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5. SLOVENSKEGA SADJARSKEGA KONGRESA Z MEDNARODNO UDELEŽBO

KRŠKO, 17. – 18. JANUAR 2024

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EFFECTS OF A CHITOSAN COATING ON THE POST-STORAGE QUALITY OF PLUM FRUIT

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ABSTRACT

The effects of a chitosan coating on the quality and storability of 'Stanley' plum fruit were investigated. Plum fruits were treated with a 1.0 % w/v chitosan coating and stored at 1 ± 1 °C under 90–95% relative humidity for 28 days, and, subsequently, held at 24 °C for four days to evaluate shelf life. Some basic physical and chemical quality indices (weight loss, fruit firmness, soluble solids content, pH, content of total sugars, inverted sugars, sucrose and acids) were evaluated after storage, and after four days of shelf life. Furthermore, the occurrence of pathogens in treated and control fruit was monitored. Weight loss was pronounced after cold storage and it almost doubled during shelf life in both groups of plums, and the results obtained show that the chitosan coating could not prevent shrivelling. Although, the chitosan-coated fruits showed higher firmness after cold storage and during shelf life (2.51 kg/cm^2, and 1.75 kg/cm^2, respectively) than the control fruits (2.28 kg/cm^2, and 1.66 kg/cm^2, respectively), the observed differences were not statistically significant. There was also no significant difference in chemical composition between treated and control fruits. However, the percentage of fruit infected with *Monilinia* spp. at the end of cold storage was slightly lower in the chitosan-coated fruit (2.00%) than in the untreated fruit (3.33%). The effectiveness of chitosan coating in maintaining plum quality during storage therefore remains questionable.

Key words: *Prunus domestica,* postharvest treatment, shelf life, weight loss, firmness

VPLIVI PREVLEKE IZ HITOZANA NA KAKOVOST PLODOV SLIVE PO SKLADIŠČENJU

POVZETEK

Raziskali smo vpliv prevleke iz hitozana na kakovost in sposobnost skladiščenja plodov sliv sorte 'Stanley'. Plodove sliv smo obdelali z 1,0 % m/v prevleko iz hitozana jih skladiščili pri 1 ± 1 °C pri 90–95 % relativni vlažnosti 28 dni, nato pa jih hranili pri 24 °C štiri dni, da bi ocenili rok uporabnosti. Nekatere osnovne fizikalno-kemijske kazalnike kakovosti (izguba mase, čvrstost plodov, vsebnost topne suhe snovi, pH, vsebnost skupnih sladkorjev, invertnih sladkorjev, saharoze in organskih kislin) smo izmerili po skladiščenju in po štirih dneh shranjevanja pri sobni temperaturi. Nadalje smo spremljali pojav patogenov pri tretiranih in kontrolnih plodovih. Izguba mase je bila po hladnem skladiščenju izrazita in se je med shranjevanjem pri sobni temperaturi pri obeh skupinah sliv skoraj podvojila, dobljeni rezultati pa kažejo, da obloga iz hitozana ni preprečila zgubanosti kožice. Čeprav so plodovi,

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prevlečeni s hitozanom, pokazali večjo trdoto po hladnem skladiščenju in med rokom trajanja (2,51 kg/cm^2 oziroma 1,75 kg/cm^2) kot kontrolni plodovi (2,28 kg/cm^2 oziroma 1,66 kg/cm^2), opažene razlike niso bile statistično značilne. Prav tako ni bilo pomembne razlike v kemični sestavi med tretiranimi in kontrolnimi plodovi. Vendar pa je odstotek plodov, okuženih z *Monilinia* spp. ob koncu skladiščenja nekoliko manjši pri plodovih, obloženih s hitozanom (2,00 %) kot pri netretiranih plodovih (3,33 %). Učinkovitost premaza s hitozanom pri ohranjanju kakovosti sliv med skladiščenjem ostaja torej vprašljiva.

