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Color Changes of Fresh-cut Swiss Chard Leaves Stored at Different Light Intensity

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ABSTRACT

In this study, the effect of continuous and periodic-light treatments on colour retention of freshly cut chard was investigated. Light sources were day light-fluorescent lamps of 1300 lux. The lamps were placed 70 cm above the samples in a cold room set-at 5°C temperature and 85-90% Relative Humidity (RH). One experimental group (L) was constantly exposed to light, another group (PL) was exposed to light for 15 min per hour. Control group (D) of samples was not exposed to light and was stored in the dark. All experimental groups were stored for 14 days. Leaf yellowing, measured by both hue angle and b values, was greater in the continuous light treatment (Group L) compared with the PL and D treatments at the end of the storage. Also, chlorophyll content of samples in L treatment was lower than PL and D treatments at the day 14. The chard leaves in the L and PL groups showed greater weight-loss when compared with the control group (D) both 7th and 14th d of storage so, the continuous light treatment increased weight-loss. The brightness (L* value) of the samples, increased in both the L and PL treatments compared with the D treatment at the end of the storage.

Key words: Chard (*Beta vulgaris* var. cicla), colour pigment, fresh-cut, light, weight loss

INTRODUCTION

Swiss chard (*Beta vulgaris* var. cicla) is a leafy vegetable that is highly appreciated in Turkey for its nutritional properties. Swiss chard is an annual cool season crop and in temperate areas it can be grown all year around. It is a green, leafy vegetable and it can be eaten boiled, baked and raw (Roura *et al*., 2000a). Chard leaves contain relatively high levels of bioactive compounds such as vitamin C and vitamin A (30 mg 100 g^{-1} and 6116 I U, respectively) and also minerals such as potassium, sodium and iron (379 mg 100 g^{-1}, 213 mg 100 g^{-1} and 1.80 mg 100 g^{-1}, respectively) (USDA, 2010). Vitamin C is a powerful antioxidant that participates in the scavenging of the reactive oxygen species, regenerating tocopherols from their radical forms (Smirnoff, 2000). However, losses in quality and shelf life are major problems faced in marketing fresh, leafy vegetables and was considered to have great impact on consumer selection (Ansorena *et al*., 2011). For green vegetables, chlorophyll content is associated with greenness (Aguero *et al*., 2011). Turgidity is also an indicator of the quality of chard leaves. In general, leafy vegetables are characterized as being very perishable, with high respiration and water loss (Kader, 2002).

Certain physical and chemical attributes of leafy vegetables have been used as indicators of quality (Roura *et al*., 2000a). Loss of moisture leads to loss of weight and shrinkage during storage (Kader, 2002). Retention of green colour is an obvious indicator of the quality of leafy

vegetable. After harvest, the quality of whole fresh Swiss chard leaves is highly dependent on the temperature and the humidity of the storage environment. Weight, water and chlorophyll loss are delayed and sensory quality is also maintained when chard is stored at a low temperature (4°C) and high levels of relative humidity (RH>87%) (Roura *et al*., 2000b).

Market quality retention in vegetables is affected by many factors, including postharvest processing, storage time and conditions such as temperature, relative humidity, light and composition of atmosphere (Weichmann, 1986; Berrang *et al*., 1990; Roura *et al*., 2000a; Goni *et al*., 2010). Minimum safe low temperatures, high RH and darkness 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 storage condition, it is used commercially on a limited scale (Roura *et al*., 2000a). Storage and exhibition of vegetables in retail markets should be done in darkness condition but exhibition of vegetables mostly done in light conditions all over the world and also in Turkey, so this light conditions hastened yellowing of leaves due to degradation of chlorophyll at light. But studies about light intensity caused degradation of chlorophyll are limited.

Dietary choices have been tending towards ready to eat products such minimal processed food because of the change in lifestyle (Garcia-Gimeno and Zurera-Cosano, 1997). The market for fresh-cut leafy vegetables has been increasing exponentially all over the world in the recent years. Fresh-cut produce has been one of the hottest commodities in grocery stores over the past 10 years (Kaufman *et al*., 2000). The industry soared to over $10 billion in US retail and food service sales in 1999 and there are no signs of the trend slowing down (Garrett, 2002). In fact, sales for cut and packaged fruit are just getting increased and new commodities such as cut tomatoes are emerging to answer the consumer's desire for more convenience in their daily life. The procedures involved in preparing minimally-processed leafy vegetables, such as grading, chopping and packaging lead to many post-harvest disorders which affect both internal and external quality; mainly the appearance of vegetables (Ferrante *et al*., 2004).

