POSTHARVEST CHANGES IN FRESH SWISS CHARD (*Beta vulgaris*, type cycla) UNDER DIFFERENT STORAGE CONDITIONS

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ABSTRACT

*The effects of storage temperature and relative humidity on the quality of Swiss chard (*Beta vulgaris, *type cycla) were investigated. Quality was assessed through determinations of water content, weight loss, chlorophyll content, pH, titratable acidity, soluble solids content and sensory evaluations. Storage conditions were 4 and 18C and 43, 86 and 98% relative humidities (RH). The quality of chard leaves was unacceptable after three days of storage at 18C, independent of the RH. Chard leaves kept at 4C and 86 and 98% RH remained acceptable for 9 days. The dehydration suffered by samples kept at 4C and 43% RH turned them unacceptable after 4 days of storage.*

INTRODUCTION

The area around Mar del Plata city is an important producer of leafy vegetables. Among them, Swiss chard (*Beta vulgaris*, type cycla) is highly appreciated in the Argentine cuisine for its nutritional properties and year round supply. Although it is similar to spinach and both products are used interchangeably in most food preparations, consumers favor Swiss chard for its lower price. Moreover, chard is one of the best potherbs of the summer and withstands hot weather better than most greens.

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However, losses in quality and shelf-life are major problems faced in marketing fresh, leafy vegetables. In general, leafy vegetables are characterized as being very perishable, with high respiration and water loss rates (Kader 1992). Because of increased dietary consumption of fresh produce, a longer market season would be desirable for both domestic and export markets. For this reason, the fruit and vegetable market has shifted from processed to fresh products (or minimally processed products) that are convenient and fresh-like (Kim *et al.* 1993).

Certain physical and chemical attributes of leafy vegetables have been used as indicators of quality. Loss of moisture leads to loss of weight and shrinkage during storage (Kader 1992). Retention of green color is an obvious indicator of the quality of leafy vegetables and was considered to have great impact on consumer selection (Francis and Clydesdale 1975). For green vegetables, chlorophyll content is associated with greenness. Turgidity is also an indicator of the quality of chard leaves.

Market quality retention in vegetables is affected by many factors, including postharvest processing, storage time and conditions such as temperature, relative humidity (RH), light and composition of atmosphere (Weichmann 1986; Berrang *et al.* 1990). Minimum safe low temperatures and high RH control are the most important tools for extending shelf life in most fresh vegetables (Barth *et al.* 1993). Although all leafy vegetables respond favorably to the application of modified atmosphere technology, this technique is used commercially on a limited scale.

The effects of storage conditions for spinach have been widely studied (Yamauchi *et al.* 1986; Ko *et al.* 1996; Yamauchi and Watada 1991). On the other hand, the information on storage conditions for chard is scarce. Kader (1992) recommends storage temperature of 0C and RH greater than 95% for a list of vegetables that includes chard. Referring to fresh-cut horticultural products, Watada *et al.* (1996), report that, although 0C generally is the desirable temperature, many are prepared, shipped and stored at 5C and sometimes as high as 10C. Storage at this elevated level can hasten deterioration substantially because Q_{10} of biological reactions range from 3 to 4 and possibly as high as 7 within this temperature region (Wiley 1997). The storage temperatures chosen for this study are representative of the retail display conditions for chard most frequent in Argentina, with and without refrigeration. The purpose of the present work was to study the effect of temperature and RH of the storage atmosphere on the shelf-life of Swiss chard. To assess changes in the quality of chard, chlorophyll content, moisture and weight losses, pH and titratable acidity, soluble solid content in juice samples and sensory attributes were analyzed for chard kept at two storage temperatures (4 and 18C) and three levels of RH (43, 86 and 98%).