Ključne besede: *Prunus domestica*, obdelava plodov po obiranju, rok uporabnosti, izguba mase, trdota

1. INTRODUCTION

The main challenge in storing plums is to reduce water loss, which leads to shrivelling and loss of firmness. Among the available postharvest management procedures, edible coatings are becoming more and more interesting as they can preserve fruit quality in an environmentally friendly and safe way (Dhall, 2013). They represent “a thin material used for wrapping various food to extend shelf life of the product which can be consumed together with the food with or without further removal and provide a barrier to moisture, oxygen and solute movement for the food” (Nayik et al., 2015). Among the various bio-based materials, chitosan, a non-toxic, high molecular weight polymer, found in the exoskeleton of crustaceans and in the cell walls of fungi, was considered as a potentially ideal compound due to its safety (GRAS), antifungal properties and ability to form semi-permeable coatings, that can be modified by methylation or incorporation of compounds with specific properties (Dhall et al., 2013).

Chitosan coatings have been used as a microbial coating on strawberries, and as a gas barrier on apples, pears, sweet cherries, peaches, and Japanese plums (Dhall, 2013; Petriccione et al., 2015; Kumar et al., 2017, Adiletta et al., 2022). However, there are only several studies related to chitosan coatings in European plums. In the study of Bal (2013), chitosan-coated plums had lower weight loss, respiration and decay rate, although soluble solids and ascorbic acid contents were not affected by the treatment. Mahmoudi et al. (2022) achieved an extension of postharvest life of plums by applying glycine betaine-coated chitosan nanoparticles, which delayed plum weight loss and tissue softening, reduced symptoms of chilling injury and maintained higher levels of ascorbic acid during storage. Since, on the one side plum (*Prunus domestica*) is one of the most important fruit species in Serbia, and on the other hand, literature data on the application of chitosan coatings are scarce, the aim of this study was to evaluate the potential effects of 1% w/v chitosan coating on physicochemical properties and pathogen incidence after 28 days of storage at 1 °C and subsequent shelf life of 'Stanley' plums grown under environmental conditions typical for Serbia.

2. MATERIALS AND METHODS

Fruit of the examined plum cultivar 'Stanley' were harvested at the maturity stage which is, according to the criteria imposed by the market, suitable for plums intended for storage and fresh consumption, i.e., at the stage when about 60–70% of the fruit surface is covered with cultivar characteristic colour, with marked firmness. The harvest date was 20th August 2020, and fruit were picked from a commercial orchard situated near Čačak (central Serbia), where all standard cultural practices (irrigation, fertilization, pruning, disease control) were applied.

The plums were transported to the laboratory of the Fruit Research Institute, Čačak and examined for defects and decay. The average fruit weight was 36.64 ± 5.16 g, which indicates a pronounced heterogeneity of the fruit harvested at this maturity stage.

The chitosan coating (1.0 % w/v) was prepared by dissolving chitosan powder in 1.0% (v/v) glacial acetic acid under continuous stirring for three hours and adjusting the pH to 5.98 using 1 N NaOH. One group of fruit was immersed in the chitosan coating solution for three minutes and air-dried at 24 °C. The untreated fruits represented the control. The coated and control samples were stored at 1 ± 1 °C under 90–95% relative humidity for 28 days, and then kept at 24 °C for four days to evaluate shelf life. All analyses were performed at harvest (day 0), after a period of cold storage (28 days), and after shelf life (28 + 4 days).

Thirty fruit per treatment were selected for the weight loss test and measured on a technical scale (Ohaus Adventurer, Parsippany, NJ, USA) at harvest and after cold storage and shelf life. Weight loss was expressed as a percentage loss of initial weight. Fruit firmness was measured in kg/cm^2, using a hand penetrometer (model FT 327, T.R. Turoni, Forly, Italy), equipped with an 8-mm spherical probe. A digital refractometer (Milwaukee Instruments, US) was used to determine the total soluble solids content (SSC). Total acids content (TA) was determined by neutralization with 0.1 N NaOH to pH 8.2, using phenolphthalein as an indicator. The results were expressed as percentage of malic acid. The pH of the pulp was measured with a pH meter (Mettler Toledo EL 20-Basic, Schwerzenbach, Switzerland). The content of total sugars, inverted sugars and sucrose was determined using the Luff-Schoorl method (Tanner and Brunner, 1979). After removing the samples from the cold chamber and after the subsequent shelf life, the number of fruits infected with pathogens was recorded and the pathogens were identified on the basis of morphological characteristics (Vasić et al., 2017)

The data obtained were subjected to a one-way analysis of variance (ANOVA). Significant differences (p = 0.05) between the mean values were determined using the Tukey post-hoc test. The statistical analyses were performed using STATISTICA 7.0 software (Statsoft Inc., Tulsa, OK, USA).