During the postharvest life of fresh-cut chard leaves, major problems have been associated with tissue decay and development of off-odours. Among tissue decay aspects, colour is an important parameter that influences consumer choice (Conte *et al*., 2008). Many factors before and after harvesting are effected color of chard leaves. In pre-harvest stage the causes of colour loss are attributed to diseases, deficiency of mineral nutrients, growing conditions, species. During the postharvest stage, the colour change may be due to unfavorable storage conditions, mechanical damages, enzymatic disorders (browning), hormone unbalances or presence of ethylene. The most part of metabolic processes that induce quality losses are temperature and light dependent therefore, good storage and market conditions may improve the postharvest life of minimally processed chard (Ferrante *et al*., 2008).

There is information on the storage conditions for whole and fresh-cut chard leaves and on the effect of processing on the storage life of leafy vegetables (Bolin and Huxsoll, 1991), but the information about the effect of light on shelf life of fresh-chard leaves is limited. Ferrante *et al*. (2004) recommends dark storage for Swiss chard because in light conditions, yellowing of Swiss chard leaves was occurred at 8 days. The same results were obtained by Ferrante *et al*. (2008). Except these two studies there is no study about chard storage under the light conditions. In this study, variation of colour during storage of fresh-cut Swiss chard leaves. The colour changes were studied under different storage conditions (continuous light, periodic light and darkness). The colour changes during cold storage were determined by measuring chlorophyll content and colour attributes (L*, b* and hue angle values).

MATERIALS AND METHODS

Plant material: In the present study, leaves of chard (*Beta vulgaris* L. var. cicla) produced under cultivation practices in the glasshouse of the Arslanbey Vocational School, at Kocaeli University, Turkey were used as plant material. The experiments were carried out during winter period the year of 2009. Swiss chard seeds were sown to 10 m^2 beds with a 25 cm space between rows to give a final number of 160 plants m^2. All plants in beds were hand harvested by detaching the plants from soil when 90% of plants reached to 7 to 10 leaf stage and mostly of leaves reached maximum size. Immediately after harvest the plants were transported a packing house.

Sample preparation, treatments and storage conditions: Samples consisted of detached leaves with stem. Yellowing, decaying, cutting and bruising leaves were discarded. The stem part of chard was cut and only leaf part was used in the experiments. Leaves of chard in all treatment groups were washed firstly tap water and secondly distilled water and for the excess water was removed, firstly the leaves of chard were placed in a plastic container and allowed to drain of water for 10 min at room temperature. After that the leaves left to dry on filter paper for 5 min. Leaves of chard used for the experiments were taken randomly amongst all leaves.

After samples slightly dried as mentioned above, packed in polystyrene foam dishes and wrapped with polyethylene stretch film.

The following treatments were applied to packaged leaves:

- **D (Control):** Fresh-cut and packaged samples were stored under darkness
- **L:** The fresh-cut and packaged samples were stored at 24 h photoperiod and this treatment named continuous light condition
- **PL:** The fresh-cut and packaged samples were stored at 15 min photoperiod per h and this treatment named periodic light condition

Light source used for illumination was fluorescent lamps at 1300 lux light density. The lamps were placed 70 cm above the samples. Three replicates (three dishes) per processing treatment and storage duration (0, 7 and 14 days) were prepared and stored in a clean cold room set at 5±1°C temperature and 85-90% relative humidity.

Colour measurements: Leaf color was determined at three different points of per leaves with a chromameter (Minolta CR 400, Minolta Camera, Co., Osaka, Japan) equipped with an 8 mm measuring head and a D65 illuminant. The chroma meter was calibrated using manufacturer's standard white plate. Color changes were quantified in the L*, a*, b* color space (McGuire, 1992). The hue angle (h°) was calculated as $h° = \tan^{-1}(b/a)$ when $a>0$ and $b>0$ or as $h° = 180+\tan^{-1}(b/a)$ when $a<0$ and $b>0$ (Lancaster *et al.*, 2000).

