Changes in the Quality of Fresh-cut Jicama in Relation to Storage Temperatures and Controlled Atmospheres

E.N. AQUINO-BOLAÑOS, M.I. CANTWELL, G. PEISER, AND E. MERCADO-SILVA

ABSTRACT: Intact jicama (*Pachyrhizus erosus*) roots are chilling sensitive, but quality of fresh-cut pieces (1.8 × 4.5 cm cylinders) was best maintained at low storage temperatures (0 to 5 °C). Respiration rates of different piece sizes were similar, and averaged 2, 7 and 10 µL $CO_2 \cdot g^{-1} \cdot h^{-1}$ at 0 °C, 5 °C and 10 °C, respectively. Storage in air at 5 °C to 10 °C resulted in surface browning and was associated with increases in phenolics and phenylalanine ammonia lyase and polyphenol oxidase activities. High CO_2 atmospheres (5 to 10%) at 5 °C were very effective in retarding microbial growth and discoloration. The source of jicama root notably affected the quality and shelf-life of the fresh-cut pieces. Fresh-cut pieces from stored roots (2 wk at 19 to 22 °C) had lower visual quality and crispness during subsequent storage than did pieces from recently harvested roots.

Key words: respiration, texture, color, acetaldehyde and ethanol, soluble solids, PPO, PAL

Introduction

JICAMA (*PACHYRHIZUS EROSUS* (L.) URban) is a tropical legume originally from Mexico and Central America and cultivated by Precolombian cultures. It is currently produced in Mexico (source of most jicama in U.S. markets), Brazil, United States, China, Indonesia, the Philippines, and Nigeria (Sørensen 1996; Fernández and others 1996). The root consists of a light or dark brown periderm, and a white, crisp, succulent and sweet-starchy pulp. It is consumed principally as a raw vegetable with lime and chile, in salads, in soups, stir-fried or conserved in vinegar with onion and chile. Also it is used as a substitute for the water chestnut (*Eleocharis dulcis*) in Chinese food (Sørensen 1996).

Postharvest studies on jicama have demonstrated that the intact root is very sensitive to chilling injury when stored at 10 °C or below (Bergsma and Brecht 1992; Cantwell and others 1992; Mercado-Silva and Cantwell 1998; Paull and Chen 1988). Different varieties of jicama may differ significantly in their chilling susceptibility (Mercado-Silva and others 1998b).

Processing of jicama by osmotic dehydration, freezing, and juice preparation has been reported (Juárez-Goiz and Paredes-López 1994). Since this root is usually consumed raw, the preparation of a fresh-cut jicama product provides an interesting processing alternative. High quality fresh-cut jicama should be white, crisp and juicy, of characteristic odor and flavor, without visible defects, and be microbiologically sound.

Minimally processed vegetables offer freshness and convenience to the consumer, the main reasons for increased sales of these products in both retail and foodservice establishments (Watada and others 1996). Other advantages of fresh-cut products include the lack of additives or preservatives, reduced transport and storage space requirements, decreased preparation time, and the possibility of offering a product of uniform and consistent quality (Garrett 1998).

Physical damage, inherent in the preparation of minimally processed products, causes an increase in respiration rates and other metabolic reactions, and therefore an increase in the rate of deterioration of these products (Cantwell 1998; Saltveit 1997; Varoquaux and others 1990; Watada and others 1990). The degree of damage suffered by the product also affects the degree to which metabolism is changed (Cantwell 1998; Saltveit 1997). Undesirable color changes are common defects of these products. Biosynthesis, oxidation and polymerization of phenolic compounds are often associated with discoloration and other color changes. Hyodo and others (1978) and López-Gálvez and others (1996) reported a high correlation between the activity of phenylalanine ammonia lyase (PAL) and the discoloration on intact and cut lettuce leaves. Discoloration becomes apparent when the phenolic compounds are oxidized in reactions catalyzed by polyphenol oxidase (PPO) and possibly peroxidases (Hanson and Havir 1979).

Low temperatures are required to reduce metabolic activity, microbial growth, and water loss of fresh-cut products (Brackett 1987; Cantwell 1998). The beneficial effect of modified/controlled atmospheres on product quality has also been demonstrated for many fresh-cut items (Gorny 1997; López-Gálvez and others 1997; Portela and others 1997; Qi and Watada 1997; Rosen and Kader 1989). High concentrations of CO_2 may reduce respiration rates, but concentrations of 20% or more can result in the accumulation of ethanol and acetaldehyde (Kader 1986; Kader and others 1989; Kennedy and others 1992) and consequently affect sensory properties of the product. Concentrations of CO_2 from 10 to 30% can inhibit enzymes of phenolic metabolism and delay darkening (Siriphanich and Kader 1985; Mateos and others 1993), softening and delay development of decay organisms (Brackett 1987; Gorny 1997). The activity of enzymes involved in discoloration decreases when oxygen concentrations are reduced from 21% to 5–8% (Kader 1986). Low O_2 and/or high CO_2 concentrations change intracellular pH and alter metabolic regulation (Siriphanich and Kader 1985).

