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EFFECTS OF CULTIVAR, MODIFIED ATMOSPHERE, AND PRE-HARVEST CONDITIONS ON STRAWBERRY QUALITY

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Abstract. **Strawberries grown at Dover, Fl. (*Fragaria* × *ananassa* Duch., cv 'Camarosa', 'Sweet Charlie', 'Rosalinda', 'FL93-100', 'Carlsbad') were harvested at two dates and evaluated for sweetness, flavor, firmness, color, and other berry-like attributes by a trained sensory panel. 'Sweet Charlie' berries grown with and without mite control were also evaluated for the same sensory characteristics. 'Camarosa' and 'Carlsbad' strawberries were also stored in 5% O_2 + 15% CO_2 at 3°C or in air at 3°C for 12 days and sensory characteristics were evaluated during storage. The cultivar evaluation demonstrated varied sensory characteristics at the two harvests. 'Rosalinda' had high flavor intensity and sweetness, but was the softest. 'Camarosa' had intermediate flavor intensity and sweetness, and was the firmest. 'Sweet Charlie' had intermediate flavor intensity and sweetness, and was rather soft. 'Carlsbad' had low flavor intensity and sweetness, and was very firm. 'FL93-100' had intermediate flavor intensity, sweetness and firmness. All cultivars had good color uniformity. Sensory characteristics changed very little during 12 days storage at 3°C, but controlled atmosphere limited softening and decay during storage. Mite control improved sweetness and flavor intensity of 'Sweet Charlie' berries, but had no impact on color or firmness.**

Introduction

Strawberry production in Florida consists of about 4,942 acres annually with a farm-gate value of about $100 million. The flavor and sensory characteristics of strawberries are very important quality attributes that influence consumer acceptability. Flavor of strawberries is mainly determined by a complex mixture of esters, aldehydes, alcohols and sulfur compounds which have been studied during the last 30 years (McFadden et al., 1965; Dirinck et al., 1977; Schreier, 1980; Hirvi and Honkanen, 1982; Perez et al., 1992). Volatile compounds in strawberries vary between cultivars (Maarse, 1989). Strawberry taste, an important component of flavor quality, results primarily from the individual and interactive sensations of sweet and sour imparted by sugars and nonvolatile carboxylic acids, respectively. In addition, biller or astringent properties sometimes can be detected as background taste characteristic in fruits of some genotypes.

Strawberries are highly perishable fruit (Li and Kader, 1989, Woodward and Topping, 1972). Studies have shown that storage in low concentrations of O_2 and high concentrations of CO_2 helps to retard loss of color and firmness of strawberries and also to control fruit decay (Li and Kader, 1989). Benefits for storing strawberries under elevated CO_2 and/or reduced O_2 have been documented (Woodward and Topping, 1972: El-Kazaz et al., 1983). Although high CO_2 and/or low O_2 levels extends shelf life, the development of off-odors is a major concern (Burton, 1982; Browne et al., 1984).

The quality of fresh strawberries is influenced by numerous climatic and cultural conditions during the growing season, including cultivar, maturity, rainfall, humidity, sunlight, fertilizer, irrigation and time of harvest (Sistrunk et al., 1983). In production of Florida strawberries the two-spotted spider mite is the leading arthropod pest (Howard et al., 1985), and causes economic losses to growers by direct damage in yield loss and quality reduction. Indirect losses come from increased cost of control, inefficient operations, environmental contamination, mite resistance to miticides, buyer reluctance and consumer awareness (Sorensen and Price, 1997).

There is little information available on the sensory characteristics of strawberries grown in Florida, and even less information available on pre-harvest and post-harvest factors that influence sensory characteristics. The objectives of this research were to establish flavor profiles of five cultivars of fresh strawberries important in Florida and to determine the effects of pre-harvest mite control and post-harvest controlled atmosphere storage on the sensory and other quality characteristics of Florida strawberries.

Materials and Methods

The cultivars 'Camarosa', 'Carlsbad', 'Sweet Charlie', 'Rosalinda', and 'FL93-100' were harvested on 1/21/97 and 2/21/97 at the University of Florida Gulf Coast Research and Education Center Dover, Fl. The strawberries were grown on double rows of raised beds covered with a black plastic mulch, with drip irrigation and fertilization practices according to standard recommendations for strawberry production in Florida (Maynard et al., 1988). Immediately after harvest, the strawberries were transported to the Food Science and Human Nutrition building at thc University of Florida in Gainesville within approximately two hours. The samples were rapidly cooled, stored at 3°C, and evaluated within 24 hours of harvest.

The second part of the experiment involved a controlled atmosphere study. 'Camarosa' and 'Carlsbad' cultivars were obtained from a commercial grower in Dover, Florida and transported to Gainesville. They were immediately forced-air cooled to 5°C within 3 hours of early morning harvest. Twenty-four flats (15 lbs. each) of both cultivars were stored in controlled atmosphere over two weeks. The flats were randomized into two treatments of air or controlled atmosphere and placed in sealed plastic storage units in a 3°C room. The CA mixture was obtained by mixing nitrogen, air and CO_2 from pressurized cylinders, and the gas mixtures were distributed uniformly into storage bags, each bag containing 6 flats of fruit. The CA atmosphere used was 5% O_2 +

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15% CO_2. The gas mixtures were humidified prior to entering the storage bags by bubbling through a container with water, which maintained the relative humidity at about 95% (Nunes et al., 1995). The O_2 and CO_2 concentrations were determined using a Shimadzu Gas Chromatograph Chromatopac C-R6A. One flat of berries was removed from each treatment, initially and after 3, 6, 9, and 12 days in storage and subjected to sensory analysis.