Chlorophyll determination: Chlorophyll a and b were extracted by grinding 2 g of the leaf tissue-with 30 mL of 80% acetone at 4°C for 12 h, followed by being filtered through Whatman No. 2 filter paper. The filtered solution volume was adjusted to 100 mL with 80% acetone. Chlorophyll content was measured spectrophotometrically at 645 and 663 nm according to Mencarelli and Saltveit (1988). Total chlorophyll content was obtained by the sum of chlorophyll a and chlorophyll b content.

Weight loss: The samples of three replicates were weighed after treatments and during the storage at 7 and 14 days. Results were expressed as percentage of weight loss relative to the initial weight (Lemoine *et al*., 2009). The same samples were used per sampling date for the determine weight loss.

Statistical analysis: Experiments were performed according to completely randomized design. All data presented were the mean of three replicates. Data were analyzed using ANOVA (Minitab for Windows) and treatment mean differences were compared using Duncan's multiple range test. Differences at p = 0.05 were considered significant.

RESULTS

Hue angle value: As shown in hue angle values (Fig. 1), hue angles of samples in all treatment groups were decreased at the day 7, but no differences were obtained between control and light treated samples. Hue angles of samples in L treatment was lower than in PL and D treatments (108.25, 115.40 and 118.52, respectively) at the day 14. Also, the differences between control (D) and continuous light treated (L) samples were statistically significant at the end of the storage.

Colour b* value: The b* values of samples during storage was given in Fig. 2. b* values of fresh-cut chard leaves in D treatment (25.37) were lower than in PL (27.85) and L (28.35) treatments at the 7th d of storage and differences between D and L treatments were found statistically significant but differences between PL and L or D treatment were not significant. At the end of the storage, however, b* values of samples in control was the lowest (28.22) and it is followed by PL (34.02) and L (37.98) treatments. Also, differences among the treatments were significant (p = 0.05). So, light treated fresh cut Swiss chard leaves were higher b* values than control samples.

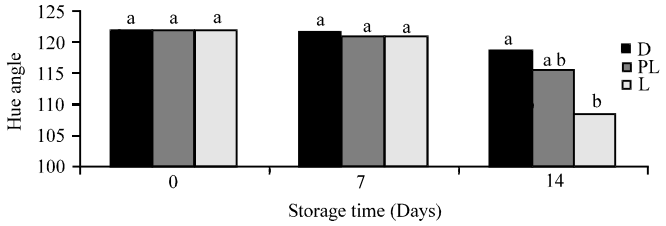

Fig. 1: Changes of hue angle values of chard leaves during storage. Each bar is the mean of three replicates (twelve samples). Means with different letters are significantly different at the 0.05 level

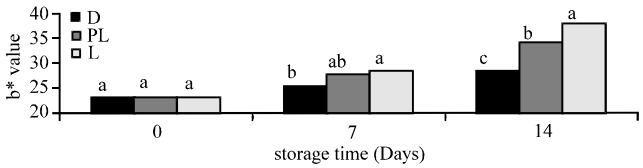

Fig. 2: Changes of b* values of chard leaves during storage. Each bar is the mean of three replicates (twelve samples). Means with different letters are significantly different at the 0.05 level

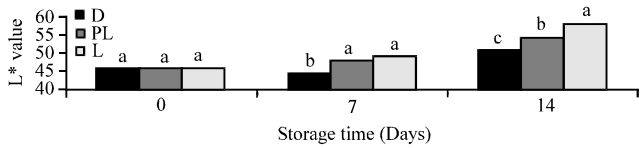

Fig. 3: Changes of L* values of chard leaves during storage. Each bar is the mean of three replicates (twelve samples). Means with different letters are significantly different at the 0.05 level

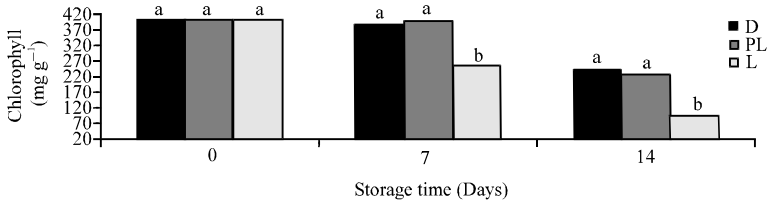

Fig. 4: Changes of total chlorophyll content of chard leaves during storage. Each bar is the mean of three replicates (twelve samples). Means with different letters are significantly different at the 0.05 level

