MA-Packaged Fruit and Vegetables – Discrepancy between Visual and Overall Freshness of Green Produce and Relations to Product Quality

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Abstract

Freshness of MA-packaged fresh fruit and vegetables is the most important quality attribute for purchase and consumption. If green produce are packaged in films with too low an O_2 transmission rate (OTR) or distributed at higher temperatures or at a slower rates than expected, quality deteriorations occur that could influence product freshness and consumer trust. Discrepancy between visual and overall freshness occurs when packaged fresh produce looks fresh but are perceived spoiled upon opening of the package. To study discrepancy of packaged fresh produce and the underlying quality attributes, wild rocket was packaged in L-OTR (0.65 pmols^{-1} m^{-2} kPa^{-1}) and H-OTR film (17.4 pmols^{-1} m^{-2} kPa^{-1}) and stored for 6 days at different combinations of time and temperatures which influenced the inside O_2 and CO_2 concentrations. The H-OTR combinations were: 1) 6 days at 2°C; 2) 2 days at 2°C and 4 days at 10°C; and 3) 3 days at 2°C and 3 days at 20°C. The L-OTR combinations were: 4) 2 days at 2°C and 4 days at 10°C; and 5) 4 days at 2°C and 2 days at 20°C. Visual freshness scores ranged from 2.7 to 11.8 and overall freshness scores from 1.3 to 12.2 on a scale from low (0) to high (15) intensity. Visual and overall freshness scores were of similar magnitude when compared for wild rocket packaged in H-OTR film but differed for wild rocket packaged in L-OTR film. The inside O_2 gas concentrations of the H-OTR packages ranged from 13.4 to 19.9 kPa while it went down to around 0.5 kPa in the L-OTR packages. Inhomogeneous color and texture, loss of green color, yellowing and browning of the cut leaf surface influenced visual freshness of leaves from the H-OTR packages. No discrepancy was observed between H-OTR packages because overall freshness was highly correlated to visual freshness (*r=0.98*). In contrast, discrepancy was observed in the L-OTR packages. In these packages overall freshness was related to off-odor formation and changes in color. Multispectral analysis could detect color and texture differences between wild rocket samples but not differences that were related to off-odor formation.

INTRODUCTION

Freshness and quality of MA-packaged fresh fruit and vegetables is related to sensory color and appearance, aroma, flavour, taste and texture (Francis et al., 2012). Freshness can be defined as 'how close a fresh produce is to the original quality at the time of evaluation' (Peneau et al., 2009). A high freshness score shows that the quality of a produce is close to the original quality. A low score, however, shows that quality is far from the initial quality. Freshness is a meta-descriptor (Frøst and Janhøj, 2007) that is related to different quality attributes. Quality can be described by a sensory panel and attributes quantified by sensory descriptive analysis (Bach et al., 2012; Løkke et al., 2012).

So far most efforts in fresh produce assurance have been targeted to optimize appearance and safety attributes and less on providing high quality products with regards to aroma, flavour and texture (Saltveit, 2003; Kader, 2010). Product appearance is a very

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important quality attribute at purchase as consumers use this attribute to evaluate produce freshness. For re-purchase, however, all sensory attributes are important; and especially that fresh produce delivers on the promise of the appearance in the package (Barrett et al., 2010). If there is discrepancy consumers become suspicious (Barrett et al., 2010). Therefore there is a need to develop a quality assurance system so product discrepancy is avoided with packaged fresh produce (Kim et al., 2004). The aim of the present study was 1) to create discrepancy between visual and overall freshness of MA-packaged fresh fruit and vegetables; 2) to determine the underlying sensory attributes of discrepancy in wild rocket; and 3) to determine if multispectral analysis could be used as a tool to identify discrepancy of MA-packaged fresh produce.

