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PHYSICAL CHARACTERISATION OF MINIMALLY PROCESSED CARROTS STORED IN VARIOUS PACKAGING OF BIODEGRADABLE MATERIALS

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Abstract

The influence of biodegradable polylactic acid based PLA films have been compared to those of conventional polymers to demonstrate the actual performance and preference of biodegradable polymers for fresh produce packaging, comparing with conventional polymers. The purpose of this study was to investigate and to compare the role of PLA for the fresh cut produce service industry. One of the commonly used polymer laminate PET/Adhesive/PP film where used to package fresh carrots, it was compared with laser perforated PET/CoPE film and with PLA films of two different thicknesses, as well as packaging in ready made cups of PLA by volume 350 ml. This study involved a number of tests to quantify the gas composition in the head spice of packaging made from used films, physical properties of packed carrots, and compatibility properties that would affect the selection criteria for biobased PLA materials to be used for fresh cut vegetable service applications. Based on the results, PLA, PET/Adhesive/PP, and laser perforated PET/CoPE film influence on minimally processed carrot physical parameters were evaluated.

Key words: *biodegradable film, minimally processed carrots, packaging, shelf life.*

1. INTRODUCTION

The carrot is the second most popular vegetable in the world after the potato. Carrot contain: sugar, a bit of proteins, organic acids, minerals- potassium, calcium, magnesium, iron, phosphorus, sodium, iron, chlorine, iodine, vitamins- group B, C, E, K, carotene and many vitamins, folic acid, fibre, a bit of fat, essential oils and other biologically active substances (Heinonen and Meyer, 2002). Carrots are an excellent source of the deep yellow carotenoids that produce vitamin A.

Fresh-cut carrots could be finding on the market place as: whole peeled (baby), sticks, and sliced, shredded, grated and diced. Minimally processed carrots consumed as ready-to-eat snacks or vegetable salads become increasingly popular, however their sale is limited because of rapid spoilage. There is shelf life limitation of minimally processed carrots from 4 to 5 days due to high respiration rate, development of off-flavour, acidification, and loss of firmness, discoloration, and microbial spoilage (Barry-Ryan et al, 2000).

Carrots usually need pealing before packaging. In industrial scale the pealing is normally accomplished mechanically (e.g. rotating carborundum drums) (Ahvenainen et al, 1998). The ideal peeling method should be hand-peeling with a sharp knife (Laurila and Ahvenainen, 2002). Experiments showed that slicing methods for ready-to-use carrots have strong effect on quality and shelf life. Shelf life may be extended by minimizing physical damage through the use of a sharp blade (Barry-Ryan and O'Beirne, 1998). Deterioration of fresh-cut vegetables due to further respiration, transpiration and enzymatic activity of living tissues after harvesting and processing is unavoidable (Nguyen and Carlin, 1994). The visual properties of minimally processed vegetables are brown

discoloration of cut surfaces which have been observed as an undesirable defect of fresh-produce (Watada, 1999; Ahvenainen, 2000). Specific phenomena for the carrots are white blush caused appearance by drying of the damaged (peeled) tissue as the carrots are exposed to air (Simoes et al, 2009). However, white blush may only be delayed for a few days (Discover the power of carrots, 2009).

Very short shelf-life products require preservation methods that will prolong their shelf-life. Packaging is a medium between product manufacturers and consumers (Meroni, 2000), packaging has a significant role in the food supply chain (Ahvenainen, 2003). The main functions of packaging are to extend the shelf life, and maintain the quality and safety of the packed goods (López-Rubio, 2004).

Polymers are the widely used packaging materials for foods (Baner and Piringer, 1999). The shelf life of foods packed in plastics depends on the permeation of gas and water vapour through the packages (Varsanyi, 1986). Polyolefin's (PE, PS), polyesters (PS), polyethylene terephtalate (PET) and polycarbonates (PC) are the principal families of thermoplastics in food packaging (Brown, 1992).

At the time being the application of vacuum and modified atmosphere packaging technologies appeared successful in extending the shelf-life and quality of the food. Fresh vegetables continue to respire after harvesting, and consequently any subsequent packaging must take into account this respiratory activity (Siverstvik et al, 2002; Spencer, 2005). After they are harvested, fruits and vegetables live on and have a limited shelf life (Laurence et al, 1995). The respiration rate is affected by product type and size, degree of preparation, product variety and growing conditions, maturity and tissue type, atmospheric composition and temperature (Kader et al, 1989). Ready to eat whole, chopped, peeled, sliced, wedged or shredded fruits, vegetables and herbs can now stay fresher longer and travel further a field – in equilibrium modified atmosphere packaging (EMAP) (Parry, 1993; Farber et al, 2003). EMAP is an effective method for prolonging the shelf-life of fresh and minimally processed produce. A minimum 2–3% of O_2 is recommended for aerobic conditions. Packaging films with intermediary permeability should be used and EMAP could passively develop within a hermetically sealed package. By flashing packages with 5% CO_2/5% O_2/90% N_2 it is possible to establish a desirable EMAP more quickly (Siverstvik et al, 2002). The packaging films typically used in the fresh produce industry are selectively breathable films that offer high clarity, good sealing, and anti-fog properties.

