Pre-Harvest Light Intensity Affects Shelf-Life of Fresh-Cut Lettuce

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Abstract

The industry of fresh-cut produce is continuously growing due to increasing demand for fresh, healthy and convenient foods. However, processing of vegetables accelerates quality deterioration due to structural, physiological and biochemical changes. Therefore, the value of the produce to the consumer is decreased by negative changes in appearance, texture, flavor and nutritional value. Cultivation practices, such as nitrogen application, light and temperature regimes and, the choice of varieties with a higher resistance to processing might greatly influence the postharvest characteristics of lettuce. In this study, the effect of light intensity during growth on shelf-life of fresh-cut lettuce was examined in different varieties. Plants were grown under controlled environmental conditions with day/night temperature 20°C/15°C, relative humidity of 70% and high (250 µmol m^{-2} s^{-1}) or moderate (120 µmol m^{-2} s^{-1}) photosynthetically active radiation (PAR) provided by white fluorescent tubes, with a 12h photoperiod. The shelf-life of plants grown under high light was two-fold that of the plants grown under moderate light. The level of leaf chlorophyll differed between light treatments and varieties. The variety with highest pre-harvest chlorophyll content had the shortest shelf life under both light conditions. The shelf life data are supported by chlorophyll fluorescence images indicating that the latter technique may be used as a quality evaluation tool.

INTRODUCTION

The industry of ready-to-use fresh fruits and vegetables is continuously growing as a result of consumer awareness of the importance of the healthy diet. Lettuce is an important agricultural commodity available over the whole year worldwide. Lettuce micronutrients, such as polyphenols, carotenoids and vitamins might be beneficial for human health by playing a role in the prevention of cancer (Hertog et al., 1992) and heart diseases (Hart and Scott, 1995). Nevertheless, the quality of fresh-cut produce is still unpredictable and the shelf life limited. New techniques for improving and maintaining quality are highly demanded in the production and distribution chain.

Pre-harvest conditions have proven to have great impact on the quality and shelf-life of the postharvest crop. Therefore, knowledge of the effects of pre-harvest conditions is important for optimizing the postharvest potential of fresh produce. However, in contrast to large number of publications on effects of abiotic stress on physiological and biochemical aspects of growing plants, relatively little has been published on these effects on the (postharvest) quality of fresh-cut fruits and vegetables. Therefore, we studied the effects of pre-harvest light intensity on the shelf-life of different cultivars of fresh-cut lettuce.

MATERIALS AND METHODS

Three *Lactuca sativa* L. cultivars ('Butterhead', 'Butterhead' breeding line showing less wound-induced browning and 'Iceberg'), were used in the experiment. The seeds were provided by Rijk Zwaan B.V., The Netherlands. The seeds were sown in boxes filled with vermiculate. The plants were grown under controlled environmental conditions in a climate room at Wageningen University, The Netherlands. Temperatures

were maintained at 20°C during the day and at 15°C during the night, and a relative humidity of 70%. Two light treatments, i.e., high (250 μmol m^{-2} s^{-1}) and moderate (120 μmol m^{-2} s^{-1}) photosynthetically active radiation (PAR) was provided by white fluorescent tubes, with a 12h photoperiod. The plants were watered daily with a nutrient solution (EC=2.0). Approximately 14 days after sowing the seedlings were replanted at a spacing of 12×5 cm. 36 days after sowing, plants were harvested and used for the experiment. The seedlings and lettuce plants were not chemically treated before and/or during the experiment, no herbicides were applied.

Storage Duration and Condition

The whole leaves (control) and leaf discs (fresh-cut) were randomly selected and placed in ventilated 25×100-mm diameter plastic Petri dishes. Leaf discs (18 mm diameter) were excised with a stainless steel cork borer. The bottom of the Petri dishes was lined with wetted filter papers to prevent desiccation. The dishes were put into storage units (Elbanton, Kerkdriel, The Netherlands) at 12°C. During storage, samples were taken weekly to assess selected quality parameters.

