Enhancing postharvest quality of fresh-cut plums with chitosan-grape seed oil edible coatings

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Abstract. Edible coatings are traditionally used to improve food appearance and conservation due to their environmentally friendly nature. In this study fresh cut (halved and pitted) plum (var. Stanley) fruits were coated by chitosan grape-seed-oil (GsO) nanoemulsion. Physical, physico-chemical, microbiological and sensorial properties were examined 3 times during 9 d refrigeration storage. The control probes wasted their safety and quality after the 4th d. The coated probes preserved their quality and safety to the end of the storage period. The fruits with chitosan coating showed smaller microbiological contamination but the chitosan GsO coated fruits showed higher values in the sensorial parameters. The coated samples preserved their sensorial parameters up to 80% on the 9th d.

1 Introduction

Plums, as many other fruits as well, contain a variety of healthy compounds, vitamins, polyphenols, antioxidants that decrease the risk of cancer and other diseases [1] but their short shelf-life time and the difficulties by transportation are a prevalent issue. The plums are coated with a natural complex wax layer, which is semi-permeable for water vapor and gases [2]. One of the possibilities to decrease the fruit waste during the manipulations or the storage is to use natural polymer combinations as edible coatings. In the biodegradable edible coatings, the most common applied ingredients are polysaccharides and lipids [3]. The polysaccharides must show water-solubility and good film forming properties, like the deacetylated, low-molecular-weight chitosan. These components act as barriers for gas and moisture exchange, reduce the waste of weight and volatile compounds and influence the antimicrobial contamination [4]. The application of plant extracts or pressed oils in the coatings is limited because they are not water-soluble, not colourless and flavourless materials, they change the mechanical properties and are sensitive for degradation in higher oxygen concentration as well [5, 6]. The used film-forming coating can act with the wax layer of the fruits as well [2]. Previous research on sweet cherry has shown that the combination of chitosan and grape-seed-oil in maintenance preserves the postharvest quality maybe better than the pure chitosan coatings [7]. The pure chitosan coating can easily lead to ragged fruit surface with obstructed effects [8].

The present work aims to investigate the effect of chitosan GsO nanoemulsion coating on halved and pitted plums during refrigerated storage.

2 Materials and methods

2.1 Raw materials and preparing of coated probes

The plum fruits (var. Stanley) were received from the orchard of the Fruit Growing Institute, Plovdiv in technical matured state. The mean fruit mass was 43 ± 5 g, the stone was 2.7 ± 0.3 g. All of the used chemicals were purchased from certificated Bulgarian distributors of food grade laboratory suppliers (Glentham Life Sciences Ltd, UK and Ikarov Ltd., Plovdiv, Bulgaria).

The halved and pitted plums dipped into chitosan solution (chitosan 1%) and chitosan-grapeseed oil emulsion (chitosan 1% + grapeseed oil emulsion 0.5 %) for 10 minutes and air-dried for 15 min. The exact preparation method of the coating solutions is described in earlier publication [9].

Uncoated {CON}, coated with chitosan (1%) {CH}, coated with chitosan (1%) {CHG} and grape seed oil emulsion (0.5%) halved and pitted fresh plums were used for experimental series. Plum halves were coated on the first day of the test series and stored at 5°C for nine days.

2.2 Investigated quality parameters

2.2.1 Physical methods

Quantitative changes (weight loss) were reported on the 1st, 4th and 9th d.

Colour parameters were determined using a colorimeter (PCE-CSM 5 portable colorimeter). The CIELAB colour parameters L, a, b, c, and ΔE were measured at measuring geometry 8°/d, Ø 8 mm, light

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source D65. A white control plate (L* = 94.3; a* = - 0.92; b* = - 0.67) was used as a calibration plate [10]. The calculated Hue angle (h°) was used for statistical evaluation:

$$Hue\ (h°) = arctan\left(\frac{b^*}{a^*}\right) \quad (1)$$

15 halved fruits from each treatment were measured from the skin and flesh side.

The *water activity* was investigated on meshed pulp from 15 halved fruits with portable digital instrument, Rotronic HP23-AW-SET-40 respectively.

