ISSN: 0975 -8542

Journal of Global Pharma Technology

Available Online at: www.jgpt.co.in

RESEARCH ARTICLE

Application of Cinnamaldehyde-Chitosan Coating to Prolong Shelf-Life of Grapefruit (*Citrus Maxima)*

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Abstract

Grapefruit (*Citrus Maxima*) is one of the most important citrus fruit cultivated in Vietnam. Its stability is quite short under ambient temperature. The edible coating could keep textural properties, sensory appearance and control respiration rate of fruits by functioning as a semipermeable vapor and gas barrier to regulate the moisture and gases in the package. Chitosan is recognized as safe and has been widely applied as a successful carrier for incorporating with the antimicrobial agents. The objective of this research was to prolong the fresh fruit quality of grapefruit by using cinnamaldehyde-chitosan coating. The results indicated that 1.0% cinnamaldehyde-chitosan application could maintain the highest fruit quality properties such as weight loss, decay rate, firmness, sugar, acidity, and vitamin C. By this application, the storage life of grapefruit could be extended to 28 days under ambient temperature.

Keywords: *Grapefruit, cinnamaldehyde, chitosan, coating, storage.*

Introduction

Citrus fruits are one the world's most important crops, and one of these, grapefruit *(Citrus paradisi),* is interesting for the secondary metabolites that it contains [1]. The metabolites present in grapefruit have an antioxidant effect and reduce atherosclerotic plaque formation [2], inhibit breast cancer cell proliferation and mammary cell tumorigenesis [3]. Grapefruit contains high levels of ascorbic acid and flavonoid antioxidants including naringin and naringenin [4]. Flavonoid properties include anti-inflammatory, antiviral and anticancer activities, an ability to inhibit platelet aggregation, and effects on capillary fragility [5, 6].

Mekong Delta will grow two special grapefruit varieties on an additional 25,000ha by 2020. The two varieties (green-peel and pink-flesh) of grapefruit have fetched high prices for many years now because of high demand in foreign countries. Cinnamaldehyde is a well-known food flavor additive. Cinnamaldehyde has low aqueous solubility and susceptible to degradation by oxidation reactions [7]. Cinnamaldehyde shows promising antifungal activities against pathogens [8, 9]. As reported by several researchers, the after-harvested use of chitosan-based coating incorporating with cinnamon oil might control the postharvest fungi in pepper, prevent the growth of microorganisms in fresh cut pear and melon, and enhance the quality of jujube fruits [10, 14]. Chitin and chitosan are polysaccharides, chemically similar to cellulose, differing only by the presence or absence of nitrogen. Chitosan is the *N*-deacetylated derivative of chitin, although this *N*-deacetylation is almost never complete.

Chitosan is a nontoxic, odorless, and biodegradable polysaccharide with good film formation and broad-spectrum antimicrobial properties. It is considered environment-friendly for agricultural uses as it is easily degraded in the environment, and nontoxic to humans. The mechanical properties of the chitosan polymer also contribute to the protection of fruit from physical damage. Chitosan has been widely used as a coating agent of various fruit mainly for protection from post-harvest losses due to microbial infections [15]. Chitosan coatings have been found to be effective in microbial control and in preserving quality in many vegetables and fruits such as table grapes and mushrooms [16]. Moreover, it can be used as a preservative for the postharvest preservation of fruits and vegetables [17, 19]. Chitosan biofilms could enhance antimicrobial effects [20, 21]. The roughness of coating film is an inherent property of chitosan-based polymer in which chitosan forms the coating film with micro-perforated structure and influences the smoothness of fruit surfaces. The inhomogeneous distribution of micropores is found on the surface of film with different concentration of chitosan.