Pigments Determination

Samples for the determination of the initial chlorophyll and carotenoid content of control and fresh-cut were taken at harvest. Pigments were extracted from leaf discs in dimethylformamide (in the dark, for one week at -22°C). The chlorophyll content was analyzed spectrophotometrically and calculated as in Wellburn (1994).

Overall Visual Quality and Shelf Life

Lettuce quality was evaluated using overall visual quality (OVQ) parameter, which was rated on a scale from 9 to 1, where 9=excellent and 1=unusable (Kader et al., 1973). An OVQ rating of 6 was considered the limit of salability.

Fluorescence Measurements

Fluorescence images of leaves and leaf discs were made with PSI Fluorcam 700MF chlorophyll fluorescence imaging system (PSI, Brno, Czech Republic); Fluorcam v. 5.0 software was used to control the imaging system and to process the images. To obtain the Φ_{PSII} images, fluorescence images produced during measuring light flashes were digitized. Those images captured in the absence of any actinic light (i.e., 'darkness'; the average irradiance produced by the measuring light flashes was <0.5 μmol m^{-2} s^{-1}, an intensity too low to produce any significant perturbation of the photosynthetic machinery) were averaged to produce an image of the F_o relative fluorescence yield, and those images made during the saturating light pulse (2500 μmol m^{-2} s^{-1}) were averaged to produce an image of the F_m relative fluorescence yield. From the two images, the computer calculated the F_v/F_m image pixel by pixel using the expression $(F_m-F_o)/F_m$. The Φ_{PSII} images were calculated using $(F_m'-F_s)/F_m'$.

RESULTS AND DISCUSSION

Initial Pigments Concentration

The content of pigments, i.e., chlorophyll and carotenoids (Fig. 1) differed between light treatments and lettuce cultivars. 'Iceberg' contained more chlorophyll and carotenoids than both 'Butterhead' cultivars. These results are in contrast with Bohn and Walczyk (2004), and might be explained by the differences in the developmental stage of the plants, i.e., maturity stage (Bohn and Walczyk, 2003) versus young plants (current work). Moreover, the concentrations of chlorophyll were higher in lettuce grown under high light than in lettuce grown under moderate light, due to enhanced thylakoid formation under more optimal light for photosynthesis, under conditions where nutrient and water were not limiting (Evans, 1996).

Overall Visual Quality and Shelf-Life

The fresh-cut lettuce showed a higher overall quality loss than the excised intact leaves (control) (Fig. 2). The limit of salability was reached quicker by 'Iceberg' than 'Butterhead' cultivars, and for lettuce grown under moderate light than for lettuce grown under high light. It appeared that the variety with highest initial chlorophyll content had the shortest shelf-life under both light conditions.

Chlorophyll Fluorescence Imaging

The effect of prolonged storage on F_v/F_m was clearly different for the intact leaves compared to fresh-cut and, for the two light treatments (Fig. 3). The reduction in F_v/F_m was quicker for the fresh-cut lettuce than for the intact leaves, and for the plants grown under moderate light than for plants grown under high light. The decrease in F_v/F_m implies damage to photosystem II, and chlorophyll breakdown. These results are in line with the OVQ data (Fig. 4), indicating that F_v/F_m might be a good, easy and quick method of assessing quality changes in fresh-cut lettuce.

CONCLUSIONS

The postharvest quality of the fresh-cut lettuce deteriorated much quicker than of the excised intact leaves. However, the shelf-life of the fresh-cut lettuce appeared to be prolonged when the plants were grown under light more optimal for growth. The differences in shelf-life between varieties appears to be a complex phenomena, which is probably linked not only to the pigment content, but also to leaf structure and content of other components.

