Effect of edible coating on destructive and optical properties of plum during postharvest

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Abestract:

Edible coatings can extend post-harvest life of fruits showing high transpiration rate. In this context, incorporation of plasticizers as additives could further improve the properties of the edible coatings. In the present study, the potential of a Versasheen®-based edible coating with sorbitol as plasticizer to improve storage life and keeping quality was evaluated on two cultivars of European plum (*Prunus domestica* L.), i.e. 'Jojo' and 'Tophit plus'. Fruit were harvested at commercial harvest and stored at 2 ± 0.5 °C for up to 28 d plus 2 d at 20 °C to simulate shelf life. Every seventh day, samples were removed from storage and non-destructively analysed considering transpiration rate and laser light backscattering imaging (LLBI; at a wavelength of 785 nm). Finally, fruit flesh firmness, soluble solids content, and titratable acidity were determined destructively. Results indicated that the Versasheen® (5%)-based coating plus sorbitol (0.2%) is a useful tool to delay fruit quality losses during cold storage (2ºC) and during shelf life. Coating of fruit of both cultivars increased their surface resistance against water vapour transfer resulting in lower transpiration rates and thus lower mass losses compared to controls. Consequently, coating of fruit considerably delayed the decrease in flesh firmness. Moreover, edible coating retarded the increase of FWHM785 in coated plums. In this context, FWHM785 proved as a rapid and non-destructive tool to monitor changes in mechanical properties in heavily coloured plums. Results highlight that edible coatings successfully extend post-harvest life of plums.

Keywords European plum, edible coating, Versasheen®, transpiration, backscattering.

1. Introduction

Coatings act as barriers against the diffusion of water vapour, O_2 and CO_2. Thus, they may maintain appearance and texture of fruit through modification and control of the internal atmosphere of the individual fruit similar to modified atmosphere storage (Turhan 2009, Vargas et al. 2008). Skin morphology and physiology of the fruit commodity are also important to control mass transfer of coated fruit (2011). Furthermore, the addition of active agents such as antioxidants and fungicidal or antimicrobial substances to the coatings can further help to restrict insect infestation and growth of micro-organisms (Krochta and DeMulderJohnston 1997).

Several studies reported the use of edible coatings for maintenance of fruit quality. In this context, chitosan was used in peaches (Li and Yu 2001), strawberries (Vu et al. 2011) and plums (Bal 2013). In other investigations, whey protein was used as coating for plums (Reinoso et al. 2008), while alginate was applied for sweet cherries (Diaz-Mula et al. 2012), plums (Valero et al. 2013) and peaches (Maftoonazad et al. 2008). In some cases, however, edible coating did not show meaningful results or even degraded fruit quality. Here, coatings induced fruit disorders by inhibition to O_2 and CO_2 exchange, thus resulting in anaerobic respiration (Yehoshua 1969).

Versasheen® (National Starch & Chemical Ltd, Hamburg, Germany) is a carbohydrate-based product, obtained from of high amylopectin-consisting waxy maize starch (99 %; Eum et al. 2009). Versasheen® dissolves easily in water, has low viscosity at high solids concentrations and is very simple to use because it requires very little drying time (Larrigaudiere et al. 2009, Sablani et al. 2007). In general, it is industrially applied to enhance the appearance of dry products such as bake products, bread and pastries. Only few papers, however, reported the application of Versasheen® coatings on fresh produces.

Furthermore, new non-destructive methods became available, which potentially may serve for non-invasively monitoring changes of fruit quality in storage. Amongst others, laser light backscattering imaging (LLBI) has been introduced to investigate variations in the quality related optical properties in fruit tissues (Baranyai and Zude 2009, Kurenda et al. 2014, Mollazade et al. 2013, Qing et al. 2007a, 2008, Romano et al. 2010).

Consequently, the objective of this study was to comprehensively evaluate the performance of this new non-destructive method and compare it with standard techniques to efficiently monitor the effect of edible coatings on the quality maintenance in two cultivars of European plum ('Jojo' and 'Tophit plus')(Turhan 2009).

2. Material and methods

2.1. Edible coating treatment and storage condition

'Jojo' and 'Tophit plus' plums (*Prunus domestica* L.) were picked in an experimental orchard near Potsdam (Germany) at commercial harvest date (137 DAFB and 140 DAFB for 'Jojo' and 'Tophit plus', respectively) in 2013 and immediately transferred to the laboratory. Fruit free of visual defects were selected, sorted into two batches each and subjected to initial analyses (see below). Plums of one batch each (n = 270 for each cultivar) were dipped in a solution of 5% Versasheen® (National Starch & Chemical Ltd, Hamburg, Germany) plus 0.2% sorbitol as plasticizer for 60 s, while fruit of the other batches were dipped in distilled water as controls. All fruit were then dried on metal nets at 20 °C for 3 h. Afterwards, plums were subjected to initial analyses and then stored in plastic boxes (3-5 kg) at 2 °C ± 0.5 °C and 90% ± 2% RH for up to 28 d plus 2 d at 20 °C. During storage, selected plums were removed after 7, 14, 21, 28 and 30 d of storage and analysed.