MATERIALS AND METHODS

Raw Material

Fresh Swiss chard (*Beta vulgaris*, type cycla), harvested at optimal maturity, was obtained from local producers. To reduce the natural variability among leaves of chard, samples were sorted for integrity, uniformity of color and size, and lack of defects. Chard leaves were soaked in a 200-ppm chlorine solution at 1-3C for 2 min. Surface moisture was removed with a manual salad centrifuge. Leaves were piled up in 120 g stacks and placed in open plastic containers. These containers were placed in boxes with RH of 97-99; 85-87 and 42.5-43.5% and stored at 4 ± 1 and at 18 ± 1C. These two temperature levels represent the marketing conditions of chard in Argentina, the first for refrigerated cabinets in supermarkets and the second for unrefrigerated greengrocer's stores. Samples stored at 18C were evaluated after 1, 3, and 4 days of storage; samples stored at 4C were evaluated after 1, 3, 7, and 11 days of storage.

Sample Storage

Holding boxes, with overall dimensions of $0.4 \times 0.3 \times 0.3$ m, were made of heavy-duty, 1/4 in. thick transparent acrylic. To create an atmosphere of ca. 98% RH, a beaker with saturated potassium sulfate solution was placed in the box. Likewise, the ca. 86% RH was obtained with a saturated potassium chloride solution and the ca. 43% relative humidity was obtained with a saturated potassium carbonate solution. These boxes were maintained in cabinets at 4 ± 1 and 18 ± 1C. Dry and wet bulb temperatures were measured with mercury in glass thermometers. From their readings the relative humidity was determined with a psychrometric chart. The bulb of one of the thermometers was wrapped in cotton gauze kept moist with distilled water to measure the wet bulb temperature.

Quality Evaluation

Samples were weighed throughout the experiment to determine weight losses. At each storage time assessed, two samples were removed for the different analysis. Stems were removed and the green tissue was ground with a home food grinder for moisture and chlorophyll determinations. Moisture was determined by the weight lost by 10 g samples after 24 h at 80C (Bastrash *et al.* 1993). Total chlorophyll in propanone extracts was determined by light absorbance at wavelengths of 660.0 and 642.5 nm with a U-3210 Hitachi spectrophotometer (AOAC 1980).

The juice of 30 g of Swiss chard was obtained with a home juice maker and centrifuged at 2000 rpm for 5 min. Juice samples were diluted (1:1) with distilled water. pH of the diluted samples was measured with a benchtop conductivity/pH meter (Jenco Electronics Ltd, Model 1671, Taiwan). The diluted samples were also titrated to pH 8.1 with 0.1 N NaOH. Other centrifuged juice samples were diluted 1:20 with distilled water to determine soluble solids as % solids with an Abbe refractometer (Kim *et al.* 1993). All assays were performed in duplicate.

Sensory Evaluation

Chard leaves were rated by the authors for color (uniformity and intensity), turgidity and aroma on a scale where 9 = very good, 5 = acceptable and 1 = poor. Samples kept at 4C were rated at days 1, 3, 5, 7, 9 and 11; samples kept at 18C were rated at days 1, 3 and 4.

Statistical Analysis

Differences among samples at different storage times and storage temperature and relative humidity were tested by analysis of variance (Box *et al.* 1978). Wherever differences are reported as significant, a 95% confidence level was used.

RESULTS AND DISCUSSION

Weight Loss and Water Content

Figure 1 shows the weight losses of chard leaves during storage at 4 and 18C and 98, 86 and 43% RH. For samples held at 4C, weight losses were greater in leaves held at 43% RH. After 11 days of storage the weight losses for 98, 86 and 43% RH were 4.47, 3.23, and 10.21%, respectively.

Water contents did not show significant changes in the first three days of storage, independent of the RH of the holding atmosphere. At days 7 and 11, however, the water contents of samples held at 43% RH had suffered significant decreases, unlike the samples held under higher RHs.

Weight losses of fresh washed vegetables can be primarily attributed to: (1) evaporation of a moisture layer that persists on the vegetable surface after washing; (2) dehydration, that is water loss due to the difference in water vapor pressure between the atmosphere and the foodstuff; and (3) respiration, which consists of breakdown of carbohydrates to yield carbon dioxide and water. In respiration, while carbon dioxide is lost to the atmosphere, water is retained by the food and weight loss is independent of moisture loss (Sastry and Buffington 1982).