3. RESULTS AND DISCUSSION

The weight loss of the plum fruit increased during cold storage and almost doubled during the shelf life (Figure 1), which can be explained by the intensive transpiration at room temperature. As a result of the high weight loss, symptoms of shrivelling were observed after shelf life. Chitosan-coated fruit showed a slightly lower weight loss after shelf life; however, an effective water vapour barrier cannot be assumed. In the study of Mahmoudi et al. (2022), 1% chitosan coating significantly reduced the weight loss of plum fruit, which was about 2% after 30 days of cold storage, while the control fruit had a similar weight loss (~6%) to those in our study. Kumar et al. (2017) found that chitosan coating successfully delayed moisture loss in Japanese plums by smoothing the pericarp surface and covering the stomata. Interestingly, Fawole et al. (2020) reported significantly higher moisture loss in chitosan-coated Japanese plums than in control fruit throughout the storage period. The effect of chitosan on weight loss therefore remains controversial.

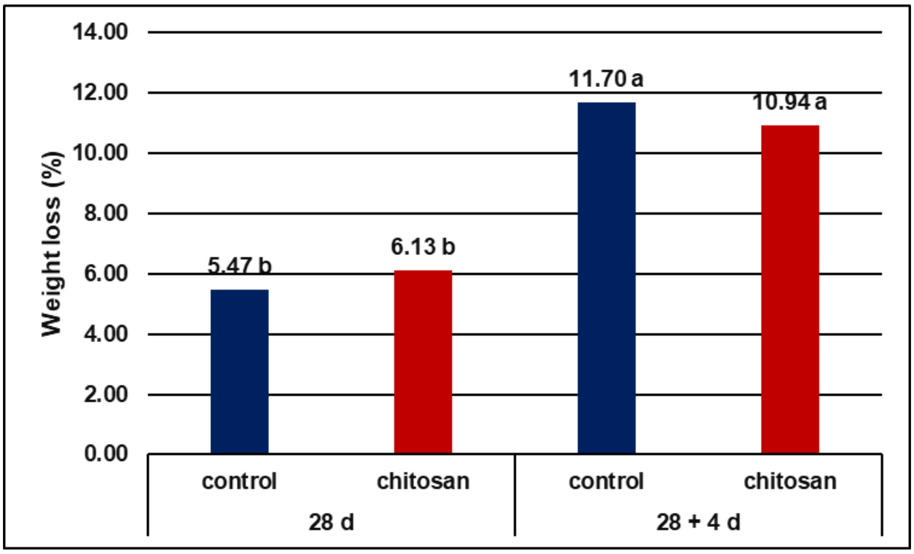

Figure 1: Effect of chitosan coating on the weight loss of plum fruit after cold storage and shelf life. Mean values followed by different letters are significantly different according to the Tukey test (p = 0.05).
Slika 1: Vpliv premaza s hitozanom na izgubo mase plodov sliv po skladiščenju v hladilnici in pri sobni temperaturi. Povprečne vrednosti, ki jim sledijo različne črke, se značilno razlikujejo glede na Tukeyjev test (p = 0,05).

The firmness of the fruit decreased noticeably during cold storage; the control fruit lost 38.54% of initial firmness, while the decrease in firmness in the chitosan-coated fruit was 32.34% (Figure 2). Although the treated fruits showed a higher firmness after shelf life in comparison to the control ones, the difference was not statistically significant. Interestingly, chitosan-coated fruit showed a slightly lower softening rate during cold storage (0.04 kg/cm^2 per day) than the control fruit (0.05 kg/cm^2 per day). However, softening during shelf life was more pronounced in the treated fruit compared to the untreated fruit (0.19 kg/cm^2 per day and 0.16 kg/cm^2 per day, respectively). The results obtained on the efficacy of chitosan in reducing the softening of European plums differ from those in the literature (Bal, 2013; Mahmoudi et al., 2022), which suggest that chitosan can effectively prevent loss of firmness, especially when combined with glycine betaine. On the other hand, the study of Adiletta et al. (2022) found no statistical difference in firmness between coated and uncoated Japanese plums during shelf life.