There are no reports on jicama as a minimally processed product. It provides a challenge as a fresh-cut vegetable since the intact root is chilling sensitive and potential benefits of modified atmospheres are unknown. The objectives of this study were to (1) determine the effects of low temperature and controlled atmosphere storage on quality changes of fresh-cut jicama, (2) to evaluate quality changes in relation to piece size, and (3) to gain some understanding of variability due to raw product source.

Materials and Methods

Raw material. Jicama roots produced in Nayarit, Mexico were obtained from Friedas Produce (Los Angeles, Calif., U.S.A.) in fall 1997 and are referred to as Nayarit jicama. Other roots were obtained directly from experimental fields at INIFAP, Guanajuato, Mexico in fall 1997 and are referred to as Bajio jicama. Roots were also obtained from commercial fields in Michoacan during February 1998 via a wholesaler in Queretaro, Mexico and are referred to as Michoacan jicama. Experiments with the Nayarit and Bajio jicamas were conducted at the Mann Laboratory, and the experiment with Michoacan roots was conducted at the laboratory in Querétaro. Roots were free of visual defects and mechanical damage and were stored at 15 to 20 °C until used.

Preparation of fresh-cut pieces. Roots were washed with potable water, the terminal parts removed, leaving an equatorial section approximately 5 cm thick. Cylinders (1.8 × 5 cm) were cut with a stainless steel borer and then recut to 4.5 cm or to 1 cm for discs. For sticks, pieces (1 × 1 × 4.5 cm) were cut with a sharp stainless steel knife. Pieces were placed in a tray on ice and covered with moistened cheesecloth to avoid dehydration during preparation. The pieces were disinfected with a sodium hypochlorite solution (50 ppm free chlorine, pH 7) for 15 s. Excess water was removed by draining and blotting with damp cheesecloth. Three to 5 pieces in a 250 mL glass jar formed one repetition per treatment.

Storage conditions of fresh-cut pieces. The glass jars were covered with cheesecloth and placed in larger glass containers through which a flow of humidified (> 95% RH) air or different controlled atmospheres passed. Flow rates were controlled by capillaries calculated to maintain CO_2 concentrations <0.5% in air storage. For respiration measurements, pieces were placed in jars individually connected to a flow of humidified air at the indicated temperatures. For the experiment on phenolic metabolism, discs (1.8 × 1 cm) were stored in a flow system of humidified air at 5 °C, 7.5 °C, and 10 °C, and samples were taken daily.

Controlled atmospheres (CA) were obtained by mixing appropriate volumes of nitrogen, O_2 and CO_2 and then passing the mixtures through water for humidification. Three controlled atmosphere (CA) experiments were carried out. In the first CA experiment, atmospheres of 1, 3, and 21% O_2 alone and in combination with 5 and 10% CO_2 were tested at 5 °C on pieces from Nayarit and Bajio jicamas. Evaluations were conducted at 0, 8 and 12 d. In the second CA experiment, atmospheres of 0.3, 3 and 21% O_2 alone in combination with 10% CO_2 were tested at 5 and 10 °C on pieces from Bajio roots, and evaluations were carried out on day 0, 4, 8, and 12. The third CA experiment was conducted on pieces from Michoacan roots stored in air or air + 13 or 20% CO_2 at 5 °C, with evaluations at day 0, 8, and 14.

Gas measurements. Oxygen and CO_2 concentrations were monitored daily during the CA experiments. Gas samples of 1 mL were injected into an infrared gas analyzer (Horiba PIR-2000) or oxygen analyzer (Applied Electrochemistry Inc. Model S-3A). For calibration standard mixtures of 5 to 15% O_2 and 5 to 15% CO_2 were used. For determination of respiration rates, CO_2 gas samples were analyzed daily and calculations were based on the difference between inlet and outlet CO_2 concentrations. A 0.5 % CO_2 standard was used for calibration.

Storage of intact roots before processing. Cylinders were prepared from Michoacan roots after 0 and 2 w storage in plastic crates at ambient conditions (19 to 22 °C). Prepared cylinders were evaluated at 5 °C in air or CA (13 or 20% CO_2 in air). Subjective and objective evaluations were carried out at 0, 8 and 14 d storage.

Subjective Evaluations. Subjective evaluations were carried out by the first 2 authors and were based on scales previously applied to jicama (Cantwell and others 1992; Mercado-Silva and others 1998b). Overall visual quality was evaluated on a 9 to 1 scale, where 9 = excellent, no defects, 7 = good, minor defects, 5 = fair, moderate defects, 3 = poor, major defects, 1 = unusable. A score of 6 was considered the limit of salability. Minor defects were usually attributed to color changes; major defects were usually due to decay. Browning was evaluated on a scale of 1 to 5, where 1 = none, 2 = slight, 3 = moderate, 4 = severe, and 5 = extreme browning. Dehydration and macroscopic decay were evaluated on scales of 1 to 5, where 1 = none, 2 = slight (up to 5% surface affected), 3 = moderate (5 to 20% surface affected), 4 = moderately severe (20 to 50%), and 5 = extreme (> 50% surface affected). Flavor was scored on a 5 to 1 scale, where 5 = full, characteristic flavor, 4 = near full typical flavor, 3 = moderate typical flavor, 2 = little typical flavor, and 1 = no flavor or not typical flavor.