MATERIALS AND METHODS

Wild rocket (*Diplotaxis tenuifolia* L.) was used as a model produce for the studies. The leaves were harvested, cooled and stored at 1°C for 3 days before packaging on a commercial packaging line. The process consisted of packaging in 185×145×70 mm trays and wrapping with oriented polypropylene film (OPP). The O_2 Transmission Rate (OTR) of the film was 17.4 (high OTR) or 0.65 (low OTR) pmol s^{-1} m^{-2} kPa^{-1}, respectively, at 23°C and 50% RH. After packaging, samples were shipped at 2°C to the Research Centre Aarslev until the storage experiment began the following day.

Storage

Packages were stored at different combinations of time and temperature. The H-OTR combinations were: 1) 6 days at 2°C; 2) 2 days at 2°C and 4 days at 10°C; and 3) 3 days at 2°C and 3 days at 20°C. The L-OTR combinations were: 4) 2 days at 2°C and 4 days at 10°C; and 5) 4 days at 2°C and 2 days at 20°C (Fig. 1).

Gas Composition

Gas compositions (O_2 and CO_2) were measured before sensory and multispectral analysis using a gas analyzer (Checkmate 9900, PBI Dansensor, Ringsted, Denmark) by placing a needle directly into the packages for gas sampling.

Sensory Descriptive Analysis

Sensory descriptive analysis was conducted at the end of the storage period. Sensory profiling was performed in compliance with international standards for sensory evaluation (ASTM STP 913, 1986; ISO 8589, 1988) using 11 trained panelists. Panelists evaluated freshness (visual and overall), color (color homogeneity, green leaf color, yellow leaf color, olive-brown leaf color, brown discoloration), odor (acidic odor, wild rocket odor, cabbage odor, rotten odor and smoked odor) and texture (rotten texture and sprinkliness of leaves). Samples were equilibrated by placing trays in one layer at room temperature 2 h before the evaluation. Samples were coded, served in a balanced randomized order in four sessions and evaluated in daylight on an unstructured 15-point line scale ranging from low (value 0) to high (value 15) intensity using the Fizz software computer system (Ver. 2.30C, Biosystemes, Couternon, France). First visual freshness of leaves was evaluated through the packaging material and then packages were opened and used for sensory descriptive analysis. After sensory analysis, overall freshness was evaluated.

Multispectral Analysis

Multispectral imaging analysis was carried out after the sensory evaluation. Three representative samples from each treatment were analysed by VideometerLab (Videometer A/S, Hørsholm, Denmark). Approximately 15 g leaves were placed on a 13-cm petri-dish and this petri-dish was then placed under the integrating sphere of the instrument. The leaves were illuminated with light in the VIS- (405, 435, 450, 470, 505, 525, 570, 590, 630, 645, 660, and 700 nm) and in the NIR-range (780, 850, 870, 890, 940, and 970 nm). Only results from the 570 and 780 nm wavelengths were used to describe color (570 nm) and texture (780 nm) differences of wild rocket (Løkke et al., 2013).

Statistical Analysis

The results were submitted to analysis of variance and the mean values were compared by Tukey's multiple range test. The gas composition and multispectral data were analyzed by one-way analysis of variance (ANOVA). The sensory data were analyzed by mixed model ANOVA and treatments were tested against treatment × panelist (Naes and Langsrud, 1998). Differences in visual and overall freshness were tested by mixed model ANOVA using visual and overall freshness as main effect and panelists as random effect.

RESULTS AND DISCUSSION

The visual quality of the wild rocket at the time of sensory evaluation and multispectral imaging analysis is shown in Figure 2. Wild rocket packaged in H-OTR film was more yellow when kept at 10 and 20°C for 3 and 4 days than when kept at 2°C for 6 days (control). Wild rocket packaged in L-OTR film had similar visual color when kept at 10°C for 4 days as the control sample. Others also report color changes of green leafy vegetables subjected to postharvest handling and storage (Tudela et al., 2013).

