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USE OF PACKAGING MATERIALS FOR EXTENDING THE SHELF LIFE OF DIPLOID PLUM VARIETY 'KOMETA'

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Polymers (films, bags and boxes) are the most widely used materials for packing of fresh fruit. Product shelf life is dependent on the packaging material barrier properties, including permeability of CO_2 and O_2. It focused on the uses of environmentally friendly biodegradable packaging materials for fresh fruit storage. Polypropylene, polylactic acid boxes and cardboard boxes placed in polylactic acid material bag were tested as packaging materials to extend the shelf life of diploid plum cultivar 'Kometa'. Qualitative characteristics of plum (weight, firmness, soluble solids content and colour changes) stored at temperature +4 ± 1 °C for 20 days were evaluated. Sensory evaluation was performed using a 9-point hedonic scale. Plum in good quality can be stored at the temperature +4 ± 1 °C for 12 days on average. Selective gas and moisture barrier properties of polylactic material ensured minimal weight loss in hermetical containers, but promoted plum ripening and hence a reduction of the storage period. The results suggested that biodegradable packaging materials could be a successful alternative to the conventional polymers for plum packaging, and could contribute to reduction of environmental pollution.

Key words: *biodegradable packaging, plum storage, quality indices.*

INTRODUCTION

Fresh fruit and berries commercially are packed, stored and sold in small quantities. In the food industry one of the most widely used packaging materials are polymers. The most popular materials are polypropylene, polyethylene, low and high density polyethylene and other films with different thickness. Dishes (trays) manufactured from polystyrene and wrapped in PVC film or hermetically sealed by melting the polymer film, are also used for packaging of soft products (including fruit, berries and vegetables). Fresh fruit shelf life is dependent on the packaging material barrier properties. Material gas permeability is one of the most important factors affecting product quality.

As the fruit in the respiration process consumes O_2, and concentration of CO_2 in the package increases, permeability of the packaging material must provide sufficient intake of oxygen in order to prevent the formation of anaerobic conditions and partial elimination of carbon dioxide from the packaging (Ke *et al*., 1991; Montanez *et al*., 2010). Therefore, it is advisable to keep fresh fruit in a modified atmosphere in equilibrium, which could be ensured choosing polymeric packaging materials with selective gas permeability. Over the past five years packaging suppliers have been introducing various forms of biodegradable plastics with selective gas properties. Some of the biodegradable polymers have already become competitive alternatives to conventional food packaging, and polylactate is considered as one the most important for fresh-food applications (Haugard and Martensen, 2003). 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 (Platt, 2006). Presently, biopackaging can be found almost everywhere on shelves in European supermarkets. Washed and unpeeled crisp baby carrots packed in 150-g portions in polylactic acid (PLA) cups with non-hermetic lids can be found on supermarket shelves in Latvia as well. However, until now PLA materials were not used for fresh fruit packaging in Latvia.

Plum fruits are highly perishable, characterized by short postharvest life at room temperature; therefore their harvest date is a crucial factor for market life and consumer acceptance (Crisosto *et al*., 2004). Today most plums in commercial production are classified as Japanese (diploid) or European (mostly hexaploid) types. Japanese plums (*Prunus salicina* and its hybrids) are mostly used for fresh markets, while European plums (*P. domestica*) may be eaten fresh or processed in a variety of ways (Okie and Ramming, 1999). Marketers usually sell plums in loose form, which shortens their shelf time significantly. Different technologies have been studied to prolong the storage time of plums. The use of modified packaging atmosphere (MAP) or box liners was a good approach to reduce 'Friar' plum (*Prunus salicina*) weight loss and maintain fruit flesh appearance for cold storage periods up to 45 days (Cantin *et al*., 2008). Positive effects of 1-methylcyclopropene were observed in terms of inhibition of ethylene production and delays of the physical, chemical, and biochemical changes associated with ripening of plum cultivars ‘Santa Rosa’ and ‘Golden Japan’ (Martínez-Romero *et al*., 2003; Salvador *et al*., 2003). The most important parameters that determine plum market life potential are fruit quality attributes, such as content of soluble solids, firmness and colour. In general, all of these properties determine consumer acceptance.

The early maturing diploid cultivar ‘Kometa’ (‘Kubanskaya Kometa’) (Еремин, 2006) is one of the most widely grown cultivars in Latvia and also several other countries (Kaufmane *et al*., 2007). The cultivar is popular due to its winter hardiness and disease resistance, and is one of the tastiest of the early plums. In the good ripeness stage ‘Kometa’ has a large fruit (33.2 g) with a firmness (2.5 kg cm^2) suitable for transportation, medium total soluble solids (10.6 Brix%) and acids (2.1%) content, and is excellent for fresh consumption (LV grant project, 2007, Nr. 030507/S92).