In the third part of the study, the effect of mite control on 'Sweet Charlie' was evaluated. Van de Vrie and Price (1994) described the methods needed for applying biological control agents of two-spotted spider mite in strawberries grown in Florida. The bare root transplants of 'Sweet Charlie' were set on 14 Oct 96 in Dover, Florida. The moderate spider mite density treatment included the release of two spotted spider mites (*Tetranychus urticae* Koch) on plants (18 Nov 96). All leaves were generally infested by 21 Jan 97. Abamectin (AgriMek) and fenbutatin-oxide (Vendex) were used according to label instructions to maintain spider mite density at 10-50 motile forms per leaflet during test period. In the low spider mite density treatment, spider mites remained at undetectable levels until 10 Jan 97. At that time, miticides were applied to maintain spider mites at less than 8/leaflet. Strawberries were harvested from each plot on 1/21/97 and 2/21/97, transported to Gainesville, and cooled to 3°C.

Sensory evaluations were performed with a trained panel of 10-12 members. In three training sessions using fresh strawberries, panelists agreed upon five strawberry attributes to rate. The five general attributes of strawberry quality that were established and investigated included color uniformity, texture, sweetness, strawberry flavor intensity and other berry fruit flavors. Panelists evaluated three whole berries per cultivar or treatment on coded plates in individual taste panel booths. All samples were evaluated on a 1 to 15 point scale (with 1 being uneven color, soft texture, low sweetness, low strawberry flavor, low other berry flavor, respectively, and 15 being even color, firm, high sweetness, and high flavor). The data collected were submitted to analysis of variance using SAS (version 6.11). In the cultivar evaluation and mite-study, sensory data were analyzed as a Randomized Complete Block Design (RCBD) with panelists serving as blocks and strawberry cultivars or mite treatments as treatments and data from the two harvests were analyzed separately. In the storage study, sensory data was analyzed as a RCBD with panelists as blocks, storage time and CA (with or without mites) as treatments. Data for each cultivar was analyzed separately.

Results and Discussion

The cultivar evaluation showed that sensory characteristics varied at the two harvests. At the first harvest, 'Rosalinda' and 'FL93-100' were rated the highest of the five cultivars for strawberry flavor intensity, while 'Sweet Charlie' and 'Camarosa' were rated slightly lower for flavor intensity (Fig. 1). 'Carlsbad' had by far the lowest flavor intensity at both harvests. At the second harvest, 'Camarosa' and 'Rosalinda' were found to have the highest strawberry flavor intensity, 'Sweet Charlie' and 'FL93-100' had moderate flavor intensity, and 'Carlsbad' again had the lowest flavor intensity.

At the first harvest, 'Rosalinda' and 'FL93-100' were rated highest for sweetness, 'Sweet Charlie' and 'Camarosa' had moderate sweetness, and 'Carlsbad' had the lowest ratings for sweetness (Fig. 2). At harvest two, 'Camarosa' and 'Rosalinda' were rated the highest for sweetness. 'Sweet Charlie' again

