

# Providing Quality of Shredded Carrots during Storage by Treatment with Ozonated Water

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**Abstract** – The objective of the current research is to evaluate the quality changes of shredded carrots treated with 2 ppm ozonated tap water for  $60 \text{ s} \pm 1 \text{ s}$ . Treated carrots have been packed in several materials (hermetically sealed by breathing polymer film BOPP Propafilm™ P2GAF, cellulose based biodegradable NatureFlex NVS and Polilactid BIO-PLA Containers) and stored at the temperature of  $+4^\circ\text{C} \pm 1^\circ\text{C}$  for 10 days. Main quality parameters using standard methods have been analysed: total carotenoids and  $\beta$ -carotene, total phenolic, antioxidant capacity, soluble solids, mass loses, moisture, pH, firmness, colour,  $\text{CO}_2$  and  $\text{O}_2$  and microbiological parameters. Testing of the samples has been carried out before packaging and during storage. In the present research it has been proved that is possible to maintain the chemical composition of shredded carrots during storage by treatment of carrots with ozonated tap water; as a result, the shelf-life of shredded carrots can prolong till 10 days.

**Keywords** – Carrots, ozone, storage, treatment.

## I. INTRODUCTION

FRESH-CUT carrots can be found on the market place as whole peeled (baby), sticks, and sliced, shredded, grated and diced. There is shelf life limitation of minimally processed carrots from 4 to 5 days due to a high respiration rate, development of off-flavour, acidification, and loss of firmness, discoloration, and microbial spoilage. Shredded carrots are an increasingly popular product, but their sales are restricted due to rapid deterioration during storage [1]. Fresh-cut fruits and vegetables have been very popular for the bioavailability of numerous vitamins, minerals and other phytochemicals. However, they may contain a wide variety of bacteria, fungi and yeast species [2].

Minimally processed vegetables (MPV) are prepared and handled to maintain their fresh nature while providing convenience to the consumer, as ready-to-eat. Producing MPV involves cleaning, trimming, peeling, coring, slicing, shredding, washing, etc. [3], [4]. Considerable interest, therefore, is currently being expressed in safer and 'environmental-friendly' sanitizing agents, including ozone [5]. The fresh produce industry is showing interest in  $\text{O}_3$  applications due to growing consumer preference for minimally processed food products, frequent outbreaks of food-related illnesses, identification of new food pathogens, and the passage of legislation governing food quality and safety [6]. Ozone extends the shelf-life of the fresh produce during storage by oxidizing the metabolic products produced during storage of the product [7]. The use of ozone in food processing has become increasingly important as a result of the affirmation of ozone as a GRAS (Generally Recognized as Safe) chemical in 1997 and its subsequent approval by the US FDA as an antimicrobial additive for direct contact with

food products of all types (FDA 2001). The Food and Drug Administration (FDA, 2011), under the ruling 21 C.F.R. 173.315, has approved the use of ozone as plant protection agents in the processing of fresh fruits and vegetables. The use of ozone in food processing has been approved to various degrees in many countries, including the USA, Japan, Australia, France and Canada [9], [10], [11], [12], [13] and which has since received formal US-FDA approval (in 2003) as a Food Additive [5]. Ozone is one of the most potent sanitizers known and is effective against a wide spectrum of microorganisms at relatively low concentrations [7]. Ozone has a wide antimicrobial spectrum, which combined with a high oxidation potential, makes it an attractive processing option for the food industry. Relatively small quantities of ozone and short contact times are sufficient for the desired antimicrobial effect and it rapidly decomposes into oxygen, leaving no toxic residues [10], [14]. Within the food industry, ozone has been used routinely for washing and storage of fruits and vegetables. Ozone can be bubbled through water into which it will partially dissolve. The ozonated water then can be used for washing and/or in transfer flumes to reduce the microbial loads of berries and other fruits and vegetables. Controlled studies report that ozonated water may actually provide greater than 90 % reduction of total bacterial counts for some vegetables. Such treatments also have been shown to reduce fungi populations and, subsequently, reduce fungal decay [7]. Though  $\text{O}_3$  is a GRAS chemical, it is also a toxic gas; toxicity is dependent on concentration and length of exposure [6]. Ozone must be manufactured on site for immediate use since it is unstable and quickly decomposes to normal oxygen. The half-life of ozone in distilled water at  $20^\circ\text{C}$  is about 20–30 minutes [7], [9], [10], [15]. Ozone is formed from molecular oxygen in an endothermic process, under a very high voltage or UV radiation, as well as from the decomposition of  $\text{O}_2$  and its further recombination [16]. Ozone is a naturally occurring substance found in our atmosphere and it can also be produced synthetically. The characteristic fresh, clean smell of air following a thunderstorm represents freshly generated ozone in nature [7]. Therefore,  $\text{O}_3$  technology is a good option for the wash-water disinfection for the fresh-cut industry, because it will reduce the need for water replacement and for high sanitizer concentration [17]. On the other hand, using ozone as a disinfectant has disadvantages, including its instability and reactivity with organic materials, and, thus, the effective elimination of microorganisms may require high concentrations that may cause sensory defects in fresh produce. In addition, some nutritional components (vitamins, amino acids, enzymes, essential fatty acids) may be altered as a result of oxidation [18].

