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IMPROVEMENT OF QUALITY AND SHELF LIFE OF STRAWBERRY WITH NANOCELLULOSE/CHITOSAN COMPOSITE COATINGS

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Abstract

Coating of strawberries with 1% chitosan (CS) and 5% nanocellulose (NCC) composite and storing at 20°C for 7 days decreased weight loss and decay percentage by 14.4 and 70.6%, respectively, as compared to the control. The content of pH and titratable acidity was not significantly different from the control. Total soluble solids (TSS) content was lower due to decrease in senescence and metabolism. The NCC/CS composite coatings had a positive effect on maintaining higher concentrations of total phenols and total anthocyanins which decreased in control fruit due to senescence processes. Sensory evaluation showed that the NCC/CS composite coatings had better visual appearance. Results of this study confirm that the NCC/CS composite coatings are useful for extending the shelf life and maintaining quality of strawberries.

Introduction

Strawberries are rich in substances related to health benefits such as vitamin C, vitamin E, β-carotene, phenolic compounds and anthocyanin pigments (Ayala-Zavala *et al.* 2004). Strawberries have a very short shelf life and senescence period due to their susceptibility to mechanical injury, texture softening, physiological disorders and infections caused by several pathogens (Vu *et al.* 2011). Many preservation methods have been used to extend the shelf life and improve the quality of strawberry, such as freezing (Marina *et al.* 2015) and heat treatment (Vicente *et al*. 2005), controlled atmospheres (Harker *et al*. 2000, Wszelaki *et al*. 2000), gamma irradiation (Peerzada *et al.* 2012) and chemical treatments (Castello *et al*. 2010). However, some of the above methods have adverse effects on color, flavor, taste and texture. Moreover, freezing treatment could make the strawberries undergo quality deterioration because of structural collapse (Galetto *et al.* 2010). The heat treatment could be easy to damage the fruit and remove many nutrients if the control methods are improper. The controlled atmospheres method could be effective at inhibiting microbial growth. However, it adversely affects the color and flavor of strawberries (Pelayo *et al.* 2003). Consumers demand more natural, environmentally friendly food, with high quality and an extended shelf life, without any chemical preservatives. In view of these factors, the use of natural materials to control physiological processes draws increasing interest (Lin and Zhao 2007). During the past years, coatings have been proposed as barriers to protect strawberry from deterioration by retarding dehydration, providing a selective barrier to moisture, oxygen and carbon dioxide, suppressing respiration, improving textural quality which helps retain volatile flavor compounds and reduce microbial growth (Lee *et al.* 2003). The effect of coatings

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with polysaccharide materials such as chitosan and cellulose derivative were studied to extend the shelf life of strawberry (Neeta *et al.* 2013). Chitosan and nanocellulose (NCC) have similar chemical structures and are expected to possess excellent biocompatibility and biodegradability (Feng *et al*. 2014). In view of this, the NCC/CS composite coatings have the potential to extend the shelf life and improve the quality of strawberry.

Nanocellulose (NCC) exhibits very interesting properties such as renewable nature, low density, high specific strength and modulus, large reactive surface (Lima and Borsali 2004). NCC is very interesting nanomaterial for production of low-cost, lightweight and very strong nanocomposites.

Chitosan (CS) has many applications in fruit and vegetable preservation due to its transparent, non-toxic, biodegradable, biofunctional, biocompatible and good film-forming charateristics (Pillai *et al*. 2009). Some authors discussed the mechanical, barrier, thermal and antimicrobial properties of NCC/CS composite films (Danial *et al*. 2014, Khan *et al*. 2012, De Mesquita *et al*. 2012). However, the effect of NCC/CS composite coatings on strawberry preservation is very rare. Therefore, the aim of this study is to evaluate the effect of nanocellulose and chitosan coating of strawberries at 20°C in preserving its quality. Strawberries coated with three different types of coatings were compared and analysed in terms of weight loss, decay percentage, titratable acidity, total soluble solids, pH, total phenols, total anthocyanins and sensory evaluation.

