Quality of grated carrot (var. Nantes) packed under vacuum

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Abstract: The quality of grated carrot (variety Nantes) was evaluated throughout 10 days of storage in two different atmospheres: air and vacuum at 2 °C. The parameters of quality were microbiological and physico-chemical. Sensory evaluation of vacuum-packed grated carrots was performed after the microbiology study. The objective was to study the use of a vacuum for preservation of this type of product. The use of a vacuum was sufficiently promising with respect to the capacity to extend the shelf life of grated carrot by reducing microbial load and by minimising physico-chemical changes. The shelf life of grated carrot under vacuum was extended to 8 days at 2 °C.

Keywords: carrot; vacuum; colour; acidity; carotenoids; micro-organisms

INTRODUCTION

The visual properties of packed products are important for consumers in the evaluation of minimally processed vegetables: the absence of colour changes (browning of the cut surfaces, yellowing of green vegetables and the fading of vegetables) as well as the absence of mechanical damage (absence of damage during cutting) are the main priorities.[1,2]

The discolouration and browning of cut surfaces are considered as the main problem of fresh-cut vegetables.[3–7] Cutting the surface can lead to the increase in the respiration of the tissues, resulting in the degradation of proteins, lipids and carbohydrates of the carrot, as well as the development of off-flavours. The cut of the surface can lead to the production of a protective layer known as 'white blush' as result of the dehydration and lignification of the carrot surface.[3] Lignification after wounding is an enzyme-stimulated reaction evaluated by the 'whiteness index'.[8,9] The micro-organisms as well as the fermentative metabolism of the plant tissues are equally responsible for the development of off-flavours during storage of fresh-cut vegetables. Generally, the growth of lactic acid bacteria can be followed by the production of acetic and lactic acids.[10] The production of organic acids causes a decrease in product pH.[10,11]

In addition, fungus (>5 log CFU *Candida* spp. g^{-1}) can induce off-flavours on fresh-cut vegetables as result of the production of CO_2, ethanol, organic acids and volatile esters.[12,13] However, little information is generally known about the relationship between the outgrowth of spoilage micro-organisms, their production of metabolites and the perception of the decay of minimally processed vegetables by consumers.[14]

This research work intended to evaluate the relationship between physico-chemical and microbiological changes and shelf life of minimally processed carrots stored in air and vacuum.

EXPERIMENTAL

Sample preparation

Carrots (var. Nantes) were hand peeled, grated and vacuum packed with a Multivac machine (Gastrovac, Wolfertschwenden, Germany). Packaging conditions were 10^2 Pa (1 mbar) and 1.5 s for closing the bag.

The material of the bags consisted of three layers: the two outer layers of polyethylene and a middle layer polyvinylidene chloride. The total thickness was 65.0 μm and permeability to O_2 was 7.0×10^{-6} mL $(m^2.Pa.day)^{-1}$ at 23 °C and 50% RH, permeability to CO_2 was 3.4×10^{-6} mL $(m^2.Pa.day)^{-1}$ at 23 °C and 50% RH, and permeability to the H_2O was 1.08 g $(m^2.day)^{-1}$ at 25 °C and 100% RH (determined by Serviços de Embalagem – UCP-ESB, 1997). The polyvinylidene chloride is responsible for impermeability to water and gas, and the polyethylene PVDC is co-extruded for its low permeability to vapour and mechanical resistance.[15]

The control samples (air) were stored in open bags. Storage under both conditions lasted 10 days at 2 °C. Six samples of carrot were used for each time of storage.

Weight loss

Bags were weighed (Sartorius basic, Sartorius, Goettingen, Germany.) before and after storage, and the

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respective weights were registered. The results were presented in % of loss of the initial weight.

Colour and whiteness index (WI)

The colour of grated carrot was measured with a colorimeter (Minolta CR-300, Minolta Corp., Ramsey, NJ, USA). The colour was analysed using the CIE: $L^*a^*b^*$ uniform colour space (Lab), where L^* indicates luminosity, a^* corresponds to a coloration on an axis from green (−) to red (+), and b^* to a coloration on an axis from blue (−) to yellow (+). The discoloration of the surface was calculated through the whiteness index (WI) calculated by the equation $WI = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}$.[3]

Soluble solids

The carrot was ground with a domestic blender to extract the juice. Soluble solids were determined by using a hand-held refractometer (ATAGO - ATC1, Atago Co. Ltd., Tokyo, Japan).

pH

The pH of the carrot juice was measured with a potentiometer, Crison, model Micron pH 2001 (Crison Instruments, SA., Barcelona, Spain).

