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# CHANGES IN ENZYME-ASSISTED PEELING EFFICIENCY AND QUALITY OF FRESH 'VALENCIA' ORANGE AND OF STORED 'VALENCIA' ORANGE AND 'RUBY RED' GRAPEFRUIT

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*Abstract.* **'Valencia' oranges were harvested at three-week intervals, beginning on 11 February and ending on 17 June 2002. Fruit were peeled after infusion with 0.25% to 0.50% Peelzyme using an automated citrus peeling machine developed by the Florida Department of Citrus. Greater than 50% peeling efficiency was achieved in fruit harvested in March and May, compared to 11% in February, 30% in April and 45% in June. Flesh firmness remained high throughout the harvest season but declined slightly during storage at 2.8 °C for 14 days. A slight increase in total soluble solids, accompanied by a steady decline in percent citric acid equivalents, resulted in a sharp increase in the °Brix to acid ratio in April, May and June. Organoleptic evaluation of sectioned fruit was conducted after 1, 7, and 14-day storage at 2.8 °C using approximately 20 taste panelists. Storage time had little effect on flavor scores of sections prepared from fruit harvested in February, March and April, but declined in May and June. 'Valencia' orange and 'Ruby Red' grapefruit, stored up to twelve weeks, were effectively peeled, however peeling efficiency declined after 15 weeks or storage.**

In a market driven by affluence, convenience, and desire for healthful alternatives, the ready-to-eat food segment is growing fast (Hodge, 2003). Although the fresh-cut market is still dominated by bagged salads, there were $719 million in sales of fresh-cut fruit in 2004 and a 17% increase over 2004 fresh-cut fruit levels in January and February of 2005. Retail is shifting from in-store cut fruit only to a mixed offering of branded and in-store items (Anonymous, 2005). Nevertheless, cut melon (especially watermelon and cantaloupe), pineapple, grape and apple are appearing on supermarket shelves (Anonymous, 2005; Cooperhouse, 2003). Enzyme peeled citrus sections are more stable than most other cut fruit products and would be ideal for school lunch programs, airline cuisine and as a product on supermarket shelves.

Enzyme-peeled segments are produced by infusion of pectinase/cellulase enzymes (Baker and Bruemmer, 1989; Bruemmer, 1981; Bruemmer et al., 1978) into the peel albedo where the peel is digested to the point where it can be easily removed. Cut citrus sections prepared by aseptic slicing have been shown to have shelf life stability for about 12 d (Rocha et al., 1996), and although some juice leakage and softening are adverse side effects of enzyme peeling, shelf life of this product is greater than the aseptic counterpart. Microbial contamination is another concern as it is with all fresh-cut products (Pao et al., 1997). Physiological condition of the peel (i.e., time of harvest) and type of citrus (orange versus grapefruit) can affect the efficacy of the enzymes used. The more enzyme used, the more leakage and softening of citrus segments will occur. Water infusion or nonenzymatic peeling method was also developed (Pao et al., 1996), but hand peeling of these segments was found to be slow and tedious.

A peeling machine was developed by the Florida Department of Citrus (Ismail and Thomas, 2002) that was found to be effective on enzyme-peeled, but not water-infused fruit. In this study citrus fruit were processed over the harvest season to understand the ability of this process to remove peel of early, middle and late harvested fruit, to remove peel of stored fruit, and to determine the effect of harvest date and storage time on quality of the processed sections.

## Materials and Methods

Citrus fruit, including 'Valencia' orange and 'Ruby Red' grapefruit, were harvested from 11 Feb. through 17 June 2002 from the Citrus Research and Education Center, Lake Alfred, Fla. Fruit were harvested at three-week intervals on seven different harvest dates during this period. After harvest the fruits were washed on a commercial packing line at CREC and peeled on the day of harvest, using the enzyme-aided peeling process.