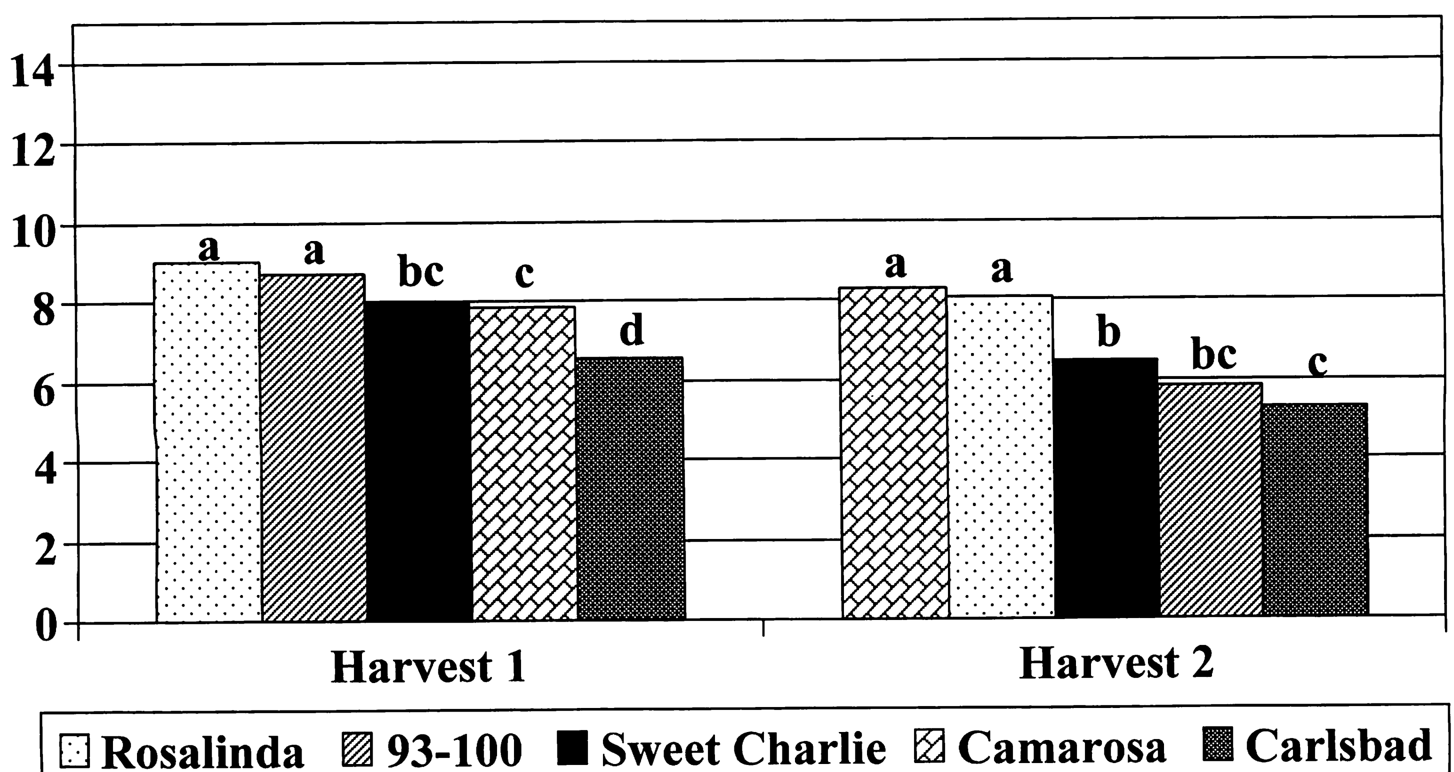

Figure 1. Cultivar Evaluation—Strawberry Flavor Intensity. Bars within a harvest date followed by the same letter are not significantly different (least significant difference, 0.05).

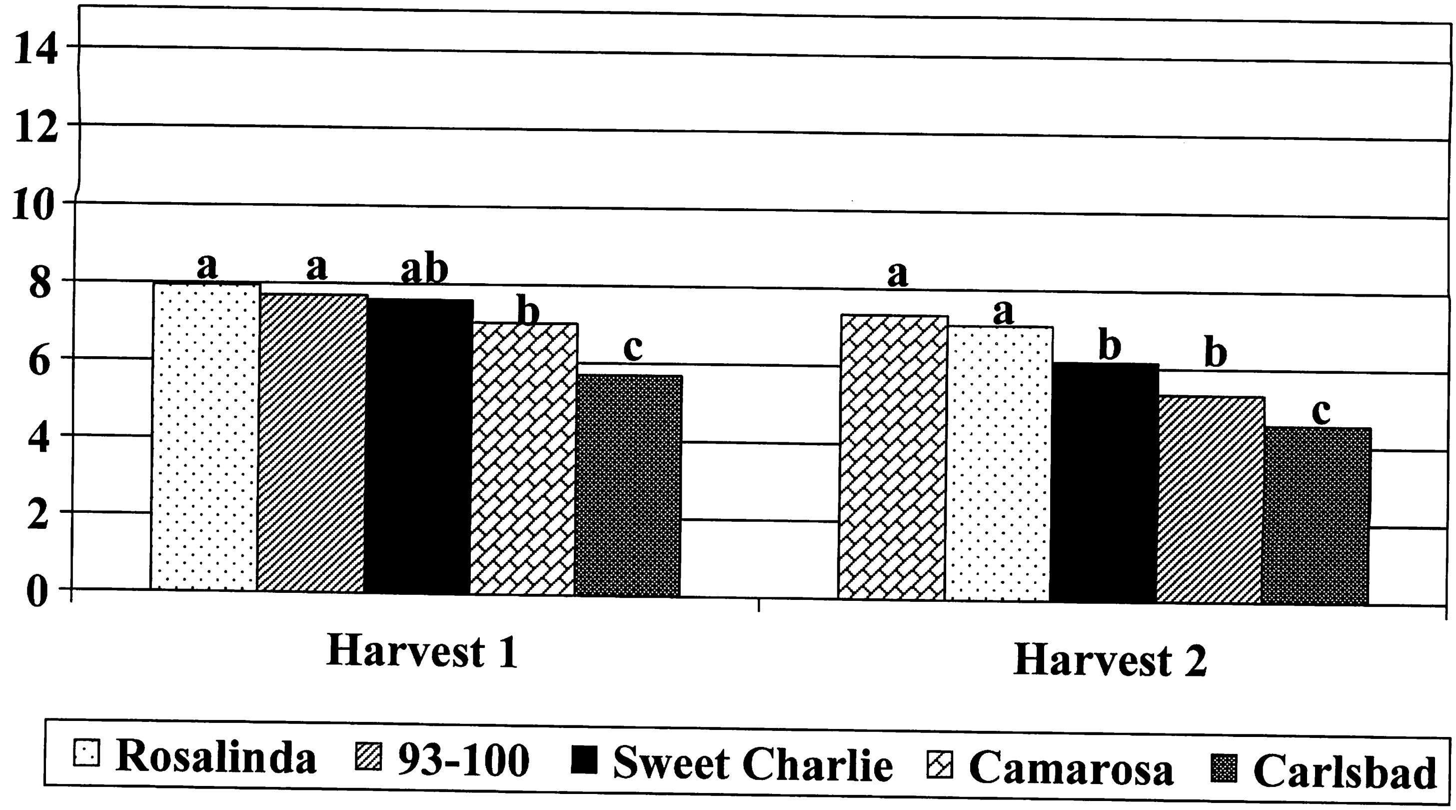

Figure 2. Cultivar Evaluation—Sweetness. Bars within a harvest date followed by the same letter are not significantly different (least significant difference, 0.05).