To the best of our knowledge, only a few studies on diploid plum postharvest performance using biodegradable polymers have been conducted. The aim of the present study was to evaluate the effect of different potential biodegradable packaging materials on the quality of plums during cold storage.

MATERIALS AND METHODS

The study focused on the uses of environmentally friendly new biodegradable packaging materials for fresh fruit storage.

Sample supply and packaging. The experiments were carried out at the Latvia State Institute of Fruit Growing in 2008. The object of the research was diploid plum ‘Kometa’ *(Prunus salicina x cerasifera*) grown in Dobele (Latvia). The fruits were manually picked at the end of July, selected in the laboratory according to similar size and colour, randomised and divided into packaging treatments on the same day. The effect of packaging material on plum quality during cold storage was determined by using the packaging treatments:

- biodegradable polylactic acid (PLA) packaging form — boxes (130 × 90 × 70 mm) manufactured with holes (total area of holes 7.9 cm^2);
- cardboard boxes (145 × 120 × 80 mm) placed in PLA film pouches, thickness 40 μm;
- polypropylene (PP) boxes (180 × 110 × 80 mm) manufactured with holes (total area of holes 14.3 cm^2) . These are typically used for fruit packaging and were used as a control.

The average sample weight in PP and PLA boxes was 400 g, but in cardboard boxes placed in PLA film pouches containing 360 g were used.

Storage conditions and analyses of samples. Samples were stored in a “Commercial Freezer/Cooler ELCOLD” at temperature +4.0 ± 1 °C in light, controlled by MINILog Gresinger for 20 days. Physical and chemical properties of plums, such as weight, firmness, total soluble solids content, colour changes and sensory analyses, were evaluated. At each time of measurement, three identical packages for each packaging mode were randomly selected on days 4, 8, 12, 16 and 20 of storage.

Loss of fruit weight was measured for each package, weighed with accuracy of 0.01 g. The weight losses were calculated as % of the initial plum weight in the package.

Firmness of intact fruit (kg cm^{-2}) was determined by penetrometer (Fruit firmness tester, TR Turoni S.r.l., Italy) equipped with a 8 mm diameter probe.

Soluble solid content (Brix%) of the plum juice was measured with a temperature compensated refractometer Atago N20 (ATAGO, Japan) according to standard LVS EN 12143 : 2001.

Colour of fruit skin was measured in a CIE L*a*b* colour system by Colour Tec PCM/PSM (COLORTEC, USA). The colour measurements were performed on 10 fruit and expressed as a Hue angle (h°). To evaluate the effect of packaging on plum quality, the total colour difference E was calculated (MacDougall, 2002).

Sensory evaluation (the overall like-dislike) was performed by trained panellists (n = 12) using a 9-point hedonic scale (Robertson *et al*., 1992).

Statistical evaluation. Data processing was carried out by General Linear Model procedure in the SPSS 17 software package. The Scheffe criterion was used to determine significant differences ($P < 0.05$) among the studied packaging treatments.

RESULTS

During cold storage plum weight loss increased significantly ($P < 0.05$) depending on the selected packaging material (Fig. 1). During 20 storage days, mass losses of plums packed in polypropylene (PP) and polylactic acid (PLA) boxes were the highest (4.9 and 4.2%, respectively) in comparison with cardboard boxes placed in hermetically closed PLA film pouches (2.8%). After the first four days of storage, plums lost 1.6% moisture in control packaging, while only 0.7% in hermetically closed package (cardboard boxes placed in PLA pouches). There was no significant difference ($P > 0.05$) between moisture losses in the PP and PLA boxes after 8 and 12 days of storage, but during the last week, plum weight was decreased more in PP boxes. Total area of holes for PP boxes was two times larger than for

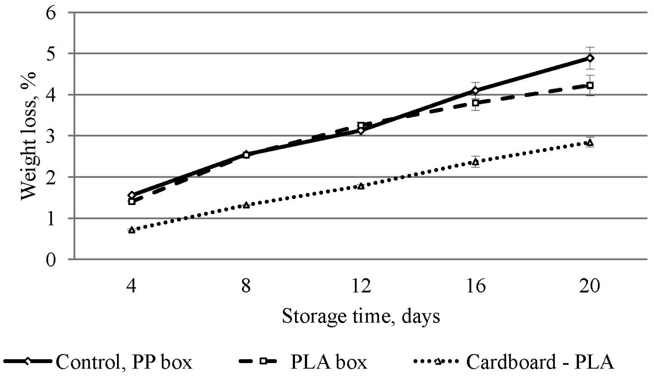

Fig. 1. Weight loss (percent of initial fresh weight) of 'Kometa' during storage at +4.0 ± 1 °C in different packaging materials. Abbreviations as in Table 1.