The number of micropores in the film surface might decrease with increasing the addition of chitosan in the coating solution system. The roughness of coating film is affected by the concentration of chitosan [22]. The preservation effect of chitosan-based coatings might be partly due to its property of slowing the respiration rate and controlling the decay of fruits, and partly due to its function of preventing the formation of off odors and retarding lipid oxidation in fruit [23, 26].Yang Gao et al [27].Evaluated the efficacy of chitosan-based coatings enriched with cinnamaldehyde on mandarin fruit cv. Ponkan during room-temperature storage. They suggested that 0.5% cinnamaldehyde-chitosan and 1.0% cinnamaldehyde-chitosan might be good formulations for maintaining the quality of mandarin fruit cv. Ponkan during room-temperature storage. Chitosan coating plus different essential oils was developed and applied to fresh blueberries in order to find more natural treatments to preserve fresh fruit quality and safety during postharvest storage [28]. Cinnamaldehyde was entrapped in monodispersed nanoparticles that were assembled from chitosan and tripolyphosphate [7]. Wassem Ahmed et al [29]. Demonstrated that chitosan could prolonge the fresh fruit quality during storage of grapefruit. Our present study focused on the examination of using cinnamaldehyde-chitosan coating to prolong the fresh fruit quality of grapefruit.

Materials and Method

Material

Grapefruit (*Citrus Maxima*) samples were collected from Vinh Long province, Vietnam. These samples were graded to remove the damaged or decay fruit as well as foreign matters. Lab utensils were used including digital balance, glassware, biuret, refractometer. Chemical substances were also used such as chitosan, cinnamaldehyde, acetic acid, Tween 80, sodium chloride, 2-6-dichloroindophenol.

Figure 1: Grapefruit (*Citrus Maxima*)

Preparation of Edible Coating of Cinnamaldehyde-chitosan

Chitosan coating, 1.5% (w/v): 30 g chitosan was added to 200 mL aqueous solution (containing 1.0% acetic acid, 2.0% Tween 80, and 0.10% sodium chloride) and stirred well at room temperature to dissolve the chitosan.

Cinnamaldehyde-chitosan coating, 0.5% (w/v): 1 g cinnamaldehyde (was added to 200 mL of the prepared 1.5% chitosan coating, stirred at room temperature, and mixed well.

Cinnamaldehyde-chitosan coating, 1.0% (w/v): 2.0 g cinnamaldehyde was added to 200 mL of the prepared 1.5% chitosan coating, stirred at room temperature, and mixed well. Cinnamaldehyde-chitosan coating, 1.5% (w/v): 3.0 g cinnamaldehyde was added to 200 mL of the prepared 1.5% chitosan coating, stirred at room temperature, and mixed well.

Fruit Treatments

All samples were cleaned with fresh water and air-dried.

The cleaned samples were soaked in 1% acetic acid (control), 0.5% cinnamaldehyde-chitosan, 1.0% cinnamaldehyde-chitosan, or 1.5% cinnamaldehyde-chitosan for 15 s, and then air-dried. Each treatment was composed of 15 fruits. The samples were kept in perforated LDPE bags and stored at ambient temperature. Samples were taken on 0, 7, 14, 21, 28 days.

Physico-chemical and Biological Analysis

Weight loss was examined with samples of 15 fruits per treatment. The fruits from each treatment were weighed at 0, 7, 14, 21, 28 days of storage. The weight loss was calculated as follows: Weight loss = (initial weight-weighing weight)*100%/ initial weight.

Decay rate was estimated by observing of 150 treated fruits and divided into three replicates. The number of rotting fruits was counted every 7 days. The following equation was used to calculate the decay rate of fruits: Decay rate = rotting fruits*100%/ total fruits.

Firmness was determined by Firmness Tester expressed as N/m. fifteen fruits were used per replicate. A homogeneous flesh sample of 5 fruits was prepared for each treatment to measure the content of total soluble solids (TSS, %), titratable acidity (TA, %), and vitamin C (VC, mg/100g). TSS content was measured with refractometer. TA content was determined by the acid-base titration method. VC content was determined by 2-6-dichloroindophenol titration [30].

Statistical Analysis

The experiments were run in triplicate with three different lots of samples. Data were subjected to analysis of variance (ANOVA) and mean comparison was carried out using Duncan's multiple range test (DMRT). Statistical analysis was performed by the Stat graphics Centurion XVI.