Objective Evaluations. Color of the flat ends of the cylinders was determined with a Minolta CR-200/300 spectrophotometer, with illuminant A and a 10° viewing angle and calibrated on a white tile. L*, a* and b* values were recorded and chroma ($C^* = (a^{*2} + b^{*2})^{1/2}$) and hue ($h\,^\circ C = \tan^{-1}(b^* / a^*)$) were calculated.

Firmness was measured by a modification of the conditions described by Mercado-Silva and Cantwell (1998) for intact jicama. Maximum rupture force and distance to penetration were determined on a TA-HD texture analyzer (Texture Technologies Corp., Scarsdale, N.Y., U.S.A.) with a flat cylindrical 3-mm probe at a penetration rate of 1 mm/s to a depth of 8 mm.

For phenylalanine ammonia lyase (PAL) activity, 4 g of tissue were homogenized with 0.4 g insoluble polyvinylpolypyrrolidone, 16 mL borate buffer (50 mM pH 8.5) and 14 (L 2-mercaptoethanol according to Ke and Saltveit (1986). After filtering and centrifugation at 12000 × g at 4 °C for 20 min, PAL activity in the supernatant was determined at 40 °C using 100 mM L-phenylalanine as substrate and measuring absorbance at 290 nm. One unit of PAL activity corresponded to the formation of 1 μmol cinnamic acid in 1 hour.

Polyphenol oxidase (PPO) activity was determined from 4 g of tissue homogenized with 0.4 g insoluble polyvinylpolypyrrolidone and 16 ml phosphate buffer (50 mM pH 6.2) according to the method described by Siriphanich and Kader (1985). After centrifugation at 12000 × g for 20 min at 4 °C, the supernatant was used for determination of PPO. Caffeic acid was used as substrate and absorbance was measured at 420 nm. One unit of PPO activity corresponds to a change of 0.1 absorbance units in 1 min.

For total soluble phenolics, 8 g of finely chopped jicama were homogenized with 15 mL 80% ethanol, filtered through 4 layers of cheesecloth and let stand 30 min before taking a 0.25-mL aliquot for spectrophotometric determination according to Hyodo and others (1978). A standard curve of coumaric acid was used for quantification.

Ethanol and acetaldehyde determinations were based on a modification of the method by Mateos and others (1993). A 2.5-g sample of chopped fresh tissue was placed in a test tube closed with a rubber stopper. Tubes were placed in a 60 °C water bath for 1 h. Headspace samples of 0.5 mL were injected into a GC (Hewlett Packard Model 5890A) equipped with a 2 mm × 1.8 m 5% Carbowax 20 M column (85 °C) and a flame ionization detector (250 °C). Retention times and standard curves of ethanol and acetaldehyde in water solutions were used for peak identification and quantification.

Microbiological examinations consisted of aerobic plate counts of Nayarit and Bajio samples after 0, 8, and 12 d storage in air or controlled atmospheres at 5 °C. Pieces were removed from separate jars in the large storage containers and a 25 g chopped sample homogenized in 225 mL

distilled water. Total aerobic plate counts were determined by a dilution series for each treatment using SMA agar and incubating at 29 °C (BAM 1984).

Experiments were conducted in a completely randomized design with a minimum of 3 repetitions per treatment unless otherwise specified. Data were calculated as averages ± standard deviations.

Results and Discussion

Physiology of intact roots and minimally processed pieces.

Respiration rates of intact jicama roots were relatively constant during 8 d storage at 0 °C, 5 °C, and 10 °C (Figure 1A). The jicama cylinders stored at 5 and 10 °C initially had respiration rates similar to those of the intact roots, but after 4 and 2 d, respectively, respiration rates increased substantially (Figure 1B). At 0 °C, respiration rates of intact and fresh-cut pieces were similar and tended to decrease with time. Respiration rates of cylinders averaged 2, 7 and 10 µL $CO_2 \cdot g^{-1} \cdot h^{-1}$ over 7 d at 0, 5, and 10 °C, respectively. The Q_{10} (0 to 10 °C) values for intact and fresh-cut jicama were 2.3 and 4.5, respectively. Similar Q_{10} values have been reported for carrot slices, melon cubes and salad lettuce (Watada and others 1996).

