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Plum shelf life enhancement by edible coating based on pectin and carboxymethyl cellulose

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Abstract

The aim of the current study was to explore the effect of carboxymethylcellulose–pectin (CMC-Pec) based coating treatments on some qualitative characteristics of plum fruits (*Prunus domestica* L.) during shelf life period at 19 °C and 65% RH (relative humidity) for eight days. In this sense, 0.5% Pectin with four concentrations of CMC (0, 0.5, 1 and 1.5%) were applied to plum fruits in a completely randomized design and weight loss, firmness, vitamin C (vit C), titratable acidity (TA), total soluble solids (TSS), pH and polygalacturonase (PG) were measured. The results showed that except vit C and firmness, other quality parameters were affected by CMC-Pec based coatings. In general, 0.5% Pec + 0.5% CMC had the best results in terms of all measured parameters and could be suggested as a coating to apply on plum fruits during postharvest periods to improve quality properties.

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Introduction

Edible films and coatings are considered as a new approach for fruits and vegetables preservation especially through past decades. There are wide ranges of materials which are used to supply edible films and coatings such as lipids, polysaccharides, carbohydrates, proteins and etc. each having many constituents. On top of that, each material includes different characteristics which cause unlike effects on food features (Bourtoom, 2008). Moreover, their usage reduces non-biodegradable packaging ingredients which lessen environmental concerns and deliberate as safe methods (Olivas *et al.*, 2008; Campos *et al.*, 2011). Edible films and coatings mostly act as modified atmosphere and regulate O_2 and CO_2 transmission between coated fruits and environment, which in turn prevents ripening process that leads to senescence and decay (Bal, 2013). Applications of edible films and coatings to maintain plum quality have been reported in several studies: hydroxypropylmethylcellulose (Navarro-Tarazaga *et al.*, 2008), whey protein (Reinoso *et al.*, 2008), versasheen (Eum and Hwang, 2009), *Aloe arborescens* and *Aloe vera* gels (Guillen *et al.*, 2013) and alginate (Valero *et al.*, 2013). There are some other works in other fruits like methylcellulose in apricot (Ayranci and Tunc, 2004).

Plums (*Prunus domestica* L.) have a short shelf life period due to fast ripening behavior after harvesting and their perishable nature. Plums have 2-6 weeks commercial shelf life depending on cultivar (Abdi *et al.*, 1997). Although maintenance of them in low temperature (0 °C) could increase postharvest life, chilling injury symptoms limit its advantages and consequently accelerate fruits quality loss (Crisosto *et al.*, 2004; Manganaris *et al.*, 2008). The changes could influence consumer acceptance as organoleptic characters of fruits are the main factors in this regard (Diaz-Mula *et al.*, 2008). Also, plum fruits contain lots of valuable compounds like vit C, polyphenols, anthocyanin and flavonoids as antioxidants which help human body fight risky diseases (Tomas-Barberan and Espin, 2001, Collin and Harrington, 2002; Scalbert *et al.*, 2005).

The polysaccharides as coating materials for fruits have been applied extensively in the past few years. They have benefits of availability, low cost, and biodegradability (Zhou *et al.*, 2008). Besides, their physico-chemical properties can also be enhanced by modifying them. Cellulose is a naturally occurring polymer, found abundantly, and usually present as a linear polymer of anhydroglucose (Kester and Fennema, 1986). Several cellulose derivatives such as methyl cellulose (MC), carboxymethyl cellulose (CMC), and hydroxypropylmethyl cellulose (HPMC) are widely produced commercially (Bourtoom, 2008). The coatings and films based on these cellulose ethers are commonly transparent, flexible, odorless, tasteless, water-soluble, and resistant to O_2 and CO_2 (Nisperos-Carriedo *et al.*, 1992). Edible coatings based on cellulose derivatives have also been used to delay ripening in some climacteric fruits like mango, papaya and avocado (Baldwin *et al.*, 1999; Maftoonazad and Ramaswamy, 2005). Sodium-CMC coating extended storage life of pineapple fruit up to 5 weeks at 10°C and 90-95% RH, whereas the control fruit had a storage life of only 28 days (Nimitkeatkai *et al.*, 2006). The application of sodium-CMC coating was also found able to postpone ripening of mango up to 32 days at 13°C and 85% RH (Carrillo-Lopez *et al.*, 2000). One more material based on polysaccharides is Pectin to use as edible coating that is non-toxic, anionic biopolymer; water-soluble and biodegradable with great properties in prevention of volatile compounds particularly O_2 transmission. They exist in cell wall of plants and based on their resource have various characters (Medeiros *et al.*, 2012). Oms-Oliu *et al.* (2008) reported effectiveness of pectin based edible coating on shelf life extension of fresh-cut melon. Avocado fruits coated with pectin based edible coating showed better results as compared with the controls in case of disease, respiration, qualitative parameters, color and texture (Maftoonazad *et al.*, 2007).

