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Research note

Effects of a composite chitosan–gelatin edible coating on postharvest quality and storability of red bell peppers

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ABSTRACT

For the first time, a composite chitosan–gelatin (CH–GL) coating was applied to peppers and its effects on fruit quality and storability were examined. Pure chitosan (CH) and gelatin (GL) coatings were studied for comparison. The CH coating inhibited microbial spoilage and prolonged the possible storage period. The GL coating contributed to fruit firmness, but did not allow for prolonged storage. The composite CH–GL coating was associated with a two-fold decrease in microbial decay, significantly ($p \leq 0.05$) enhanced fruit texture and prolonged the possible period of cold storage up to 21 days and fruit shelf-life up to 14 days, without affecting the respiration or nutritional content of the fruit.

1. Introduction

Red bell peppers (*Capsicum annuum* L.) are one of the most popular health-promoting crops traded on the global market (AgMRC, 2011). The crucial problem facing marketers of this crop is its relatively short shelf-life, which stands at about 2 weeks and limits exports to distant markets. The primary reasons for pepper quality deterioration are water loss and microbial decay that is mainly caused by *Alternaria alternata* and *Botrytis cinerea* (Fallik et al., 1999). Finding an effective approach to prolong pepper storage is a matter of great practical significance. Edible coatings based on natural materials are a promising safe and healthy tool for extending the shelf-life of fresh agricultural products (Dhall, 2013). Polysaccharide chitosan is widely used for the formation of edible coatings due to its inherent antimicrobial properties (Dutta et al., 2009). The addition of gelatin was reported to enhance the efficacy of chitosan formulations (Pereda et al., 2011). To the best of our knowledge, composite chitosan coatings have not been previously applied on pepper fruit. Moreover, the effect of pure chitosan coating on the quality and storability of peppers has received only a small amount of research attention (El Ghaouth et al., 1991).

The goal of the current work was to improve the physiological and microbial quality of red bell peppers and to prolong the period of time for which these fruit can be stored. For this purpose, a composite chitosan–gelatin (CH–GL) edible coating was utilized. The effects of pure chitosan (CH) and gelatin (GL) coatings on fruit quality were also studied and compared with those of the combined CH–GL coating.

2. Materials and methods

Red bell peppers (*Capsicum annum* L. cv. Vergasa) were harvested from the Arava valley in the south of Israel in the winter season, then brushed and dried, as previously described (Fallik et al., 1999). The fruit were randomly packed in 3–5 kg cartons, 15–20 fruit in each. Four treatments were conducted: (a) chitosan coated peppers, (b) gelatin coated peppers, (c) chitosan–gelatin coated peppers and (d) uncoated peppers which served as a control. For each treatment three cartons were used for replicates. Three experiments were performed. The experiments differed in their storage conditions. (a) *Regular storage* (14/5) = 14 days at 7 °C and RH of 95%, then 5 days at 20 °C and RH of 75%. (b) *Prolonged cold storage* (21/5) = 21 days at 7 °C and RH of 95%, then 5 days at 20 °C and RH of 75%. (c) *Long shelf storage* (14) = 14 days at 20 °C and RH of 75% with no prior cold storage. Each of the described experiments included three coating treatments and control. For each experiment, all fruit were collected at the same time, treatments were applied at the same time, quality examinations were performed at the same time. The results were compared within each experiment.

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Gelatin (GL) coating. Gelatin powder (Sigma–Aldrich) was dissolved in sterilized Double Distilled Water, DDW (1%, w/v) and the solution was stirred at 45 °C for 45 min. *Chitosan (CH) coating.* Chitosan powder (Sigma–Aldrich) was dissolved in sterilized DDW (2%, w/v) that included 0.7% of acetic acid (Sigma–Aldrich) and the solution was stirred at 30 °C for 2 h. *Chitosan–gelatin (CH–GL) coating.* To a chitosan (2%, w/v) solution prepared as described above, gelatin powder (1%, w/v) was added and the solution was stirred at 45 °C for 45 min. Peppers were hand-coated with the cold coating solutions by a paint brush and dried in a drying tunnel for 2 min at 38 °C.

Fruit firmness was measured at zero time and at the end of each storage period as previously described (Hamson, 1952) utilizing an Inspekt 5 dynamic firmness analyzer (Hegewald and Peschke, Germany). Fruit weight loss was evaluated by weighing fruit at zero time and at the end of each storage period and calculating the percentage weight loss. For ethanol, acetaldehyde and carbon dioxide measurements, 5 mL air samples were withdrawn from the fruit internal atmosphere using a gas-tight syringe and injected into the gas chromatograph (GC). The ethanol and acetaldehyde concentrations were analyzed with a Varian 3300 GC equipped with a flame ionization detector and 20% Carbowax 20 M packed column using helium as the carrier gas. Column, injector and detector temperatures were 80, 110 and 180 °C, respectively. The carbon dioxide concentration was analyzed by a Gow-Mac Series 580 GC equipped with a thermal conductivity detector and Alltech Chromosorb 80/100 (1/8 in. × 1.2 m) column after passage through a molecular sieve 5 Å 45/60 (1/8 in. × 1.2 m). The oven, injector and detector temperatures were 35, 110 and 150 °C, respectively. Total soluble solids (~50 μL of the juice from 1 g of fruit sample) were measured by a digital Refractometer (Atago, Japan). To measure biochemical parameters, peppers were cut in a 2.5 cm × 2.5 cm, freeze-dried, frozen using liquid nitrogen and crushed. Each sample represented a blend of 15 different fruit from the same treatment. The ascorbic acid concentration was measured by the enzyme kit (Ascorbic Acid TEST Kit- lot- HI3850 Hanna Instruments, USA) utilizing a previously reported method (Beutler and Beinstingl, 1980). Total phenol content was analyzed using the Folin–Ciocalteu colorimetric method (Remorini et al., 2008). Antioxidant activity was evaluated by 1,1-diphenyl-2picrylhydrazyl DPPH radical scavenger (Sanchez-Moreno et al., 1998). Fruit decay is expressed as percentage of the infected fruit in a box. Fruit were considered decayed once fungal mycelia appeared on pericarp or calyx. For fruit inoculation, *B. cinerea* inoculum was prepared as described by El Ghaouth et al. (1992). Fruit were washed with 70% ethanol and then punctured by a 1.5 mm diameter nail. Each wound site was inoculated with 40 μL of a spore suspension (10^4 spore mL−1). Fruit were stored at 20 °C (RH 95%) for 24 h and then were coated with CH, GL and CH–GL coatings. Control was coated with DDW. The experiment was maintained for 12 days.