EMAP technology is certainly not new and was pioneered in Europe in the 1970's. In 2004 PerfoTec launched its online laser perforation system for EMAP. Significant increases in shelf-life can be achieved by the on line PerfoTec laser perforation system, an EMA pack with the optimum O_2 and CO_2 concentrations required by the packaged vegetables. This concept allows packers to perforate the film during the packing process. In this way the best possible film permeability can be made for the actual respiration of each packed product (PerfoTec, 2009)**.** Multivac FreshSAFE is one of methods to extend shelf life; it helps to search for optimal packaging of any product. The efficiency and effectiveness of FreshSAFE have been confirmed by the Institute for Agrotechnology and Food Innovation at Wageningen University in the Netherlands (Multivac, 2009). Micro perforation is adjusted for the product's respiration rate, flexible and quick customization of permeability for different products and one film could be used for variety of products. However, when using these technologies, careful attention must be paid to the effect on the survival and growth of pathogenic organisms (U. S. Food and Drug Administration Center for Food Safety and Applied Nutrition, 2001).

The row materials such as fossil fuel and gas for conventional polymer production could be partially replaced by greener agricultural sources, which should also participate to the reduction of CO_2 emissions (Narayan, 2001). Over the past five years packaging suppliers have been introducing various forms of biodegradable plastics. The market of biodegradable polymers at the present is growing based on considerations that consumers and recycling regulations will drive demand for

environmentally-friendly packaging. Some of the biodegradable polymers have already competitive alternatives to conventional food packaging; polylactate (PLA) is being one most important of them (Haugard and Martensen, 2003).

BIO PLA 121 is fantastic for fresh food products, it is manufactured from NatureWorks PLA – polylactic acid (certified compostable to EN 13432), a polymer derived form cornstarch, an annually renewable product. BIO PLA films comply with the appropriate food contact regulations of the EU member states, the USA and most other countries through the world, they are non-toxic and may be used in direct contact with all types of food. Demand for bioplastics in Europe experienced its first boom in 2006, according to a survey by the European Bioplastics Association. Currently bioplastics account only for less than one percent of the European plastics market. Prospective amount of biodegradable packaging market at 2010 could be about 10% (1st European Bioplastics Conference, 2006). Biodegradable polymers market introduction has started successfully all over Europe (Platt, 2006).European Bioplastics Association estimates the global production capacities of bioplastics to increase six times until 2011. Most important application sectors of biodegradable polymers at the present time are mainly for organically produced foods packaging, conventional fruit and vegetables as well as bread and bakery products, ready-to-eat foods, service packaging, shopping bags, catering products, bio waste bags, mulch films, horticulture auxiliaries. At present PLA is the most widely used biodegradable polymer for fresh-food applications. Presently, biopackaging can be found almost everywhere on the shelves in European supermarkets. Supermarket – Sainsbury in the UK was first who recognized the opportunities for compostable plastics packaging (European Bioplastics, 2007). Supermarket chains such as Delhaize (Belgium), Iper (Italy), Albert Heijn (Netherlands), Migros (Switzerland) and WalMart are actively placing their trust in biopackaging and introduced its first range of fresh produce in PLA (2nd European Bioplastics Conference, 2007; Bastioli, 2005).

Seiyu Ltd., supermarket chain in Japan, on 2009, planed to introduce eco-friendly vegetables-based PLA (polylactic) containers for fresh-cut vegetables and fruits, and to expand that practice throughout Japan (Seiyu introduces biodegradable PLA containers, 2009). Seiyu aims to cut the weight of packaging materials by 5% by 2013 and to increase the sales share of eco-friendly products to 5% by 2012. Washed not peeled crisp baby carrots packed by 150 g in PLA cups with none hermetical lids can be found on the supermarket shelves in Latvia as well.
The objective of this study was to investigate the effect of biodegradable polylactic acid based (PLA) packaging films and thermoformed cups on the EMA development and physical parameters of minimally processed carrots during cold storage at +4±0.5 °C for 15 days packed in passive (air) atmosphere and compare the results to the effect of conventional packaging from PET/Adhesive/PP and laser perforated laminate PET/CoPE films – 12 µm polyester, solvent free laminated to 50 µm co-extruded polyethylene.

2. MATERIALS AND METHODS

2.1. Experimental design

Experiments were carried out at the Department of Food Technology, Latvia University of Agriculture in 2009. The objects of the research: locally in Latvia grown carrots, stored for 4 month at the planter storehouse in conditions +4±0.5 °C temperature and 80% RH were used for minimally processed produce storage experiments and shelf life detection. Medium size roots (2–3 cm dia.) free of defects were selected. Carrots were washed and manually sliced into small discs on the height of 10 to 15 mm. The cut carrots were mechanically processed in abrasive carborundum peeling machine and vacuum packed by 5 kg for delivering to the laboratory. The purpose of such carrot's processing

was to obtain a new kind pellet like diverse on the market product which could be interesting for consumers as snacks.