To our knowledge, little is known about the effect of these materials as edible coating especially in combination in plum fruits during shelf life period. Thus, the current study was carried out to elucidate their efficiency in this regard. Changes of weight loss, firmness, pH, vitamin C (vit C), titratable acidity (TA), total soluble solids (TSS) and polygalacturonase (PG) were monitored in plum fruits subjected to edible coatings based on combination of Pec and CMC.

Materials and methods

Plant materials, coatings preparation and treatments

Plum fruits (*Prunns domestica* L.) Cultivar 'Golden drop' were hand-harvested at physiologically mature stage from a commercial orchard in Shabestar, East Azerbaijan, Iran. Then, they were transported to the laboratory immediately, washed and air-dried for 2 hours on paper towel and screened based on uniformity of shape, size and peel color. Fruits were divided into 5 groups of 40 fruits in each. Fruits were dipped in different concentrations of aqueous solutions of 0.5 Pec + 0, 0.5, 1 and 1.5 % CMC plasticized with 0.3% w/v glycerol for 60 sec in which 0.5 Pec + 0 CMC were considered as control. All fruits were then air dried for approximately 60 min and stored at 19°C and 65% RH for ten days. Experiment design was completely randomized design (CRD) with three replications for each treatment.

To prepare coatings, 0.5% Pectin with different amounts of (0, 0.5, 1 and 1.5 %) CMC mixed in distilled water and the coatings solutions were mixed for 40 min by stirring at 60 °C. After complete dissolving and getting the clear liquid, glycerol 3% w/v was added and again the solutions were mixed for 30 min by stirring at the same temperature. Then they stored at room temperature to get cold.

Qualitative attributes evaluation

Weight loss, firmness, TA, TSS, Vit C, pH

Weight loss was determined initially and in each sampling during storage and calculated as: weight loss = (W0 −Wf)/ W0 ×100 in which W0 was the initial sample weight and Wf, the final sample weight. The results were reported as weight loss percentage. Firmness was measured on two sides of each fruit, after the removal of the skin fruit, by an Effegi penetrometer (Model FT-011) with an 8 mm diameter flat probe. Total acidity (TA) was measured by titration with 0.1N NaOH up to pH 8.1 and expressed as percentage of malic acid equivalent per 100 g fresh weight. Total soluble solids (TSS) were determined by measuring the refractive index of juice using a digital refractometer (Model PAL-1) at 20 °C and . Vit C content (mg/100g) of the samples was determined by the titramitric method (AOAC, 2000) in which visual titration method of reduction of 2,6-dichlorophenolindophenol dye was used. Three replicates were assessed for each measurement. The pH was recorded with a pH meter (Hana instrument, Italy).

PG activity

The activity was assayed based on the release of decreasing groups produced by PG and measured by spectrophotometer. Sodium acetate buffer (pH=4.5) was used for enzyme extraction. 50µl enzyme extract was mixed with 950 µl Sodium acetate buffer and 1ml of 0.3% polygalacturonic acid then incubated at 30 °C for 45 min. To stop the reaction, 800 µl of 0.1 M borate buffer (pH=9) 0°C and 200 µl of 1% cyanoacetamide solution were added to the reaction mixture and boiled for 10 min. After cooling down, the absorbance was measured at 276 nm. A blank was determined in the same way without enzyme addition. The standard curve was built with α-D-galacturonic acid as reducing sugar. One unit (U) of PG activity was defined as the amount of enzyme that releases 1 µmol of galacturonic acid per min under the assay conditions (Aguiló-Aguayo *et al.*, 2010).

Statistical analysis

Analysis of variance (ANOVA) carried out with SPSS (version 16, SPSS Inc., Chicago, IL.) software. Differences between means were compared using Duncan's new multiple range test (with significancy at

P ≤0.05).

Results and discussion

The obtained results about TA demonstrated that TA decreased (P≤0.01) (Table 1) as time passed, reached to minimum at the end of storage as a common process. Edible coating containing 0.5%Pec+0.5%CMC significantly (P≤0.01) (Table 1) showed the highest amount, but other concentrations of CMC in combination with 0.5%Pec surprisingly even acted worse than control (Fig. 1). TA decrease mostly is due to using TA as substrate in respiratory metabolism and changing to sugars. Alginate edible coating delayed TA decrease of plum fruits and coated fruits had higher TA amount (Valero *et al.*, 2013). Plums coated with *Aloe spp.* and versasheen® showed higher content of TA (Eum and Hwang, 2009; Guillen *et al.*, 2013).