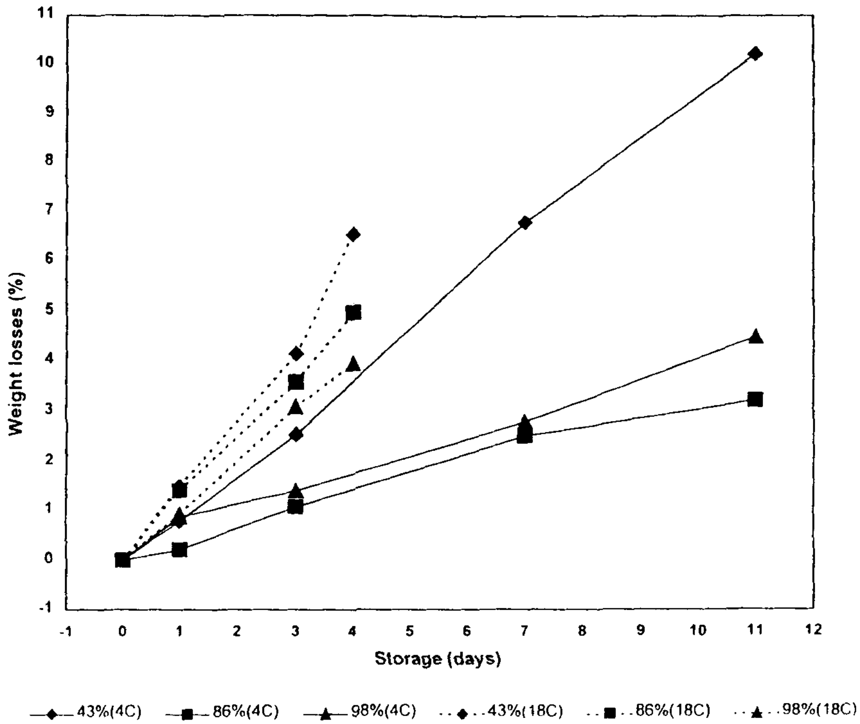

FIG. 1. WEIGHT LOSSES, AS A PERCENTAGE OF FRESH WEIGHT, DURING STORAGE OF SWISS CHARD LEAVES

The weight losses observed in chard kept at 98 and 86% RH, in which no significant decreases in water contents were detected, could be attributed to evaporation and respiration. For chard kept under a 43% RH atmosphere, dehydration would also play an important role. A decrease in water content alone does not account for all the weight lost by samples stored at 43% RH. The balance could be attributed to higher metabolic rates induced by water stress in plant tissues caused by low ambient humidity. Results in soluble solids content were consistent with this hypothesis.

For chard kept at 18C (Fig. 1), weight losses after 4 days were 3.95, 4.91 and 6.53% for RH of 98, 86 and 43%, respectively. For samples held at 98 and 86% RH, water content did not fall significantly for the first 3 days of storage. At day 4, however, samples held at 98% RH lost 0.79% and samples held at

86% RH lost 2.31% of their initial water content. Samples that were held at 43% RH showed a steady decrease in water content that reached 2.97% after 4 days of storage.

Storage temperature affects the three mechanisms to which weight losses were attributed above. Higher temperatures result in higher heat transfer coefficients favoring evaporation of the surface moisture layer. The effect of temperature on dehydration is harder to assess. It involves: (1) water migration from the interior to the surface of the foodstuff, (2) changes in the critical and equilibrium water contents of the material and (3) changes in the heat transfer coefficient between air and the food (Singh and Heldman 1993). While for most solutions the water activity is not affected significantly by temperature, the water activity of many food materials increases with temperature (Toshimasa 1990). Therefore, by increasing the driving force, higher storage temperatures would increase dehydration. Changes in all these factors, induced by increases in temperature, tend to favor dehydration. Respiration also increases with temperature. A 10C increase in temperature results in a Q_{10} value between 1 and 5, with a mean of 2, for respiration of fruits and vegetables (Wiley 1997).