Result & Discussion

Effect of Cinnamaldehyde-chitosan Coating on Weight Loss, Decay Rate and Firmness of Grapefruit

Weight loss and decay rate are important parameters used to evaluate fruit storage tolerance. During storage at room temperature, the weight loss rate of each sample gradually increased. This could be due to a water vapor pressure gradient in different compartments of the fruit cell tissue, through which moisture was transferred from the fruit into the immediate environment [31].

Chitosan forms a film on the surface of the fruit, which hinders the exchange of water vapor, thereby reducing water loss through transpiration [32]. During storage at ambient temperature, the decay rate of fruit gradually increased with storage time. Chitosan reacts with cinnamaldehyde, forming imine linkages; moreover, cinnamaldehyde cross links the chitosan chains [33, 34], so the antifungal activity of the composite film was increased, the disease resistance of the fruit was increased, and the fruit rot incidence rate was reduced [35].

Table 1: Effect of cinnamaldehyde-chitosan concentration (%) to weight loss (%) of grapefruit during storage

Time (day)	Weight loss (%)			
	1.0% acetic acid (control)	0.5% cinnamaldehyde-chitosan	1.0% cinnamaldehyde–chitosan	1.5% cinnamaldehyde–chitosan
0	0	0	0	0
7	2.34±0.05^{a}	1.68±0.04^{b}	0.75±0.08^{c}	0.73±0.03^{c}
14	3.29±0.02^{a}	2.11±0.07^{b}	1.02±0.06^{c}	1.01±0.02^{c}
21	4.65±0.07^{a}	3.38±0.05^{b}	1.64±0.03^{c}	1.62±0.07^{c}
28	7.59±0.11^{a}	4.08±0.02^{b}	1.79±0.05^{c}	1.76±0.02^{c}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Table 2: Effect of cinnamaldehyde–chitosan concentration (%) to decay rate (%) of grapefruit during storage

Time (day)	Decay rate (%)			
	1.0% acetic acid (control)	0.5% cinnamaldehyde–chitosan	1.0% cinnamaldehyde–chitosan	1.5% cinnamaldehyde–chitosan
0	0	0	0	0
7	1.23±0.06[a]	0.69±0.03[b]	0.46±0.04[c]	0.45±0.07[c]
14	2.49±0.02[a]	1.58±0.01[b]	0.73±0.07[c]	0.70±0.03[c]
21	4.77±0.02[a]	2.11±0.04[b]	1.03±0.02[c]	1.01±0.04[c]
28	7.54±0.03[a]	3.55±0.04[b]	1.16±0.04[c]	1.14±0.03[c]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Firmness is one of the most critical quality attributes influencing consumer appeal and marketing of fresh fruit. Blueberries normally soften during the postharvest chain, which consequently decreases fruit shelf life and reduces fruit market value [36]. Cell wall modification caused by the hydrolysis of starch to sugar and the degradation of pectin was also reported to relate to postharvest firmness changes in blueberries [36]. Chitosan coatings maintained fruit firmness through at least 2 possible mechanisms: maintenance of high turgor by reducing water loss and decrease of pectin degradation by reducing microbial populations on the fruit. Chitosan coating most likely prevented fruit water loss, and the lipophilic property of the essential oils may have further reduced the water permeability of the coating [28].

Table 3: Effect of cinnamaldehyde-chitosan concentration (%) to firmness (N/m) of grapefruit during storage

Time (day)	Firmness (N/m)			
	1.0% acetic acid (control)	0.5% cinnamaldehyde–chitosan	1.0% cinnamaldehyde–chitosan	1.5% cinnamaldehyde–chitosan
0	28.68±0.04[a]	28.68±0.04[a]	28.68±0.04[a]	28.68±0.04[a]
7	26.33±0.02[b]	27.57±0.01[ab]	28.52±0.03[a]	28.54±0.01[a]
14	23.48±0.07[b]	25.22±0.03[ab]	27.66±0.04[a]	27.69±0.05[a]
21	21.19±0.02[b]	23.18±0.02[ab]	26.95±0.08[a]	26.98±0.11[a]
28	19.35±0.14[b]	21.79±0.07[ab]	25.46±0.05[a]	25.49±0.06[a]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Effect of Cinnamaldehyde-chitosan Coating on the Contents of Sugar, Acidity, and Vitamin C of Grapefruit

The contents of sugar, acid, and vitamin C are important nutritional quality indices of fruit, and will affect the taste of fruit .Coating changing the composition of the gas within the fruit (oxygen and carbon dioxide), thereby affecting the respiratory metabolism and delaying the formation and degradation of carbohydrates in the fruit [37].