2.2. Packaging and storage of samples

The study involved preliminary preparation of different polymer pouches from laminatedPET/Adhesive/PP, laser perforated film of PET/CoPE specially designed for fresh carrots packaging**,** BIO PLA 121 transparent film with thickness 25 and 30 μm, and use of BIO PLA containers with non hermetical lids, followed by packaging of minimally processed carrots in passive (air) atmosphere. Carrot pellets were packed by 150±5.0 g in polymer bags size of 160 x 160 mm, made from roll stocks and sealed in passive (air) atmosphere on the vacuum packaging machine Multivac A300 and in ready-made thermoformed PLA containers with non hermetical lids volume of 350 ml. Follow-up to measure the influence of different materials on the colour stability, minimally processed carrot pellets were not chemically treated before packaging to eliminate white blush development. Packages were stored in Commercial Freezer/Cooler ELCOLD at temperature +4±1 ºC (controlled by MINILog, Gresinger electronic) 15 days. The results were reported as averages of those two determinations. At each time of measurement, two identical packages for each packaging material were randomly selected on sampling days (day 0) and after 2, 4, 7, 9, 11, and 14 storage days; six measurement repetitions of each sample were performed. A characteristic of materials used in experiments is shown in the Table 1. The materials for experiments were selected with different water vapor transmutation rate and various thicknesses. The influence of biodegradable polylactic acid based PLA films have been compared to those of conventional polymers to demonstrate the actual performance and preference of biodegradable polymers for fresh produce packaging, comparing with conventional polymers.

Table 1. Characteristics of materials used in experiments

Sample Nr.	Packaging material	Thickness,	Barrier properties	Source
1.	BIO PLA containers with non hermetical lids,	Volume: 350 ml δ=100 μm	—	http://www.bioplastics.lv/
2.	BIO PLA 121 transparent film	δ=25.0 μm	WTR: 70 g/m^2 d ±10% at +23 °C and HR 85%: (ASTM F 1249) OTR: 610 cm^3/m^2 d bar at +23°C and HR 50%: (DIN 53380-3)	BIO PLA 121 transparent films, France, www.polyfilms.eu
3.	BIO PLA 121 transparent film	δ=30.0 μm	WTR: 55 g/m^2 d ±10% at +23 °C and HR 85% (ASTM F 1249) OTR: 500 cm^3/m^2 d bar at +23 °C and HR 50%: (DIN 53380-3)	BIO PLA 121 transparent films, France, www.polyfilms.eu
4.	PET/Adhesive/ PP	δ=65.0 μm	WTR: 10 g/m^2 d ±10% at +23 °C and HR 0%: OTR: 110 ml/m2/24 h at +23 °C and HR 90%:	Tecnopac data sheet
5.	PET/CoPE for fresh carrots packaging laser perforated film	12PET/50CoPE	OTR: 100 cm^3/m^2/23 hours at +23 °C CO_2TR: 500 cm^3/m^2/23 hours at +23 °C	Scan Store® Packaging A/S datasheet, Denmark

The purpose of this study was to investigate and to compare the role of PLA for the fresh cut produce service industry. BIO 121, the film manufactured from poly-lactic acid (PLA) has excellent quality features such as exceptional transparency and high surface gloss. The film is made of annually renewable primary product starch and completely biodegrade into carbon dioxide and water. BIO 121 food contact films are non-toxic and may be used in direct contact with all types of foodstuff. BIO 121 complies with EC regulation 1935/2004/CE, EC 2002/72/EC and amendment 2004/1/EC, 2004/19/EC and 2005/79/EC, as well as with FDA 21CFR 176.170.

One of the commonly used polymer film to package fresh carrots where used laminate PET/Adhesive/PP film, it was compared with laser perforated PET/CoPE film and with PLA films of two different thicknesses, as well as packaging in ready made containers covered with non hermetical lids of PLA by volume 350 ml. This study involved a number of tests to quantify the gas composition in the head spice of packaging made from used films, physical properties of packed carrots, and compatibility properties that would affect the selection criteria for biobased PLA materials to be used for fresh cut vegetable service applications. Based on the results, PLA, PET/Adhesive/PP film, and laser perforated PET/CoPE film performances were evaluated.

2.3. Physical analysis

The following mechanical and physical characteristics were analyzed:

- *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 analyser OXYBABY® V O_2/CO_2. These packs were sampled in duplicate and whole experiment repeated tree times.
- *Moisture content.* Moisture content accordant at the storage time was determined by using verified balance KERN (Germany) with precision ±0.001g; mass loss calculation (%) – were determined by weighing on the electronic scales.
- *Texture measurement.* Texture for minimally processed carrot samples was determined as cutting force (in N) by using TA-XTplus Texture Analyser. Cutting force was determined for six carrot pellet samples. For the sample cutting force determination a special probe with knife edge for a cut test HDP/BSKBLADE SET WITH KNIFE was applied. The maximum cutting force (in N) was detected at the deformation rate 10 mm/s and distance 10 mm. Samples for cutting were placed centrally under the knife edge. Plotting force (in N) versus storage time (in days), the hardness change of carrot pellets in each packaging material was calculated. The maximum cutting force (N) was used as an index for the cut test.
- *Color measurement.* Color measurements were performed during the storage in CIE L*a*b* color system using *Color Tec PCM/PSM* device and the results were expressed as whiteness index (WI) using equation (Bolin and Huxsoll, 1991):

$$WI = 100 - \left[(100 - L^*)^2 + a^{*2} + b^{*2}\right]^{0.5} \quad (1)$$

Where L*, a* and b* are the lightness (L), greenness and (a) and blueness (b) values for the carrot samples at days (day 0) and after 2, 4, 7, 9, 11, and 14 storage days. The whiteness index (WI) was calculated each day of measurement. The *Color Tec PCM/PSM* device was calibrated to a standard white tile. Carrot pellets of 20 from each package (10 pellets per package) were measured for each application and the means of 20 measurements were calculated.