The objective of the current research is to evaluate the quality changes of shredded carrots treated with ozonated tap water during storage.

## II. MATERIALS AND METHODS

## A. Materials

The object of the research was serotinous 'Nante' carrot (*Daucus carota* L.) hybrid 'Nante/Forto' harvested in Zemgale region (Latvia) in the first part of October 2012 and was immediately used for experiments.

## B. Processing, Packaging, and Storage of Carrots

Carrots were rinsed under the tap water, then peeled and shredded using Philips Comfort HR 7605 device. The disinfection consisted of immersion of shredded carrots in tap water ozonated to a 2 ppm for 60 min  $\pm$  1 min. The ozone was produced using the High concentration Ozone water generator and Oxygen generator (SOZ-YWS); ozone concentration in water was measured using DO3 device.

TABLE 1  
CHARACTERISATION OF PACKAGING MATERIALS

No.	Packaging material	Thickness	Barrier properties
1	BOPP Propafilm™ P2GAF	$\delta = 38 \pm 1 \mu\text{m}$	OTR: 3000 cm <sup>3</sup> /m <sup>2</sup> per 24 hrs; CO <sub>2</sub> TR: 12000 cm <sup>3</sup> /m <sup>2</sup> 24 hrs.
2	NatureFlex NVS film	$\delta = 35 \pm 1 \mu\text{m}$	OTR: 3000 cm <sup>3</sup> /m <sup>2</sup> per 24 hrs; CO <sub>2</sub> TR: 12000 cm <sup>3</sup> /m <sup>2</sup> 24 hrs.
3	Bio-PLA Containers	$\delta = 30.0 \mu\text{m}$	WTR: 55 g/m <sup>2</sup> d $\pm$ 10 % at 23 °C and HR 85 % (ASTM F 1249) OTR: 500 cm <sup>3</sup> /m <sup>2</sup> d bar at 23 °C and HR 50 %: (DIN 53380-3)

Shredded carrots were packed by 100 g  $\pm$  5.0 g in DuniForm PP trays (138 mm x 114 mm x 53 mm) hermetically sealed by breathing polymer film BOPP Propafilm™ P2GAF (Biaxially oriented polypropylene), cellulose based biodegradable NatureFlex NVS and Polilactid BIO-PLA (biodegradable polylactic acid) containers (Table 1).

Samples within 10 days were stored in a Commercial Freezer/Cooler "Elcold" at the temperature of  $+4.0 \pm 0.5$  °C. The results were reported as mean values of all determinations. Samples were analyzed before packaging (day 0) and after 3, 5, 8 and 10 days of storage; ten measurement replications of each sample were performed.

## C. Moisture

Moisture content was determined by ISO 6496:1999 according to the storage time by verified balance KERN (Germany) with precision  $\pm$  0.001 g.

## D. pH

pH value was measured using JENWAY 3510 pH-meter, by standard method LVS ISO 5542:2010.

## E. Mass Losses

The sample mass was determined by a digital precision balance ( $\pm$  0.1 g). At each sampling time, for each type of carrots, the mass was measured three times on different samples [19].

F.  $\beta$ -carotene

For extraction, a representative portion of the sample (1 g) was accurately weighed in a glass test tube. Then 5 ml of chilled acetone was added, and the tube was held for 15 min with

occasional shaking at  $4 \text{ }^{\circ}\text{C} \pm 1 \text{ }^{\circ}\text{C}$ , vortex at a high speed for 10 min, and finally centrifuged at  $1370 \times g$  for 10 min. Supernatant was collected into a separate test tube, and the compound was re-extracted with 5 ml of acetone followed by centrifugation once again as above. Both of the supernatants were pooled together and then passed through the Whatman filter paper No. 42. The absorbance of the extract was determined at 449 nm wavelength in a UV-Vis spectrophotometer [20]. Blank samples for raw carrots were prepared as described above. A working standard containing 32  $\mu\text{g ml}^{-1}$  was prepared from 1 mg  $\text{ml}^{-1}$  stock solutions kept at  $4 \text{ }^{\circ}\text{C}$ . From this working standard, different dilutions were made to spike the samples. Blank samples of 1.0 g were spiked with working standards to obtain final concentrations 16.0  $\mu\text{g g}^{-1}$ , 8.0  $\mu\text{g g}^{-1}$ , 4.0  $\mu\text{g g}^{-1}$ , 2.0  $\mu\text{g g}^{-1}$ , 1.0  $\mu\text{g g}^{-1}$ , 0.5  $\mu\text{g g}^{-1}$ , 0.25  $\mu\text{g g}^{-1}$ , 0.125  $\mu\text{g g}^{-1}$ , 0.062  $\mu\text{g g}^{-1}$ , 0.031  $\mu\text{g g}^{-1}$  and 0.015  $\mu\text{g g}^{-1}$  of  $\beta$ -carotene and extracted as described previously. Calibration curves were plotted by taking Optical Density value to the respective concentrations by back extrapolation methods. These curves were used to quantify the  $\beta$ -carotene content in the samples analyzed [20].