Colour L* value: L* values of samples were 45.65 at the beginning of storage and it was increased samples in PL (47.93) and L (48.84) treatments but decreased in D (44.22) at the 7th day (Fig. 3). At the end of the storage period, however, L values of samples in all treatments group were increased. The lowest L values were measured in the group D (50.68) and it is followed by PL (54.21) and L (57.59). The differences between the treatments were significant ($p<0.05$).

Total chlorophyll content: Total chlorophyll content of samples in all treatment groups was decreased at the day 7 (Fig. 4). But this decrease was the high in L (251.26 mg g^{-1}) treatment compared to PL (393.17 mg g^{-1}) and D (381.92 mg g^{-1}) treatments, and also differences between L and D, or L and PL treatments were significant but differences between D and PL treatments were not significant at the day 7. The same trend was obtained at the 14th day. The initial chlorophyll content of fresh-cut chard was an average 400 mg g^{-1} Fresh Weight (FW). At the day 14, leaves in control had 60% and periodically light treated leaves had 55% of initial chlorophyll content while continuously light treated leaves presented only 22% of initial value.

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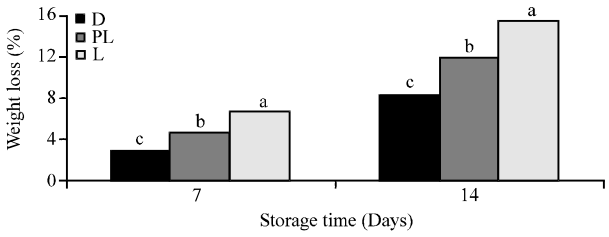

Fig. 5: Changes of weight loss of chard leaves during storage. Each bar is the mean of three replicates (twelve samples). Means with different letters are significantly different at the 0.05 level

Weight loss: Weight loss increased markedly in both light treated and control samples after 7 and 14 d of storage (Fig. 5) and differences among the treatments were significant at p = 0.05 level. Also, weight loss was the high fresh-cut chard leaves in L treatment and it is followed by PL and D treatments at the end of the storage. So, light treatment was increased weight loss of samples compared with control group.

DISCUSSION

Green colour is most important quality criteria for green leafy vegetables for customer preference (Roura *et al*., 2000b) and colour change is the first visible symptom of senescence in many horticultural crops and may compromise their economic value (Ferrante *et al*., 2004). The catabolism of leaf pigments is tightly connected with storage conditions. The presence of light may influence the storage in promoting or preserving the chlorophyll degradation (Kader, 2001). In general, all horticultural crops included vegetables were stored in darkness. But in marketing stage, light used to exhibition of vegetables and it is known that light enhanced degradation of chlorophyll so that yellowing was occurred in all leafy vegetables. In this study two light intensity was investigated to provide market condition. In present work it was found that green color of fresh-cut Swiss chard decreased (Fig. 1, hue angle values and Fig. 2 b* values) under both continuous and periodical light conditions compared to control samples.

It was found in a previous study (Kasim and Kasim, 2007) that yellowing of leaf in Brussels sprouts was reduced by light and yellowing was increased in broccoli due to opening florets. In the present work, light treatment increased the yellowing of the chard leaves, unlike Brussels sprouts. Furthermore, Ferrante *et al*. (2004) was found that yellowing of Swiss chard leaves stored at light condition began after 8 days. Also, Ferrante *et al*. (2008) was suggested that Swiss chard can be stored until 8 days without any visible changes under light conditions. In the present study, yellowing of fresh-cut Swiss chard leaves was begun at the day 7 in all treatment groups. But it was higher L and PL treatments than D treatment. Also, yellowing of leaves was increased at the end of the storage especially L treatment. So, as a results of b* value and hue angle, Swiss chard leaves should not stored in continuous light conditions. But for retail market, it was suggested that the periodic light treatment could be preferred instead of 24 h photoperiod for delayed leaf yellowing.