Titratable acidity

An aliquot of 25 g of carrot was diluted with 250 mL of distilled water boiled. After dilution, 25 mL of this solution was titrated with 0.1 mol L^{-1} of NaOH, until a pH of 8.3 was reached. This measurement was performed with a potentiometer with a combined electrode of pH Ingold 57/120 U402 and a Crison MicropH 2002 (Crison Instruments, S.A., Barcelona, Spain). The results were calculated in g malic acid kg^{-1} carrot.

Carotenoids

Ten grams of carrot were diluted in 50 mL of distilled water and 10 mL of the mixture were centrifuged (Heraeus Sepatech Medifuge, Grasbrunn, Germany) for 5 min at 2700 × g, rejecting the supernatant. Eight millilitres of acetone were added, homogenised (Ultra-Turrax T 25, Jank & Kunkel, IKA-Labortechnik, Breisgau, Germany) and water was added to make up the solution to 10 mL, which was centrifuged again at 2700 × g during 5 min. The supernatant was poured into a cuvette and the absorbance at 480 nm (A_{480}) was measured with a spectrophotometer UV-1601 (UV–Visible Spectrophotometer, SHIMADZU Corp., Tokyo, Japan). The carotenoid concentration (in mg L^{-1}) was calculated as $4.4 \times A_{480}$.[16] The blank used was acetone 80%. The whole procedure was carried out in the dark because carotenoids are sensitive to light. The carotenoid content was expressed in g kg^{-1} carrot.

Microbiology

A sample of 10 g of each bag was diluted with 90 mL of sterile NaCl solution and homogenised in a Stomacher (400 classic BA6041, Seward, Norfolk, UK) for 1 min. The counting of micro-organisms at 30 °C and 7 °C followed the methodology of NP 4405,[17] the counting of yeast and moulds at 25 °C followed the NP 3277-1[18] and the counting of lactic acid bacteria followed ISO 15214.[19]

Sensory analysis

After the microbiology results had been obtained, sensory evaluation was performed by a trained panel (19 evaluators) on samples that had been vacuum packed and stored at 2 °C for 8 days. The control sample was prepared on day zero and vacuum packed and stored at 2 °C as the other samples. The sensory analysis was performed 4 h later on samples of day zero, day 2, day 5 and day 8. The parameters evaluated were global appreciation, general appearance, odour, texture and flavour and the scale used the scores 1, very bad; 3, not good; 5, very good.

Statistical analysis

The descriptive analysis consisted of the calculation of media and standard deviation for cardinal variables. The Kolmogorov–Smirnov test was used to verify the normality of the distribution of cardinal variables. Due to reduced sample size the Mann–Whitney test (non parametric) was used to compare medium orders of non-independent samples. The Kruskal–Wallis test was used to compare medium orders of three or more independent samples for the physico-chemical analysis and the microbiology. The Spearman correlation coefficient was calculated to quantify the intensity between pairs of variables (non-parametric correlations).

Student's t-test was used to compare medium orders of two independent samples for the sensory analysis. A P level of critical significance was used to reject the null hypothesis (rejected when $P < 0.005$).[20]

RESULTS AND DISCUSSION

Weight loss

After the second day of storage there was a discrepancy between the weight loss of vacuum-and air-stored carrots, with a loss of weight lower in vacuum, 2% of the initial weight after 10 days at 2 °C (Fig. 1). Significant differences were found between weight loss of air and vacuum stored samples from the second day of storage ($P < 0.05$). In air-stored carrots, a loss of water of about 10% was found after 10 days at 2 °C (Fig. 1); this loss was reduced by vacuum because there is no air to absorb the moisture from food, as already found in another study with potatoes.[21] Also, a vacuum inhibits the respiration of samples, leading to lower weight loss.

