CHANGES IN THE PHYSICAL PARAMETERS OF ORGANIC AND CONVENTIONAL CARROTS DURING HOUSEHOLD STORAGE

Running title: Household carrot storage impacts on stiffness

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Food storage technologies can contribute to the reduction of food wastes, which accounts for 670 million tons in developed countries annually. Studies show that the majority of wasted foods originates from households instead of industries, therefore storage practices play a key role in the reduction of discarded food. On household level, storability can be influenced by controlling temperature and air humidity, however, cultivation technology fundamentally defines the shelf life of a product.

In this study, the impact of generally applied household storage practices on the physical parameters were compared, using commercial organic and conventional carrot samples. Two temperature settings (4 °C, 12 °C) were combined with two packaging (bulk, plastic bag) for both samples; storage was maintained for three weeks. According to the results, packaging had a very positive effect on the shelf-life of carrots in all measured parameters. In the case of the Sinclair IQ quality parameter, mass loss and average red color change, a significant difference was measured already on the third day of storage between packed and unpacked groups, independent on storage temperature and agricultural production method.

Introduction

The domestic carrot (*Daucus carota subsp. sativus*) was the seventh most important vegetables crop in 2021 with 41 million tons of yield (Shahbandeh 2023). Its high nutritional, beneficial physiological and good physical properties make it essential in human diet. The environmental and economic importance of organic farming is not questionable (Bender 2020). According to Alexander (2013), around 670 million tons of food produced in industrialized countries are lost every year, much of it still fit for human consumption. However, the shelf life of horticultural crops in households is significantly affected by the fact that long term storage, as used in the industry, cannot be achieved. In such cases, the physical and organoleptic characteristics of the crops can be reduced significantly during the short term storage (Kaszab 2013). The high relative humidity of the air in the storage room is important for maintaining the freshness of the product and quality, especially in case of products without packaging or even stored in bulk. In case of humidity level below optimum, the transpiring product can easily lose a significant part of its initial water content (Sáray, 2002).

The acoustic resonant method and the impact method are non-destructive, rapid, physical methods for determining maturity and monitoring physical changes during storage (Muha and Istella 2005). Zsom et al (2005) tested the shelf-life of peppers by storing samples unpackaged and in low-density polyethylene bags at 10°C and 20°C. The acoustic stiffness coefficient was calculated from the characteristic resonance frequency and sample weight. It was found that packaging itself increases the shelf life of the product on the counter providing the beneficial (relatively high) equilibrium relative humidity level inside the package.

We hypothesized that: (1) The storability of organic carrot differs from conventional one, because of lower level of nitrogen used in organic farmings; (2) Packed organic carrots keep their storability better than bulk stored products.

Materials and Methods

Plant material

Conventional carrot samples were purchased from local supermarket, while organic samples were ordered from an organic producer on 2023. After visual inspection, four-four roughly identical groups of both organic and conventional carrots were created consisting of 10-10 pieces. After numbering, samples were prepared for storage in the laboratory of the Department of Food Measurement and Process Control, Hungarian University of Agriculture and Life Sciences. According to the aims of the experiment, household storage environments were modelled using two storage temperatures (4°C, 12°C) and two typical storage types (packed and bulk). For packed storage, resealable and perforated plastic bags were used. The experiment used codes for the identification of samples (Table 1). The planned duration of the experiment was four weeks.

Temperature	4°C				12°C			
Storage type	Bulk		Packaged		Bulk		Packaged	
Storage type code	NPAC	NPAO	PAC	PAO	NPBC	NPBO	PBC	PBO

Table 1. Storage type codes for modeling typical household carrot storage technologies. NP: non-packed, P: packed, A: 4 °C, B: 12 °C, last character: C refers to conventional, while O refers to organic cultivation origin

Instrumental measurements

For the documentation of changes in carrot flesh firmness, non-destructive techniques (Sinclair IQ tester and machine vision system) were used in every third or fourth day. Every carrots of each treatments were measured.

Sinclair IQ

The surface firmness of the carrots was measured using a Sinclair IQ device. The instrument provides a non- destructive method to measure the firmness of vegetables and fruits. The Sinclair IQ tester consists of a holder and a measuring head (a bellows) located above it. A low mass impact sensor is placed at the end of the bellows, the product is impacted by this air pressure bellows. During the measurement, the rotating movement of the rollers on the tray provides four points of measurement on the sample surface. For each carrot sample, three measurements were performed and the average of these measurements determined the surface firmness of the carrot.