The enzyme peeling process included a dip in 80.6 °C water for 2 min, perforation in four locations per fruit by the auto-peeling machine (Florida Department of Citrus, Lake Alfred, Fla.), infusion twice under 27 inches vacuum with 0.25% (grapefruit) or 0.50% (orange) Peelzyme (Novozymes, Krogshoejvej, Denmark) solution for 7 min, incubation in 43 °C water for 30 min, and auto-peeling by machine. Fruit sections were packed in ziplock bags and stored at 2.8 °C for quality studies.

Firmness was tested on peeled sections using the Texture Analyzer with a 20 mm flat probe with speed set at 1.5 $mm \cdot sec^{-1}$ and distance of 2 mm. Ten fruit per treatment were tested with 4 measurements per fruit. The °Brix and acid were measured using juice squeezed from the 10 fruits used in firmness testing. °Brix was read using a Leica Abbe Mark II Refractometer (Buffalo, N.Y.) and acid was calculated by titration. For sensory analysis, 20 people tasted 2 orange sections and rated flavor through the Fresh Cut Product Rating Questionnaire using a 9-point hedonic scale, where 9 = "like ex-

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tremely" and 1 = "dislike extremely". Peeled fruit were also analyzed for microbial populations using aerobic plate counts (OSA) and counts of yeast and mold (APDA).

For the fruit storage study, fruit were obtained from BHG Inc. (Seald Sweet red grapefruit), east coast (Ocean Spray red grapefruit) and Hunts Brothers ('Valencia' orange). The grapefruit were stored at 7.3 °C and the oranges at 3.4 °C. The peeling commenced on the day the fruits were stored (23 May 2002) and repeated every three weeks through 17 Oct. 2002. Fruits were examined for decay prior to peeling and 20 sound fruits were selected from each carton with 5 replications totaling 100 fruit per peeling test.

### Results and Discussion

Peeling efficiency of 'Valencia' oranges is shown in Fig. 1. Peeling efficiency is defined as the ratio of the number of fruit completely peeled to the total number of fruits, and presented as a "percent efficiency". Peeling efficiency was variable over the season with fruit harvested in March and May being most easily peeled (over 50% efficiency) and fruit harvested in February, April and June, being peeled less efficiently (11% in February, 30% in April and 45% in June). Storage of intact 'Valencia' oranges and 'Ruby Red' grapefruit did not affect peeling efficiency for up to 12 weeks, but peeling efficiency declined after 15 weeks of storage (data not shown).

Figure 2 shows the firmness of peeled 'Valencia' oranges harvested over the season and held 1-14 d in storage after peeling. Peeled fruit firmness remained fairly stable over the harvesting season with initial fruit firmness of peeled sections (1 d) being slightly firmer than those stored 14 d. With a slight increase in soluble solids and slow decline in acids over the season, the °Brix/acid ratio increased (Fig. 3) starting in March and reached its highest point in June. In stored, peeled fruit sections, there were no obvious differences in °Brix levels in fruit stored 1, 7 or 14 d (Fig. 4A). For titratable acidity, although it declined over the season, did not show much difference due to storage of peeled sections for 14 d, except for the February-harvested fruit, where the longer stored fruit exhibited less acidity (Fig. 4B). The °Brix/acid ratio, although it increased over the season, did not show differences due to storage of peeled sections for 14 d except for June-harvested fruit, for which the longer stored fruit exhibited a lower ratio (Fig. 4C).

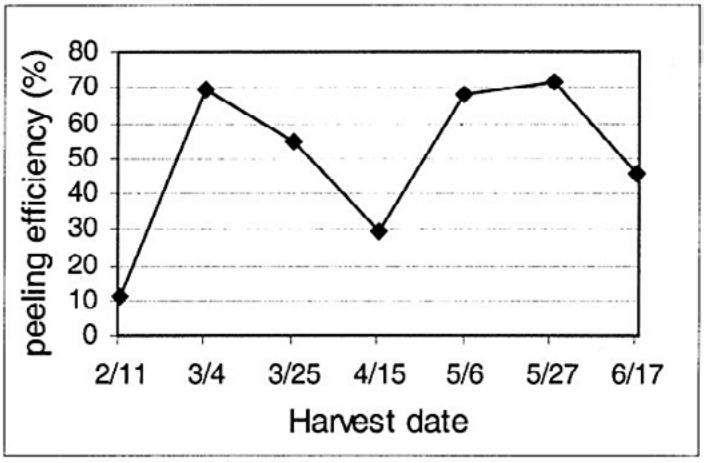



Fig. 1. Peeling efficiency over the harvest season for 'Valencia' oranges.