The combination of different OTR-values, storage temperature and time (Fig. 1) resulted in different inside packaging atmospheres (Fig. 3). The inside O_2 gas concentration of the H-OTR packages ranged from 13.4 to 19.9 kPa while it dropped down to 0.5 kPa in the L-OTR packages. The CO_2 concentration increased to 1.7 to 8.4 kPa in the H-OTR packages and reached 15.8 kPa in the L-OTR packages (Fig. 3). It is well-known that gas composition of MA-packaged fresh produce change in response to oxygen- and carbon dioxide transmission rates of the packaging material, product fill weight, package surface area and product respiration rates (Mahajan et al., 2007).

Visual and Overall Freshness

The visual and overall freshness scores differed between treatments (Fig. 4). Visual scores ranged from 2.7 to 11.8 and overall scores from 1.3 to 12.2 on a scale from low (0) to high (15) intensity. Within treatment, visual and overall freshness scores were similar for wild rocket packaged in H-OTR film but differed for wild rocket packaged in L-OTR film. The highest visual freshness score was obtained in the H-OTR packages kept at 2°C for 6 days and in the L-OTR packages kept at 10°C for 4 days, followed by the H-OTR packages kept at 10°C for 4 days, the L-OTR packages kept at 20°C for 2 days and the H-OTR packages kept at 20°C for 3 days (Fig. 4). Interestingly, wild rocket packaged in L-OTR film stored at 10°C for 4 days was evaluated significantly higher in visual freshness than wild rocket packaged in H-OTR film kept at similar conditions (Fig. 4). Overall, samples that were packaged in L-OTR film had significant higher visual freshness scores than those packaged in H-OTR film at a comparable temperature and time (Fig. 4). Better color retention and visual appearance is one of the benefits of MA packaging of fresh produce (Artés et al., 2007).

When overall freshness scores were compared, however, there were no significant differences between samples with respect to film OTR-value at comparable storage conditions (Fig. 4). All H-OTR packages had comparable visual and overall freshness scores and scores for visual freshness were highly correlated with scores for overall freshness ($r=0.98$). Freshness of these leaves could therefore be determined at purchase from the promise of the visual appearance in packages. In contrast there was no such relationship between visual and overall freshness of leaves from the L-OTR packages (Fig. 4). Apparently, other quality attributes than appearance influenced the freshness of these leaves after storage.

Sensory and Multispectral Analysis

The results of the sensory evaluation showed that wild rocket varied on different quality attributes depending on packaging method (Fig. 5). The H-OTR leaves varied on appearance like color homogeneity, green color, yellowing and brow discoloration of cut edges of leaves; texture attributes like rotten texture and sprinkliness and odor attributes like cabbage odor and rotten odor (Fig. 5). Inhomogeneous color and texture, loss of green color, yellowing and browning of the cut leave surface influenced the visual freshness of leaves from the H-OTR packages. In contrast, the L-OTR packages varied on odor attributes like acidic odor, wild rocket odor, rotten odor and smoked odor which were first evaluated after opening of the packaging film (Fig. 5B). The L-OTR leaves also varied on green color, olive-brown color and sprinkliness attributes. Discrepancy occurred in the L-OTR treatments and was especially seen in the L-OTR packages kept at 10°C for 4 days. This treatment had similar visual freshness score as the control sample but differed in overall freshness score (Fig. 4). From these results it was clear that wild rocket packaged in H-OTR film had better clues of product quality than wild rocket packaged in L-OTR film. The L-OTR packages had mainly non-visible clues related to off-odors (Fig. 5B). For this reason it may be difficult to point out L-OTR packages with low overall freshness scores just from appearance. Off-odour formation and quality deterioration is one of the challenges of inappropriate MA-packaging of fresh produce (Kim et al., 2004; Ko et al., 1996; Tudela et al., 2013) as seen in our study with the L-OTR packages kept at 10°C for 4 days.

The results of the multispectral analysis showed that there were significant differences in color between the control and the other samples except for the samples stored at 10°C for 4 days in L-OTR (Fig. 6A). This result was in agreement with the sensory analysis (Fig. 5A) and it shows that multispectral analysis can be used for color measurement of wild rocket if color differs between samples. Regarding texture the multispectral analysis only detected differences between samples kept at 20°C for 2 days in L-OTR and the other samples (Fig. 6B). In sensory analysis, texture expressed as sprinkliness also differed between samples in a similar manner (Fig. 5A).