- *Analyses of pH.* During the storage experiments, the pH of the carrot pellets was followed as well. A sample of 50±1 g was followed by a mixer – commercial blender PHILIPS HR

1341/00). The pH was measured with the pH meter 3510 (Jenway) according standard LVS EN 1132.

2.4. Statistical analysis

The results were processed by mathematical and statistical methods. Statistics on completely randomized design were 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 means of hardness, moisture and mass lose by different packaging materials.

3. RESULTS AND DISCUSSION

All samples besides PLA containers were packed and hermetically sealed under passive air ambiance. The suitable atmospheric composition in the package headspace is necessary to avoid the deteriorative processes which limit product shelf-life. The atmosphere in packages of minimally processed carrot pellets stored in Commercial Freezer/Cooler ELCOLD at temperature +4±1 ºC is analyzed to determine the levels of oxygen and carbon dioxide concentration in the head space. Five types of packaging materials were applied. A commercially available and recommended for fresh produce packaging polylactic acid (PLA) based film (25 and 30 µm) packaging, containers made from PLA (volume of 350 ml) with none hermetically closed lids were compare to the effect of two kinds of conventional polymers with various barrier properties – PET/CoPE laser perforated film foreseen for fresh carrots packaging with OTR: 100 cm^3/m^2/23 hours at +23 °C and for comparison PET/Adhesive/PP with OTR: 110 ml/m2/24 h at +23°C and HR 90% and high WTR: 10 g/m^2 d ±10% at +23°C and HR 0%. As it is seen, the oxygen transmitting rate for above mentioned conventional polymers is similar. The initial atmosphere in all packages was not modified – a passive air ambiance (21% O_2 and 79% N_2) was applied.

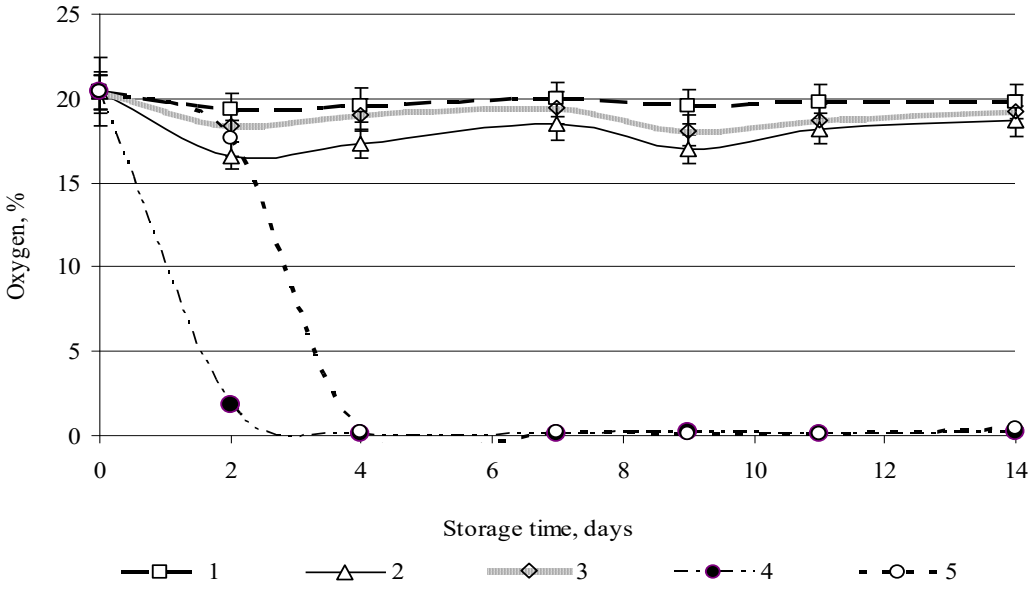


Fig.1. The effect of packaging materials on the headspace oxygen (O_2) concentration (%) in packs with carrot pellets during storage at +4±0.5 °C temperature: 1 – BIO PLA containers with non hermetical lids; 2 – BIO PLA 121 (δ=25 µm) pouches; 3 – BIO PLA 121 (δ=30 µm) pouches; 4 – PET/Adhesive/PP pouches; 5 – PET/CoPE pouches.

In EMAP, the permeation of the package to respiration gases is the main factor used to obtain the adequate atmospheric composition. Consequently, the evolution of gas composition was registered during cold storage. In Figure 1 the dynamics of O_2 concentration is presented, in Figure 2 – dynamics of CO_2 concentration in head space of packages from different materials.

As a result of carrot's breathing the content of O_2 decreases at a set time and CO_2 content increases. The changes of gas composition in different hermetically closed packaging made of various materials are disparate. Packaging carrot pellet within PLA films with different thicknesses generated the most useful modified atmosphere in the range of 16–18% O_2 and 5–10% CO_2 already after 2 storage days, nevertheless those conditions is not the optimum in regard to O_2 concentration, which has been established too high to provide a minimal respiration of fresh vegetables. In future at all the storage time within 15 days equilibrium between O_2 and CO_2 concentration develops. These conditions resulted in retention of quite good textural, aroma and flavor characteristics. Atmospheric conditions obtained with two PLA films were ordered with their respective permeation values, although no significant differences ($p<0.05$) were reached for PLA-25 and PLA-30 (Koide and Shi, 2007) checked the data of gas composition evaluation for green peppers stored in biodegradable PLA-25 film produced in Japan, and after 7 storage days at temperature +10 °C found a similar head space gas composition. In PLA containers the gas composition formed close to atmospheric, with slightly elevated CO_2 concentration.