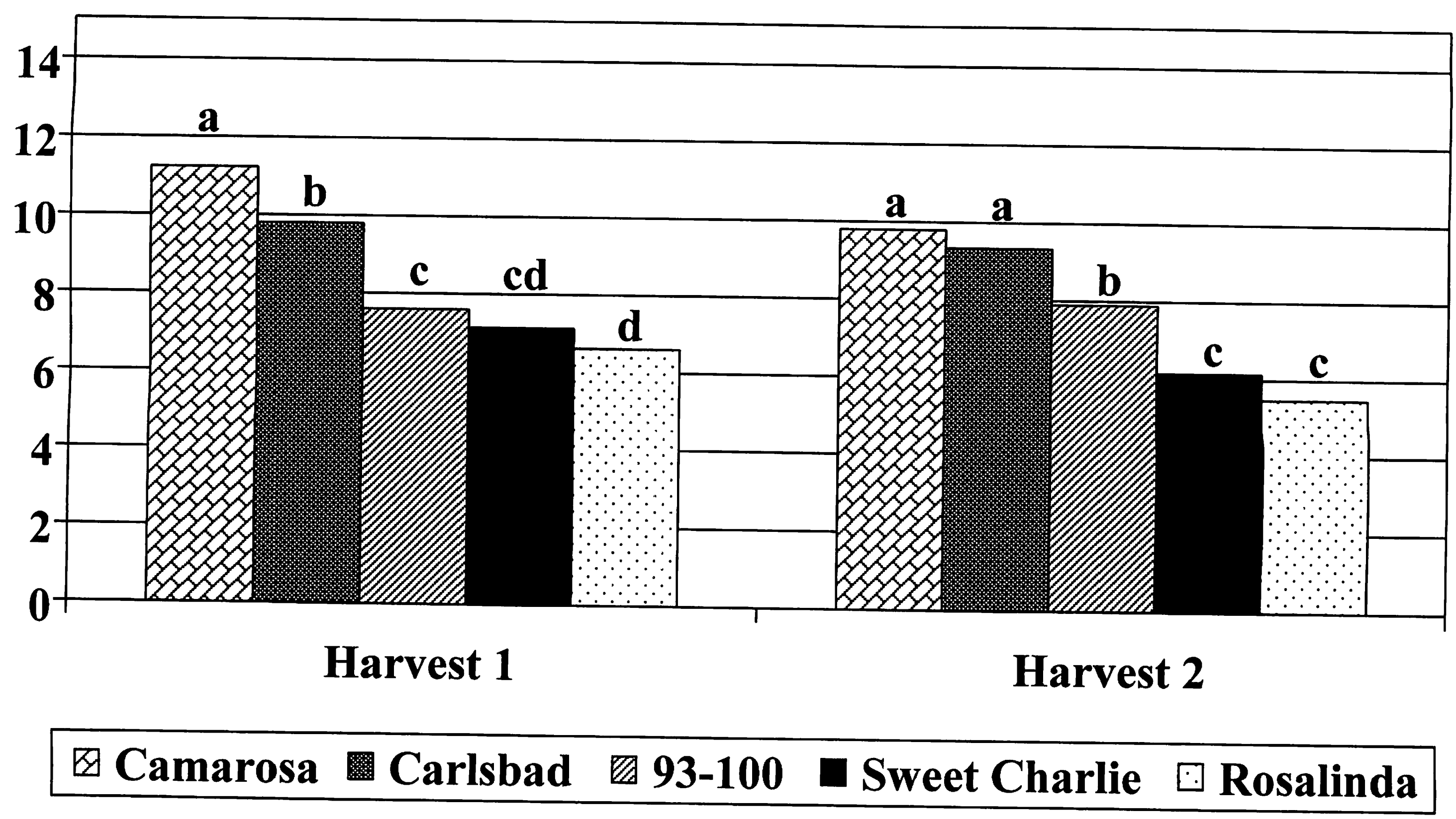

Figure 3. Cultivar Evaluation—Firmness. Bars within a harvest date followed by the same letter are not significantly different (least significant difference, 0.05).