## G. Total Carotenoids

Total carotenoids were analyzed by a spectrophotometric method (used the UV/VIS spectrophotometer Jenway 6300) at 440 nm [21]. A sample of 1g of homogenized shredded carrots sample was placed in 100 ml conic flask and 30 ml of 96 % ethanol was added. The sample was stirred on a magnetic stirrer for 15 min then 25 ml of petrolether was added and stirring was continued for one more hour. After 1 hour when both layers were completely divided, the top yellow layer was used for further detection of carotenoids at 440 nm. Carotene equivalent (KE) was found, using a graduation curve with  $\text{K}_2\text{Cr}_2\text{O}_7$ .

## H. Colour Analysis

Colour of the carrots was evaluated by measuring CIE  $L^*$ ,  $a^*$ , and  $b^*$  parameters by means of "ColorTec-PCM/PSM" (ColorTec Associates, Clinton, USA).  $L^*$ ,  $a^*$ , and  $b^*$  indicate whiteness/darkness, redness/greenness, and blueness/yellowness values, respectively. The maximum value for  $L^*$  is 100, which would be a perfect reflecting diffuser. The minimum for  $L^*$  is zero: black. The values of  $a^*$  and  $b^*$  axes have no specific numerical limits. Positive  $a^*$  is red and negative  $a^*$  is green. Positive  $b^*$  is yellow and negative  $b^*$  is blue [22].

## I. Total Phenolics

The total phenolic content of carrots was determined using Folin-Ciocalteu colorimetric method [23], [24]. Total phenolic content was expressed as gallic acid equivalent (GAE) 100  $\text{g}^{-1}$  dry weight (DW) of the sample.

J. Total Antioxidant Capacity (DPPH $^{\cdot}$ )

The antioxidant capacity of carrots was measured by the DPPH radical method according to Fallar and Fialho [25]. Inhibition of DPPH $^{\cdot}$  in percent ( $I\%$ ) of each extract sample was calculated as follows:

$$\% I = \frac{A_0 - A_t}{A_0} \times 100,$$

where  $A_0$  represents the absorbance of DPPH solution alone measured at zero time, and  $A_t$  is the absorbance for each sample

at the times of 15 min, 30 min and 60 min after the addition of the DPPH solution. The value of  $A_0$  is considered 100 % [25].

#### K. Soluble Solids

The content of soluble solids ( $^{\circ}$ Brix) was determined at the temperature of  $+20\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$  with a digital refractometer (deviation of measuring instrument face value  $\pm 0.1\%$ ) by standard method ISO 2173:2003.

#### L. Firmness

A structure analyser "TA.XT.plus texture Analyser" (Stable Micro Systems Ltd., Surrey, UK) and measuring probe HDP/BSK (blade set with knife, supplied with the Texture Analyser) were used for firmness determination. The system was equipped with a compression cell of 50 kg and software Texture Exponent 32. Firmness was measured as the maximum penetration force (N) reached during tissue breakage. The measuring parameters were: pre-test speed  $2\text{ mm s}^{-1}$ ; test speed  $2\text{ mm s}^{-1}$ ; post-test speed  $10\text{ mm s}^{-1}$ ; penetrating distance 23 mm into the carrot. The measurement was triggered automatically at 0.04903 N. The maximum force required for sample cutting was calculated as an average of 10 measurements [26].

#### M. Microbiological Analyses

Samples for microbiological testing were prepared by a dilution method in conformity with standard LVS EN ISO 6887-1:1999 and 6887-4:2044. TPC (total plate count) – determined in conformity with standard LVS EN ISO 4833:2003A; yeast and mould plate count – determined in conformity with standard LVS ISO 21527-2:2008. Plate counts were evaluated as decimal logarithm of colony forming units (CFU) per gram of a product ( $\log\text{ cfu g}^{-1}$ ).

#### N. Gas Composition

The dynamics of gas composition inside each hermetically sealed package headspace within the storage time was measured as a percentage of oxygen and carbon dioxide by a gas analyzer OXYBABY®V  $\text{O}_2/\text{CO}_2$ . The packs were sampled in duplicate, and the whole experiment was repeated three times.

#### O. Mathematical Data Processing

The results were processed by statistical methods. Statistics on a completely randomized design was determined using the General Linear Model (GLM) procedure SPSS, version 16.00. Two-way analyses of variance ( $p \leq 0.05$ ) were used to determine significance of differences between different samples.

### III. RESULTS AND DISCUSSION

#### A. $\text{O}_2$ and $\text{CO}_2$ Composition

$\text{CO}_2$  and  $\text{O}_2$  gas composition changes inside a package during storage of carrots for 10 days are presented in Fig. 1 and Fig. 2. It was determined that oxygen content changes inside a package with non-treated carrot samples were significant ( $p = 0.024$ ) – the content decreased compared to the acquired results of carrots treated in ozonated water during the same time of storage. Significant results were observed in experiments, when shredded carrots were packaged in Polilactid BIO-PLA

containers and BOPP Propafilm™ P2GAF. Namely, inside Polilactid BIO-PLA packaging the content of  $\text{O}_2$  approached 10.9 %; however, inside BOPP Propafilm™ P2GAF films – 10.1 %.