Acoustic stiffness

The acoustic method was used to follow the global stiffness change of the samples during storage. The sample excitation is performed by a gentle hit carried out with a wooden stick. The impact causes the sample vibration and the resulting sound response is recorded by a microphone connected to a computer. Software on the computer (developed by the MATE Institute of Food Science and Technology) displays the recorded sound response. The software uses the fast Fourier transformation to convert this time-based change into a frequency-based change. From this spectrum, the characteristic frequency of the sample can be determined. The acoustic stiffness coefficient can be calculated using the equation $S = f^2 \cdot m \cdot 10^{-6}$ (N/mm), where f is the characteristic frequency of the sample (Hz) and m is the mass (g).

Mass change

The mass change of carrots was compared to the first day's mass (100%). Mass was measured with a laboratory balance of 1 g accuracy.

Color change

The color of the carrots was examined using a machine vision system. A Hitachi HV-C20 color camera was used to record the images. The samples were illuminated with indirect, homogeneous white light. The software developed by MATE Institute of Food Science and Technology was used to analyze the image. Using the image recorded by the camera, after object segmentation, the average red, average blue and average green color of carrots were determined. These parameters represent the color of the carrot.

SPSS and MS Excel software were used for further data analysis. In the figures, means and their 95% confidence intervals were plotted.

Results

Figure 1 shows the change in surface firmness of carrots from different cultivations stored under different storage conditions. The figure shows that the groups are separated into two large groups according to surface firmness during storage, packed and unpacked groups. The difference between the packed and bulk samples becomes significant even after three days of storage in terms of Sinclair IQ values (Figure 1), regardless of cultivation type and storage temperature. Non-packed samples show a steep decrease throughout the whole storage time. After 13 days, their further measurement became impossible. Within package type, no significant differences were found between the Sinclair values of samples measured on the same day. The highest values were measured in the case of packaged conventional samples.