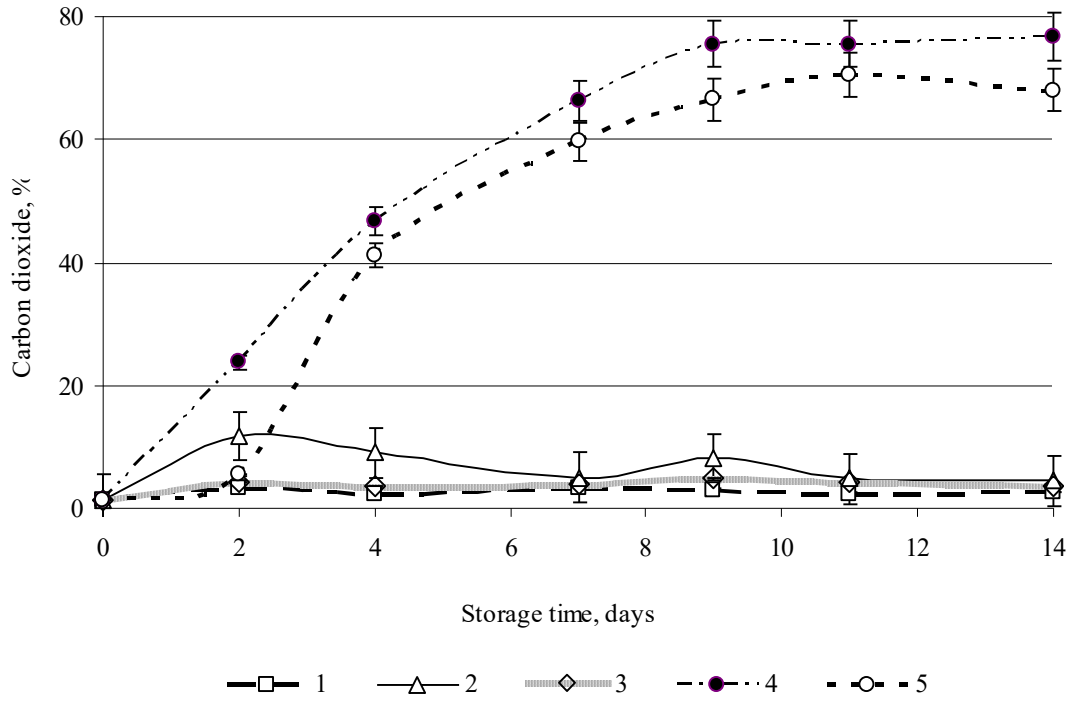


Fig.2. The effect of packaging materials on the evolution of headspace oxygen (CO_2) concentration (%) in packs with carrot pellets during storage at +4±0.5 °C temperature: 1 – BIO PLA containers with non hermetical lids; 2 – BIO PLA 121 (δ=25 μm) pouches; 3 – BIO PLA 121 (δ=30 μm) pouches; 4 – PET/Adhesive/PP pouches; 5 – PET/CoPE pouches.)

By contrast, packaging in PET/Adhesive/PP film showed CO_2 and O_2 content (>20% and <3%, respectively) already at the second storage day and after 4 storage days absolutely anaerobic conditions (CO_2>40%, O_2 – 0%) generated potential harmful for vegetable quality retention. Generally, a high concentration of CO_2 resulted to the suppression of aerobic metabolits and could induce the development of off-flavour due to the change from an aerobic to the anaerobic (fermentative) metabolism (Del Nobile et al, 2006). Although, PET/CoPE laser perforated film has been foreseen from its producer for fresh minimally processed carrots packaging, our experiments proved by facts that after 4 storage days the O_2 content reached the bottom 0% OF O_2 and CO_2>40%, indicating about anaerobic (fermentative) microbiological metabolism to be started in both PET/Adhesive/PP and PET/CoPE film packages.

The equilibrium modified atmosphere (EMA) evolution in head space of PLA film packaging during storage of carrot pellets at +4±0.5 °C temperature is demonstrated in the Figure 3. After 2 storage days CO_2 content increased till 8%, oxygen O_2 content decreased till 17%, the changes in gas composition were not essential till 9 storage days when PLA film of 25 µm were used. After obviously the respiration rate decreased, the O_2 content in the package increased, respectively. An unexpected results showed experiments with carrots packed in non hermetically closed PLA containers – the O_2 content all the storage time remains constant close to ear composition, CO_2 content all the 14 storage days was 3-4%, nevertheless it does not influenced the physical parameters of carrot pellets. It means that cheaper packaging solution could be used.