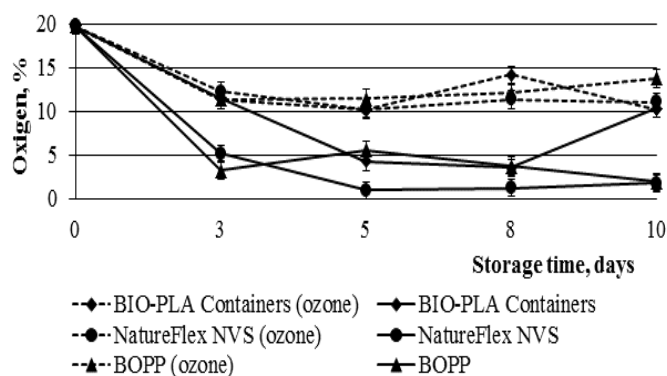


Fig. 1.  $\text{O}_2$  dynamics inside a package of shredded carrots during storage.

Differences in oxygen composition changes inside a package during storage of carrots could mainly be explained with different airtightness of packaging.

As can be seen in Fig. 1,  $\text{O}_2$  values (obtained after 10 days of storage) ranged between 1.8 % – 10.4 %, depending on the type of packaging. However, low  $\text{O}_2$  amount could be deemed favorable for the reduction of enzymatic browning [4].

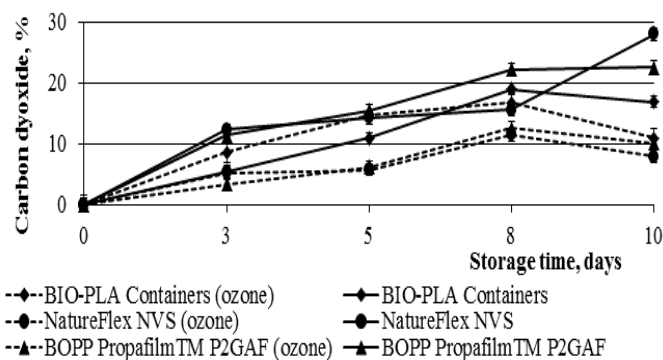


Fig. 2.  $\text{CO}_2$  dynamics inside a package of shredded carrots during storage.

Insignificant differences were found in carbon dioxide content ( $p=0.594$ ) inside a package with ozonated and non-ozonated carrots after 10 days. It is necessary to indicate that Gomez-Lopez (2012) reported that the level of ozone treatment was beneficial for retarding the physiological metabolism of carrots and thereby maintaining the quality during 9 days of storage [27].

#### B. Total Phenols and Total Antioxidant Capacity

The results of the present study indicated that the content of total phenols of shredded carrots treated with ozonated water decreased during storage, but the decrease after ten days of storage was not significant ( $p = 0.096$ ). It was determined that it was possible to maintain phenolic compounds in carrots by processing them shortly with ozonated water.

Significant differences in antioxidant capacity ( $p = 0.006$ ) were observed between treated and non-treated (control) shredded samples after ten days of storage (Fig. 3).

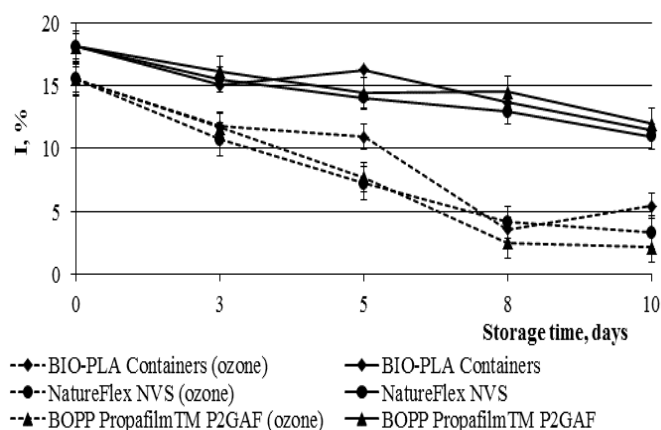


Fig. 3. DPPH dynamics of shredded carrots during storage.

The antioxidant capacity value of non-ozonated samples after ten days of storage was 10.96 % – 11.98 % and 2.12 % – 5.43 % of ozonated samples (Fig. 3) that was 5 – 2 times less comparing with non-ozonated shredded carrots depending on the packaging material.

### C. Total Carotenoids and $\beta$ -carotene; Colour

Carotenoids in fresh-cut products are highly susceptible to oxidative deterioration due to the enhanced susceptibility under acute abiotic stress. In the present study, ozonation reduced the content of carotenoids in shredded carrots. In general, a negative impact was not reported for ozone and carotenoids,  $\beta$ -carotene contents of the shredded carrots.