The b* values represent the yellow/red color and the increases in the b* values indicated increases in leaf yellowing. The decrease in the green pigmentation is an indication of a loss of chlorophyll during storage. In this study, both b* values (Fig. 2) and hue angle values (Fig. 1) of chard leaves correlated well ($r^2 = 0.8226$; $t = 9.63$, $p<0.01$). Therefore, the yellowing process in chard

leaves kept at L and PL conditions was associated with both decrease hue angle and increase in the b* value and also decrease in chlorophyll content. Furthermore, the L value of samples was retained best in the L and PL groups when compared with the D. So, the light treatment increased the brightness of samples.

For green vegetables, chlorophyll content is associated with greenness therefore, changes in chlorophyll content should correspond to changes in colour which in turn are indicative of changes in quality (Roura *et al*., 2000b). The results of the chlorophyll measurement indicated that light increased the degradation rate of chlorophyll in fresh-cut leaves. This process might be caused by the degradation of carotenoids. Biswal (1995) reported that the degradation of carotenoids makes chlorophyll pigments susceptible to bleaching by light. Chlorophyll degradation was slower in group D than in the L and PL environments. Ferrante *et al*. (2004) found that leaf yellowing of Swiss chard began after 8 days of storage in light. The type of chard used (Ferrante *et al*., 2004) was different from the one that was used in the present study, in which leaf yellowing was observed after 7 days of storage.

Most fresh vegetables contain 85-95% water (Ryall and Lipton, 1978). Leafy vegetables are particularly vulnerable to rapid water loss because of their greater surface-to-volume ratio (Kays, 1991). The loss of moisture results in a reduction in the fresh weight of harvested vegetables, often accompanied by loss of freshness, appearance and texture (Roura *et al*., 2000a). Generally, a loss of 5-10% moisture results in unmarketable products. The maximum acceptable weight loss of a cabbage is 7% (Kays, 1991). In this study, samples of all treatment groups lost weight during storage (Fig. 5) however, the weight loss of the samples at the 7th day did not exceed 7%.

CONCLUSIONS

In this study, the effect of two different light treatments on yellowing of fresh-cut Swiss chard leaves was studied. It was shown that exposure to a continuous light treatment at 1300 lux (L) density increased the brightness (L* value) of the samples, but was not effective for reducing yellowing compared with samples stored in darkness. Storage under continuous light (Group L) treatment did not increase the shelf life of chard. The same results were obtained to periodical light treatment. So, both continuous and periodical light treatments were increased leaf yellowing due to chlorophyll degradation compared to darkness. Therefore, for the storage of Swiss chard prior to marketing the dark storage should be preferred. Since, leaf yellowing of fresh-cut Swiss chard in PL treatment was lower than L treatment, it was suggested that fresh-cut chard leaves could be exhibited in low light intensity for marketing for delayed leaf yellowing.

REFERENCES

Aguero, M.V., A.G. Ponce, M.R. Moreira and S.I. Roura, 2011. Lettuce quality loss under conditions that favor the wilting phenomenon. Postharvest Biol. Technol., 59: 124-131.

Ansorena, M.R., M.G. Goni, M.V. Aguero, S.I. Roura and K.C. Di Scala, 2011. Application of the general stability index method to assess the quality of butter lettuce during postharvest storage using a multi-quality indices analysis. J. Food Eng., 92: 317-323.

Barth, M.M., E.L. Kerbel, S. Broussard and S.J. Schmidt, 1993. Modified atmosphere packaging protects market quality in broccoli spears under ambient temperature storage. J. Food Sci., 58: 1070-1072.

Berrang, M.E., R.E. Bracket and L.R. Beuchat, 1990. Microbial, color and textural qualities of fresh asparagus, broccoli and cauliflower stored under controlled atmosphere. J. Food Protect., 53: 391-395.

Biswal, B., 1995. Carotenoid catabolism during leaf senescence and its control by light. J. Photochem. Photobiol. B: Biol., 30: 3-13.

Bolin, H.R. and C.C. Huxsoll, 1991. Effect of preparation procedures and storage parameters on quality retention of salad-cut lettuce. J. Food Sci., 56: 60-62.