Materials and Methods

Strawberries were bought from the local market in Qiqihar, China. Only fruits having uniform ripening stage, size, color, shape and without physical injuries were selected. Chitosan (deacetylation of 85% with a medium molecular weight), was purchased from Sigma-Aldrich Canada Ltd.. Nanocellulose aqueous suspension was prepared according to the method of Wei *et al*. (2012).

Chitosan solution (1 wt%) was prepared by mixing 1 g of CS, 1 ml of acetic acid and 98 ml of distilled water for 4 hrs in a stirrer and centrifuged at 1500 rpm. Subsequently, NCC suspension (5 wt%, dry basis) was added into the CS solution. The mixture was then stirred at 1000 rpm for 6 hrs followed by sonication for 10 min to remove the bubbles. Final composite solution was termed as NCC/CS.

Strawberries without disinfected surface were immersed in 2% sodium hypochlorite solution for 2 min, then air-dried for 2 hrs at room temperature with forced air. Total mass of 3 kg strawberries was randomly divided into three groups. Strawberries without any coated treatment are used as control, the chitosan coated strawberries are termed as CS, the nanocellulose/chitosan composite coated strawberries are termed as NCC/CS. The strawberries were immersed in the coating solution for 30 sec and dried by air drying for 2 hrs at 20°C, then the strawberries were placed in PP plastic boxes and stored at 20°C and 35 – 40% relative humidity.

In order to measure weight loss, the strawberries were weighed each day during the storage period using an electronic balance (UWA-K-015, Xiamen Andong Electronics Co., Ltd., Fujian, China). Fifteen fruits in three repetitions were used to measure the weight loss.

The number of decayed strawberries was recorded everyday in set of ten fruits (in three replicates). The decay percentage of fruits was calculated as compared to control.

Strawberry pieces were homogenized for 1 min at high speed using a hand-held blender. The pH of the strawberry puree was measured with a calibrated pH meter (Sartorius PP-50, Goettingen, Germany) according to the method of Aday *et al*. (2011). The total soluble solids content was measured by using hand refractometer (Atago Co., Tokyo, Japan) following the method of Caner *et al*. (2009). The titratable acid content was measured according to Mazumdar *et al*. (2003).

The total phenols content was measured by Folin-Ciocalteu method with minor modifications (Neeta *et al*. 2013). Five ml of distilled water and 4 g homogenized sample were added in a flask and stirred for 5 min. Afterwards, 50 ml.c. 96% ethanol was added and mixed for 2 h. Then, the mixture was filtered, and residues were washed three times with 10 ml.c. 80% ethanol. The filtrate was collected in 100 ml.c. volumetric flask and volume was made up to 100 ml with distilled water. Absorption coefficient was measured after 30 min at 760 nm using spectrometer (Bibby Scientific Limited, Staffordshire, UK).

The total anthocyanins content was measured according to Lees *et al*. (1972) with minor modifications. Initially, 5 g samples were mixed with 40 ml of ethanol and 1.5 mol/l HCl solution and homogenized for 1 min. Then, the mixture was filtered and the filtrate was collected in a 100 ml volumetric flask, and volume was made up to 100 ml with distilled water. Absorbance coefficient was measured at 535 nm using a spectrometer (Bibby Scientific Limited, Staffordshire, UK).

The sensory evaluation was carried out according to the method of Bai *et al.* (2003). The sensory quality included color, taste, texture, flavor and overall acceptability after 7 days' storage period. Strawberries were randomly presented to nine panelists for sensory evaluation, they scored the differences between the samples: 0 - 2 represented extreme dislike; 3 - 5 fair; 6 - 8 good; and 9 excellent for color, taste, texture, flavor and overall acceptability. Panelists used water to cleanse their mouth from residual taste between the samples.