Gomez-Lopez (2012) reported that ozone treatment ( $10 \text{ mg L}^{-1} - 10 \text{ min}$ ) significantly reduced carotenoid contents in sliced carrots. However, the differences between the control and ozonated samples at the end of 30 days of storage were actually small [27].

Experimentally, it was established that there were no significant differences in carotenoid and  $\beta$ -carotene content after 10 days of storage of all carrot samples packed in different materials and treated with ozonated water ( $p = 0.115$  and  $p = 0.597$ ) comparing with non-stored fresh samples. Chauhan et al. (2011) have reported that since carotenoids undergo rapid auto-oxidation by reactivity with molecular oxygen, the protective mechanism by means of enzymatic reduction is minimal. The oxidative effect of ozone on food products is described as a surface phenomenon [28].

Food processing has both positive and negative effects on the levels of carotenoids in food, but overall it is more evident that processing may be beneficial through the disruption of a matrix (cell walls), which facilitates their release and solubilisation as free or esterified/glycosylated forms in appropriate solvents, or after long heating times, leading to chemical changes [29].

The colour of carrot roots results mainly from pigment accumulation in the root tissue. The roots of the investigated carrot cultivars differed with respect to  $L^*$ ,  $a^*$  and  $b^*$  colour parameters. The influence of different packaging materials and storage time on the values of lightness ( $L^*$ ), redness component ( $a^*$ ), and yellowness component ( $b^*$ ) are shown in Table 2.

TABLE 2  
COLOUR INTENSITY OF CARROTS DEPENDING ON PACKAGING MATERIALS AND STORAGE TIME

Packaging material	Storage time, days	Colour intensity		
		L*	a*	b*
Shredded carrots treated with ozonated water				
BIO-PLA Containers	0	45.67 ± 1.70	17.06 ± 0.74	41.44 ± 2.90
	3	44.84 ± 2.14	16.71 ± 0.75	36.05 ± 2.63
	5	44.52 ± 1.41	17.80 ± 0.97	37.37 ± 2.60
	8	45.46 ± 1.75	17.83 ± 1.59	36.83 ± 2.09
	10	42.81 ± 1.26	17.26 ± 0.24	39.27 ± 1.72
NatureFlex NVS	0	45.67 ± 1.70	17.06 ± 0.74	41.44 ± 2.90
	3	44.71 ± 0.52	17.06 ± 1.31	36.06 ± 2.00
	5	44.07 ± 0.35	16.49 ± 0.95	35.34 ± 2.42
	8	44.84 ± 2.30	16.41 ± 1.52	37.14 ± 2.84
	10	43.10 ± 0.33	16.67 ± 0.79	40.05 ± 1.68
BOPP Propafilm™ P2GAF	0	45.67 ± 1.70	17.06 ± 0.74	41.44 ± 2.90
	3	45.35 ± 1.59	15.70 ± 1.69	36.06 ± 2.19
	5	44.06 ± 1.78	17.21 ± 0.77	35.66 ± 3.27
	8	46.10 ± 1.00	15.76 ± 1.72	37.34 ± 3.83
	10	43.11 ± 1.02	16.39 ± 0.91	36.18 ± 3.36
Shredded carrots non-treated with ozonated water				
BIO-PLA Containers	0	56.79 ± 0,39	22.21 ± 0.93	44.93 ± 0.85
	3	56.43 ± 0,96	20.75 ± 0.81	43.73 ± 0.58
	5	54.42 ± 1.64	20.68 ± 1.52	42.85 ± 1.02
	8	53.85 ± 0.68	20.17 ± 0.37	40.94 ± 0.63
	10	53.14 ± 0.52	19.89 ± 0.62	39.14 ± 1.73
NatureFlex NVS	0	56.79 ± 0,39	22.21 ± 0.93	44.93 ± 0.85
	3	54.20 ± 0.72	17.80 ± 0.91	34.55 ± 1.43
	5	57.15 ± 1.18	19.89 ± 0.56	35.05 ± 1.19
	8	56.42 ± 0.42	19.27 ± 0.72	34.73 ± 0.27
	10	55.63 ± 0.84	18.73 ± 0.32	34.21 ± 0.36
BOPP Propafilm™ P2GAF	0	56.79 ± 0.39	22.21 ± 0.93	44.93 ± 0.85
	3	57.23 ± 1.08	20.44 ± 1.12	43.97 ± 1.31
	5	54.20 ± 0.84	20.51 ± 0.31	20.51 ± 0.31
	8	53.94 ± 0.58	19.75 ± 0.64	42.97 ± 0.62
	10	53.26 ± 0.52	19.37 ± 0.73	41.74 ± 0.61

There were no big differences found in redness component ( $a^*$ ) and yellowness component ( $b^*$ ) values between the analyzed carrot samples that mainly could demonstrate a similar colour of analyzed carrots. The values of lightness ( $L^*$ ) markedly differed ( $p < 0.05$ ) comparing ozonated and non-ozonated carrot samples during storage in different packaging materials.