CONCLUSIONS

Discrepancy in freshness occurred in packaged wild rocket stored under anaerobic conditions (anoxia) as in the L-OTR film. In the H-OTR packages where O_2 concentrations were held at aerobic conditions discrepancy was not observed. Off-odors such as acidic odor, rotten odor and smoked odor developed in the L-OTR packages. Samples kept at 20°C for 2 days had higher intensities of off-odors than samples kept at 10°C for 4 days. There was no visual clue for off-odor formation in the L-OTR samples kept at 10°C for 4 days and this affected the overall freshness scores after opening of the package. Multispectral analysis could detect wild rocket color and texture differences but not quality differences related to off-odor formation.

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Figures

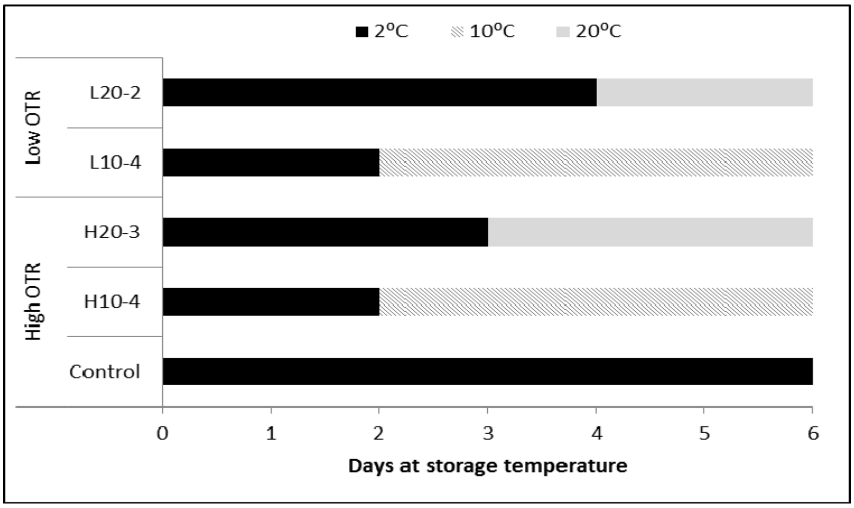

Fig. 1. Storage design for packaged wild rocket. Samples were stored in high OTR-film; 6 days at 2°C (control), 2 days at 2°C and 4 days at 10°C (H10-4) or 3 days at 2°C and 3 days at 20°C (H20-3); or in low OTR-film; 2 days at 2°C and 4 days at 10°C (L10-4) or 4 days at 2°C and 2 days at 20°C (L20-2) before analysis.

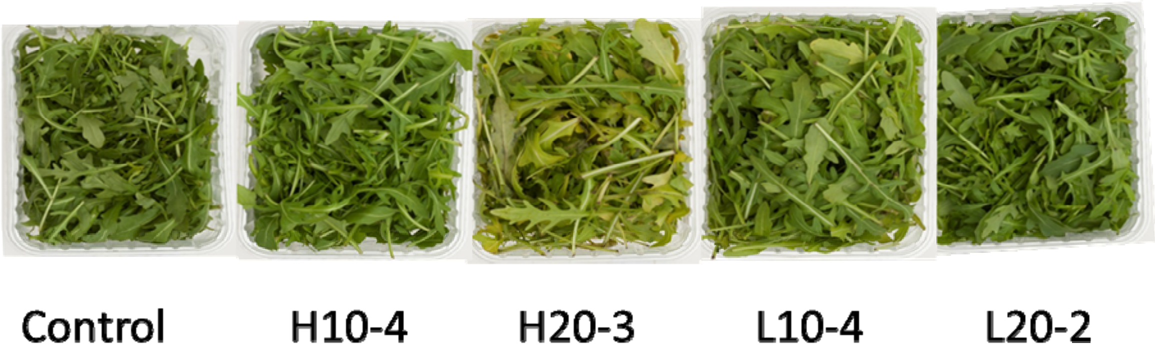

Fig. 2. Visual quality of wild rocket at evaluation. See Figure 1 for abbreviations. Photo: Jens Michael Madsen, Aarhus University.