The experiment was measured in a completely randomized design with three replications. Data analyses were performed by one-way analysis of variance (ANOVA) and DMRT comparisons and means were compared by the least significant difference ($p < 0.05$).

Results and Discussion

Weight loss in fresh fruits and vegetables is mainly attributed to the loss of water caused by transpiration and respiration processes and is a major cause of quality deterioration. All strawberries showed a gradual loss of weight during storage and there were no significant differences between the control and coated samples after one day of storage (Fig.1). At the second day, weight loss of the strawberries in NCC/CS was the lowest as compared to the control. At the seventh day, the weight loss was 31.8 % for the CS compared to the NCC/CS which exhibited 17.6 %. The results showed coatings are clearly effective in conferring a physical barrier to moisture loss retarding dehydration and fruit shrivelling (Almenar *et al.* 2006). The presence of NCC is thought to increase the tortuosity in the chitosan films leading to slower water vapor diffusion processes and hence, to a lower permeability (Azeredo *et al*. 2010).

The decay percentage of strawberries in NCC/CS was reduced significantly ($p < 0.05$). Fig. 2 shows that the decay percentage of strawberries increased gradually with storage time in control, CS and NCC/CS. At the end of storage, 93% of strawberries in control showed visual signs of decay. The coated strawberries showed decay percentage in CS (66.7) and in (20.8) NCC/CS, respectively as compared 93% in control. The lower decay percentage was correlated with the inhibited microbial populations in strawberries coated with CS (Vargas *et al.* 2006). Another possible reason was the synergy of NCC, the anti-bacteria mechanism of NCC (Danial *et al*. 2014).

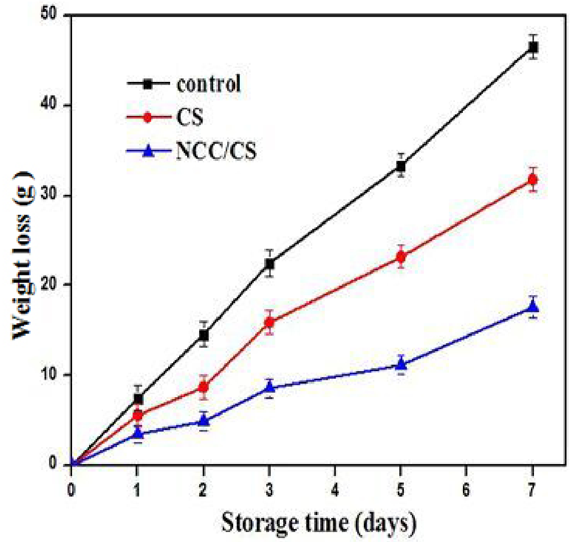

Fig. 1. Weight loss of strawberries in control (■), CS (●) and NCC/CS (▲) stored at 20°C during 7 days' storage.

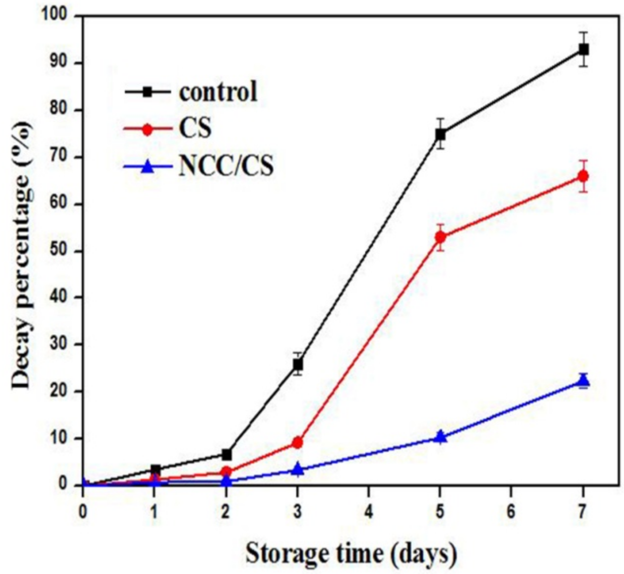

Fig. 2. Decay percentage of strawberries in control (■), CS (●) and NCC/CS (▲) stored at 20°C during 7 days' storage.