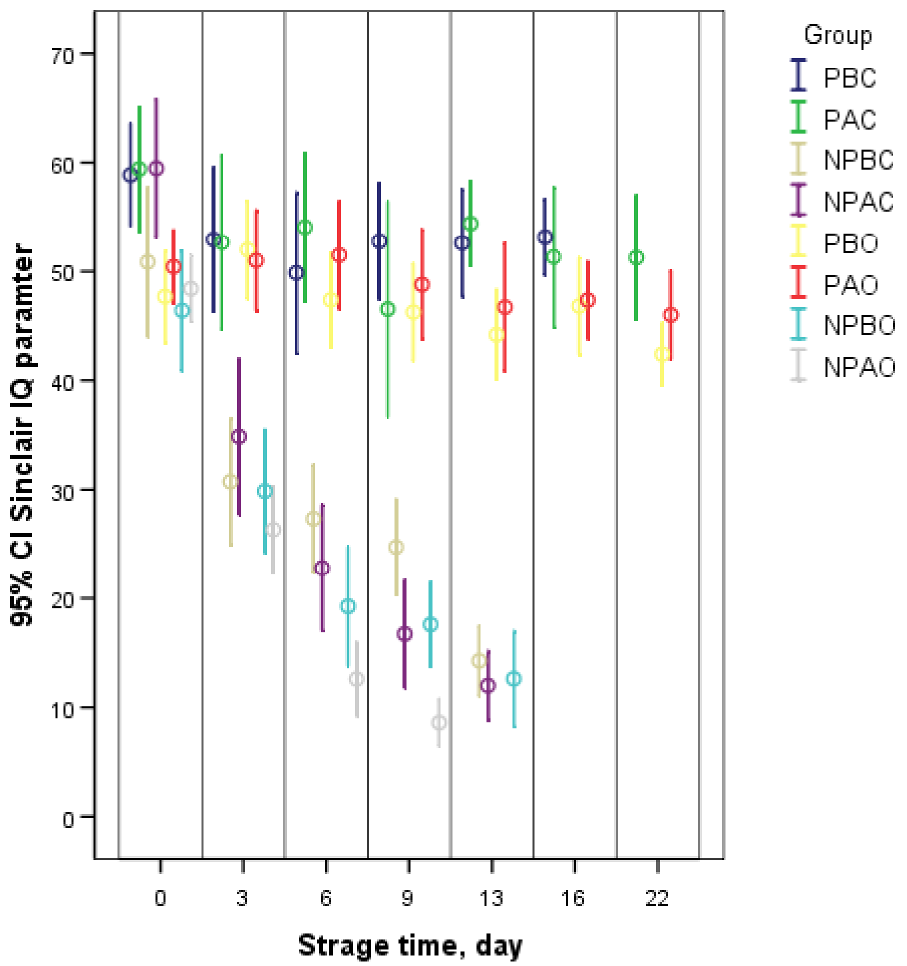

Figure 1. Sinclair IQ parameters of organic and conventional carrot samples stored for 22 days at 4 and 12ºC, packaged or bulk. Legend: PBC: packed conventional, 12ºC, PAC: packed conventional, 4ºC, NPBC: bulk conventional, 12ºC, NPAC: bulk conventional, 4ºC, PBO: packed organic, 12ºC, PAO: packed organic, 4ºC, NPBO: bulk organic, 12ºC, NPAO: bulk organic, 4ºC

Acoustic stiffness values of carrot samples showed gradually higher standard deviations (Figure 2); therefore, the package-based separation is not justified here. Especially, packaged organic samples overlap with non-packaged ones. After the 6th day of storage, packaged conventional and the group of non-packed samples sepatate significantly. Packed conventional samples had the highest acoustic stiffness values.

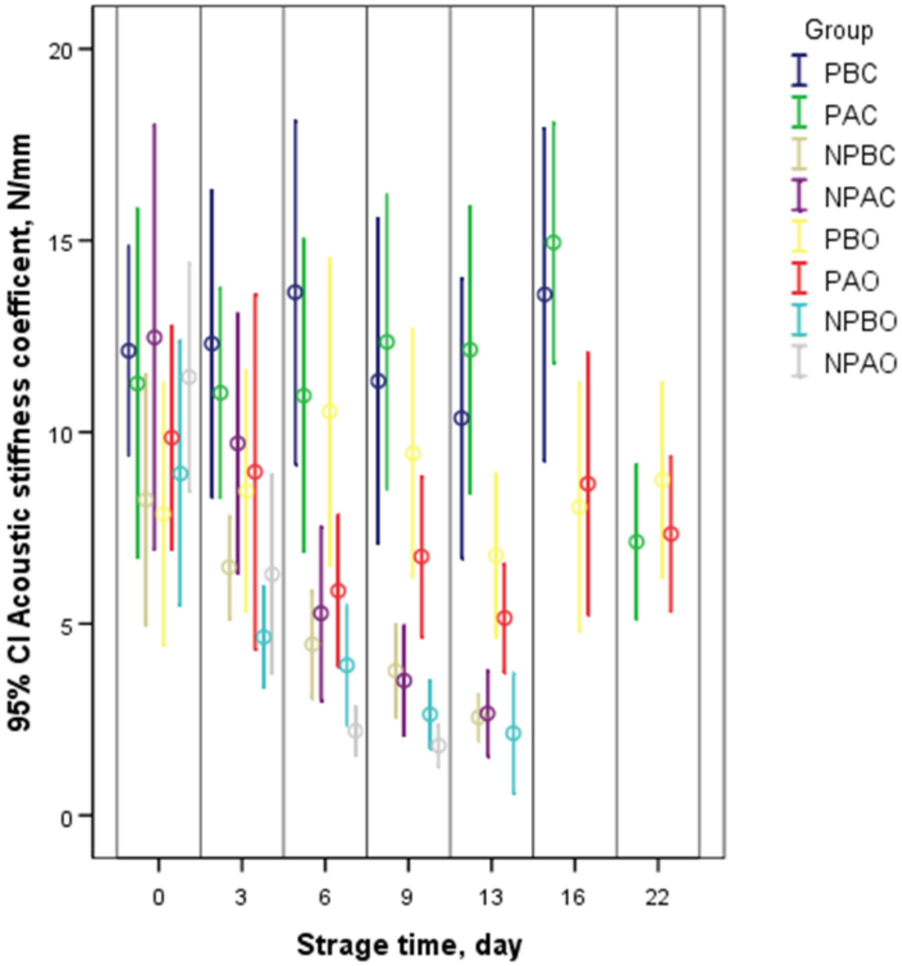

Figure 2. Acoustic stiffness coefficient of organic and conventional carrot samples stored for 22 days at 4 and 12ºC, packaged or bulk. Legend: PBC: packed conventional, 12ºC, PAC: packed conventional, 4ºC, NPBC: bulk conventional, 12ºC, NPAC: bulk conventional, 4ºC, PBO: packed organic, 12ºC, PAO: packed organic, 4ºC, NPBO: bulk organic, 12ºC, NPAO: bulk organic, 4ºC

The change in mass is a very good indicator of the beneficial effects of packaging. Regarding mass change of stored carrots (Figure 4), both temperature and packaging had significant impact on the gradual mass loss of samples. Packaging had higher influence on the extent of mass loss. Packaged samples showed only minimal mass decrease over 22 days, while non-packed ones lost even the half of their original mass after 13 days of storage, so the quality of these carrots degraded significantly.