Instrumental texture analysis: The puncture test was performed with a StableMicroSystems TA2XT stable texture analyser. The sample deformation rate was 1 mm/s and the deformation was maximized in 10 mm. Ten repetitions were used from each treatment on the both sides of the halves for the statistics. The rupture curves show the values of the Young's modulus of as the slope of the first linear section, the strain and the stress at the yield and at the break point.

2.2.2 Physico-chemical methods

The *Brix* was investigated on meshed pulp from 15 halved fruits with portable digital instrument, Kern ORF3SM.

Titratable acidity (TA) was investigated by titration of the fruit juice (compressed) with NaOH (0.1 N) in triplicate and expressed as g of malic acid equivalent per 100 g fresh weight [11]. The pH of the pulp was obtained in triplicate by a Milwaukee MW1 02-FOOD digital pH meter.

The *total antioxidant capacity* of extracts from fruit halves was investigated in triplicates by the free radical scavenging activity (DPPH) and ferric reducing antioxidant power (FRAP) assay. The total polyphenol content (TPP) was detected by spectrophotometric way. All the three methods were described in details by Petrova et al. [12].

2.2.3 Microbiological methods

The microbiological safety analysis was performed based on international standards:

- Total plate counts (BS EN ISO 4833-1: 2013) [13]
- Molds and yeasts (BS ISO 21527-2: 2011) [14]
- *Escherichia coli* (BS ISO 16649-2: 2014) [15]
- Coliforms with colony-count technique (BS ISO 4832:2006) [16]
- *Salmonella* (BDS EN ISO 6579-1:2017/Amd 1:2020) [17]

2.2.4 Sensory analysis

A total of six samples labeled with 3-digit numbers were randomly provided to trained panel participants. Appearance, shape and size, color, fruity taste, aroma, texture and browning around the stone were the selected attributes. Each sensory attribute was rated for quality on a structured 9-point scale with values ranging from "absolutely no quality" (1) to "extremely good quality" (9) [18].

All of the methods were applied at the 1st, the 4th and the 9th d of the refrigeration.

2.2.5 Statistical analysis

The statistical analysis was performed using the statistical software Statistica. T-Test was used to find significant differences (p = 0.05) between sensory attributes.

3 Result and discussion

3.1 Results of the physical methods

The fastest weight loss (Table 1) was seen at the control probes, 14.94% during four days and 21.18% during nine days. The coated probes showed more slowly waste, 6.43% and 6.12 % during four days and 18.42% and 17.08% during nine days for CH and CHG coatings respectively. The weight loss reduction of the CHG coating is better, but the differences between the coatings are not significant. Similar changes were shown by Li et al. [8] for Layer-by-layer (Chitosan-alginate) coated plums.

Table 1. Physical properties of the coated plums

	Weight loss, %	Hue, h°		AW
		Skin	Flesh	
1st d				
CON	0.00	38.65± 8.73bA	72.73±3.15cB	0.935
CH	0.00	34.83± 9.31aA	69.43±4.51bB	0.941
CHG	0.00	46.60± 7.25cA	64.52±3.84aA	0.941
4th d				
CON	14.94	39.68±10.00bA	70.87±3.81cB	0.923
CH	6.43	36.27± 8.02aA	65.08±5.3bAB	0.910
CHG	6.12	52.10± 5.89cAB	61.25±3.43aA	0.939
9th d				
CON	21.18	41.52± 8.34aA	62.61±2.64aA	0.907
CH	18.42	53.02±12.05bB	60.96±2.77aA	0.903
CHG	17.08	54.06± 7.53bB	60.61±3.32aA	0.915

a, b, c: different lowercase letters show significant differences between the coating treatments.

A, B, C: different uppercase letters show significant differences between the days of the investigation.

Colour parameters, Hue angle: The coating and the storage time both cause differences in the Hue values (Table 1). These differences may present a connection between the colour and the antioxidant or polyphenol content, but it should be studied in details in the future. The colour differences between the coated samples are

reduced for the fruit flesh and disappear during the storage. Similar changes of the Hue value of coated plums were detected by Kumar et al. [19].

The values of water activity AW (Table 1) were reduced during the shelf-life in similar measure and it seems that the reduction does not depend on the coating, but maybe on the soluble solid content, as it is shown later.