Martin-Belloso and Soliva-Fortuny (2011) reported that carrots exposed to ozone gas during storage had a lighter, less intense colour than untreated carrots [17]. In another study with ozone, carrots showed an increase in luminosity after processing and decrease in the chrome [11]. Similar results were obtained in the present research, too.

#### D. Soluble Solids

In the present research, significant differences ( $p = 0.026$ ) in the content of soluble solids between ozonated and non-ozonated carrots were obtained (Fig. 4). It means that ozone negatively influences soluble solid content in carrots; as a result, it decreased by 33 %.

However, a very similar tendency was observed in changes in the content of soluble solids in ozonated and non-ozonated shredded carrots during their storage (Fig. 4). It was detected that after 10 days of storage, not depending of packaging material, the decrease in the content of soluble solids in ozonated carrots was 10 % and in non-ozonated carrots – 8 % that is not significant ( $p = 0.448$  and  $p = 0.281$ ).

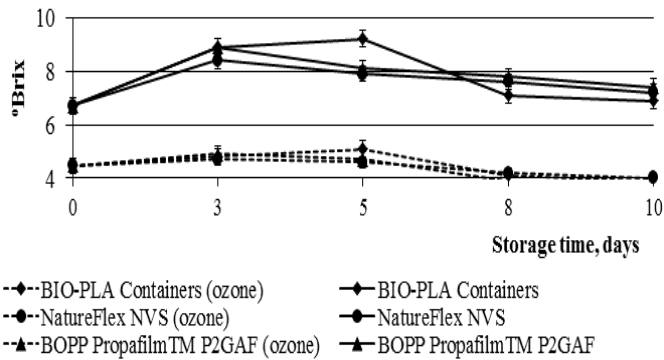


Fig. 4. Dynamics of soluble solids of shredded carrots during storage.

On the last day of storage, only main differences between ozonated and non-ozonated shredded carrot samples in the content of soluble solids were established.

#### E. pH

In the present research, it was proved that ozonated water insignificantly ( $p = 0.447$ ) influenced pH value of shredded carrots (Fig. 5). However, it is necessary to indicate that pH value of ozonated carrots was lower after 10 days of storage compared to pH value of non-ozonated carrots.

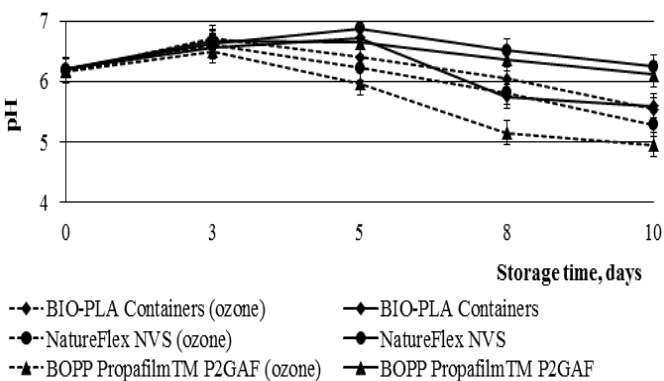


Fig. 5. Dynamics of pH value of shredded carrots during storage.

Significant influence of packaging material on pH value changes of ozonated and non-ozonated carrots was detected. As a result, a decrease in pH value was obtained in carrots packaged in BOPP Propafilm™ P2GAF for ozonated and non-ozonated carrots.

However, not so pronounced decrease in pH value was obtained in carrots packaged in Polylactid BIO-PLA.

#### F. Moisture and Mass Losses

Water migration phenomena and the resulting moisture content change in food products affect their shelf-life through undesirable modifications of their physical, sensory and microbial qualities [30]. Therefore, it is very important to determine the moisture content of shredded carrots in a package to foresee their shelf-life in general. Experimentally, it was established that insignificant differences in moisture content and mass loss values after 10 days of storage of all analysed shredded carrot samples packed in different packaging materials were found ( $p = 0.208$  and  $p = 0.157$ ).

#### G. Firmness

Texture is a critically important component of fresh-cut fruit and vegetable quality, which is difficult to analyze commercially. Due to commercial difficulties in testing product quality, it is often assumed that “if it looks good, it tastes good” [17]. Significant influence ( $p = 0.043$ ) of ozone on firmness of shredded carrots was detected in the present research. Firmness changes of shredded carrot samples during storage in various packaging materials are presented in Fig. 6.

In the present experiments it was detected that ozonated shredded carrots were harder than non-ozonated carrots – the firmness value of ozonated shredded carrots was by 19 % higher compared to non-ozonated carrots at the beginning of storage. The increase in a firmness value was obtained in carrots during their storage, as well (Fig. 6) that could mainly be explained with moisture migration through the packaging material as well as some biochemical and chemical processes occurring during the storage, which promoted hardening.

In total, a significant increase in the firmness value of analyzed carrot samples ( $p = 0.015$ ) was obtained in present experiments after 10 days of storage. Although the biggest fluctuations of firmness during the storage were detected in non-ozonated samples, only a slight increase in a firmness value was obtained in ozonated carrots that could mainly be explained with possible postharvest changes in cellulose and hemicellulose contents due to  $O_3$  [6].