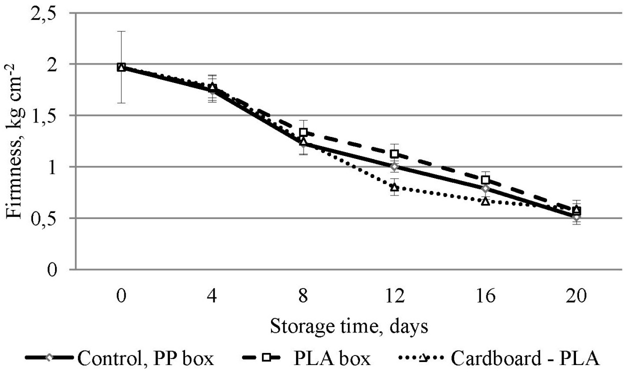

Fig. 2. Firmness of 'Kometa' during storage at +4.0 ± 1 °C in different packaging material. Abbreviations as in Table 1.

PLA boxes (14.3 and 7.9 cm^2, respectively), which allowed faster drying of plums. The airtight containers, according to material selective gas and moisture permeability, ensured minimal weight loss, but still promoted ripening of plums.

The changes of plum firmness during storage characterised fruit ripening degree. At the beginning of study, plum firmness was 2.0 kg cm^{-2} for the tested 'Kometa'. After 8 day storage the firmness of plums was not significantly ($P > 0.05$) influenced by packaging type (Fig. 2). After 12 days of storage, plum firmness in cardboard boxes placed in PLA pouches was slightly higher, but not significantly different compared with PP packaging (1.0 and 1.1 kg cm^{-2}, respectively), but plums in hermetical PLA pouches were softer (0.8 kg cm^{-2}). This can be explained by influence of the appropriate equilibrium atmosphere.

At the beginning of experiment total soluble solid content for 'Kometa' was 8.7 Brix%, characterising a slightly unripe plum stage. The total soluble solid content changed during storage, but during the first two weeks a significant difference ($P > 0.05$) was not observed (Fig. 3). Total soluble solids content in cardboard boxes placed in PLA pouches (9.1 Brix%) had increased at day 12 of storage and in PP packaging (9.2 Brix%) after 16 days of storage. The sensory evaluation also indicated differences between samples packed in various materials, which might be due to

Table 1

QUALITY OF 'KOMETA' PLUMS ESTIMATED BY SENSORY PANELLISTS (n=12)

Storage time, days	Packaging type			
	before packaging	control, PP box	PLA box	cardboard - PLA
0	5.9*			
4		5.8	5.7	5.7
8		6.2	6	6.5
12		6.6	6.5	5.7
16		5.4	5.8	5
20		4.9	5	4.7

Control, PP box — polypropylene (PP) boxes (180 × 110 × 80 mm; total area of holes 14.3 cm^2); PLA box, polylactic acid (PLA) boxes (130 × 90 × 70 mm; total area of holes 7.9 cm^2); cardboard – PLA, cardboard boxes (145 × 120 × 80 mm) placed in PLA film pouches, thickness 40 µm.

*Degree of liking: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 =like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely

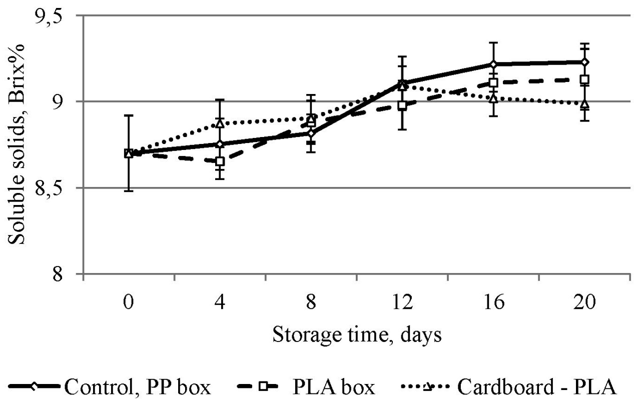

Fig. 3. Soluble solids content of 'Kometa' during storage at +4.0 ± 1 °C in different packaging material. Abbreviations as in Table 1.

changes of acids and other organic compounds during plum ripening.