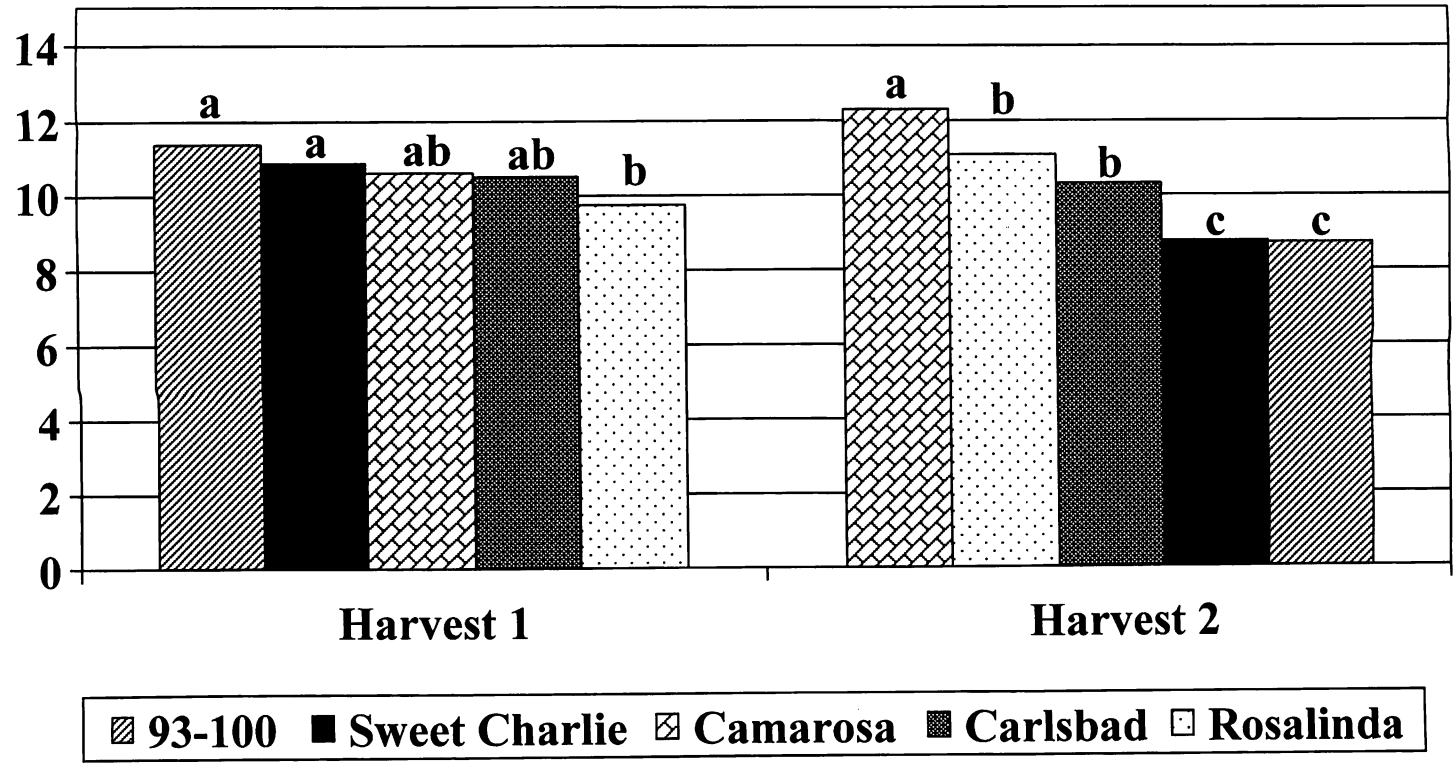

Figure 4. Cultivar Evaluation—Color Uniformity. Bars within a harvest date followed by the same letter are not significantly different (least significant difference, 0.05).

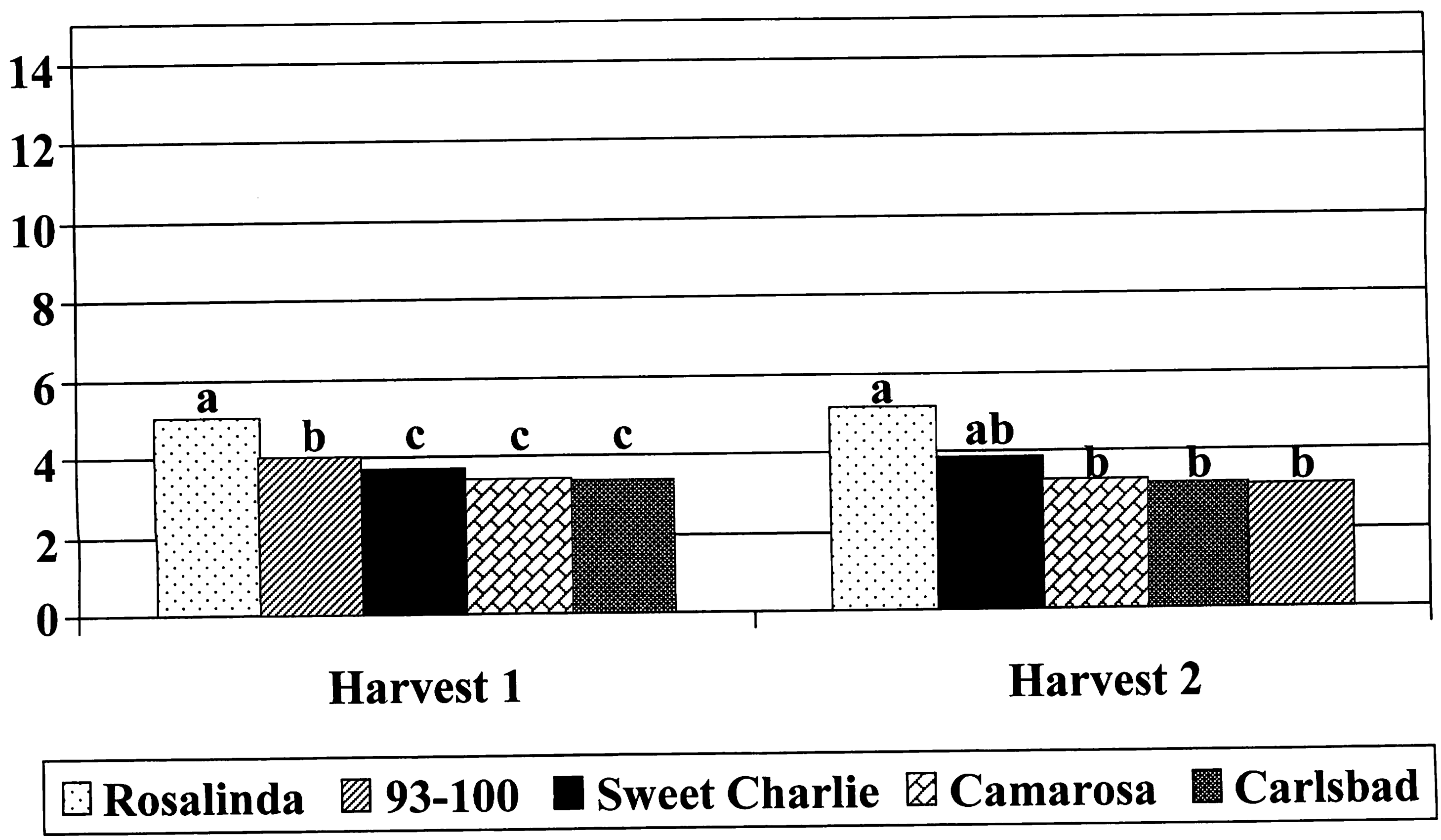

Figure 5. Cultivar Evaluation—Other Berry Intensity. Bars within a harvest date followed by the same letter are not significantly different (least significant difference, 0.05).