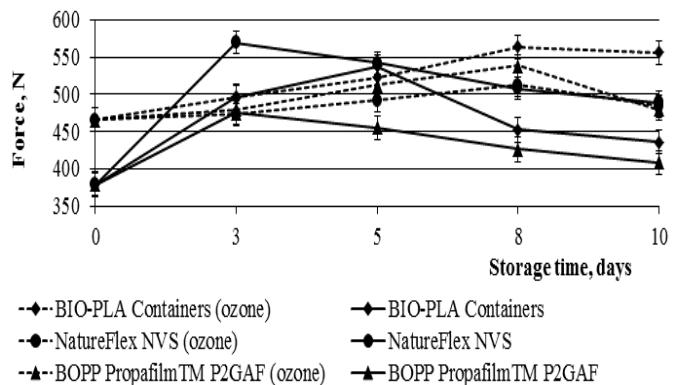


Fig. 6. Dynamics of firmness value of shredded carrots during storage.

#### H. Microbiological Parameters

Microorganisms are an important factor to consider in dealing with MP fresh fruits and vegetables because microbial spoilage has economic consequences of importance but most importantly because consumer safety is at risk with foodborne

illness [31]. However, ozonation is used as a surface decontamination method for fruits and vegetables [28].

In the present research it was proved that it was possible to provide the microbiological safety of shredded carrots by their treatment with ozonated water. As a result, it was possible to decrease the total count of microorganisms and moulds (Fig. 7 and Fig. 8).

In the present study, it was found that by treatment of carrots with ozonated water it was possible to significantly ( $p=0.0001$ ) reduce standard plate count (SPC) by  $8.83 \log \text{cfu}^{-1}$ . It mainly indicates that the potency of  $\text{O}_3$  as an effective agent against a wide range of both pathogenic and spoilage microorganisms at relatively low concentrations makes it attractive for food applications [6].

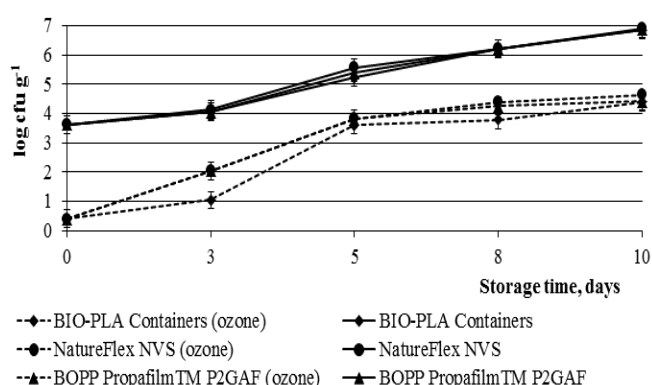


Fig. 7. MAFAM dynamics of shredded carrots during storage.

Jacksens et al. (2003) reported that the microbial load should not be more than  $5.70 \log \text{cfu g}^{-1}$  in order to guarantee 5–6 days of shelf life for minimally processed carrots [32].

In the present study, it was found that the total aerobic mesophilic bacteria count of shredded carrots treated with ozonated water was around  $4.63 \log \text{cfu g}^{-1}$  on the 10<sup>th</sup> day of storage; however, similar results for non-treated carrots were acquired on the 5<sup>th</sup> day of storage. Therefore, it is possible to conclude that the shelf-life of shredded carrots could be 5 days longer if they could be treated with ozonated water before packaging.

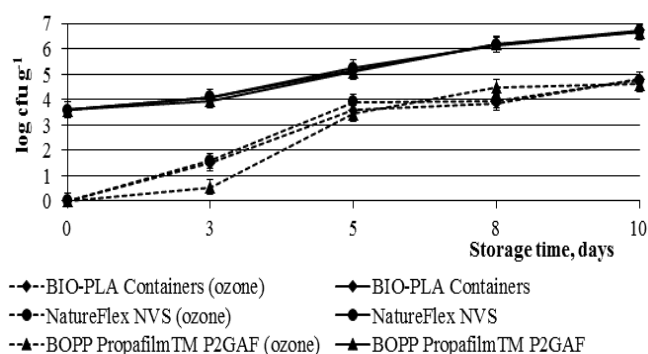


Fig. 8. Mould count dynamics of shredded carrots during storage.

The presence of *E. coli* in the tested samples of shredded carrots treated with ozone has not been detected in any sample, confirming that this product does not offer a risk factor for the consumers' health.

#### IV. CONCLUSIONS

Within experiments it was ascertained that ozonated water significantly influenced antioxidant capacity and content of soluble solids, firmness value and microbiological parameters of fresh shredded carrots; however, it did not significantly influence phenolic compounds, carotenoids and  $\beta$ -carotene content, color changes and pH value.

During experiments it was ascertained that it was possible to maintain the quality of shredded carrots during storage in several packaging materials mainly by their treatment with ozonated water.

Shelf-life of shredded carrots treated with ozonated water is 10 days, and that of non-treated carrots – 5 days.