The change in the texture properties of the halved plums shows the moisture state and the healthy stage of them. After the dipping into the coating solution, a thin film layer formed on the surface of the fruit and the coated halves show higher values in the yield and rupture points. At the beginning of the storage, the control pieces waste their moisture content and their surface of them hardens, but later the remainder water content flows out, between the cells and their turgor slows down. The film layer slows down the water evaporation and the interactions between the coating molecules and the cell materials gate the disintegration of the cells. In that case, the coated pieces waste their hardness and elasticity more slowly. There are no significant differences between the effect of the chitosan and the chitosan-grapeseed-oil coatings (Fig. 1).

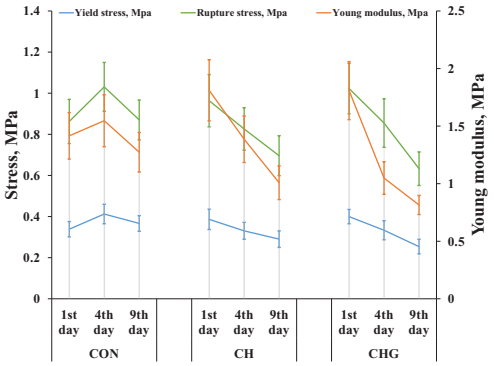

Fig. 1. Texture parameters of the uncoated and coated halved plums, unpeeled samples

The drying up of the flesh side is more intensive than the peel for the uncoated and chitosan coated halves. The chitosan-grapeseed-oil coating changed the surface properties of fruit pieces and they show more similar hardness values during the storage [20] (Fig. 2).

3.2 Physico-chemical parameters:

The increasing of the Brix during the storage (Table 2a) is the result of the drying. It is slowly at the beginning, but later became very fast for the CH coated probes, and much more slowly for the CHG coated fruits. The differences and the changes in the total acidity (pH) and in the titratable acidity (TA) of the samples is not significant during in the storage and for the different coatings (Table 2a).

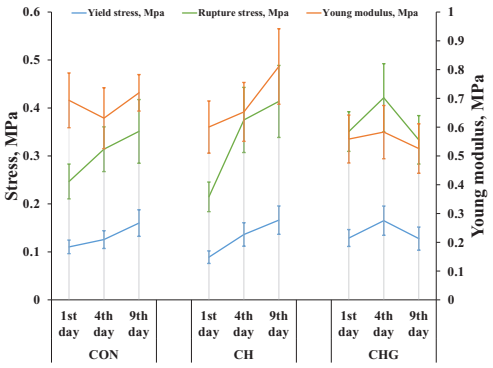

Fig. 2. Texture parameters of the uncoated and coated halved plums, fruit flesh

Table 2a. Physico-chemical properties of the coated plums

	Soluble solid content, Brix	Total acidity, pH	Titratable acidity, mg/100g
1st d			
CON	24.96±1.53bA	3.53±0.21	0.69±0.05
CH	20.26±1.21aA	3.62±0.26	0.58±0.04
CHG	21.96±1.20abA	3.59±0.24	0.67±0.04
4th d			
CON	25.03±1.53bA	3.60±0.21	0.71±0.05
CH	20.72±1.27aA	3.76±0.22	0.62±0.04
CHG	22.19+1.23abA	3.60+0.19	0.68+0.04
9th d			
CH	28.56±1.55abB	3.66±0.21	0.56±0.04
CHG	25.60±1.40aB	3.84±0.25	0.58±0.04

The smaller total polyphenol content (TPP) of the coated probes is maybe a result of the smaller dry content (Table 2b). The decrease of the polyphenol content is faster at the beginning for all the samples. The decrease is the smallest with CHG coatings. The evaluation of antioxidant activity is not possible by single biochemical method [21]. In this study the most commonly DPPH and FRAP assays [22] were used in parallel to show the changes during the shelf-life. The antioxidant activity at the beginning is very similar or a bit higher for the coated samples, because the coatings also have antioxidant activity. During the storage, the activity decreased a bit for the CON and CH coated samples but was stable for the CHG coated fruits. At the end of the storage, the higher antioxidant content is a result of the strong dehydration (Table 2b).