Colour

A significant increase of the WI was observed for both air- and vacuum-stored samples, and this was significantly higher for air samples ($P < 0.05$) from the third day of storage (Fig. 2). It seems that increased

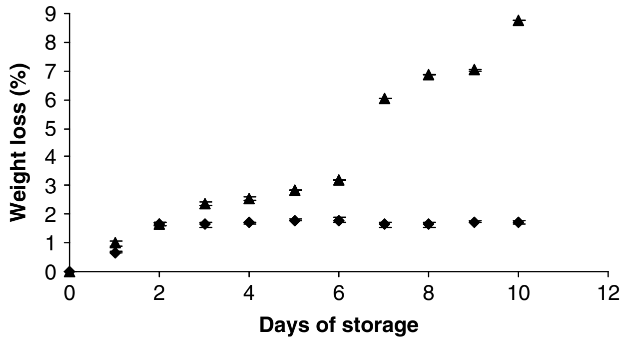

Figure 1. Weight loss (%) of grated carrot during 10 days of air and vacuum storage at 2 °C. (▲), Air; (♦), vacuum.

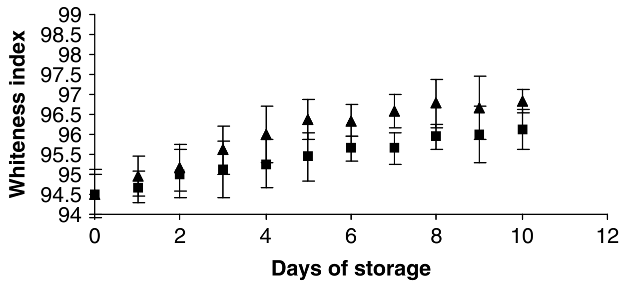

Figure 2. Whiteness index of grated carrot during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

moisture loss (Fig. 1) contributed to a higher surface whitening of the samples, as already stated by other authors.[22]

The whiteness index revealed that carrots packed in vacuum are more protected from dehydration and lignification, which contribute to the whitening of carrots stored in air. The surface whitening may result from drying-out effects on the cut surface and may be followed by the synthesis of lignin.[23]

Luminosity (L^*) has been used by several authors as an indicator of vegetable deterioration.[24] An increase of the L^* value was observed during storage due to the whitening of the samples. This fact was more visible in air stored samples (Fig. 3); significant differences were found between air and vacuum samples ($P < 0.05$) from the third day of storage.

A strong positive correlation was found between colour changes (increase of L^* value) and storage time ($R = 0.99$; $P < 0.01$).

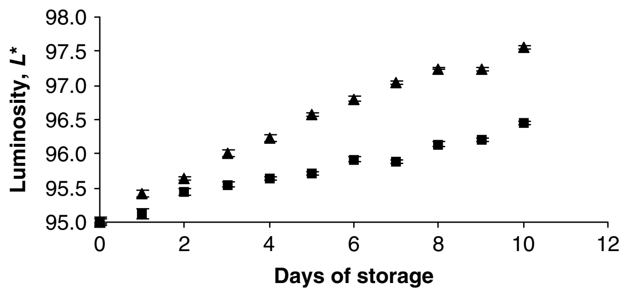

Figure 3. L^* (luminosity) of grated carrot during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

pH

The pH decreased during the storage time. This should reflect an increase in acidity, which did not happen (Fig. 4). This decrease in pH could be due to the production of CO_2, which, by reacting with the water of the tissues, might induce a release of H^+. However, there was no significant reduction of the acidity ($P > 0.05$), and no differences were noticed between air- and vacuum-stored carrots. After the fourth day of storage, differences were significant between air- and vacuum-stored carrots (Fig. 5).

Soluble solids

The content of soluble solids did not change during the 10 days of storage (data not presented) and it was around 10°Brix, both for air and vacuum conditions.

Carotenoids

From the fourth day of storage carotenoid content was significantly higher for vacuum-packed carrots ($P < 0.05$) (Fig. 6). The loss of carotenoids is related to the auto-oxidation (by free radicals), which occurs in air, as well as to enzymatic oxidation.[25] Peeling carrots exposes the phloem, where carotenoids are more concentrated, to air and light. Vacuum eliminates oxygen from the headspace, reducing the potential for oxidation and the consequent loss of carotenoids as noted.