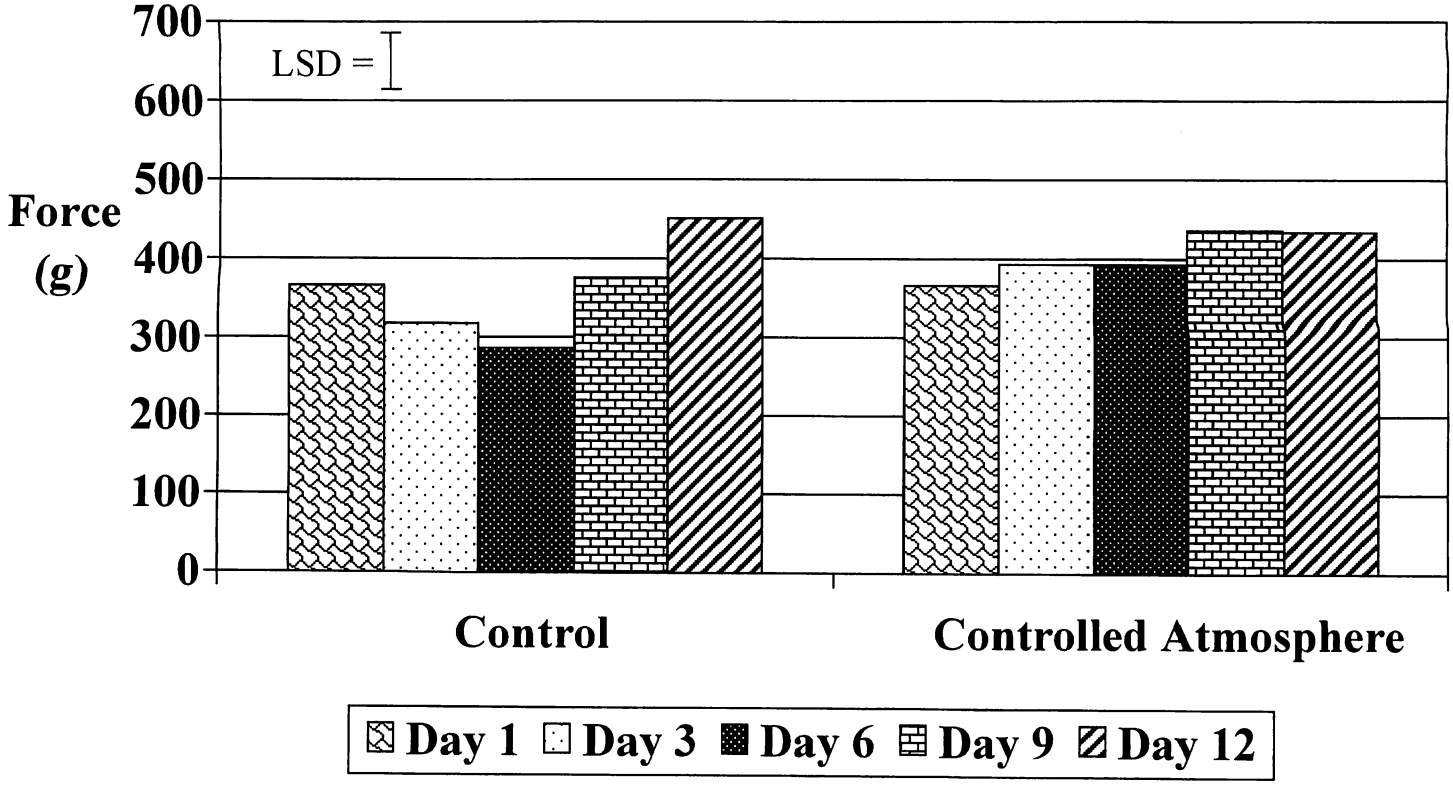

Figure 6. Controlled Atmosphere Study: Camarosa—Instron Firmness. Least significant difference for time × treatment interaction for Camarosa = 70 g.