Piece type and size did not greatly affect the respiration rates of minimally processed jicama (Figure 2), whereas rates differed principally due to storage temperature. Saltveit (1997) proposed that the wounding response generally increased with increased damage, and that after reaching a certain severity, additional injury would not increase the metabolic response, suggesting an overlapping of damaged areas. However for jicama, respiration rates were similar for the cylinders, discs and sticks although the cut surface areas (30.5, 10.7, and 20.0 cm^2, respectively) were different. Others indicate that the respiratory response to wounding depends on the type of vegetable or fruit as well as its state of development or maturity, and may not differ from that of the intact product. For example, longitudinal carrot slices had the same respiration rates as the intact roots (Cantwell 1998). Rosen and Kader (1989) reported that respiration rates of pear and strawberry slices were similar to rates of the intact products.

Changes in visual quality and color in relation to storage temperature.

The visual appearance of minimally processed jicama stored in air at 0 °C, 5 °C, and 10 °C was excellent or very good during the first 5 d of storage. After 10 d, cylinders stored at 0 °C had an excellent appearance, while those at 5 °C were scored as having good quality and those at 10 °C had fair quality (Figure 3A). Discoloration was the factor that most contributed to a reduction in quality of pieces stored in air at 10 °C. The relationship between changes in visual appearance and hue values is readily apparent in Figure 3B. Hue changed drastically over 10 d at 10 °C, was maintained at 5 °C and increased slightly at 0 °C (this was associated with a translucent appearance by d 10).

Another important factor in the loss of quality of the minimally processed jicama pieces was microbial growth. No macroscopic decay was found on Bajio jicama pieces during 5 d at 0 °C, 5 °C, or 10 °C. By 10 d, decay was slight-moderate in pieces stored at 10 °C, but still undetectable at 0 °C and 5 °C (Figure 3C). Firmness (maximum rupture force and distance to rupture) measurements indicated that there were no consistent differences in texture during 10 d at the 3 storage temperatures (data not shown).

These results indicate that quality of minimally processed jicama is best maintained at low storage temperature. It was necessary to store the fresh-cut pieces at 0 °C to 5 °C to prevent discoloration, minimize respiration rates and retard microbial growth, although the intact roots are very

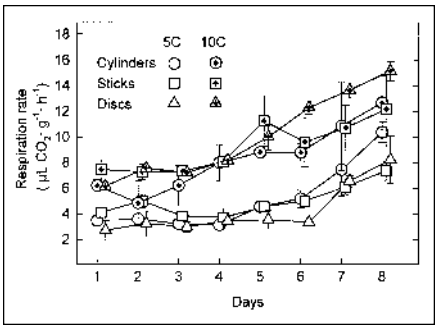

Figure 2—Respiration rates of cylinders (1.8 × 4 cm), sticks (1 × 1 × 4 cm) and discs (1.8 × 1 cm) of Bajio jicama stored in air at 5 and 10 °C. Each data point is the average of 3 replications ± std. deviation.

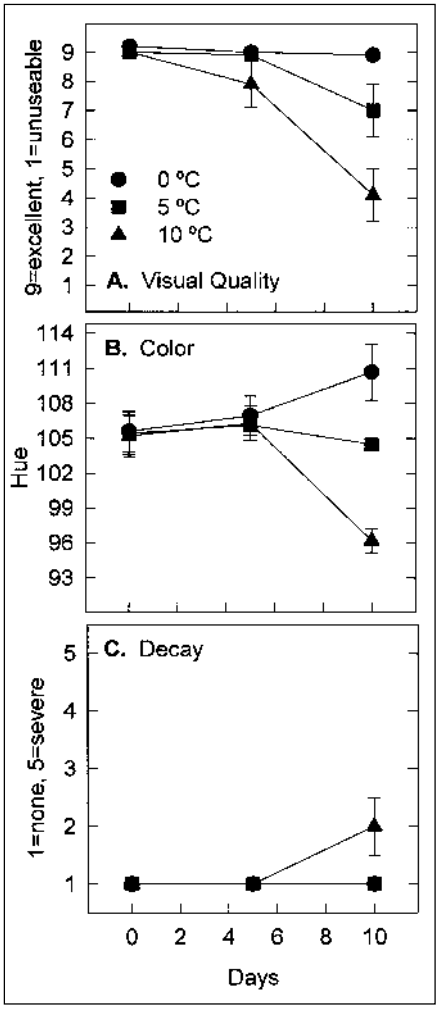

Figure 3—Visual quality (A), hue color value (B), and macroscopic decay (C) of cylinders of Nayarit jicama stored in air at 3 temperatures. Each data point is the average of 3 replications ± std. deviation.