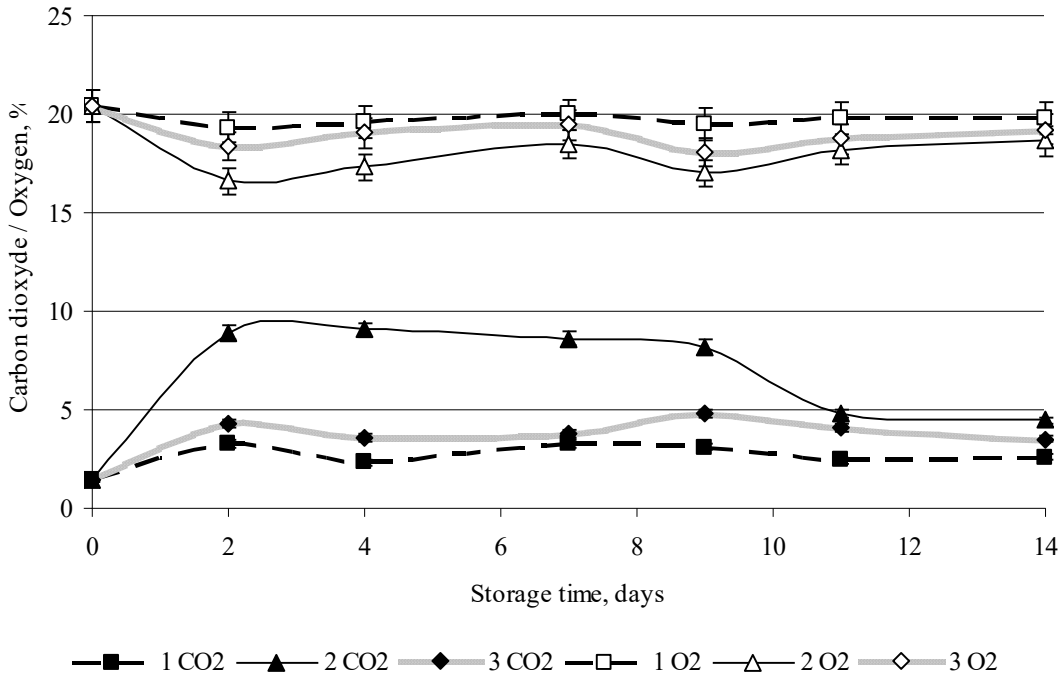


Fig. 3. The EMA evolution in head space of PLA packaging during storage of carrot pellets at +4±0.5 °C temperature: 1 – BIO PLA containers with non hermetical lids; 2 – BIO PLA 121 (δ=25 µm) pouches; 3 – BIO PLA 121 (δ=30 µm) pouches.

Mass losses are a result of drying of the processed carrot tissue and may have contributed to a reduction in appearance scores. Mass loss due to water vapour permeation through the packaging film was measured (Fig. 4). As can be seen, the mass losses are dependent on the packaging material water vapour permeation through the material ($p<0.05$) and are disparate. After 7 to 9 storage days at temperature +4±0.5 ºC in PLA film pouches of both thicknesses samples presented the higher value of mass loss (<0.5%) till 6%, what within 14 storage days gradually increased till 8%. It has been explained with elevated water vapour permeability of PLA films and however equilibrium of gas composition established, respiration rate of carrot pellets was high. Despite the gas composition in PLA containers was close to air composition, mass loses in this packaging was < 2% at the end of 14 storage days, yet the decrease of mass in PET/Adhesive/PP and PET/CoPE was noteless – close to 0%.

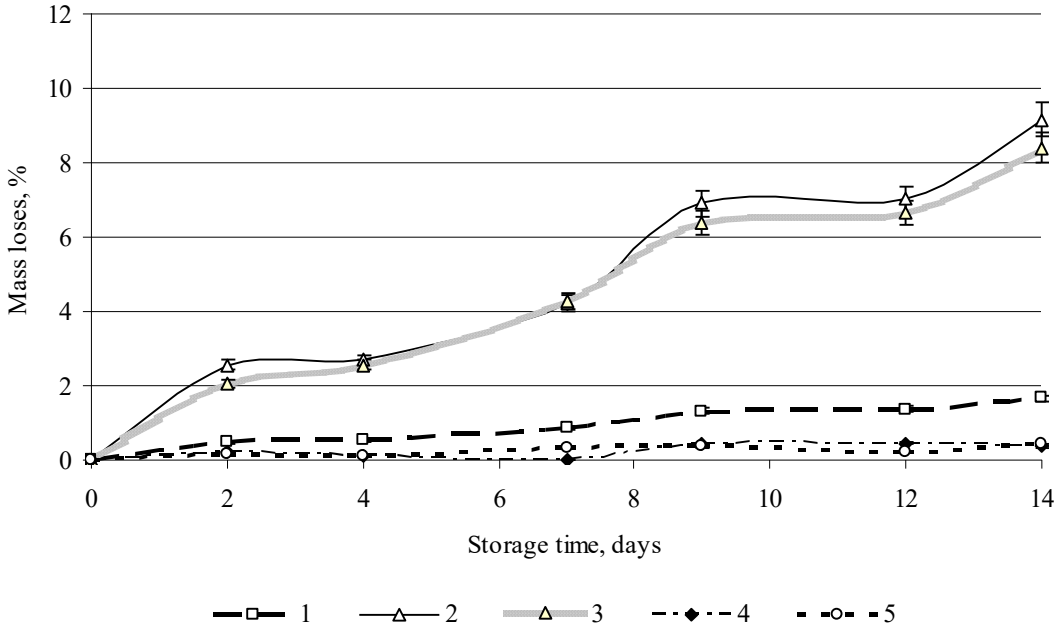
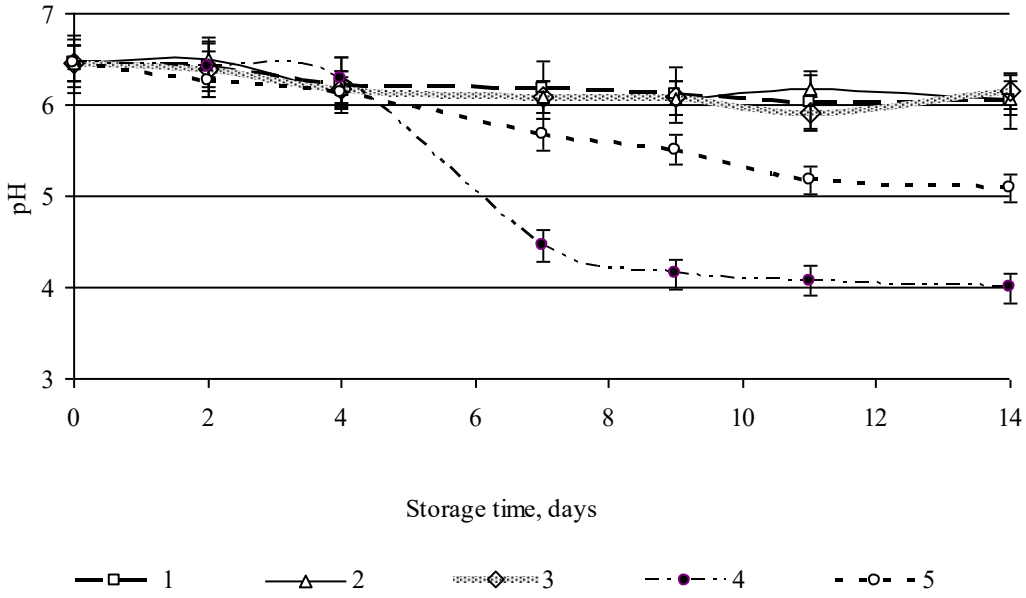