2.2. Fruit quality analysis

2.2.1. Fruit transpiration, total resistance, flesh firmness, soluble solids content, and titratable acidity

2.2.2. Laser light backscattering imaging

2.3. Statistical analysis

Analyses of variances (ANOVA) were performed using SAS software (Version 9.3., SAS Institute Inc. Cary, USA). The main effects of edible coating on quality of 'Jojo' and 'Tophit plus' plums were analysed as a factorial ANOVA, using the 'GLIMMIX' procedure (PROC GLIMMIXED).

3. Results and Discussion

3.1. Effects of edible coating on internal plum quality

In the present study, coating fruit with Versasheen® plus sorbitol successfully reduced transpiration and increased fruit resistance to water vapour losses in both 'Jojo' and 'Tophit plus' plums (Fig. 1). In a previous study of Eum et al. (Eum et al. 2009), treatment with Versasheen® plus sorbitol but also Versasheen® alone also reduced mass losses in Sapphire' plums. However, these authors assumed that higher mass losses in uncoated plums during storage were mainly caused by higher respirational CO_2 losses. The differences between transpiration rates and resistance to water vapour losses of 'Jojo' and 'Tophit plus' plums observed during storage, may indicate different fruit epidermal and cuticle structures of the fruit of these cultivars (Valero et al. 2013).

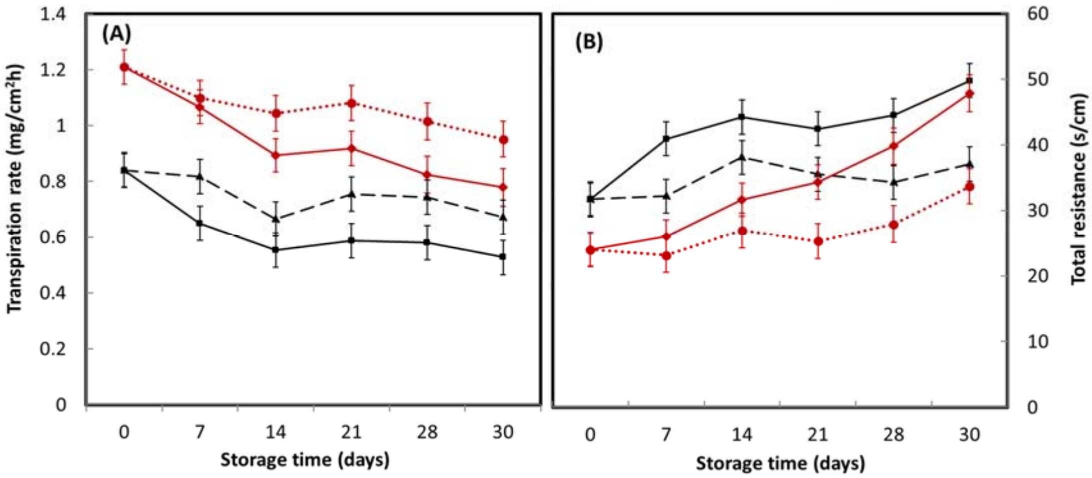

Fig. 1 (A) Transpiration rate and (**B**) total resistance to water vapour transfer of controls (dashed lines) and coated (full lines) 'Jojo' (squares and triangles) and 'Tophit plus' (diamonds and circles) plums during storage at 2 °C for 28 d plus 2 d at 20 °C. Vertical bars represent 95% confidence intervals of the means (n=42). Measurements were performed at 21.0 ° C ± 0.5 °C and 57% ± 3% rH.

Versasheen® coatings plus sorbitol indeed significantly slowed down softening in cold stored 'Jojo' and 'Tophit plus' plums (Fig. 2A, Tab. 1). These results, thus, reflect earlier findings on 'Sapphire' plums obtained during 4 d of storage at room temperature (Eum et al. 2009). In addition to the decrease in water losses, application of coating materials may also inhibit ripening induced changes in biochemical cell wall properties, e.g. by conversion of insoluble protopectins into soluble pectins (Krishna and Rao 2014), which in turn protects cell wall structure (Bal 2013).

