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Effect of perforation packaging on quality of fresh-cut carrot during storage

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ABSTRACT

The aim of this work was to evaluate the effect of packaging perforation on quality of carrot slices during cold storage at 5 °C. Polyethylene bags with different number of perforations (3, 4, and 6) were used in this experiment. Headspace oxygen concentration, respiration, weight loss, surface color, firmness, pH, and soluble solid content were examined throughout storage. It was observed, that all the investigated packaging were effective in maintaining the quality of carrot slices compared to the control. There was no symptom of decay until 12 days. In addition, pH, soluble solid content, and firmness showed nonsignificant change. Moreover, weight loss of packed carrot slices was below 2% after 12 days of storage. Packed carrot had better appearance at the end of experiment (12 days) than that of control.

KEYWORDS

carrot, fresh-cut, MAP, storage

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INTRODUCTION

Fresh-cut is currently a growing market because of its convenience, and availability (Alandes et al., 2009; Zsivanovits et al., 2018). Demand for fresh-cut vegetables is continuously increasing. Consumers inspect freshness carefully to estimate nutritional value and ability to promote health (Mastromatteo et al., 2012). The requirement of minimal processing leads to new packaging solutions (Rico et al., 2007).

Fai et al. (2016) utilized solid fruit and vegetable residue flour to make biodegradable film. The film packaging of 0.15–0.23 mm thickness was applied using immersion, spraying, and film covering technique on sliced and shredded carrot. Biodegradable film was able to delay weight loss and whitening of the samples during 15 days of cold storage at 5 °C. Another study found that microperforated polypropylene based bags had benefit in extending shelf-life of fresh cut carrot (Mastromatteo et al., 2012). Guimarães et al. (2016) also reported that the passive modified atmosphere packaging with nanoparticles and starch coating was able to prevent loss of volatile compounds, protected the majority of organic acids, assisted in preservation of antioxidant capacity. Modified atmosphere packaging is one of the powerful techniques being widely used for extending the shelf-life of fresh-cut product.

Carrot is an important vegetable used popularly in ready-to-eat salads due to rich source of vitamin A and potassium. Fresh-cut carrot had high respiration rate, therefore perforation packaging is useful to enhance gas exchange and to prevent anaerobic conditions (Klaiber et al., 2005). The earlier report figured out that product easily deteriorated rather by depleting oxygen than by increasing of carbon dioxide (Barry-Ryan et al., 2000). Thus, it is good to monitor the headspace gas composition with microperforation (Del-Valle et al., 2004). Low oxygen composition inside the packaging and cold storage are commonly used to slow down the respiration of commodity (Klaiber et al., 2005).

The aim of this study was to investigate the effect of packaging with different number of perforations (3, 4, and 6 of ∅87.5 ± 12.5 μm) on quality of carrot slices during storage at 5 °C.

MATERIALS AND METHODS

Materials

Carrots (*Daucus carota* L.) were obtained from the wholesale market, Hungary. Collected samples were transported to the laboratory of the university in Budapest, Hungary.

Laser perforation of polyethylene (PE) films of 50 μm thickness was used for preparation of packages (10 cm × 15 cm). The perforated holes were made with diameter of 87.5 ± 12.5 μm.

Carrot processing and packaging procedures

Carrots were selected the same size with diameter of 3 cm, peeled and cut into slices of 0.5 cm thickness. After that, carrot slices were washed with tap water, surface moisture was removed by ambient air and then divided into 4 groups. There were 30 bags per group and the average weight was 50 ± 2 g per bag. Carrot slices were packed in PE bags (10 cm × 15 cm) with different number of perforations (3, 4, and 6) similar to Dawange et al. 2016. A packaging

machine (Multivac, Wolfertschwenden, Germany) was used to seal the packages keeping 6–7% oxygen as the initial oxygen concentration in the packs. Samples, put on the plastic tray without packaging, served as control. After packaging, all groups were stored at 5 ± 0.5 °C and relative humidity (RH) of 85–90% for 12 days.

Measurements

Measurements were carried out on day 0 (before packaging), 4th, 8th, and 12th day during storage period. Ten packages from each group were removed from chamber at each interval for analysis.

Respiration, weight loss, headspace oxygen concentration, firmness, surface color, pH, and soluble solid content were measured at 20 °C during the experiment.

Headspace oxygen concentration. The headspace oxygen concentration in the packages was determined by O_2/CO_2 gas analyzer (ICA, UK) at each interval of storage. A small silicon septum was stuck to the packs and a needle was pierced into the package through this septum to draw the gas. The oxygen concentration value was displayed on the digital panel of instrument.

Respiration rate. Respiratory intensity as carbon dioxide production was measured for an hour in a closed respiratory system containing several hermetically closed plexi glass containers equipped with FY A600-CO2H carbon dioxide sensors connected to an Almemo 3290-8 data logger (Ahlborn Mess-und Regelungstechnik GmbH, Germany). Results were expressed in milliliter of CO_2 produced per kilogram of fruit in 1 h ($mL \cdot kg^{-1} \cdot h^{-1}$).