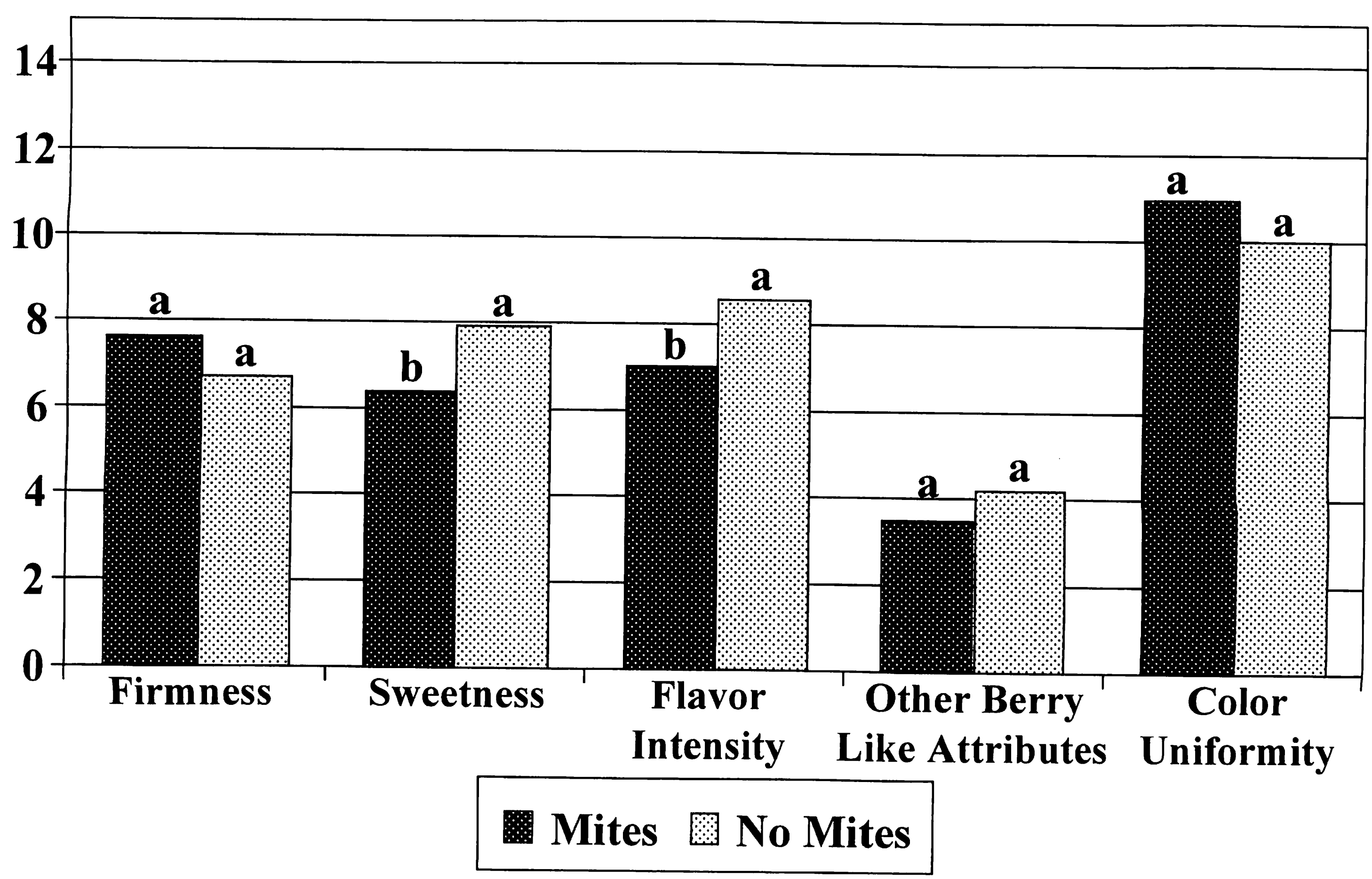

Figure 7. Mite Study: Harvest 1. Bars followed by the same letter are not significantly different (least significant difference, 0.05).