Microbiology

There were significant differences between air- and vacuum-stored carrots in the counts of yeasts and moulds ($P < 0.05$) after the first day of storage

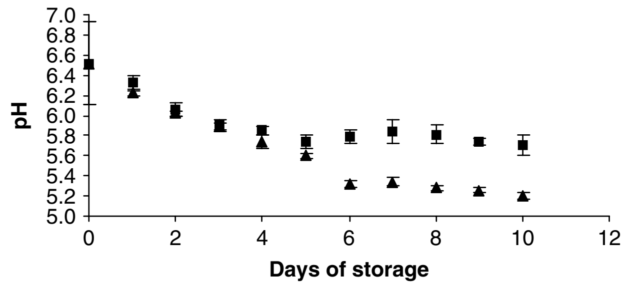

Figure 4. Changes in pH of grated carrot during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

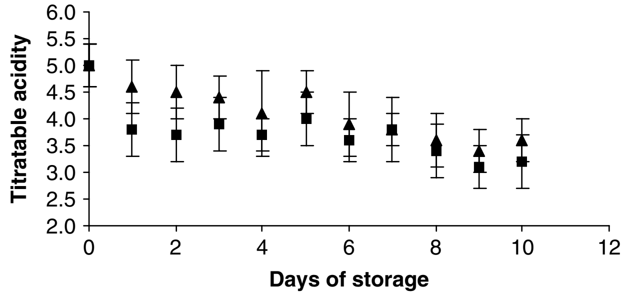

Figure 5. Titratable acidity (g malic acid kg^{-1} carrot) of grated carrot during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

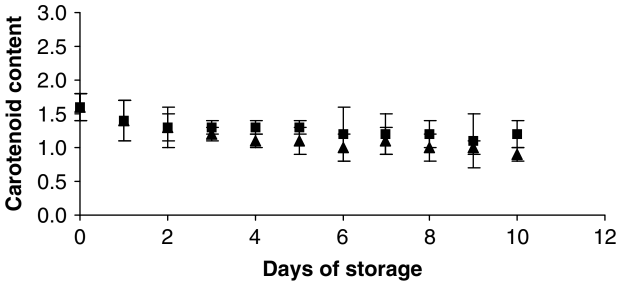

Figure 6. Carotenoid content (mg kg^{-1} carrot) of grated carrot during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

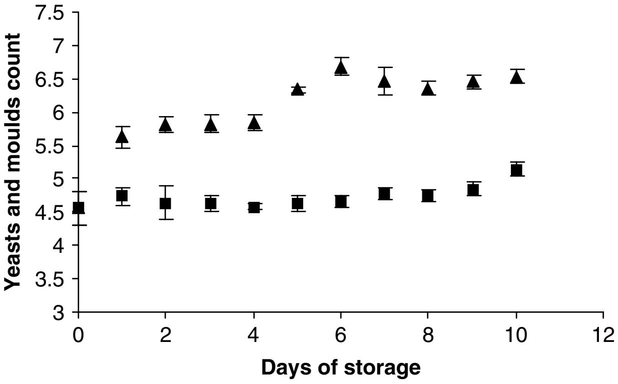

Figure 7. Counts of yeasts and moulds (log CFU g^{-1}) in grated carrot during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

(Fig. 7). Using a value of 5 for the log CFU g^{-1} as the acceptable maximum limit,[26] vacuum storage seems to be a useful way to maximise the shelf life of the product, allowing an increase of 9 days compared to air storage. Nevertheless a storage period longer than this had a negative effect on the properties of carrots, and this was characterised by production of gas, development of off-flavours and the formation of visible colonies.

The lactic acid bacteria never exceeded the maximum limit (log CFU g^{-1} = 7)[26] during 10 days both in air and vacuum (Fig. 8).

The total counts of micro-organisms at 30 °C and 7 °C never exceeded the maximum acceptable limit of log CFU g^{-1} = 8,[26] showing the beneficial effect of vacuum packaging. Differences were significant ($P < 0.005$) between air and vacuum samples from the first day of storage (Figs 9 and 10).