The increases in the rates of weight loss due to the different mechanisms would explain the faster weight losses in chard kept at 18C compared with those observed at 4C. Working with individually exposed spinach leaves, Watada *et al.* (1987) reported larger weight losses at 20 than at 10C (ambient humidity was not indicated). However, the decreases in water content between days 3 and 4 of storage for chard kept in 98 or 86% cannot be attributed to the aforementioned mechanisms. By day 4 all samples presented extensive wilting and the properties of fresh chard had been greatly affected. Sastry *et al.* (1978) proposed that rises in transpiration rate for certain commodities stored close to saturation conditions could be due to fungal growth or microbial spoilage. In chard leaves held at 18C brown spots (probable evidences of fungi spoilage) appeared after 3 days of storage. A possible explanation for the decreases in water content after day 3 would be either that fungal growth increases the transpiration rate or that deterioration of the cell structure lowers the water holding capacity of the material.

Chlorophyll Content

The greenness of leafy vegetables is related to chlorophyll; therefore, changes in chlorophyll content should correspond to changes in color, which, in turn, are indicative of changes in quality. Chlorophyll content in chard leaves during storage at 4 and 18C and different RH are shown in Fig. 2. Due to the wide variability in analytical results only the samples at 4C and 43% RH and at 18C and 43% RH presented chlorophyll contents significantly different from the initial content after 11 and 4 days, respectively. The initial chlorophyll content was 43.7 mg/100 g of wet sample. After 11 days at 4C and 43% RH the chlorophyll content dropped to 22.14 mg/100 g of wet sample and after 4 days at 18C and 43% RH to 17.08 mg/100 g wet sample. Chlorophyll degradation has been shown to be affected by many factors, including temperature and RH (Perrin and Gaye 1986). The fact that no significant changes in chlorophyll content were detected in the samples held under 98 or 86% RH would indicate that high RH retards chlorophyll degradation in chard leaves. The rate of chlorophyll loss is temperature dependent, especially in fresh vegetables (Yamauchi and Watada 1991). The fact that chard leaves in 43% RH lost more chlorophyll after 4 days at 18C than after 11 days at 4C is indicative of this phenomenon. Yamauchi *et al.* (1986) reported that spinach leaves stored at 25C retained *a* chlorophyll for up to 2 days and *b* chlorophyll for up to 3 days of storage. These authors also reported that spinach leaves deteriorated rapidly after 3 days of storage with the onset of yellowing.

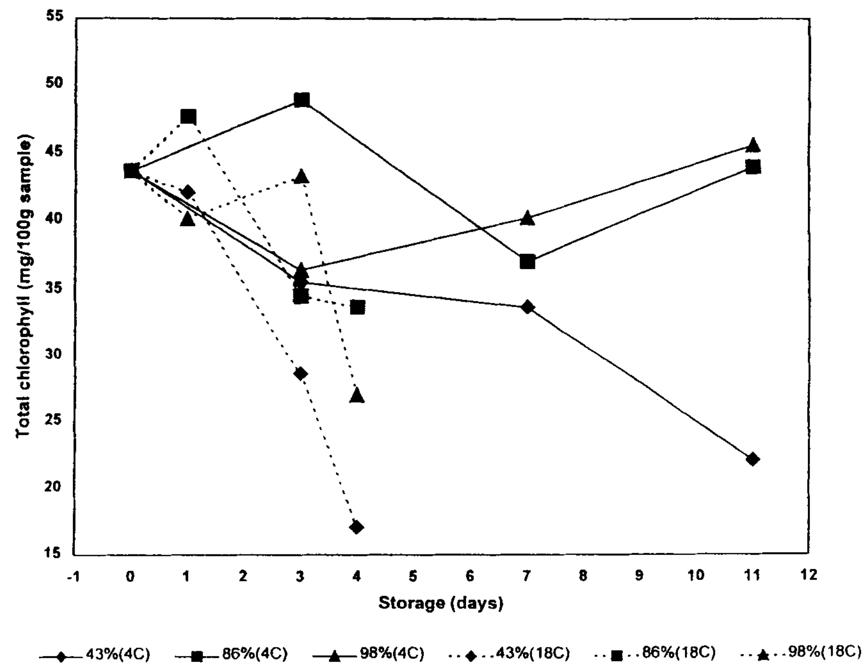

FIG. 2. TOTAL CHLOROPHYLL CONTENTS, AS MG PER 100 G OF FRESH SAMPLE, DURING STORAGE OF SWISS CHARD LEAVES

Soluble Solids Content

For days 1 and 3 of storage the soluble solids (SS) contents of samples held at 18C were significantly lower than the contents of samples held at 4C. For samples held at the same temperature, and after day 1 of storage, those under 43% RH always presented SS contents significantly lower than those under 86 and 98% RH. Finally all samples presented significant decreases in SS during the first day of storage.