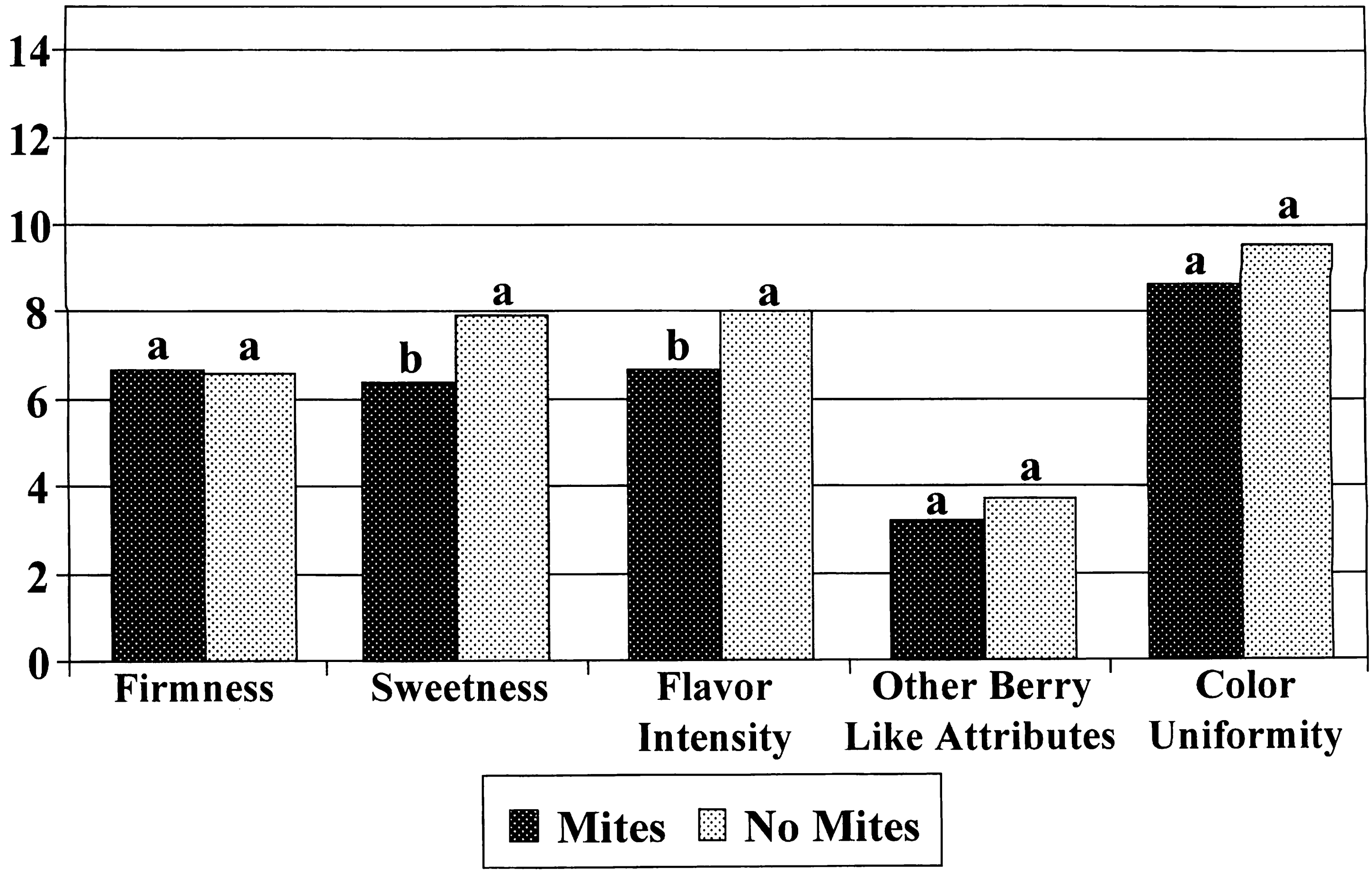

Figure 8. Mite Study: Harvest 2. Bars followed by the same letter are not significantly different (least significant difference, 0.05).

demonstrated moderate sweetness, followed by 'FL93- 100', and 'Carlsbad' had the lowest sweetness at both harvests.

There was more variability in firmness between cultivars than for any other attribute (Fig. 3). At the first harvest, 'Camarosa' was rated the firmest, followed by 'Carlsbad'. 'FL93-100' was considerably less firm, and 'Sweet Charlie' and 'Rosalinda' were the softest. At harvest two, the same general pattern was observed.

At the first harvest, 'FL93-100' and 'Sweet Charlie' had the highest color uniformity, followed by 'Camarosa' and 'Carlsbad'. 'Rosalinda' was evaluated the lowest for color uniformity (Fig. 4). At harvest two, 'Camarosa' was rated the highest, followed by 'Rosalinda', 'Carlsbad', 'Sweet Charlie', and 'FL93-100'. However, all had overall good color uniformity due to the fact that these were specifically selected for good color.

'Rosalinda' had the highest other berry flavor ratings at both harvests. The other berry characteristic was defined as some berry-type of flavor other than traditional strawberry flavor (Fig. 5). At the first harvest, 'FL93-100' was the second highest followed by 'Sweet Charlie' and 'Camarosa'. At harvest two, 'Sweet Charlie' was the second highest followed by 'Camarosa' and 'Carlsbad'. However, 'Rosalinda' was the only cultivar with significant levels of this attribute.

In the controlled atmosphere study, results were identical for both 'Camarosa' and 'Carlsbad', and as a consequence, only the 'Camarosa' data will be discussed. There were no significant differences due to storage atmosphere or storage time for flavor, sweetness, strawberry color, and other berry flavor characteristic (data not shown). However, firmness as measured by the Instron indicated changes in firmness (Fig. 6). The firmness of the control berries dropped after day 3 and 6, and went up at day 9. Firmness was maintained and steadily increased in the berries held under CA. Controlled atmosphere also slowed the decay during storage as compared to the control.

In the mite study, 'Sweet Charlie' had increased sweetness and strawberry flavor intensity at both harvests when grown with no detectable levels of spider mites (Figs. 7, 8). Color and firmness were not significantly different between the treatments (data not shown).

The knowledge acquired from this research might be used to develop better cultural practices, improved cultivars, postharvest storage techniques for Florida strawberries, and to maintain flavor and reduce decay during storage. Other pre-harvest factors such as sunlight, moisture levels, and fertilizer may influence sensory characteristics, and needs further investigation.

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CONTROLLED ATMOSPHERE STORAGE SUPPRESSES MICROBIAL GROWTH ON FRESH-CUT WATERMELON

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Abstract. **The increasing consumption of fresh-cut produce has led researchers and industry to look for techniques that can increase postharvest life of these products while assuring safety and quality. Controlled atmosphere storage has been used to increase storage life of fresh fruits and vegetables since it slows physiological processes and suppresses microbial growth. Seedless watermelons (*Citrullus lanatus* Thumberg) were cut in 2.5 cm cubes and stored at 3°C for 15 days under five different atmospheres: air, 3% O_2, 3% O_2 + 5% CO_2, 3% O_2 + 10% CO_2, 3% O_2 + 15% CO_2, 3% O_2 + 20% CO_2(balance nitrogen). The concentrations of 3% O_2 + 15% CO_2 and 3% O_2 + 20% CO_2 inhibited bacterial development during the entire storage time, but had negative effects on the visual quality of the cubes.**

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Introduction

The fresh-cut produce industry has shown a pattern of increasing market size in the United States. In the last ten years, several studies have revised projections for the growth of this industry. In 1992, Hurst and Schuler mentioned that the fresh-cut industry predicted a market of $4 to 8 billion by the year 2000. More recently, however, Hodge (1995) noted that, by 1999, this industry will have annual sales of about $19 billion.

Watermelon (*Citrullus lanatus*) production in Florida is also on the rise. According to the Florida Agricultural Statistics Service (1997), the state produced 714 million lb for the 1995-1996 season, corresponding to $50 million, with an increase in planted acreage over previous seasons.

With the increase in consumption of fresh produce, quality is a concern of researchers and industry in this field. Fresh-cut products are more perishable than the intact counter part, a consequence of the physical stresses associated with the processing techniques. Even the removal of the epidermis of a fruit or vegetable represents physical damage to the tissue, which becomes subject to intense physiological changes. These changes, in addition to microbial contamination, significantly shorten postharvest life of produce (King Jr. and Bolin, 1989; Cantwell, 1992; Cantwell, 1995a; Brecht, 1995; Schlimme, 1995; Watada et al., 1996).