Taking into consideration the specific characteristic of diploid plums that at room temperature they ripen well, which ensures adequate quality and taste, fruits with initial Hue value 15.2 (more red skin colour tone, a* = 21.7 and b* = 5.9, respectively) were selected. Results of colour measurements showed that the slowest change in Hue angle occurred in PLA and PP boxes, and the most rapid in cardboard boxes placed in PLA pouches (Fig. 4). After four days of storage, the largest Hue angle value (22.7) was observed for plums in cardboard boxes placed in PLA pouches, while in the control PP and PLA boxes it was lower (15.0 and 18.5, respectively). Compared with the control packaging, the total area of holes for PLA boxes was smaller, which may have caused increased accumulation of CO_2 and O_2 around the fruit due to faster plum ripening. During further storage, colour of the plum skin became darker for all samples, and at the end reached 7.1 in control PP and 10.6 in PLA packaging. The skin colour tone (Hue

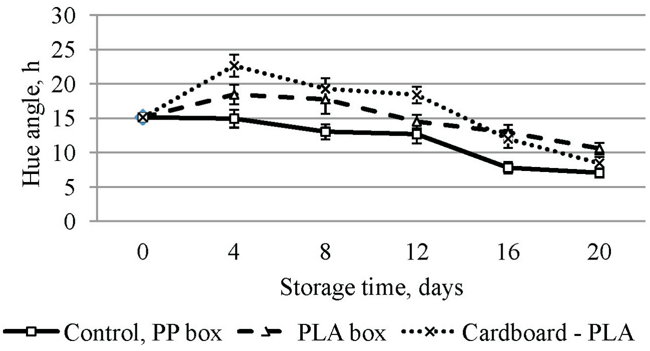

Fig. 4. CIE L* a* b* colour space (expressed by Hue angle) of 'Kometa' during storage at +4.0 ± 1 °C in different packaging material. Abbreviations as in Table 1.

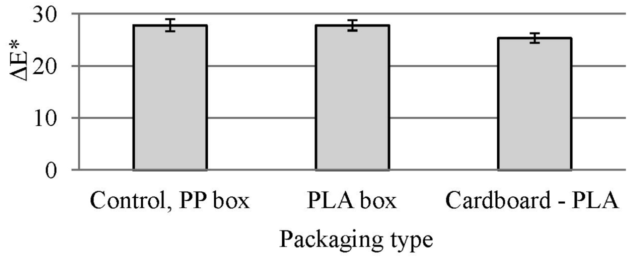

Fig. 5. The total colour difference (ΔE*) of 'Kometa' during storage at +4.0 ± 1 °C in different packaging material. Abbreviations as in Table 1.

value of 8.5) differed for plum fruit in cardboard boxes placed in PLA pouches ($P < 0.05$). Regarding the total colour difference (E*), fruit colouring differed significantly ($P < 0.05$) in the hermetical PLA pouches compared to the other packaging, but there was no significant ($P > 0.05$) difference between the total colour difference in PP and PLA boxes (Fig. 5).

Sensory analysis showed that optimal shelf-life of packed 'Kometa' fruit at temperature +4 ± 1 °C is about 12 days. The panellists also observed differences in quality of plums depending on packaging (Table 1). Plums packed in cardboard boxes placed in PLA pouches were evaluated as the tastiest after 8 days of storage (6.5), while for plums in control PP and PLA boxes equivalent sensory evaluation was reached after 12 days (6.6 and 6.5, respectively). This again indicated plums in hermetical PLA pouches ripen faster. Breathable and biodegradable lidding films with an appropriate oxygen transmission rate can create a modified atmosphere in equilibrium and maintain quality of fresh fruit produce during storage.

DISCUSSION

In a gas tight container, living vegetables and berries will modify the atmosphere due to respiratory O_2 uptake and CO_2 output. Consequently, packaging material has low permeability, anaerobic conditions will soon prevail and cause odours and poor flavours. With highly permeable packaging materials, the in-pack atmosphere will be similar to that of the external atmosphere composition, and respiration will not be reduced (Day, 1993). In our experiment the gas composition in packages was not estimated, but on the basis of our previous studies, it is likely that when PLA packaging material was used, CO_2 was removed insufficiently, which promoted the ripening process of plums (Dukalska *et al.*, 2008). Decreased fruit firmness during storage is associated with polysaccharide hydrolysis and changes in fruit flesh cell structure (Prasanna *et al.*, 2007). The changes of fruit cell walls are dependent on content of protopectin and enzyme activity. In addition, fruit tissue softening during ripening and senescence is triggered by ethylene (Gorny *et al.*, 2002). As reported by Goliáš (2007), plum (*Prunus domestica*) skin and flesh softening was lower at low O_2 and higher CO_2 concentrations, especially during shelf life. After 60 days of cold storage, plums (*Prunus salicina*), packed in modified atmosphere packaging box liners with higher CO_2 and lower O_2 levels had a higher incidence of chilling injury symptoms (Cantin *et al.*, 2008). According to Manganaris *et al.* (2008), uses of refrigeration technologies can reduce plum softening, but long-term storage under 0 °C promotes development of chilling injury (CI) symptoms. The results indicated that the development of CI symptoms in 'Fortune' plums is associated with abnormalities in cell wall metabolism, including a reduction in pectin solubilisation and depolymerisation and decreased ripening-associated modification of galactose-rich pectin polymers. In our study, various CI symptoms, such as gel breakdown, flesh bleeding, and flesh translucency (overripe) were visually evaluated during storage, immediately after cutting plums in half (Fig. 6). Our results suggest that the development of chilling injury in plums is related to climatic adaptations of the cultivar, storage conditions and packaging.