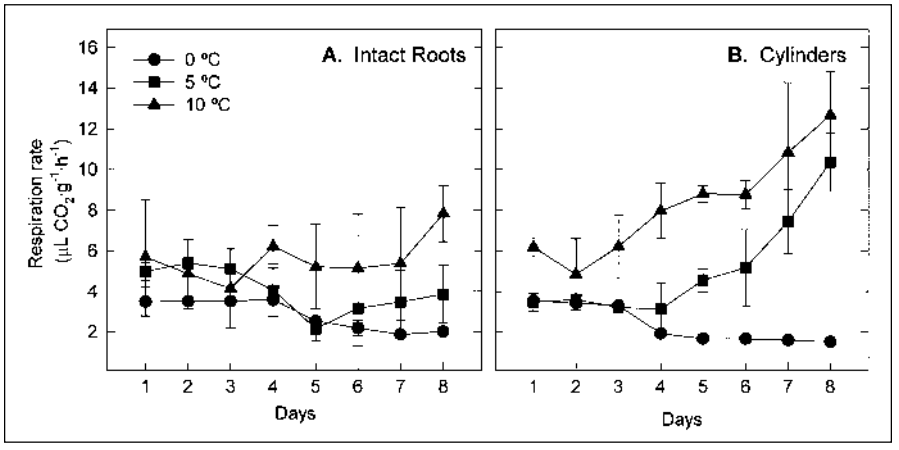

Figure 1—Respiration rates of intact roots (A) and cylinders (1.8 × 4 cm) (B) of Bajio jicama stored in air at 3 temperatures. Each data point is the average of 3 replications ± std. deviation

susceptible to chilling injury at 10 °C or below (Cantwell and others 1992; Mercado-Silva and others 1998a). This apparent contradiction is explained in part because the assessment of chilling injury in intact products usually occurs after transferring the product to 20 °C. In the case of fresh-cut pieces, however, it is appropriate to evaluate them at storage temperature without a transfer period. In addition, benefits due to low temperature control of microbial growth on fresh-cut products far outweigh quality defects that may result from the gradual onset of chilling injury.

Relationship between discoloration and phenolic metabolism

The synthesis of phenolic compounds via PAL and subsequent oxidation by PPO could be related to the observed changes in color of jicama at 5 °C or above (Hanson and Havir 1979). At 5 °C, PAL activity was low and remained constant during the 9 d of storage (Figure 4A); at 7.5 °C and 10 °C maximum levels of activity were observed at 6 and 4 d, respectively, and after this, activity decreased. This pattern was similar to that observed in lettuce by Hyodo and others (1978) and López-Galvéz and others (1996). Creasy and others (1986), in work on sunflower leaf discs, and Strack (1996) proposed that this pattern of PAL enzyme activity could be due to the synthesis of a proteinaceous inactivator of PAL.

PPO activity in jicama discs did not change much at the different storage temperatures, after an initial rapid increase during d one (Figure 4B). PPO activity declined after 4 d regardless of storage temperature (Figure 4B). It is possible that the initial stimulation in PPO activity is a direct result of mechanical injury (Stevens and Davelaar 1997).

The synthesis of phenolic compounds soluble in alcohol increased during storage at all temperatures, but the rate and magnitude of the increase were directly related to the storage temperature (Figure 4C). Total phenolic compounds increased after the increases in PAL activity were observed, but as PAL activities decreased later in storage, total phenolics continued to increase. The production of phenolic compounds has been associated with the process of wound healing (Sukumaran and others 1990; Walter and others 1990). On fresh-cut jicama browning began on the cut surfaces and then moved inward. This suggests that the synthesis of phenolic compounds in jicama pieces may also be a wound healing response, and that temperatures of 5 °C or below restrict the process and therefore limit discoloration. There was only a slight increase in PAL activity of jicama pieces at 5 °C (Figure 4A).

Color changes at these intermediate storage temperatures were best represented by calculations of chroma (Figure 4D). There was a high linear correlation between chroma values and the concentration of phenolics (r = 0.91). There was also a good relationship between maximum PAL activity and phenolic accumulation, results similar to those reported by López-Galvéz and others (1996) for lettuce pieces. Although PPO is involved in the browning process and there were always measurable levels of activity, there was not a direct association between PPO activity and browning, an observation reported in other studies. Hyodo and others (1978) working on lettuce in the presence of ethylene, and Coseteng and Lee (1997) studying different apple cultivars did not observe a correlation between PPO activity and the development of browning.

Effect of controlled atmospheres at 5 °C and 10 °C on quality parameters of fresh-cut jicama

Since there is no published information regarding effects of controlled atmosphere on quality of stored jicama, atmospheres beneficial to other minimally processed vegetables were selected for study (Gorny 1997). In the first CA experiment, atmospheres of 1, 3, and 21% O_2 alone and in combination with 5 and 10% CO_2 were tested at 5 °C on pieces from Nayarit and Bajio jicama. There are notable differences in the intact roots of these two types of jicamas. Nayarit roots have a thicker periderm and less succulent pulp than Bajio roots, and Mercado and others (1998b) reported that Nayarit roots were less susceptible to chilling injury than 'Agua Dulce' Bajio roots. Soluble solids concentrations also differ, and in the present study averaged 4.7 and 6.9% in pulp of Nayarit and Bajio roots, respectively. Fresh-cut pieces from both types of jicama maintained excellent or very good visual quality during 8 d independent of storage atmospheres (data not shown). After 12 d, visual quality was only maintained in atmospheres with 5 and 10% CO_2. In addition, quality of the Bajio pieces was lower than that of Nayarit jicama, principally due to differences in macroscopic decay. Aerobic plate counts also differed between the two types of jicama roots. After preparation on d 0, Nayarit and Bajio pieces had microbial loads of 6.5×10^2 and 1.4×10^4, respectively. By d 8, Nayarit air-stored pieces had microbial counts of 2×10^7, counts on Bajio pieces were 1 to 1.5 logs higher, and counts on pieces in CO_2 atmospheres were 0.5 to 1 logs lower than those of the corresponding air-stored pieces.