A slight increase in the SSC value was observed during cold storage, but there were no marked differences between the treated and non-treated fruits, while the chitosan-coated fruit showed a higher value of this parameter than the non-coated fruit after the shelf life (Figure 3). The reported data on the effect of chitosan on SSC in both European and Japanese plums are contradictory; in several studies chitosan was found to promote the increase in SSC (Bal, 2013; Mahmoudi et al., 2022), in others a delay in SSC increase was found (Liu et al., 2014; Kumar et al., 2017; Adiletta et al., 2022), while Fawole et al. (2020) observed no differences between treatment and control.

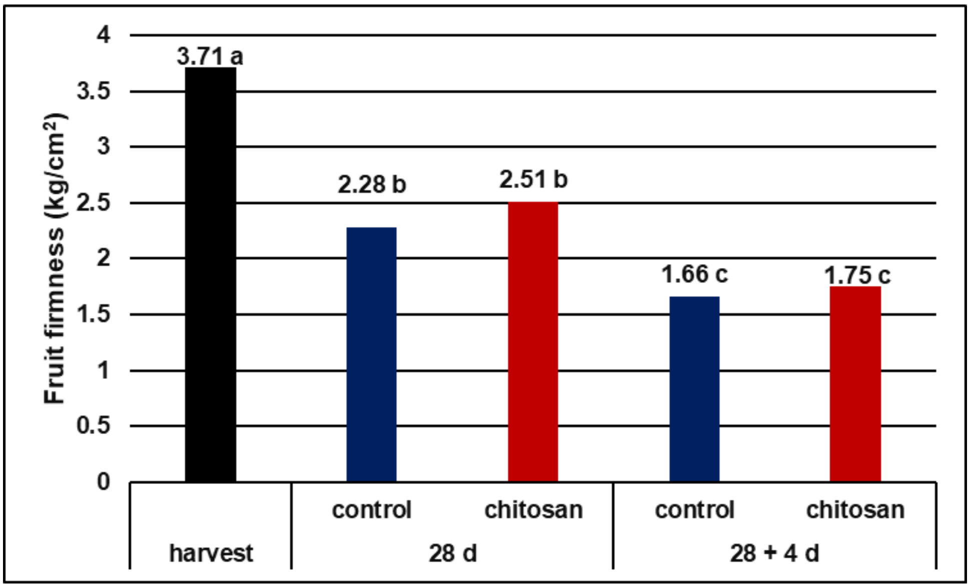

Figure 2: Effect of chitosan coating on the firmness of plum fruit after cold storage and shelf life. Mean values followed by different letters are significantly different according to the Tukey test (P = 0.05).
Slika 2: Vpliv premaza s hitozanom na trdoto plodov sliv po skladiščenju v hladilnici in pri sobni temperaturi. Povprečne vrednosti, ki jim sledijo različne črke, se značilno razlikujejo glede na Tukeyjev test (P = 0,05).