It was proved that the packaging materials tested within the research insignificantly influenced quality parameters of analyzed shredded carrots during their storage. However, more recommendable Polilactid BIO-PLA containers could be indicated.

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#### **Ingrīda Augšpole, Tatjana Rakcejeva, Lija Dukalska, Līga Skudra. Kvalitātes nodrošināšana ar ozonētu ūdeni apstrādātiem rīvātiem burkāniem uzglabāšanas laikā**

Pētījuma mērķis bija novērtēt kvalitātes izmaiņas svaigos rīvātos burkānos, kas tika apstrādāti ( $60 \pm 1$ ) s ar 2 ppm ozonētu krāna ūdeni uzglabāšanas laikā. Ar ozonētu ūdeni apstrādātie burkāni bija iepakoti dažādos bioloģiski sadalāmos (biodegradējamus) hermētiski noslēgtos iepakojuma materiālos: *NatureFlex™ NVS*, *BIO-PLA* trauciņos, *BOPP Propafilm™ P2GAF* plēvē ar augstām barjerīpašībām un uzglabāti lesusskapī ( $+4 \pm 1$ ) °C temperatūrā desmit dienas. Izmantojot standarta metodes, rīvētu burkānu paraugos tika analizēti: kopējais karotinoīdu,  $\beta$ -karotīna un kopējais fenolu saturs, antioksidantu aktivitāte, šķīstošās sausas saturs, masas zudumi iepakojumā, CO<sub>2</sub> un O<sub>2</sub> saturs iepakojumā, mitrums, pH, stingrība, krāsa un mikrobioloģiskie parametri (zarnu grupas baktērijas, raugi un pelējumi, kā arī mezofili aerobie un fakultatīvi anaerobie mikroorganismi). Paraugu testēšana tika veikta pirms iepakojšanas un uzglabāšanas laikā. Šajā pētījumā tika pierādīts, ka ar ozonētu ūdeni apstrādātos rīvātos burkānos ir iespējams saglabāt atbilstošus kvalitātes rādītājus. Tā rezultātā rīvētu burkānu derīguma termiņu, tos apstrādājot ar ozonētu ūdeni, var paildzināt līdz desmit dienām, taču neapstrādātus rīvētus burkānus var uzglabāt līdz piecām dienām. Pētījumā konstatēja, ka ozonētam ūdenim bija būtiska ietekme uz antiradikālo aktivitāti, šķīstošās sausas sastāvu, stingrību un mikrobioloģiskajiem

parametriem pētītajos burkānu paraugos. Savukārt uz  $\beta$ -karotīnu, kopējo karotinoīdu, kopējo fenolu un pH saturu būtiskas izmaiņas nenovēroja. Pētījumā pierādījās, ka iepakojuma materiālam bija būtiska ietekme uz burkānu kvalitātes rādītājiem uzglabāšanas laikā. Jāatzīmē, ka *BIO-PLA* trauciņi bija visvairāk piemērotais iepakojums rīvētu burkānu uzglabāšanai, salīdzinot ar citiem pētījumā lietotajiem iepakojuma materiāliem.

**Ингрида Аугшполе, Татьяна Ракчеева, Лия Дукальска, Лига Скудра. Обеспечение качества тёртой моркови, обработанной озонированной водой во время хранения**

Целью данного исследования являлся анализ качества тёртой моркови, обработанной озонированной проточной водой при концентрации 2ппм в течение  $(60 \pm 1)$  сек. в процессе хранения. Обработанные образцы моркови были упакованы в разные материалы (герметично закрытые полимерной плёнкой BOPP Propafilm™ P2GAF контейнеры, на базе целлюлозы, изготовленной биodeградируемой плёнкой NatureFlex NVS и Polilactid BIO-PLA) и хранились при температуре  $+4 \pm 1$  °C в течение десяти дней. Следующие параметры качества были проанализированы с использованием стандартных методов: общее количество каротиноидов и  $\beta$ -каротин, общий состав фенольных соединений, антирадикальная активность, растворимое сухое вещество, уменьшение массы, влажность, pH, жёсткость, цвет, состав CO<sub>2</sub> и O<sub>2</sub> газов, а также микробиологические параметры. Анализ образцов проводился перед упаковкой и в процессе хранения. В течение данных исследований было доказано, что химический состав тёртой моркови возможно сохранить в процессе хранения путём обработки моркови озонированной водой; в результате срок годности тёртой моркови можно продлить до десяти дней, срок годности необработанной моркови – 5 дней. Также было установлено, что озонированная вода имеет существенное влияние на антирадикальную активность образцов, состав растворимого сухого вещества, мягкость и на микробиологические параметры свежей тёртой моркови; в свою очередь незначительное влияние выявлено на  $\beta$ -каротин, изменения цвета и состав фенольных соединений, каротинов, pH. Было доказано, что в процессе исследований тестируемые упаковочные материалы не имели значимого влияния на качество моркови в процессе хранения. Необходимо заметить, что материал Polilactid BIO-PLA всё же больше подходит для упаковки при хранении тёртой моркови, чем остальные тестируемые упаковочные материалы.