Table 1. ANOVA for dependent variables for coating treatments, storage time and their interactions for plum fruits.

	Time	Treatment	Time*Treatment
Firmness	15.386**	0.903^{ns}	2.722*
Weight loss	79.772**	2.131*	1.252^{ns}
TSS	7.447**	5.347*	2.416*
TA	29.642**	32.493**	19.319**
pH	38.35**	7.11**	0.651^{ns}
Vit C	8.761**	0.248^{ns}	1.413^{ns}
PG activity	35.856**	10.587**	6.466**

Note: * P≤0.05, ** P≤0.01, ^{ns} non-significant.

In case of TSS feature, the maximum and minimum amounts of TSS were observed in control (0.5% Pec) and combination of 0.5% Pec with all concentrations of CMC edible coatings (P≤0.05) (Table 1). In our point of view, edible coating represented better results because of less changes in TSS value when it's compared with day 0 (Fig. 2). As time passes, TSS amounts increased (P≤0.01) as at the end of the shelf life period the highest amount was noticed. No differences in TSS amount were detected in coated "sapphire" plums and controls (Eum and Hwang, 2009).

Table 2. effect of coatings on quality parameters and PG activity of plum fruits during storage at 19 °C.

Treatment coatings	Firmness	Weight loss	TA	TSS	pH	Vit C	PG activity
Control (0.5%Pec)	9.14	10.83^{ab}	1.5^{b}	11.53^{b}	3.603^{a}	8.4	0.2085^{c}
0.5%Pec+0.5%CMC	9.89	9.40^{a}	1.6^{a}	10.76^{a}	3.612^{a}	7.933	0.2036^{b}
0.5%Pec+1%CMC	8.72	10.69^{ab}	1.41^{c}	10.3^{a}	3.681^{ab}	8.4	0.2042^{bc}
0.5%Pec+1.5%CMC	9.81	12.82^{b}	1.43^{c}	10.41^{a}	3.695^{b}	8.467	0.1966^{a}

Togrul and Arslan (2004) stated that 1.1% CMC-based edible coating acted better than controls since cause less changes in TSS amounts of mandarin.

The best result in pH property was achieved in controls and similarly 0.5%Pec+0.5%CMC edible coating (Table 2) and others showed pH enhancement (P≤0.01) (Fig. 3). During maintenance time of plum fruits pH noticeably increased and at the end of period reached the top. The pH changes in mandarins coated with a CMC edible coating depended on coating's concentrations. Higher concentrations of CMC caused higher pH and lower concentrations next to beeswax caused lower pH. It was reported that control fruits had higher pH and all fruits showed an increasing trend in pH amount during storage (Togrul and Arslan, 2004).

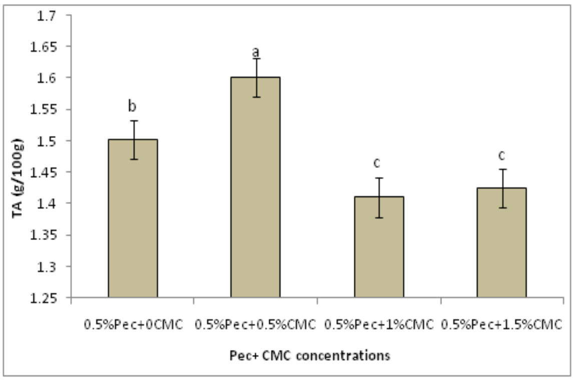

Fig. 1. The effect of coating formulations based on Pec+CMC on TA amounts of plum fruits at 19 °C for eight days. (Data are mean+95% interval confidence).

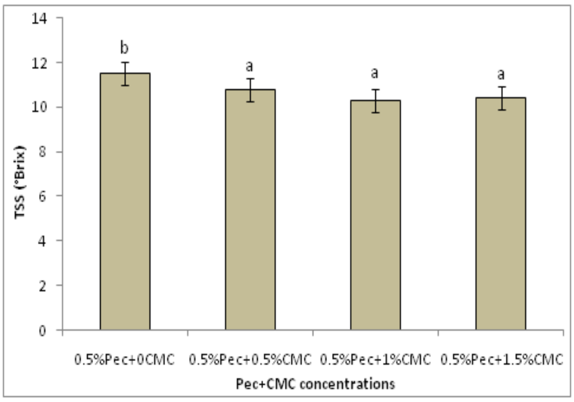

Fig. 2. The effect of coating formulations based on Pec+CMC on TSS values of plum fruits at 19 °C for eight days. (Data are mean+95% interval confidence).