Fig.4. Effect of packaging materials on mass losses of carrot pellets during storage at +4±0.5 °C temperature:1 – BIO PLA containers with non hermetical lids; 2 – BIO PLA 121 (δ=25 µm) pouches; 3 – BIO PLA 121 (δ=30 µm) pouches; 4 – PET/Adhesive/PP pouches; 5 – PET/CoPE pouches

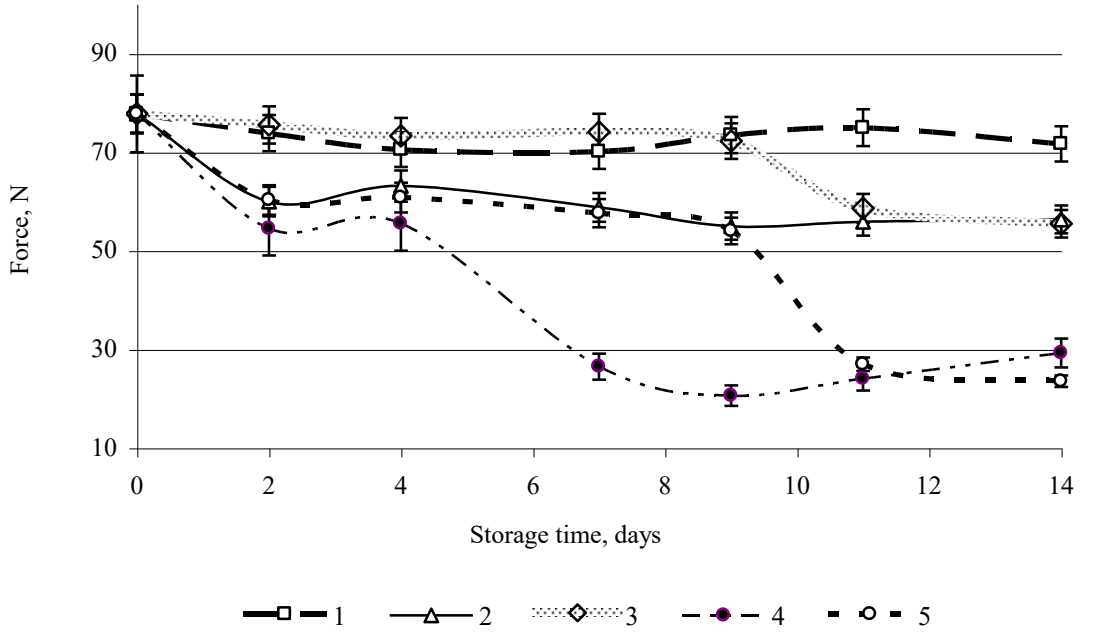
The pH values of minimally processed carrot pellets in different packages are illustrated in Figure 5. All three investigated PLA material constitutive influence on the pH value at the storage time does not observed ($p>0.05$). The most rapid rate of decrease occurred in packages made from conventional polymers when the pH as of fourth storage day dropped down significantly from initial value 6.4 to 4.1 after during the storage till 14 days. In this case the pH value decrease is related with increase of CO_2 content at the storage time, obviously witch have been as a result of microbiological reactions in anaerobic conditions, sugar utilization and rapid carbon dioxide release (Figure 2). Subjective evolution of appearance of carrots were made throughout the 14 day storage period, deterioration was noticed already at the fourth storage day – in anaerobic ambience the carrots became tender and glutinous with unpleasant acidulated odor. On the contrary, the pH changes of carrots packed in all

biodegradable polylactic acid (PLA) based packages were not remarkable ($p<0.05$), as could be prospective according with established aerobic conditions in the packages.