In a second CA experiment on the more perishable Bajio jicama pieces, CA mixtures with 10% CO_2 at 10 °C maintained excellent visual quality for 4 d, whereas air and low O_2 atmospheres resulted in a loss of visual quality due to discoloration and decay (Figure 5B and D). By 8 d, however, the 10% CO_2 atmospheres were insufficient to delay the onset of browning and

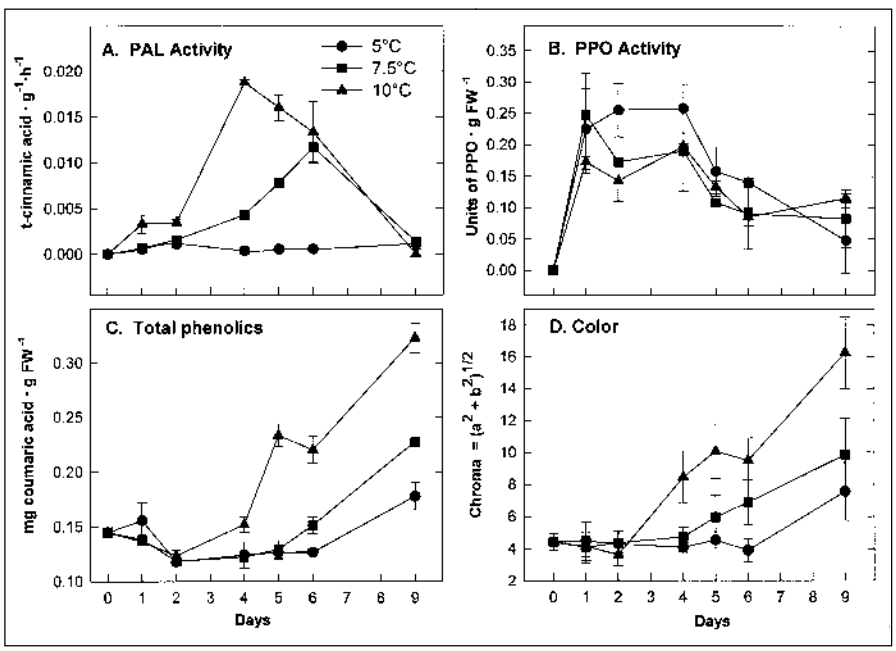

Figure 4—Phenylalanine ammonia lyase (PAL) activity (A), Polyphenyl oxidase (PPO) activity (B), total phenolic compounds (C), and Chroma color values (D) of Bajio jicama discs stored in air at different temperatures. Each data point is the average of 3 replications ± std. deviation.

decay (Figure 5B, D, and F). Controlled atmospheres at 5 °C maintained excellent visual appearance of the jicama cylinders during 8 d (Figure 5A). After 12 d, the 10% CO_2 atmospheres maintained visual quality of jicama pieces better than low oxygen atmospheres alone or 3% O_2 + 20% CO_2 (Figure 5A). The 10% CO_2 atmosphere with 3% O_2 was not as effective as 10% CO_2 combined with air or 0.3% O_2 due to microbial growth (Figure 5E). Although discoloration at 5 °C was slight, the 10% CO_2 atmospheres were more effective in retarding discoloration than air or low O_2 atmospheres (Figure 5C). Pieces stored in 20% CO_2 were injured by this atmosphere as evidenced by development of some discoloration and an increased susceptibility to microbial growth (Figure 5E).

Reduction in the rate of browning can be explained by modifications in the synthesis and/or degradation of phenolic compounds due to reduced O_2 concentrations or low temperatures. Mateos and others (1993) concluded that with CO_2 concentrations < 20%, PAL activity of lettuce pieces was reduced as a result of decreased cytoplasmic pH. Siriphanich and Kader (1985) demonstrated that cytoplasmic pH of air stored lettuce was 6.7, whereas tissue exposed to 20% CO_2 had a cytoplasmic pH of 6.3. Considering that the pH optimum for PAL activity is 8.5, a reduction in pH would result in decreased activity which in turn would result in a decreased rate of phenolic synthesis. This could explain the lack of discoloration observed on jicama pieces at 5 °C in 10% CO_2 and the delay in discoloration observed in pieces at 10 °C in high CO_2 atmospheres.