Conte, A., G. Conversa, C. Scrocco, I. Brescia, J. Laverse, A. Elia and M.A. Del Nobile, 2008. Influence of growing periods on the quality of baby spinach leaves at harvest and during storage as minimally processed produce. Post. Biol. Technol., 50: 190-196.

Ferrante, A., L. Incrocci, R. Maggini, G. Serra and F. Tognoni, 2004. Colour changes of freshly-cut leafy vegetables during storage. J. Food Agric. Environ., 2: 40-44.

Ferrante, A., L. Incrocci and G. Serra, 2008. Quality changes during storage of freshly-cut or intact swiss chard leafy vegetables. J. Food Agric. Environ., 6: 60-62.

Garcia-Gimeno, R.M. and G. Zurera-Cosano, 1997. Determination of ready-to-eat vegetable salad shelf-life. Int. J. Food Microbiol., 36: 31-38.

Garrett, E.H., 2002. Fresh-Cut Produce: Tracks and Trends. In: Fresh-Cut Fruits and Vegetables, Science, Technology and Market, Lamiranka, O. (Ed.). CRC Press, USA., pp: 1-11.

Goni, M.G., M.V. Aguero, M.R. Moreira, A. Ponce and S.I. Roura, 2010. Ring characterization of quality indices in butterhead lettuce cultivated under mulch and bare soil. J. Food Quality, 33: 439-460.

Kader, A.A., 2001. Quality assurance of harvested horticultural perishables. ISHS Acta Hortic., 553: 51-56.

Kader, A.A., 2002. Postharvest Technology of Horticultural Crops. 3rd Edn., ANR Publications, Oakland, CA., ISBN: 9781879906518, Pages: 535.

Kasim, R. and M.U. Kasim, 2007. Inhibition of yellowing in Brussel sprouts (*B. oleraceae* var. gemmifera) and broccoli (*B. oleraceae* var. italica) using light during storage. J. Food Agric. Environ., 5: 126-130.

Kaufman, P., C.R. Handy, E.W. McLaughlin, K. Park and G.M. Green, 2000. Understanding the dynamics of produce markets: Consumption and consolidation grow. Food and Rural Economics Division report, Economic Research Service, U.S. Department of Agriculture. Agriculture Bulletin No. 758, pp: 32. http://www.ers.usda.gov/Publications/AIB758/.

Kays, S.J., 1991. Postharvest Physiology of Perishable Plant Products. Van Nostrand Reinhold, New York, USA., pp: 356-357.

Lancaster, J.L., M.G. Woldorff, L.M. Parsons, M. Liotti and C.S. Freitas *et al*., 2000. Automated Talairach atlas labels for functional brain mapping. Hum. Brain Mapp., 10: 120-131.

Lemoine, M.L., P. Civello, A. Chavez and G. Martinez, 2009. Hot air treatment delays senescence and maintains quality of fresh-cut broccoli florets during refrigerated storage. LWT Food Sci. Technol., 42: 1076-1081.

McGuire, R.G., 1992. Reporting of objective color measurements. Hortic. Sci., 27: 1254-1255.

Mencarelli, F. and M.E. Saltveit Jr., 1988. Ripening of mature-green tomato fruit slices. J. Am. Soc. Hortic. Sci., 113: 742-745.

Roura, S.I., L.A. Davidovich and C.E. del Valle, 2000a. Postharvest changes in fresh swiss chard (*Beta vulgaris*, type cycla) under different storage condition. J. Food Qual., 2: 137-147.

Roura, S.T., L.A. Davidovich and C.E. Valle, 2000b. Quality loss in minimally processed Swiss chard related to amount of damaged area. Lebensmittel Wissenscaft Technol., 33: 53-59.

Ryall, A.L. and W.J. Lipton, 1978. Handling, Transportation and Storage of Fruits and Vegetables. Vol. 1, AVI Publications, Westport, CT, USA.

Smirnoff, N., 2000. Ascorbate biosynthesis and function in photo-protection. Philos. Trans. R Soc. Lond B Biol. Sci., 355: 1455-1464.

USDA, 2010. Swiss chard. U.S. Deportment of Agriculture, Agricultural Research Service. USDA National Nutrient Database of Standard Reference.

Weichmann, J., 1986. Effect of controlled atmospheres on the sensory and nutritional qualities of fruit and vegetables. Hort. Rev., 8: 101-127.