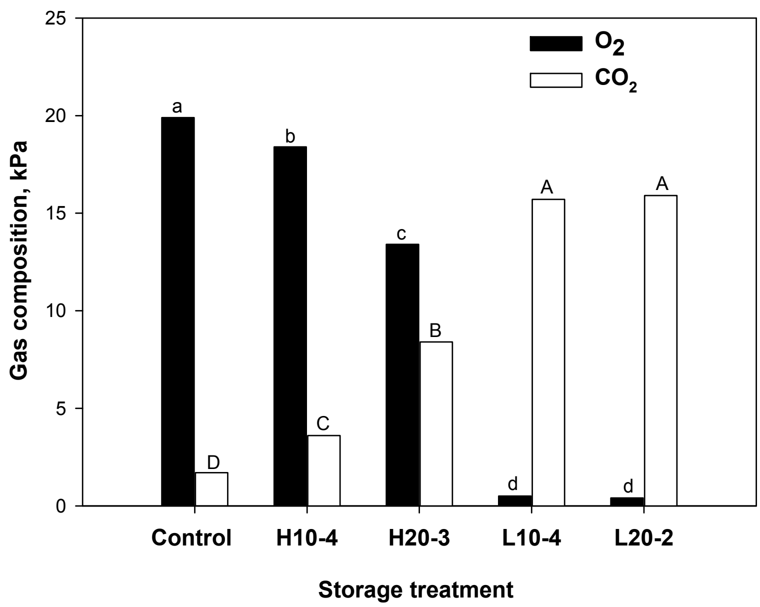

Fig. 3. Headspace gas composition of packaged wild rocket at sensory evaluation. Different letters show significant differences at *P=0.05*; different small letters show differences in O_2 and capital letters in CO_2. See Figure 1 for abbreviations.

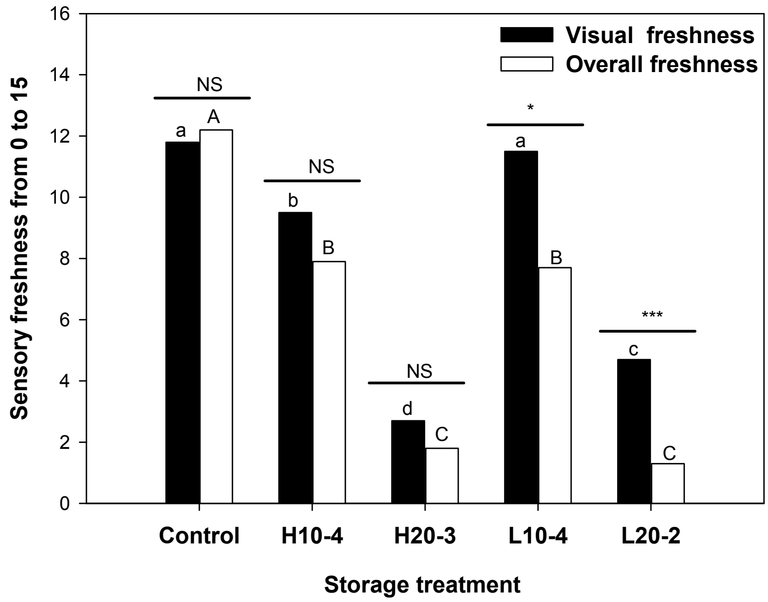

Fig. 4. Visual and overall freshness of packaged wild rocket. Different letters show significant differences at *P=0.05*; small letters show differences for visual freshness and capital letters for overall freshness. Significant difference between visual and overall freshness within each treatment is shown with lines and codes; NS: non-significant at *P>0.05*; **P≤0.05* and ****P≤0.001*. See Figure 1 for abbreviations.