ACKNOWLEDGEMENTS

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Figures

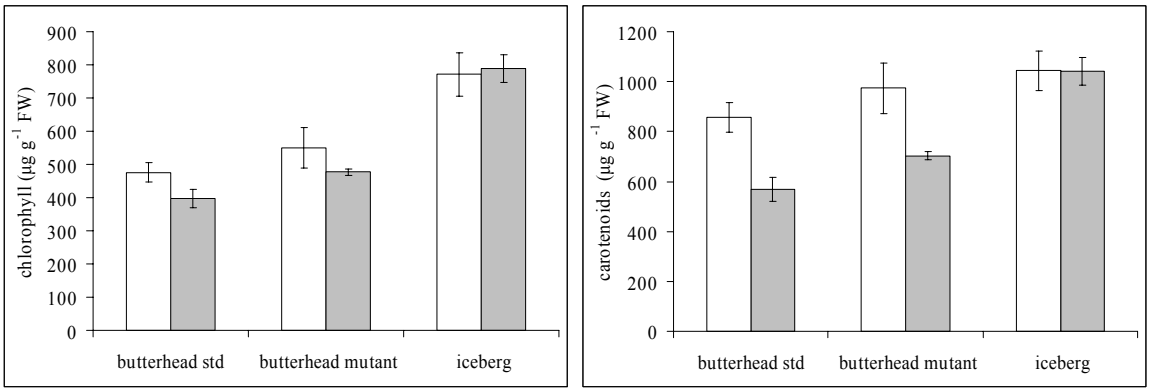

Fig. 1. Mean values ± SE of initial concentrations of chlorophyll (left) and carotenoids (right) in lettuce samples grown under high (white bars) and moderate light (grey bars).

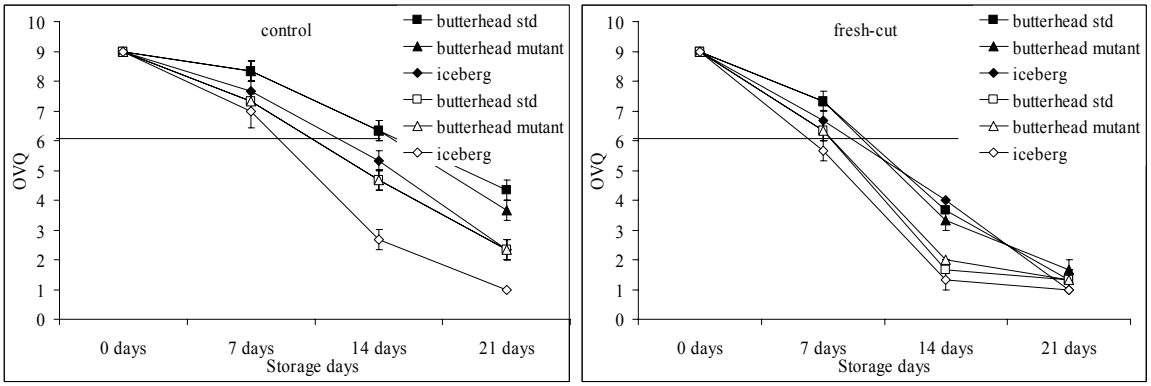

Fig. 2. Mean overall visual quality (OVQ) ± SE for excised intact leaves (left) and fresh-cut produce (right) of lettuce cultivars grown under high (closed markers) and moderate light (open markers).