Firmness and vit C attributes showed no significant differences between control (0.5% Pec) and other coating treatments (Table 1 and 2). Though, adding CMC to 0.5% Pec caused better results. To identify, regarding firmness, 0.5 and 1% CMC in combination with 0.5% Pec preserved fruit firmness more appropriately and in case of vit C, once more, 1 and 1.5% CMC + 0.5% Pec caused better outcomes and the minimum and maximum vit C values was observed at 0.5% Pec and 0.5% Pec + 1.5% CMC edible coatings. Through maintenance time, vit C content primarily increased and reached the highest at day 4 and then slightly decreased but despite this reduction, its amount at the end of the storage was higher than harvesting time. Fruit firmness declined as time passed and this trend was obvious amongst sampling dates. The least value was measured at the end of storage. Guillen *et al.* (2013) reported no significant differences on firmness between coated and control plum fruits. carboxymethylchitosan-based coating had no effect on vit C content of pear (Zhou *et al.*, 2008).

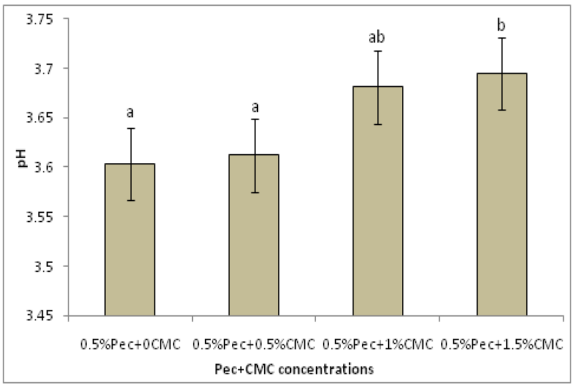

Fig. 3. The effect of coating formulations based on Pec+CMC on pH of plum fruits at 19 °C for eight days. (Data are mean+95% interval confidence).

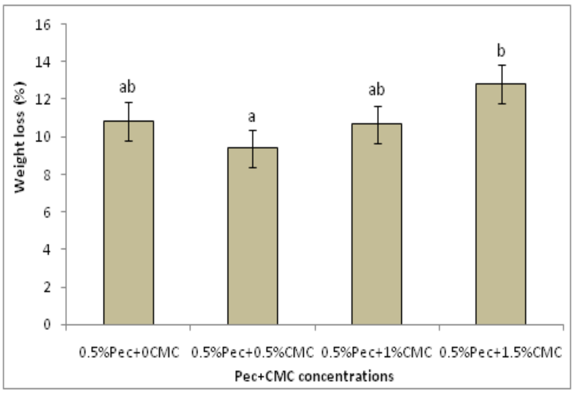

Fig. 4. The effect of coating formulations based on Pec+CMC on weight loss of plum fruits at 19 °C for eight days. (Data are mean+95% interval confidence).

Weight loss of plum fruits increased (P≤0.01) during storage at 19 °C (Table 1). However, obtained data demonstrated that 0.5%Pec+0.5% CMC-based edible coating significantly (P≤0.05) decreased weight loss in comparison to control and controversy 0.5%Pec+1.5% CMC- based edible coating increased it (Fig 4, Table 2). Effectiveness of coatings in preventing of fruit weight loss has been previously reported by Valero *et al.* (2013) and Guillen *et al.* (2013). Also, in some cases coatings enhanced weight loss (Navarro-Tarazaga *et al.*, 2008) that overall could describe our results.

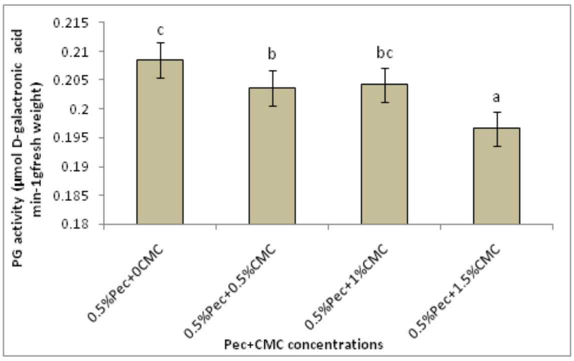

Fig. 5. The effect of coating formulations based on Pec+CMC on PG activity of plum fruits at 19 °C for eight days. (Data are mean+95% interval confidence).

PG activity decreased till 4 days of storage and then increased. PG activity affected by a combination of Pec and CMC edible coatings in which 0.5%Pec+1.5%CMC and 0.5%Pec+0.5%CMC significantly reduced the enzyme activity compared to control (Fig 5). Since PG is one of the cell wall hydrolysis enzymes and its activity increased during ripening and after harvesting, a reduction in its activity could prevent softening.

Conclusion

Regarding to positive effects of edible coating based on Pec-CMC on qualitative attributes of plum fruits, its application during postharvest life could be considered as a safe and stimulating method. Results of current study suggested that 0.5% Pec + 0.5% CMC could be applied in this regard.

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