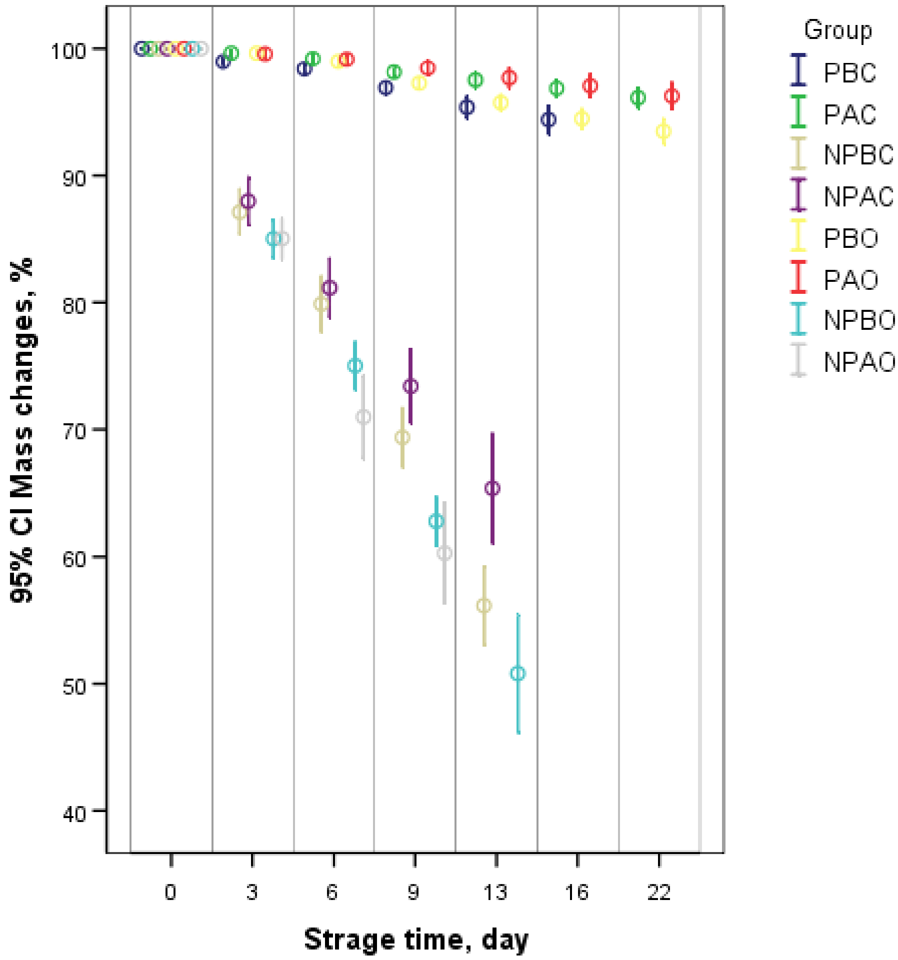

Figure 3. Mass changes of organic and conventional carrot samples stored for 22 days at 4 and 12ºC, packaged or bulk. Legend: PBC: packed conventional, 12ºC, PAC: packed conventional, 4ºC, NPBC: bulk conventional, 12ºC, NPAC: bulk conventional, 4ºC, PBO: packed organic, 12ºC, PAO: packed organic, 4ºC, NPBO: bulk organic, 12ºC, NPAO: bulk organic, 4ºC

In case of packaged samples, temperature also had an effect on the change in mass. Samples stored at 12°C lost more mass than those stored at 4°C, while the cultivation method had no effect on packaged samples. For the unpackaged samples, the groups were separated according to the cultivation method. The mass of conventionally grown samples decreased less than that of organic carrots.