Acetaldehyde concentrations increased slightly during storage in air at 5 °C, whereas all controlled atmospheres resulted in notable increases after 8 d (Figure 6A). In air + 10% CO_2 acetaldehyde increased 4 times, and 3% O_2 resulted in a 6 fold increase. The 0.3% O_2 + 10% CO_2 or the 20% CO_2 atmospheres resulted in the highest increases in acetaldehyde, about 10 times the concentrations of air-stored pieces. Ethanol concentrations also varied according to the O_2 concentrations in the CA mixture, and by 12 d, the pieces in the 0.3% O_2 + 10% CO_2 atmosphere had the highest concentrations (Figure 6B). One of the risks of atmosphere modification is the induction of anaerobic respiration and the consequent production of acetaldehyde and ethanol. The concentrations of acetaldehyde and ethanol in jicama cylinders did not correlate well with the development of off-odors (data not shown). López-Gálvez and others (1997) found low but highly significant correlations between off-odors and fermentative volatile concentrations in lettuce pieces, and in-

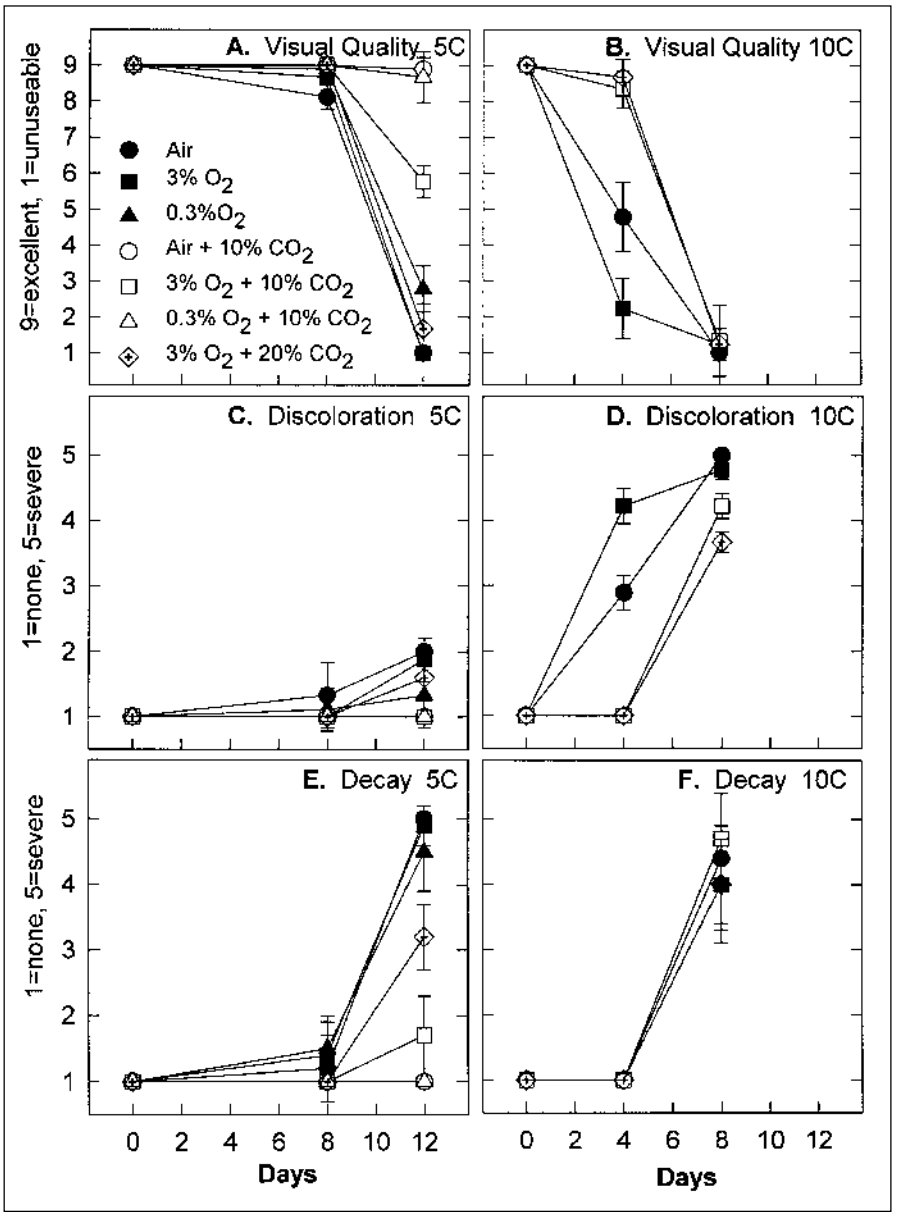

Figure 5—Changes in visual quality (A, B), browning discoloration (C, D), and macroscopic decay (E, F) of Bajio jicama cylinders stored at 5 and 10 °C in different controlled atmospheres. Each data point is the average of 3 replications ± std. deviation.