Diploid plum cultivar 'Kometa' can be stored in good quality for 12 days on average at temperature +4 ± 1 °C, depending on packaging material. Selective gas and moisture barrier properties of polylactic material ensured minimal weight loss, but promoted plum ripening and hence a reduction of the storage period. Sensory evaluation of plums showed that, using hermetical PLA packaging, its shelf life is 8 days without substantial changes of quality. The results

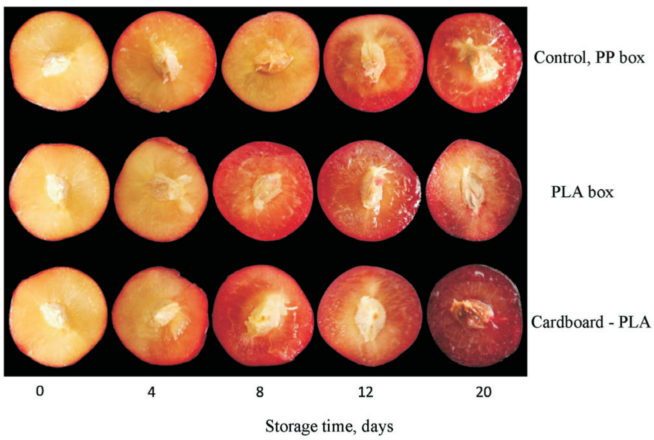

Fig. 6. Effect of packaging on 'Kometa' flesh colour changes during storage at +4.0 ± 1 °C (before packaging, and on days 4, 8, 12 and 20 of storage).

suggested that biodegradable packaging materials could be a successful alternative to the conventional polymer for plum packaging, and could contribute to reduction of environmental pollution.

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IEPAKOJUMA MATERIĀLU IETEKMES IZMANTOŠANA, LAI PAGARINĀNU DIPLOĪDĀS PLŪMJU ŠĶIRNES 'KOMETA' UZGLABĀŠANAS LAIKU

Polimēri (plēves, paciņas, kastītes) ir tirdzniecībā plašāk lietotie iepakojuma materiāli svaigu augļu iesaiņošanai. Produktu uzglabāšanas laiks ir atkarīgs no iepakojuma materiālu barjerīpašībām, tajā skaitā CO_2 un O_2 caurlaidības. Pētījums veikts Latvijas Valsts augļkopības institūtā 2008. gadā un vērsts uz videi draudzīgu biodegradējamo iepakojumu materiālu izmantošanu svaigu augļu uzglabāšanai. Pētījuma gaitā diploīdās šķirnes 'Kometa' plūmes ievietotas polipropilēna, polilaktīdskābes materiālu kārbiņās un kartona kārbiņās, kas savukārt ieliktas polilaktīdskābes plēves maisiņā. Plūmes uzglabātas 20 dienas +4 ± 1 °C temperatūrā, nosakot to kvalitatīvos rādītājus: masas zudumus, blīvuma, šķīstošās sausnas satura un krāsas izmaiņas. Plūmju sensorās analīzes veiktas, izmantojot deviņu punktu hedonisko skalu. Labā un tirdzniecībai piemērotā kvalitātē plūmes +4 ± 1 °C temperatūrā var uzglabāt vidēji 12 dienas. Polilaktīdskābes materiālu selektīvās gāzu un mitruma barjerīpašības hermētiski noslēgtos iepakojumos nodrošināja minimālus mitruma zudumus, taču paātrināja plūmju nogatavošanos, samazinot uzglabāšanas laiku. Pētījuma rezultāti liecina, ka plūmju iepakošanu biodegradējamos iepakojuma materiālos var veiksmīgi izmantot kā alternatīvu tradicionālajiem polimēru materiāliem, un tas būtiski mazinātu vides piesārņojumu.