Table 4: Effect of cinnamaldehyde-chitosan concentration (%) to total soluble solid (°Brix) of grapefruit during storage

Time (day)	Total soluble solid (°Brix)			
	1.0% acetic acid (control)	0.5% cinnamaldehyde–chitosan	1.0% cinnamaldehyde–chitosan	1.5% cinnamaldehyde–chitosan
0	8.46±0.04[a]	8.46±0.04[a]	8.46±0.04[a]	8.46±0.04[a]
7	7.24±0.03[b]	7.98±0.02[ab]	8.32±0.02[a]	8.34±0.05[a]
14	6.97±0.02[b]	7.43±0.07[ab]	8.13±0.01[a]	8.15±0.04[a]
21	6.40±0.06[b]	7.04±0.04[ab]	8.02±0.06[a]	8.05±0.08[a]
28	6.15±0.05[b]	6.97±0.02[ab]	7.94±0.03[a]	7.96±0.04[a]

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Table 5: Effect of cinnamaldehyde-chitosan concentration (%) to acidity (%) of grapefruit during storage

Time (day)	Acidity (%)			
	1.0% acetic acid (control)	0.5% cinnamaldehyde–chitosan	1.0% cinnamaldehyde–chitosan	1.5% cinnamaldehyde–chitosan
0	1.64±0.01^{a}	1.64±0.01^{a}	1.64±0.01^{a}	1.64±0.01^{a}
7	1.51±0.03^{b}	1.56±0.02^{ab}	1.63±0.02^{a}	1.64±0.01^{a}
14	1.42±0.05^{b}	1.48±0.04^{ab}	1.60±0.04^{a}	1.60±0.03^{a}
21	1.26±0.02^{b}	1.31±0.03^{ab}	1.55±0.03^{a}	1.56±0.02^{a}
28	1.14±0.03^{b}	1.23±0.02^{ab}	1.52±0.02^{a}	1.53±0.00^{a}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Table 6: Effect of cinnamaldehyde–chitosan concentration (%) to vitamin C (mg/100g) of grapefruit during storage

Time (day)	Vitamin C (mg/100g)			
	1.0% acetic acid (control)	0.5% cinnamaldehyde–chitosan	1.0% cinnamaldehyde–chitosan	1.5% cinnamaldehyde–chitosan
0	24.11±0.03^{a}	24.11±0.03^{a}	24.11±0.03^{a}	24.11±0.03^{a}
7	22.51±0.02^{b}	22.69±0.05^{ab}	23.55±0.02^{a}	23.58±0.05^{a}
14	20.30±0.04^{b}	21.53±0.02^{ab}	23.43±0.05^{a}	23.47±0.04^{a}
21	19.43±0.06^{b}	21.04±0.03^{ab}	23.00±0.03^{a}	23.03±0.02^{a}
28	18.75±0.03^{b}	20.48±0.05^{ab}	22.92±0.01^{a}	22.95±0.04^{a}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Conclusion

Chitosan has a broad range of applications in the food industry, one of which is its application as an edible coating material. The chitosan coating creates a semi-permeable barrier that can reduce water loss and alter the natural exchange of gases between the fruit and the external atmosphere, thereby reducing respiration, slowing senescence in fruit and vegetables, and inhibiting microbial decay. Chitosan has become a prospective alternative treatment for fruit and vegetables due to its natural character, antimicrobial activity, and elicitation of defense responses in plant tissue. We have successfully applied cinnamaldehyde-chitosan coating to maintain grapefruit (*Citrus Maxima*) quality during storage.

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