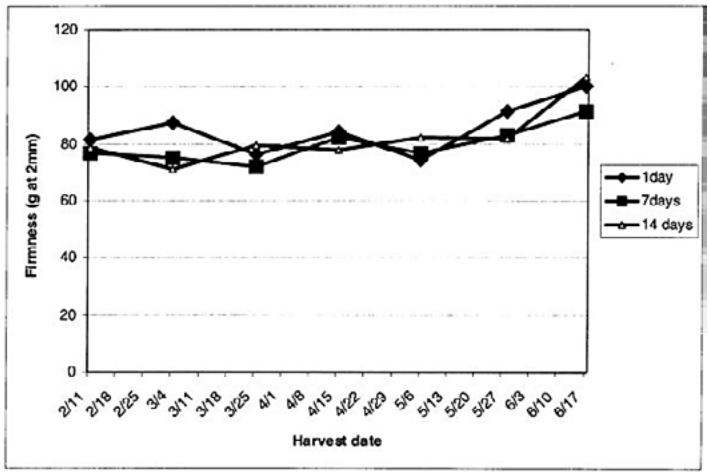



Fig. 2. Firmness of peeled 'Valencia' oranges over the harvest season and during storage after processing.

Sensory studies revealed that late season (June) fruit were less preferred than fruit harvested earlier, and that generally when there were differences, the peeled fruit sections stored 14 and sometimes the 7 d were less preferred than 1-d stored fruit (Fig. 5), and in February and May/June the 14-d stored fruit were least preferred. Aerobic plate counts showed that there was no clear pattern due to time of harvest other than a slight increase in colony forming unites (cfus) for mid-season fruit, but that the longer the peeled fruit sections were stored, the higher the plate counts (14-d fruit > 7 d > 1 d) as would be expected. Nevertheless, microbial populations remained below 5 log10 cfu per gram fruit tissue (Fig. 6). Yeast and mold counts on APDA were similar (data not shown).

### Conclusion

Although the data for April may be an outlier, these studies show the effect of harvest date on peeling efficiency, with February, March and June probably requiring more enzyme, more incubation time, or a higher frequency of enzyme incubation for efficient peeling. The quality of the peeled product in terms of firmness was not affected so much by season as by

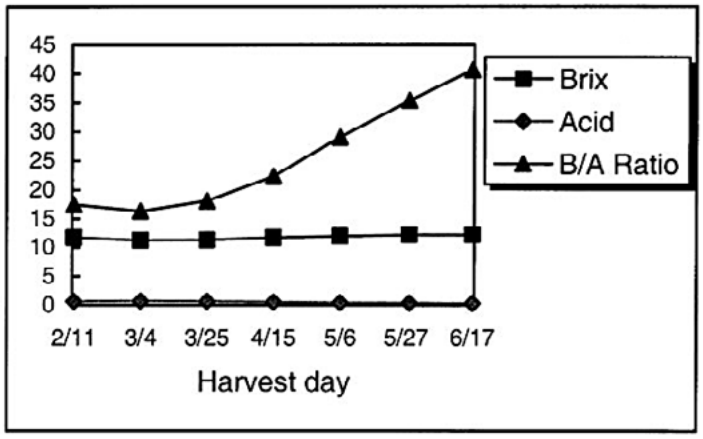
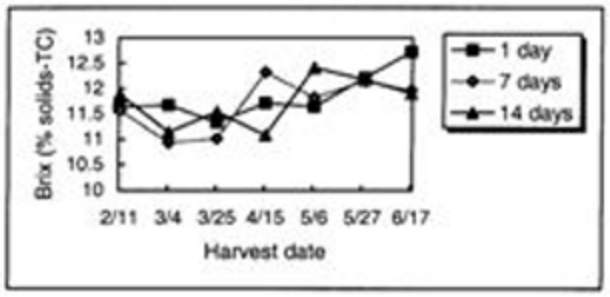
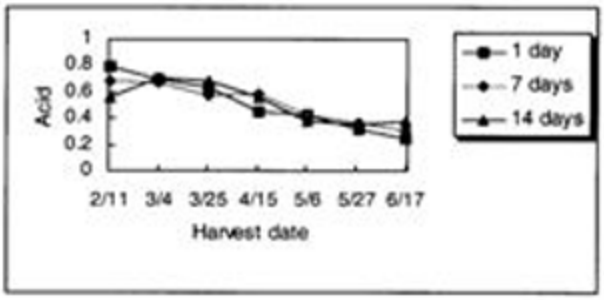