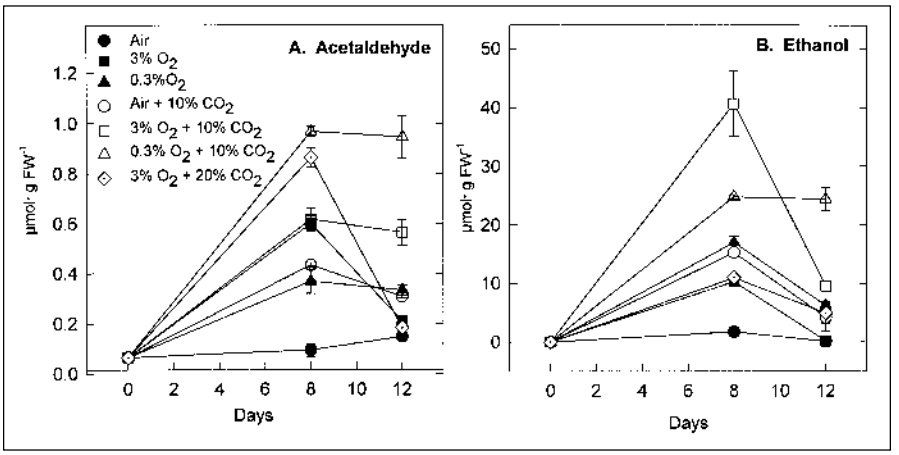

Figure 6—Concentration of acetaldehyde (A) and ethanol (B) of Bajio jicama cylinders stored at 5 °C in different controlled atmospheres. Each data point is the average of 3replications ± std. deviation.

terpreted this to indicate that other volatiles must be contributing to off-odor development. This may also be the explanation in the case of jicama pieces.

Concentrations of soluble solids increased from 4.5% on day 0 to an average 5.3 and 5.5% after 8 d at 5 °C and 10 °C, respectively. An increase in soluble solids concentrations of intact jicama stored below 10 °C has been noted previously (Mercado-Silva and others 1998a). Low temperature sweetening is a common phenomenon during storage of roots and tubers (Wismer and others 1995). Marangoni and others (1996) and Parkin and Schwobe (1990) reported degradation of starch and accumulation of sucrose and other sugars in potatoes stored at 2 °C and 3 °C, respectively.

Effect of intact root storage on quality of fresh-cut pieces

Cylinders prepared from recently harvested jicama (2 d from harvest) were compared with those prepared from the same lot of roots stored 2 w at ambient temperature. The visual quality of the cylinders from unstored roots remained excellent or very good during 14 d at 5 °C (Figure 7A) under air or high concentrations of CO_2. However, pieces obtained from the stored jicama pieces had decreased quality by d 8. This loss of visual quality corresponded to an increased yellowing of the pieces (data not shown). The 13% CO_2 atmosphere helped maintain visual quality in jicama from both fresh and stored roots. Although maximum rupture forces of pieces from unstored and stored roots were similar (Figure 7B), the distance to rupture increased in the pieces prepared from the stored roots (Figure 7C). This increase in distance to rupture is associated with less crisp or spongier jicama tissue (Mercado-Silva and Cantwell 1998). The data also suggest that the high CO_2 atmosphere decreased the crispness of the pieces from the stored roots. These results provide some indication that for best shelf-life and quality of minimally processed jicama pieces, the roots should be prepared as soon as possible after harvest. The effect of root storage is likely to be an even more important consideration in the case of jicama subjected to short periods at chilling temperatures.

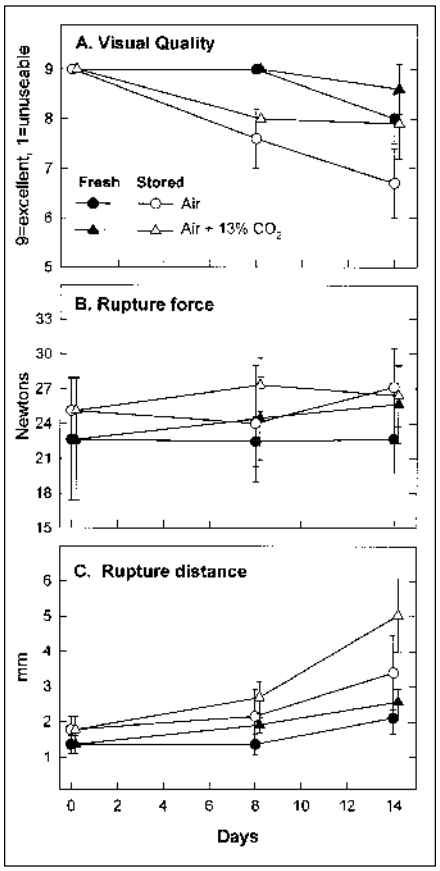

Figure 7—Visual quality (A), rupture force (B), and rupture distance (C) of Michoacan jicama freshly harvested or stored 14 d at ambient temperature (19-22 °C) before processing. Each data point is the average of 3 replications ± std. deviation.

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