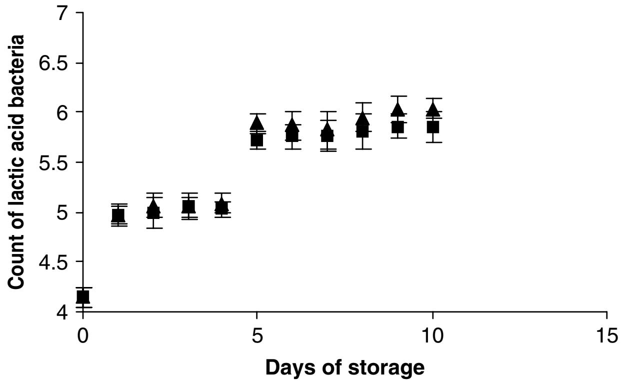

Figure 8. Counts of lactic acid bacteria counting (log CFU g^{-1}) in grated carrot during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

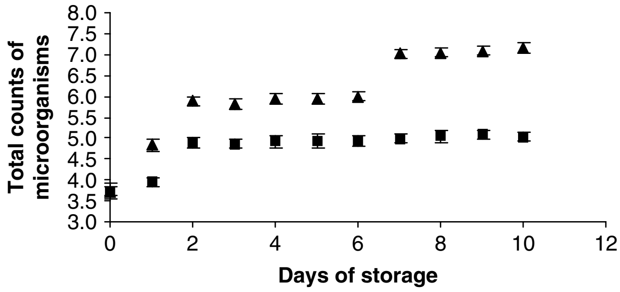

Figure 9. Total counts of micro-organisms (log CFU g^{-1}) in grated carrot at 30 °C during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

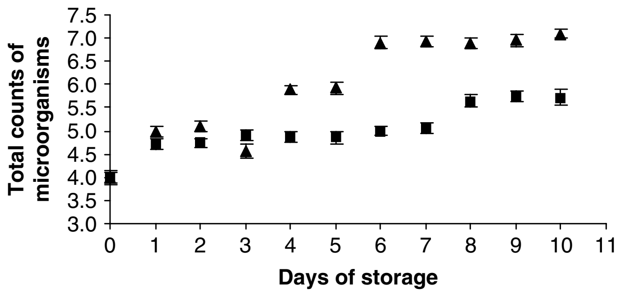

Figure 10. Total counts of micro-organisms (log CFU g^{-1}) in grated carrot at 7 °C during 10 days of air and vacuum storage at 2 °C. (▲), Air; (■), vacuum.

Sensory analysis

No significant difference were found by sensory panelists between samples from day zero and the eighth day of storage in terms of global appreciation

Table 1. Sensory evaluation of vacuum-packed grated carrot during storage at 2 °C

	Sensory parameter				
Days of storage	Global appreciation	General appearance	Odour	Texture	Flavour
0	4.16 (0.55)	4.03 (0.88)	3.75 (0.72)	4.31 (0.47)	4.18 (0.59)
2	4.02 (0.70)	4.13 (0.72)	3.77 (0.70)	4.23 (0.53)	4.14 (0.62)
5	3.48 (0.82)	3.83 (1.02)	2.99 (1.05)	3.86 (0.83)	3.67 (0.86)
8	3.99 (0.79)	4.02 (0.80)	3.75 (0.92)	4.13 (0.68)	4.07 (0.88)

Results are given as the average (STD).

($P = 0.463$), general appearance ($P = 0.946$), odour ($P = 0.992$), texture ($P = 0.342$) or flavour ($P = 0.774$. For all these parameters the score was around 4 (Table 1) on a scale from 1 to 5, which corresponds to a good appreciation.

CONCLUSIONS

The microbiological criteria used to access deterioration of grated carrots are in agreement with physico-chemical changes, mainly noticeable by counting the yeasts and moulds, emphasising the idea that the quality evaluation of freshly cut vegetables must be based not only on microbial counts but also on physico-chemical aspects. Sensory evaluation of vacuum-packed grated carrots was in agreement with microbiological and physico-chemical evaluation. The shelf life of carrots was increased to 8 days in vacuum storage compared with an almost rejection of samples after the first day of storage in air. Vacuum storage appears to be a potentially beneficial technology to extend shelf life of minimally processed carrots. Preservation of grated carrots during 8 days presents a most convenient product for consumers and food services or catering.

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