The fresh carrot pellet firmness described by cutting force (N) at the 0 day was 78 N, at the storage time it was affected by packaging material. As shown in Figure 6, changes on firmness varied with the permeability of film.



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PLA

121 (δ=25 µm) pouches; 3 – BIO PLA 121 (δ=30 µm) pouches; 4 – PET/Adhesive/PP pouches; 5 – PET/CoPE pouches

The phenomena observed was that the firmness of carrot pellets packed in PLA containers does not change, however the gas composition in containers was close to that of air composition. Carrots packed in films with higher barrier properties decreased their firmness till 20 N during storage (PET/Adhesive/PP and PET/CoPE pouches), while the firmness of samples packed in both PLA films did not varied essentially, was allowable and decreased till 55 N after 11 storage days, in the core the pellets were crisp and juicy. The decrease in firmness of carrot pellets in response to high CO_2 content (> 60%) and microbial spoilage appears to be common characteristics of vegetables. Changes on firmness are related with other factors such as moisture and weight loss at the storage time as well.

Colour is an important attribute because it is usually the first property the consumer observes. The Hunter (L*, a*, b*) values were measured in order to describe the Whiteness index WI changes of fresh and stored carrot pellets. The WI at each experimental day has been calculated using equation (1). The effect of packaging materials and passive initial air atmosphere on the color (WI) changes of minimally processed carrot pellets is shown in Figure 7.

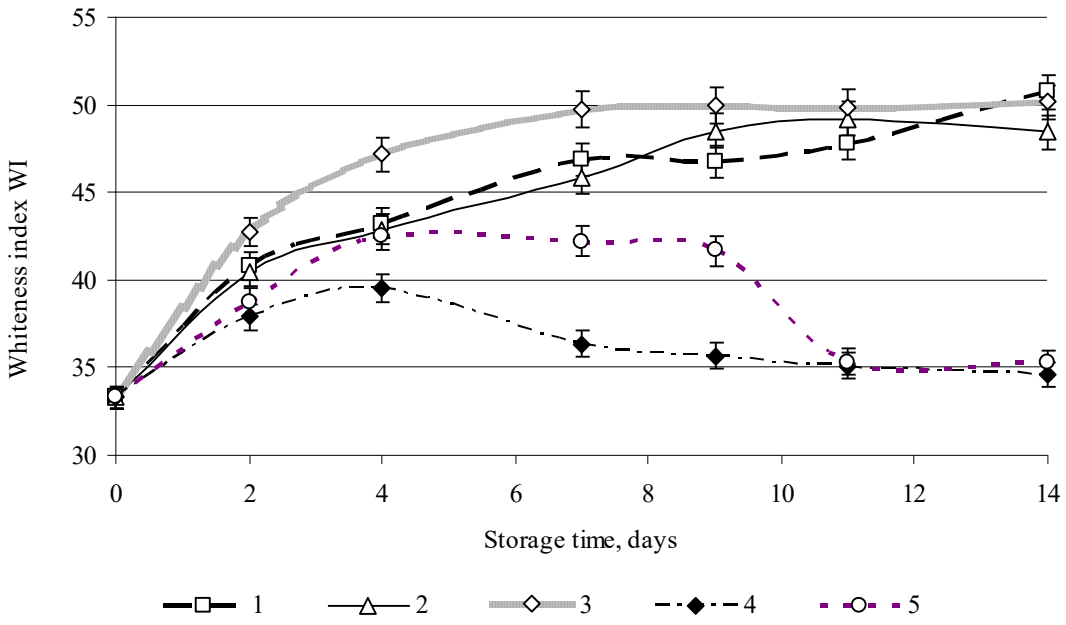


Fig.7. The effect of packaging materials on the color (whiteness index) changes of minimally processed carrot pellets during cold storage at +4±0.5 °C temperature: 1 – BIO PLA containers with non hermetical lids; 2 – BIO PLA 121 (δ=25) pouches; 3 – BIO PLA 121 (δ=30) pouches; 4 – PET/Adhesive/PP pouches; 5 – PET/CoPE pouches.

As chemicals was not used to protect the typical orange color of carrots, the results showed that the whiteness index of samples changed significantly ($p<0.05$) during 14 days of storage in all three used PLA packaging materials; still at the end of storage the disparity among them was not noticed. The Whiteness index of samples packed in conventional PET/Adhesive/PP and PET/CoPE pouches during the first 4 storage days increased similarly as in PLA packed, though in after days due to low water vapour transmitting rate, O_2 content decrease close to 0% and CO_2 content rise above than 40%, WI

gradually decreased and after 11 storage days was the same as before packaging – the surface of carrot pellets became wet, sticky and product was quite spoiled.

4. CONCLUSION

The physical parameters of minimally processed carrot pellets stored in biodegradable polylactic acid (PLA) based film packages thickness of 25 and 30 µm, PLA containers volume of 350 ml, and conventional polymers PET/Adhesive/PP pouches and PET/CoPE pouches were determined and results compared. No remarkable difference in colour, hardness and mass losses among two thickness PLA film packaging after 14 storage days at +4±0.5 °C temperature was observed. None hermetically closed PLA containers could be suggested for successful carrot pellet packaging. Shelf life of minimally processed carrots packed in polylactic acid (PLA) based packaging could be 7 to 8 days, in conventional polymer packaging – only 3 to 4 days. The results suggest that biodegradable PLA packaging to be successful alternative to the conventional polymer packaging.

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