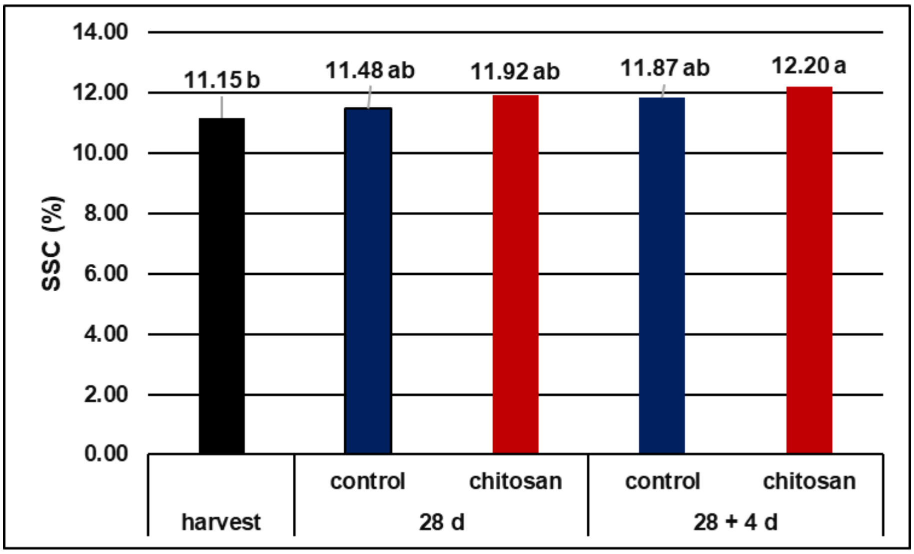

Figure 3: Effect of chitosan coating on the soluble solids content (SSC) of plum fruit after cold storage and shelf life. Mean values followed by different letters are significantly different according to the Tukey test (p = 0.05).
Slika 3: Vpliv prevleke s hitozanom na vsebnost topne suhe snovi (SSC) plodov sliv po skladiščenju v hladilnici in pri sobni temperaturi. Povprečne vrednosti, ki jim sledijo različne črke, se značilno razlikujejo glede na Tukeyjev test (p = 0,05).

The content of total sugars and inverted sugars increased slightly during storage in both fruit groups. The sucrose content decreased, which may be a result of hydrolysis and conversion to glucose and fructose as constituent subunits (Table 1). The chitosan coating delayed the change in TA during storage, so that the values at harvest and at the end of cold storage of the coated fruits were almost the same (Table 1), which is consistent with the results of Fawole et al. (2020). The cited authors also found the highest TA values after shelf life in chitosan-treated fruits than in the control ones.

Table 1: Effect of chitosan coating on the basic chemical properties of plum fruit after cold storage and shelf life
Preglednica 1: Vpliv premaza s hitozanom na osnovne kemijske lastnosti plodov sliv po skladiščenju v hladilnici in pri sobni temperaturi

Treatment	Storage time (day)	Total sugars (%)	Inverted sugars (%)	Sucrose (%)	Total acids (%)	pH
Control	0	7.12 ± 0.18 b	4.29 ± 0.08 b	2.69 ± 0.11 a	0.71 ± 0.03 c	3.43 ± 0.02 b
	28	7.96 ± 0.45 a	5.39 ± 0.28 a	2.44 ± 0.20 ab	0.79 ± 0.02 ab	3.45 ± 0.03 b
	28 + 4	7.76 ± 0.39 ab	5.27 ± 0.14 a	2.37 ± 0.23 ab	0.74 ± 0.04 bc	3.66 ± 0.06 a
Chitosan	0	7.12 ± 0.18 b	4.29 ± 0.08 b	2.69 ± 0.11 a	0.71 ± 0.03 c	3.43 ± 0.02 b
	28	8.16 ± 0.24 a	5.54 ± 0.19 a	2.49 ± 0.05 ab	0.69 ± 0.01 c	3.58 ± 0.06 a
	28 + 4	7.56 ± 0.12 ab	5.23 ± 0.12 a	2.22 ± 0.01 b	0.81 ± 0.01 a	3.64 ± 0.04 a

Values are expressed as means ± standard deviations, n=3. Mean values followed by different letters within a column are significantly different according to the Tukey test (p = 0.05).

The only pathogen detected in both fruit groups was *Monilinia* spp., and the number of infected fruits after 28 days of cold storage was higher in the control group (3.33%) than in the chitosan-treated group (2.00%). Since the infected fruits were removed, no infection was detected after shelf life. The data obtained indicate a potential antimicrobial effect of chitosan and are in agreement with data reported for plums (Bal, 2013), sweet cherries (Dang et al., 2010; Tokatlı and Demirdöven, 2020) and nectarines (Chiabrando and Giacalone, 2016). Although the antimicrobial activity of chitosan has not been elucidated in detail, the polycationic nature of this compound is thought to be a key factor in the interruption of fungal growth (Bautista-Baños et al., 2006).

The application of a chitosan coating did not significantly reduce the loss of weight and firmness during storage of 'Stanley' plums. However, the pronounced shrivelling and decrease in firmness can be explained by the early harvest, which has become common among Serbian plum producers. The results suggest potential antifungal properties of the chitosan coating; therefore, future research should focus on the antimicrobial activity of chitosan, which as a non-toxic, biodegradable material could potentially suppress the occurrence of pathogens during storage.

4. ACKNOWLEDGMENTS

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