TSS content of strawberries in control was higher and differed significantly ($p < 0.05$) from the strawberries in NCC/CS (Table 1) and the increase was correlated to considerable loss of water during storage, in addition to solubilisation of cell wall polyuronides and hemicelluloses

(Hernandez-Munoz *et al.* 2008). TSS content of strawberries decreased gradually in NCC/CS (Table 1). This decrease was attributed to the physiological processes like respiration, transpiration and senescence (Vachon *et al.* 2003). The pH of strawberries decreased during storage. The initial pH of 4.5 decreased to the final pH of 3.6, 3.9 and 3.7 in control, CS and NCC/CS, respectively. The result was still above the average reported values for ripe strawberry of 3.3 (Elena *et al*. 2013). The TA content of strawberries decreased during storage significantly. Strawberries in CS and NCC/CS showed the higher content of TA i.e. 0.53 and 0.57%, respectively, which was significantly superior to that in control. TA reduction may be expected as a result of metabolic changes in fruit or due to the use of organic acids in the respiratory process (Montero *et al*. 1996).

Table 1. TSS, pH and TA of strawberries in control, CS and NCC/CS stored at 20°C during 7 days.

	Days	Control	CS	NCC/CS
TSS (g/100 g)	0	7.2 ± 0.80^a	7.2 ± 0.70^a	7.2 ± 0.30^a
	3	7.4 ± 1.10^a	7.3 ± 0.60^a	6.2 ± 0.40^a
	7	6.5 ± 0.60^a	7.5 ± 0.60^a	5.4 ± 0.40^b
pH	0	4.5 ± 0.10^a	4.5 ± 0.10^a	4.5 ± 0.10^a
	3	4.0 ± 0.10^b	4.0 ± 0.10^b	4.0 ± 0.10^a
	7	3.6 ± 0.10^c	3.9 ± 0.10^b	3.7 ± 0.10^a
TA (g/100 g)	0	0.75 ± 0.01^a	0.75 ± 0.01^a	0.75 ± 0.01^a
	3	0.51 ± 0.02^b	0.66 ± 0.01^b	0.69 ± 0.02^b
	7	0.42 ± 0.02^b	0.53 ± 0.01^b	0.57 ± 0.02^b

Mean values and standard deviation (n = 3). Subscripts in a column indicate significant differences during the storage time ($p < 0.05$).

Total phenols content of strawberries in three groups progressively decreased during storage, but strawberries in control had a significantly ($p < 0.05$) greater decrease (Fig. 3). Macheix *et al*. (1990) reported that the decrease in phenols might be due to breakdown of cell structure as the fruit senesce. At the end of storage, the phenols content of strawberries in CS and NCC/CS were 0.67 and 0.75 mg/g, respectively. Incorporation of CS with NCC maintained higher total phenols content, the result confirmed that NCC/CS composite coatings may form a protective barrier on the fruit surface and reduce the oxygen supply for enzymatic oxidation of phenols.

Color changes of fruits occurring during postharvest are attributed to the synthesis of carotenoids and anthocyanin and the degradation of chlorophyll (Han *et al*. 2004). The highest value of anthocyanins content was observed at third day in control (Fig. 4). At the end of storage, all the coated strawberries had a progressive increase in anthocyanin concentrations significantly ($p < 0.05$). Strawberries in NCC/CS exhibited higher total anthocyanins content which suggests that the NCC/CS composite coatings acted as a gas barrier to modify the internal atmosphere in the fruits (higher levels of CO_2 and low levels of O_2), and this in turn may retard the biochemical reactions leading to anthocyanin synthesis (Tzoumaki *et al.* 2009).