Fig. 3. °Brix, titratable acidity, and Brix/acid ratio of freshly harvested 'Valencia' orange fruit over the harvest season and during storage after processing.

A




B

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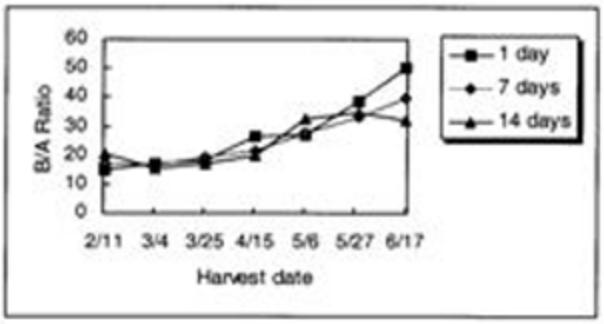


Fig. 4. The (A) °Brix, (B) titratable acidity, and (C) Brix/acid ratio of peeled 'Valencia' oranges over the harvest season and during storage after processing.

the time the peeled sections were stored after processing. Flavor of the peeled segments did decline some in later-harvested fruit (May-June) when the °Brix/acid ratio was higher due to a slight increase in °Brix and decrease in acidity over the

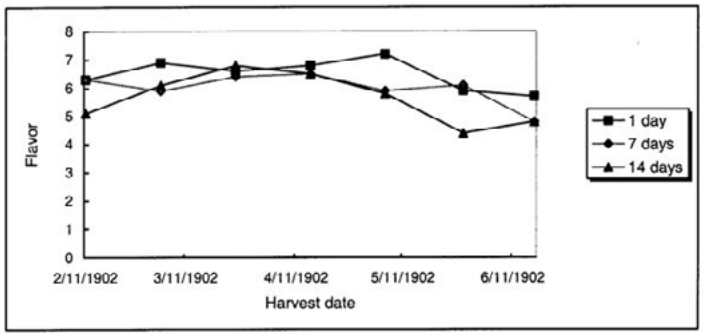


Fig. 5. Flavor of peeled 'Valencia' oranges over the harvest season and during storage after processing.

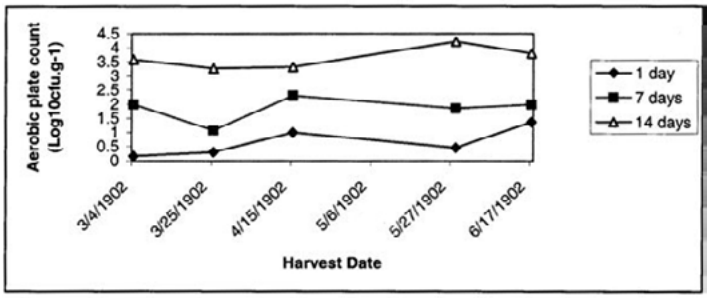


Fig. 6. Aerobic plate count of peeled Valencia oranges over the harvest season and during storage after processing.

harvest season. Flavor scores also tended to be lower, and microbial counts higher the longer the peeled sections were stored.

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