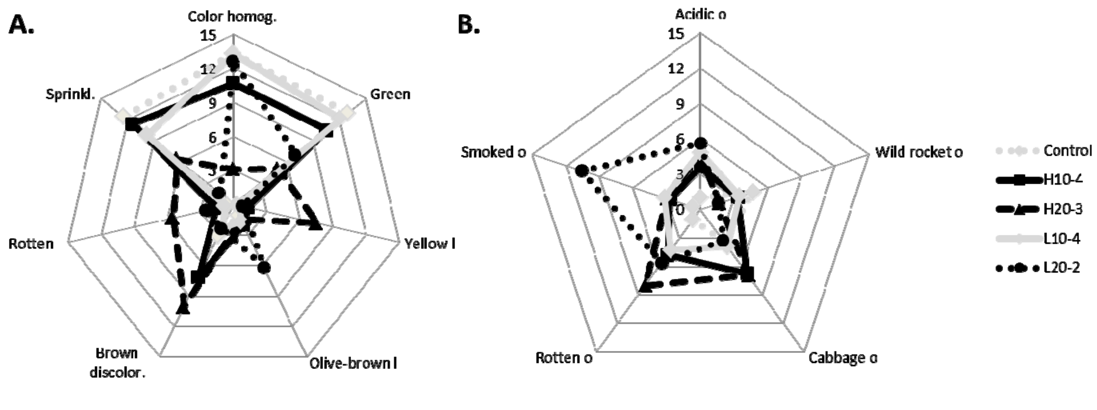

Fig. 5. Spiderplot of sensory scores for wild rocket leaves from 0 = low intensity to 15 = high intensity. All attributes are significant different at *P≤0.001* except for cabbage odor which are different at *P*≤0.01. (A) Appearance and texture; (B) odor. l = leaves; o = odor. See Figure 1 for abbreviations.

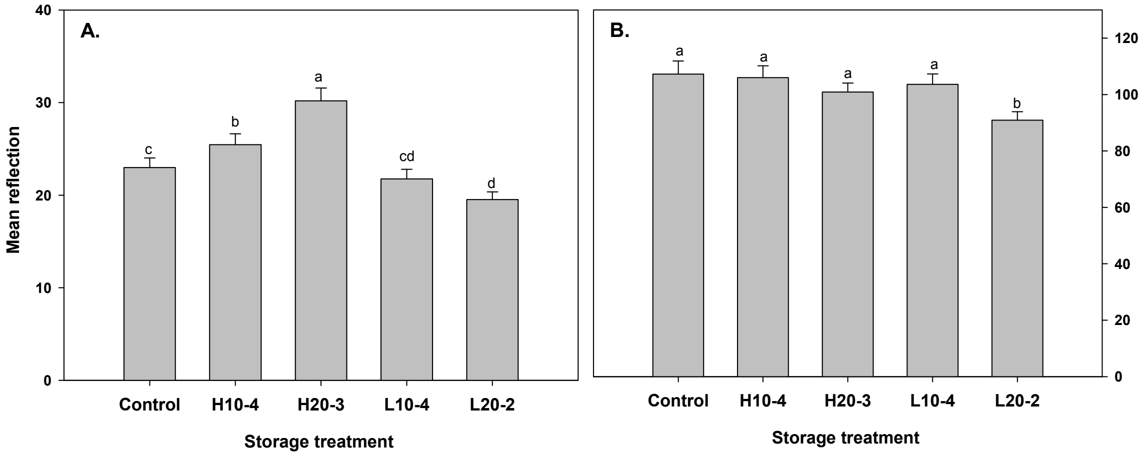

Fig. 6. Multispectral imaging of wild rocket at (A) 570 nm for color and (B) 780 nm for texture. Different letters show significant differences at *P=0.05*. See Figure 1 for abbreviations.