Higher storage temperature contributed to higher weight losses. For non-packed samples, organic samples showed significantly higher weight loss, than conventional ones regardless of storage temperature.

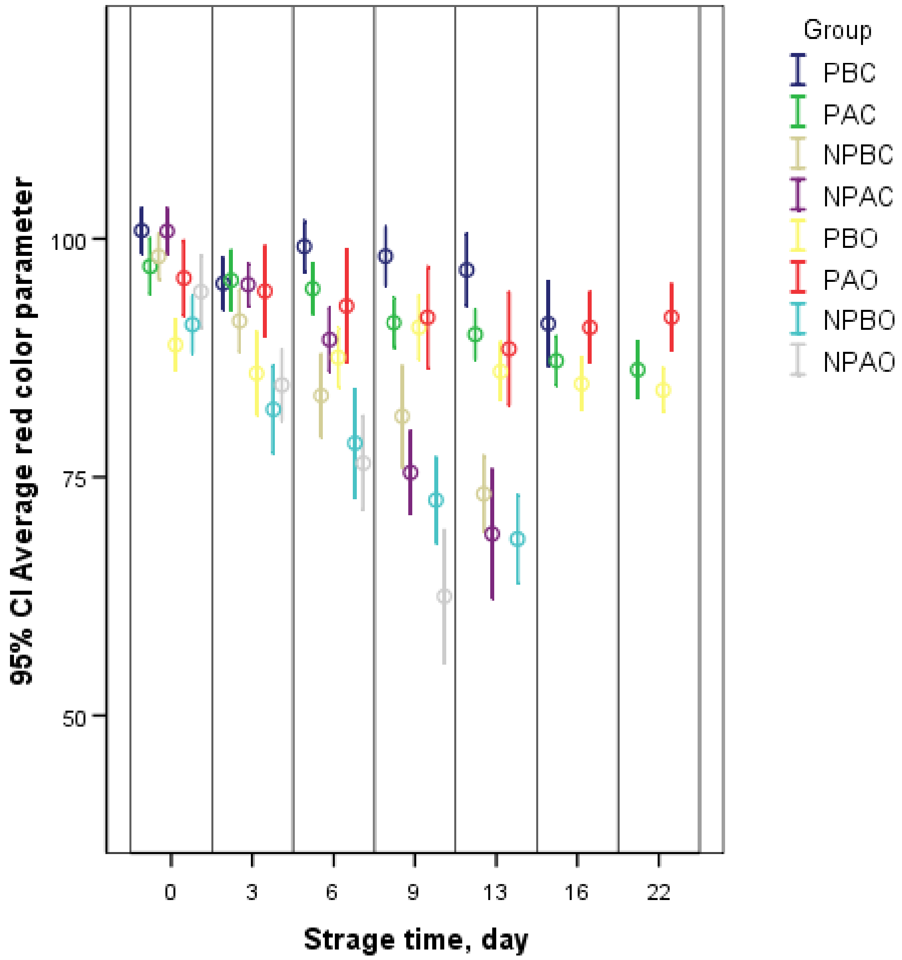

Figure 5. Average red color parameter changes of organic and conventional carrot samples stored for 22 days at 4 and 12ºC, packaged or bulk. Legend: PBC: packed conventional, 12ºC, PAC: packed conventional, 4ºC, NPBC: bulk conventional, 12ºC, NPAC: bulk conventional, 4ºC, PBO: packed organic, 12ºC, PAO: packed organic, 4ºC, NPBO: bulk organic, 12ºC, NPAO: bulk organic, 4ºC

The red color parameter of the investigated carrot samples do not show higher deviations until the 6th day of storage, when the non-packed samples start to lose their red color. On the 9th day, the two sub-groups sepatate significantly. Interestingly, higher storage temperature was more favorable for maintaining the original red color. The red color of organic samples were slightly lighter, than that of the conventional ones.

In case of average green and average blue parameters, it can be observed that the values decrease with storage (not shown), but due to the large variance of the groups, packed and unpacked groups are not separated

Conclusions

According to our results, among the examined variables (storage temperature, packaging and cultivation type), packaging had the greatest effect on the preservation of carrot quality during storage. Packing in a resalable perforated plastic bag had a very positive effect on the shelf life of organic and conventional carrots for all measured parameters. For the Sinclair IQ parameter, weight loss and average red color change, a significant difference ($p<0.05$) was determined already on the third day of storage between the packed and unpacked groups, independent on storage temperature and agricultural production method.

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