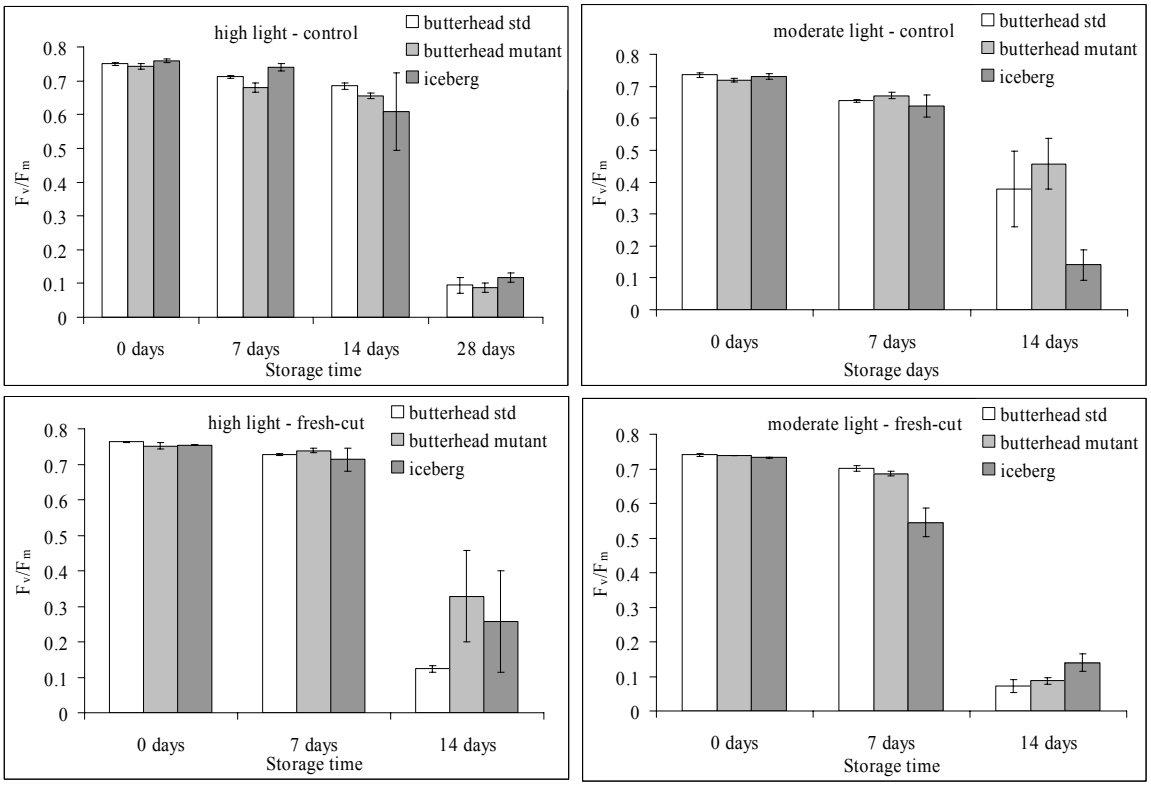

Fig. 3. Mean F_v/F_m ± SE for excised intact leaves (upper panels) and fresh-cut produce (lower panels) of lettuce cultivars grown under high (left panels) and moderate light (right panels).

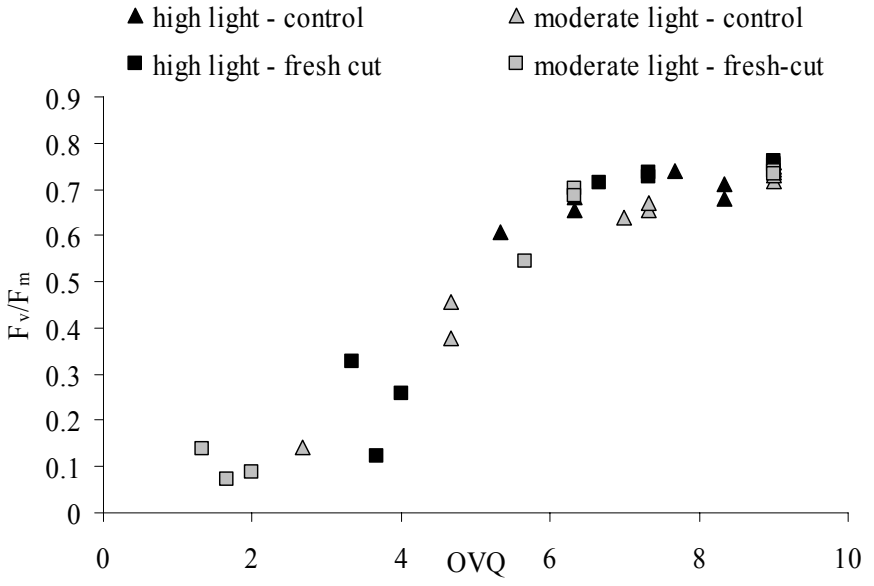

Fig. 4. Relationship between overall visual quality (OVQ) and mean F_v/F_m ± SE for fresh-cut and intact leaves of lettuce cultivars grown under high and moderate light.