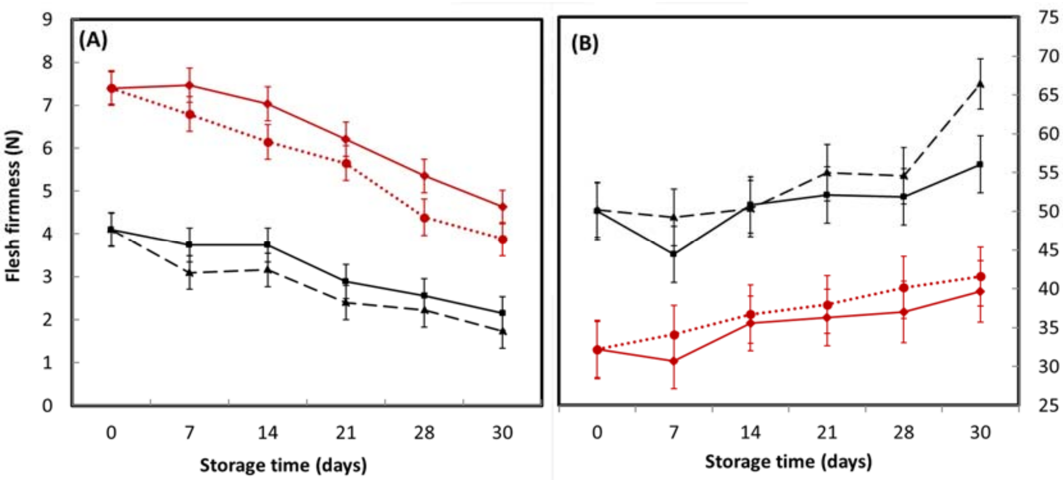

Fig. 2 (A) Flesh firmness and (B) $FWHM_{785}$ for controls (dashed lines) and coated plums (full lines) of 'Jojo' (squares and triangles) and 'Tophit plus' (diamonds and circles) during storage at 2°C for 28 d plus 2 d at 20°C. Vertical bars represent 95% confidence interval of the means (n=42).

Coating plums with Versasheen® plus sorbitol did not significantly alter the mean fruit sugar content as indicated by SSC, which was constant during cold storage and simulated shelf life in fruit of both cultivars (Tab. 1). The same was observed in room temperature stored 'Sapphire' plums, coated only with Versasheen® (Eum et al. 2009). In addition, coating with Versasheen® did not affect the observed decline of TA in 'Jojo' and 'Tophit plus' plums during cold storage (Tab. 1). The reduction in TA but not in SSC may indicate that organic acids are the major substrates of the generally low respiration during cold storage and not free soluble sugars.

3.2. Effects of edible coating on optical properties of plums

Backscattering parameters of stored plums were indeed affected by edible coating (Tab. 1). In coated 'Jojo' plums, $FWHM_{785}$ increased to a lower extent than in controls, especially at the end of cold storage and during shelf life (Fig. 2B). The lower $FWHM_{785}$ observed in coated fruit compared to controls may directly reflect their higher firmness. Basically, the overall intercellular spaces may increase with fruit softening (Harker et al. 1997) and, as a consequence, an increase in scattering within the tissue can be expected during fruit maturation (Peng and Lu 2007). On the other hand, Hashim et al. (Hashim et al. 2014) reported that backscattering parameters (e.g. FWHM and inflection point) of bananas obtained at 785 nm decreased with fruit hardening during storage at chilling temperatures. Here, light penetration into the compact tissues of firm fruit is more difficult and, hence, the photons took a straight trajectory and a more direct reflection occurred instead of backscattering thus reducing $FWHM_{785}$. Consequently, evaluation of backscattering properties at 785 nm provides a helpful tool to rapidly and non-destructively analyse changes in mechanical properties in stored heavily coloured plums.

Table 1 Statistical analysis of the effects of edible coating* and storage time on postharvest quality parameters and optical profile of $FWHM_{785}$ (using LLBI) of 'Jojo' and 'Tophit plus' plums during 28 d at 2 °C plus 2 d at 20 °C.

	Parameters	Treatment				Factor				
		Jojo		Tophit plus		VS	CV	T	VS × CV	VS × T
		Control	VS	Control	VS					
Fruit quality parameters	Transpiration rate (mg cm^{-2} h^{-1})	0.76 c	0.63 d	1.05 a	0.95 b	**	**	**	NS	**
	Total resistance (s cm^{-1})	34.9 b	42.5 a	24.9 c	34.8 b	**	**	**	NS	**
	Flesh firmness (N)	2.8 d	3.2 c	5.7 b	6.3 a	**	**	**	NS	*
	SSC (°Brix)	17.4	17.1	18.6	18.7	NS	**	NS	NS	NS
	TA (g per 100 mL of tissue sap)	1.06	1.13	0.78	0.80	NS	**	**	*	*
Optical properties	$FWHM_{785}$ (%)	54.2 a	52.2 b	37.2 c	35.3 c	*	**	**	*	NS

Values are means of each treatment. Statistical significant (LSD test, p<0.0.5) differences between means are indicated by different letter. Significance of effects of treatments (VS, Versasheen® plus sorbitol; CV, cultivar: T, storage time) and their interactions on the various parameter are also indicated (*: p<0.05; **: p< 0.01; ns: not significant).

Conclusions

In conclusion, using Versasheen® plus sorbitol effectively but cultivar specifically prolonged storability and shelf life of plums. The positive effects of the edible coating resulted from the pronounced reduction of fruit transpiration and, thus, delayed firmness losses. On the other hand, as fruit SSC and TA did not change in response to the treatment, this edible coating did not negatively affect internal fruit quality in plums of both cultivars. Analyses of the backscattering parameter $FWHM_{758}$, in contrast, closely reflected variations in fruit firmness. Thus, it proved to be a rapid and non-destructive means to monitor changes in mechanical properties in heavily coloured plums.

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