Weight loss. Carrot slices were weighed at day 0 and at each storage interval. The difference between initial and each storage period was considered as total weight loss during that interval and calculated as percentage of fresh weight.

Surface color. Surface color of carrot slice was measured with a portable Minolta Chroma Meter CR-400 (Minolta Corporation, Osaka, Japan). CIE L^*, a^*, and b^* color characteristics were determined at the cortex of each slice. Results were expressed as whiteness index (WI) [$WI = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{0.5}$] and chroma value (CV) [$CV = (a^{*2} + b^{*2})^{0.5}$], respectively (Bolin & Huxsoll, 1991).

pH. Twenty grams of fresh-cut carrot were homogenized, after that the juice was extracted. The pH of carrot juice was measured by a hand-held pH meter (Testo 206-pH1).

Firmness. Firmness of carrot slices was determined at three points from the cortex of each carrot slice, using Stable Micro System TA-XT Plus, UK. The compression force was applied by using a cylindrical probe (diameter $d = 2$ mm) mounted on the machine, and the penetration depth of 2 mm. The results were expressed in Newton (N).

Soluble solid content. Soluble solid content of carrot juice (SSC, %) was determined by a hand-held ATAGO PAL-1 digital refractometer (Atago Co. Ltd., Tokyo, Japan).

Statistical analysis

All data were processed by SPSS (IBM, USA) using analysis of variance (ANOVA) with the factors: number of perforations (3, 4, and 6) and storage day, followed by Tukey's method

with a significance level of $P < 0.05$. The results were reported as mean with standard deviation.

RESULTS AND DISCUSSION

Fig. 1 showed the development of headspace oxygen concentration in the packages with different number of perforations during storage. At the first 4 days, the oxygen concentration in all perforation packages increased rapidly from about 6.0% to around 18.5% and maintained in a similar range till the end of experiment. The evolution of the headspace gas composition in the package depends on packaging material, film surface area, storage temperature, and respiration rate of produce (Klaiber et al., 2005). In our study, the oxygen concentration inside the packages increased rapidly at the first 4 days and there was no difference among packaging's with 3, 4, and 6 perforations. According to the observations of our experiment, 3 perforations already provided high gas exchange rate, obtained the atmospheric gas concentration surrounding the sample after 4 days, but on the other hand, it was also able to slow down senescence processes compared to control.

The respiration rate of carrot slices during storage is shown in Fig. 2. The carbon dioxide production of all samples increased during storage period.

Different number of perforations did not affect the respiration of carrot slices throughout 12 days of storage, compared to control. No significant difference was detected among groups.

Weight loss of all samples occurred gradually as the storage time increased (Fig. 3a). The control samples obtained the highest value in weight loss. At the first 4 days, the weight loss was about 0.7% for perforated packs and 1.2% for the control. Later on, the weight loss of control and perforated packs were around 3.8 and 1.7%, respectively, at the end of experiment. The weight loss of control was much higher compared to perforated packs. Similar behavior was observed in perforation packaging for carrot (Dawange et al., 2016) and for fresh fruit (Nguyen et al., 2020).