Table 2b. Physico-chemical properties of the coated plums

	Total polyphenol content (TPP), µmol TE/100g	AOA DPPH,	AOA FRAP,
		mg GAE/100g	
1st d			
CON	24.96±1.53bA	3.53±0.21	0.69±0.05
CH	20.26±1.21aA	3.62±0.26	0.58±0.04
CHG	21.96±1.20abA	3.59±0.24	0.67±0.04
4th d			
CON	25.03±1.53bA	3.60±0.21	0.71±0.05
CH	20.72±1.27aA	3.76±0.22	0.62±0.04
CHG	22.19+1.23abA	3.60+0.19	0.68+0.04
9th d			
CH	28.56±1.55abB	3.66±0.21	0.56±0.04
CHG	25.60±1.40aB	3.84±0.25	0.58±0.04

3.3 Microbiological safety analysis

All the samples preserved their safe statement without pathogens, but there was microbiological contamination on all samples. The grape seed oil decreases the number of the microorganisms, but the safety preservation effect of the pure chitosan coating was stronger (Table 3).

Table 3. The result of the safety analysis for the plum coated with chitosan and GSO emulsion

Count, cfu/g	Total plate counts	Molds and yeasts	*E. coli*	*Coli-forms*	*Salmo-nella*
1st d					
CON	1.5×10^5	7.9×10^3	< 10	< 10	Not detected
CH	< 10	< 10	< 10	< 10	
CHG	2.3×10^4	1.7×10^3	< 10	< 10	
4th d					
CON	1.1×10^6	6.1×10^4	< 10	< 10	Not detected
CH	6.9×10^4	7.0×10^2	< 10	< 10	
CHG	1.2×10^5	3.8×10^3	< 10	< 10	
9th d					
CH	1.6×10^5	3.1×10^3	< 10	< 10	Not detected
CHG	2.1×10^6	2.4×10^5	< 10	< 10	

3.4 Sensorial properties

On the 1st d of the storage, no significant differences were observed in the fruit taste, aroma and cut surface between the control and the coated probes. The chitosan and the GsO treatments were rated highest for overall preservation of size and shape (80% on the 9th d), and the chitosan treatment (1%) better preserved the fruit flavor and the aroma until 80%. In general, all coated samples showed a high degree of preservation of fruit hardness during the storage (in the range of 80% for coated samples and 50% for controls – Fig. 3).

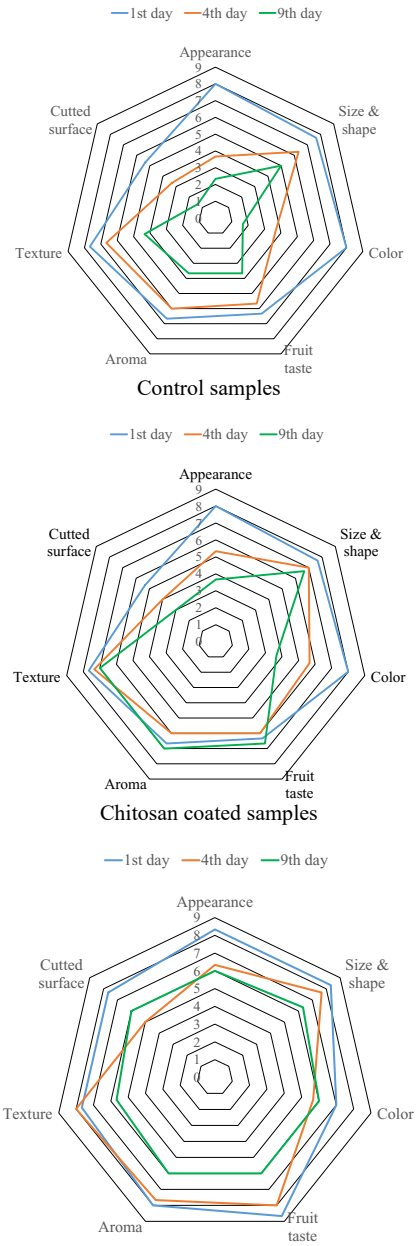

Fig. 3. The results of the sensory analysis for the control and the coated fruits

4 Conclusions

The applied coatings preserved the safety and quality of the halved and pitted plum fruits for maximum nine days. In further experiments, the emulsion coating will be applied to enhance the quality of other fruits during refrigerated storage.

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