For each test 15 randomly selected fruit from each treatment (=60 fruit for test) were tested. Microsoft office excel spreadsheets were used to calculate the means, standard deviations and standard errors. Statistical analysis was performed by JMP 7 (SAS Institute Inc., Cary, NC, USA), including a LS Means Differences Tukey HSD.

3. Results and discussion

3.1. Prolonging fruit storability

In the first experiment, the fruit were stored under typical pepper storage conditions (14 days at 7 °C and then 5 days at 20 °C) and it was confirmed that the coatings did not cause negative effects. In the second experiment, the cold-storage (7 °C) was extended to 21 days. In the third experiment, the shelf-storage (20 °C) was extended to 14 days.

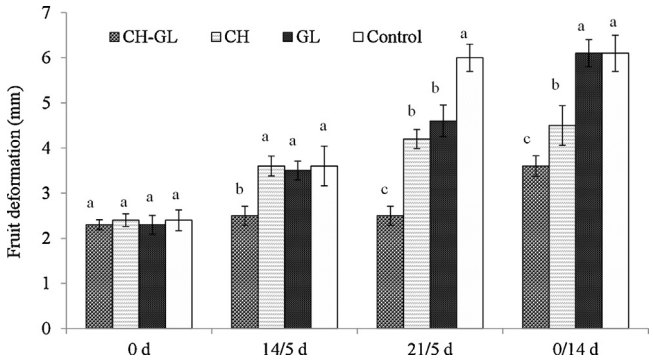

Fig. 1. Firmness of the peppers. The data were normalized according to the zero time measurements of each storage period. The data represent means of 15 replications, 95% *t*-based confidence intervals. Values in sampling time followed by different letter are significantly (at $p \leq 0.05$) different according to Tukey–Kramer HSD.

Peppers firmness is shown in Fig. 1. After regular storage (14/5 days), slight texture enhancement caused by the composite CH–GL coating was observed. After the extended cold storage, uncoated fruit showed dramatic texture degradation, whereas significantly less degradation was observed among the fruit coated with CH or GL. Notably, the firmness of the fruit coated with the composite CH–GL coating remained practically unchanged from the zero-time measurement. After the prolonged shelf-life storage, uncoated fruit and fruit coated with GL only showed dramatic texture degradation, CH-coated peppers showed significantly less texture degradation and, as in previous experiment, the CH–GL coated fruit showed superior firmness. Since they are hollow, peppers are very sensitive

Table 1
Weight loss of the peppers. The data represent means of fifteen replications, 95% *t*-based confidence intervals. The values in columns followed by the different letter are significantly (at $p \leq 0.05$) different according to Tukey–Kramer HSD test.

Weight loss (%)	14 days at 7 °C 5 days at 20 °C	21 days at 7 °C 5 days at 20 °C	14 days at 20 °C
CH–GL	4.33 ± 0.37 a	6.52 ± 0.15 b	8.27 ± 0.29 c
CH	4.08 ± 0.31 a	5.89 ± 0.13 c	8.12 ± 0.27 c
GL	3.99 ± 0.14 a	5.87 ± 0.13 c	10.60 ± 0.27 a
Control	3.98 ± 0.13 a	7.28 ± 0.20 a	9.33 ± 0.24 b

Table 2
CO_2 in the pepper internal atmospheres. The data represent means of fifteen replications, 95% *t*-based confidence intervals. The values in columns followed by the different letter are significantly (at $p \leq 0.05$) different according to Tukey–Kramer HSD.

CO_2 (ppm)	14 days at 7 °C 5 days at 20 °C	21 days at 7 °C 5 days at 20 °C	14 days at 20 °C
CH–GL	2.02 ± 0.24 a	2.39 ± 0.12 a	1.25 ± 0.04 a
CH	1.99 ± 0.24 a	1.75 ± 0.14 bc	0.87 ± 0.05 b
GL	2.02 ± 0.15 a	2.02 ± 0.14 ab	1.18 ± 0.11 a
Control	1.76 ± 0.19 a	1.45 ± 0.09 c	0.88 ± 0.05 b

Table 3
Decay incidence of the coated and uncoated peppers after 21 days at 7 °C and additional 5 days at 20 °C. An infection diameter of the peppers inoculated with *B. cinerea* measured after 12 days of storage at 7 °C. The data represent means of fifteen replications, 95% *t*-based confidence intervals. The values in columns followed by the different letter are significantly (at $p \leq 0.05$) different according to Tukey–Kramer HSD.

	Decay incidence (%) 21/5 days	Infection diameter (cm) 12 days post inoculation
CH–GL	10.62 ± 2.21 b	2.51 ± 0.14 b
CH	7.42 ± 3.59 b	2.31 ± 0.19 b
GL	17.34 ± 1.98 a	2.75 ± 0.15 ab
Control	25.32 ± 7.06 a	3.08 ± 0.15 a