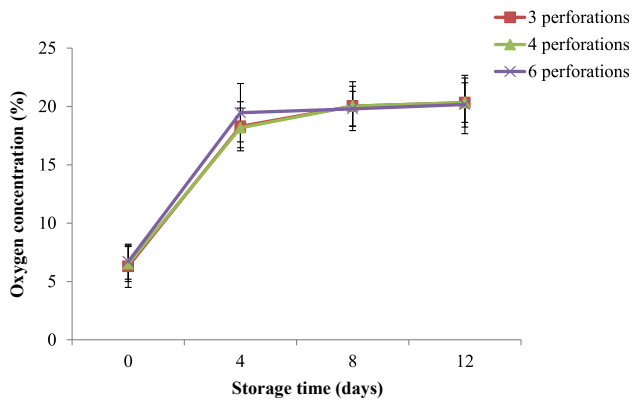

Fig. 1. Oxygen concentration in the packages during storage

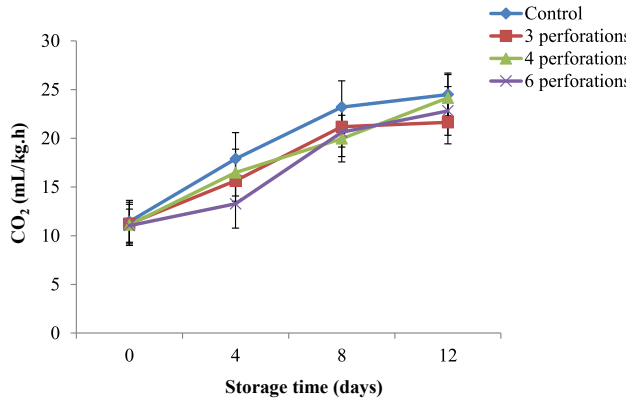

Fig. 2. Carbon dioxide production of carrot slices during storage

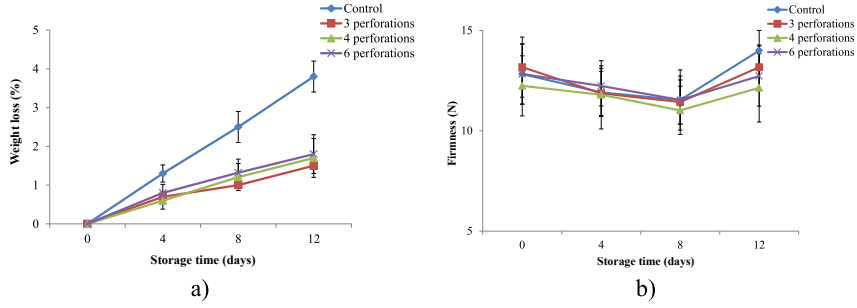

Fig. 3. Weight loss (a) and firmness (b) of carrot slices during storage

In this work, the firmness of carrot slices was determined using the penetration force into the cortex of each slice. Fig. 3b presented the changes in firmness of carrot slices during storage at 5 °C. The firmness decreased slightly throughout 8 days of storage and then increased. However, no significant difference was observed between groups. The decline in firmness at the first 8 days might be due to the natural aging of commodity. Later on, the increase in firmness could result in moisture loss of product causing wither. There was no significant difference in firmness between perforated packs and control at the end of experiment. It was in agreement with earlier report of Dawange et al. (2016) for carrot slices. These authors found that the increase in firmness was due to dehydration and the beginning of lignification throughout storage.

Total soluble solid of carrot slices increased slightly during storage for all groups, but no significant difference was observed compared to the initial time. There was no variation in soluble solid content among perforated groups and control (Fig. 4a).

Similarly, the pH of all carrot samples remained steady during storage (Fig. 4b). There was no significant difference among groups.

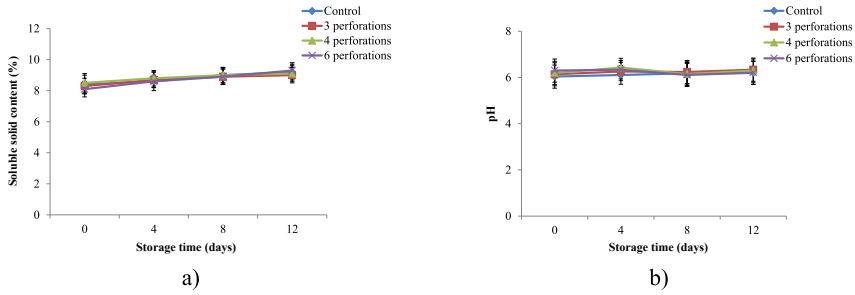

Fig. 4. Soluble solid content (a) and pH (b) of carrot slices during storage

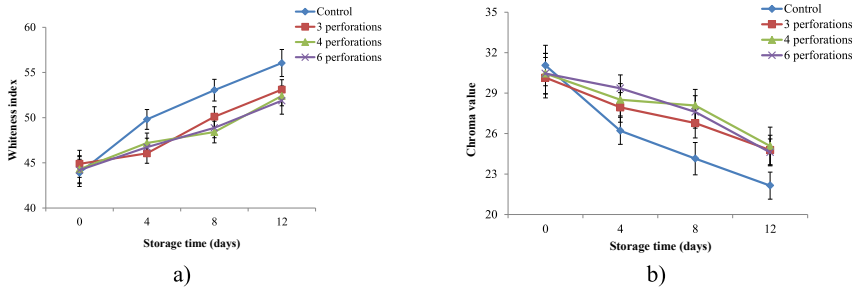

Fig. 5. Whiteness index (a) and chroma value (b) of carrot slices during storage

The changes in color values (L^*, a^*, and b^*) determined the values for WI and CV. WI of carrot slices increased during cold storage from the initial value around 43 to a range of 51–56 (Fig. 5a). The perforated packaging samples had lower value in WI than control during storage. WI was the highest level for control.

Similarly, CV of carrot slices decreased from the initial value approximately 30 to a range of 22–25 within 12 days of storage (Fig. 5b). The CV was a minimum for control samples at the end of storage.

In our work, WI and CV showed that there was a fading of color during storage. Our results were in agreement with previous studies (Izumi and Watada, 1994; Dawange et al., 2016). These authors reported that WI increased together with the formation of white tissue on the carrot surface throughout storage. Surface discoloration occurs due to dehydration of outer tissues, whitening of surface and lignification during storage (Kaszab et al., 2008). Those are the most common symptoms causing the quality loss of fresh-cut carrot during storage (Klaiber et al., 2005). However, our results indicated that packaged carrots retained better appearance compared to control. This could be that control samples exposed directly to the cold air thus the outer tissue became shriveled faster compared to packed samples. The difference among packaging samples was insignificant.

CONCLUSION

The results of this experiment presented basic information about the effect of packaging with different number of perforations (3, 4, and 6) on quality of carrot slices during storage. There was no significant difference among perforated packages. Packages used in this study could maintain the appearance of carrot slices for 12 days at 5 °C. However, achieving modified atmosphere depends on the quantity of product in the particular size of pack and the number of perforations. Experiments evaluating the number and size of perforations are suggested for further research.

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