The energy sources available in the tissues of freshly harvested vegetables are free amino acids and carbohydrates (Heimdal *et al.* 1995). The decreases in SS could be attributed to sugar consumption through respiration.

The decrease in SS during the first day of storage could then be attributed to an increase in metabolic rates brought about by harvesting stress. Higher storage temperatures result in higher respiration rates in fresh cut vegetables (Watada *et al.* 1996) and this would explain the differences between samples stored at 4 and 18C. The greater losses in SS at lower RH suggest that lower RHs cause higher levels of metabolism, perhaps by inducing water stress in the plant tissues.

Titratable Acidity and pH

No significant changes in titratable acidity were found under any of the storage conditions assessed. All samples presented pH values in the range of 6.3 to 6.5. Albrecht *et al.* (1991) reported a similar pH value of 6.29 for fresh spinach leaves. On the other hand, Babic *et al.* (1996) reported gradual increases in the pH values of spinach leaves during storage at 5 and 10C related to microbial growth. The fact that our samples were immersed in a chlorinated solution would explain the different results.

Sensory Analysis

Results from the sensory evaluation are presented in Table 1. While color and turgidity of chard leaves changed to levels that made them unacceptable at one time or another, the changes in aroma did not reach levels of unacceptability until after 11 days at 4C or 4 days at 18C.

In general color evolved from the bright, light green characteristic of freshly cut chard leaves to a dull and darker green. These changes occurred faster at higher temperatures and lower RH. However, the condition of unacceptability in color was assigned to different changes. Samples stored at 4C and 86% RH presented an unacceptable dark shade of green by day 11; samples stored at 18C and 86 and 98% RH presented brown spots by day 4, probably indicative of fungal growth and samples stored at 4 and 18C and 43% RH became unacceptable because of yellowing that coincide with the chlorophyll degradation shown in Fig. 2.

TABLE 1.
SENSORY EVALUATION OF CHARD LEAVES STORED UNDER DIFFERENT TEMPERATURE AND RELATIVE HUMIDITY CONDITIONS

		Sensory attribute								
		Turgidity			Color			Aroma		
Sample Treatment	Day	43%	86%	98%	43%	86%	98%	43%	86%	98%
4 C	0	9	9	9	9	9	9	9	9	9
	1	7.3	8.3	8.3	7.7	7.3	8.3	9	8.3	9
	3	5.3	7.7	8	5.3	7	8	8.3	8	8.7
	5	4.3	6.3	7.3	5.3	6.7	7.7	8	8.3	8
	7	3.3	6	6.3	3	6	7	8	8	8.3
	9	3	5	5.7	3	5.3	6	7	7.3	7.3
	11	1	3	3.3	1	4.3	5	7	7.3	7
18 C	0	9	9	9	9	9	9	9	9	9
	1	7	9	9	7	9	8	8	9	9
	3	4	6	6.3	4	6	7.3	7.3	8	8
	4	1.7	3	4	1	3	4	5	5	5

A sample with a score less than 5 in any of the sensory attributes was considered unacceptable.

The rates at which the firmness of chard leaves was lost also increased with higher temperature and lower RH. Wiley (1997) reported that texture of green vegetables usually becomes unacceptable when they lose about 2% of their water content. For the panelists, the loss of turgidity of chard leaves was the most important attribute to consider in determining its acceptability. Considering both color and wilting, the panel established the following acceptability limits: 9 days at 4C and 98 and 86% RH; 3 days at 4C and 43% RH; 1 day at 18C and 43% and 3 days at 18C and 86 and 98% RH.

CONCLUSIONS

The quality of fresh Swiss chard leaves is highly dependent on the temperature and humidity of the holding atmosphere. Since all samples held at 18C were spoiled after 3 days of storage, refrigeration is required to extend shelf-life beyond this time. At low temperatures, high levels of RH delayed weight, water and chlorophyll losses, and helped maintain sensory attributes. In this respect no preferences between 86 and 98% RH could be established.

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