‘Premium Select’ allowed 14 days storage at 0° or 5° C without undesirable changes. At 5° C O₂ levels dropped below 1% and CO₂ levels reached 15% after 9 days in storage (Fig. 9). At 0° C, it took 12 days to reach the equilibrium levels of 1.5% O₂ and 11% CO₂. In spite of these very low levels of O₂, when the cups kept at 5° C were opened after a 14-day storage period, only a slight off-odor was detected but it quickly dissipated and no off-flavors were apparent when the pieces were consumed. Packages kept at 0° C showed no undesirable aroma. Otherwise, the pieces stored at both temperatures for 14 days showed no signs of deterioration while maintaining acceptable levels of soluble solids, acidity, pH and firmness (data not shown).

4. Discussion and conclusions

The main factor studied affecting the quality of fresh-cut pineapple was temperature. The post-cutting life of pulp pieces varied from 4 days at 10° C to over 2 weeks at 0° C. This extended life at temperatures well below the chilling injury limit for whole fruits had been previously reported (O’Connor-Shaw et al., 1994; O’Hare, 1994). At all temperatures, the end of commercial life was characterized by a sharp rise in respiration preceding an increase in ethylene production (Fig. 1). Continuation of storage beyond this point led to the appearance of off-flavors and odors and microbial spoilage.

No signs of chilling injury were detected at any point in the pulp pieces, even for those kept at 0° C for 2 weeks. This could be due to the short duration between removal from refrigerated storage and quality evaluation (about 3 h), since some of the symptoms do not develop until several days after transfer to non-chilling temperatures (Paull and Rohrbach, 1985). This is not likely to be a commercial problem since, due to
the nature of fresh-cut products, they should be consumed shortly after removal from refrigeration. In addition, the elevated CO2 and reduced O2 levels associated to the CA and MA might also have reduced the incidence of internal brown- ing (Rohrbach and Paull, 1982; Chitarra and da Silva, 1999).

With temperature being the main factor in fresh-cut pineapple conservation, the main advantage of atmosphere modification was a better retention of color. Reduction of O2 concentration to 8% or lower improved the final appearance as reflected by higher final chroma values. Increasing CO2 concentration to 10% had the added advantage of retained luminosity (L) of the pulp pieces. This could be due to a lower activity of browning enzymes such as polyphenol oxidase. Also, elevated CO2 atmospheres may have delayed micro- bial growth.

Juice leakage from pulp pieces could be an important factor of deterioration of fresh-cut pineapple. Neither refrig- eration nor atmosphere modification reduced the incidence of this problem. However, the ‘Premium Select’ cultivar was less prone to leakage than ‘SC3620’.

The very low respiration rates (CO2 production of about 0.3 μL kg−1 s−1) of pulp pieces at 0, 2.2 and 5 °C allowed the use of a MA film such as Mylar®, with a low O2 transmission rate, without development of permanent off-odors or flavors due to anaerobiosis.

Acknowledgements

Antonio Marrero was the recipient of a Ministerio de Educación y Ciencia scholarship. We thank Dole Fruit Interna- tional for partial funding of this research.

References