Sensory evaluation showed that the coatings with NCC/CS significantly ($p < 0.05$) improved the quality of strawberry compared to that of control while maintaining the overall acceptability at higher scores. At the end of storage, strawberries in NCC/CS got higher sensory scores than those in control and CS for the color, taste, texture and flavor tested. The strawberries in control decayed and exhibited poor appearance. These results suggest that NCC/CS composite coatings can be used successfully for extending the shelf life and improving the quality of strawberry stored at 20°C.

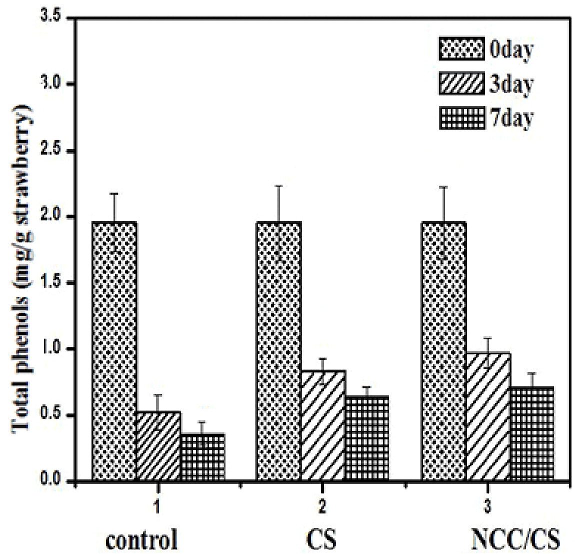

Fig. 3. Total phenols content of strawberries in control, CS and NCC/CS stored at 20°C during 7 days' storage.

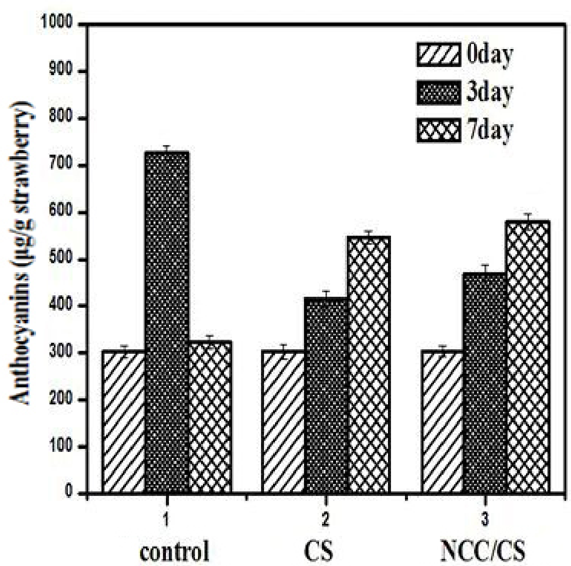

Fig. 4. Total anthocyanins content of strawberries in control, CS and NCC/CS stored at 20°C during 7 days' storage.

Table 2. Sensory evaluation of strawberries in control, CS and NCC/CS stored at 20°C during 7 days' storage.

Treatments	Sensory evaluation				
	Color	Taste	Texture	Flavor	Overall acceptability
Control	3.3° ± 0.22^{a}	2.4° ± 0.23^{a}	2.1° ± 0.46^{a}	2.8° ± 0.27^{a}	2.6° ± 0.21^{a}
CS	7.4° ± 0.19^{b}	7.1° ± 0.28^{b}	7.4° ± 0.33^{b}	7.3° ± 0.26^{b}	7.5° ± 0.15^{b}
NCC/CS	8.9° ± 0.27^{c}	8.1° ± 0.19^{c}	8.3° ± 0.51^{c}	8.2° ± 0.31^{c}	8.5° ± 0.19^{c}

Mean values and standard deviation (n = 3). Subscripts in a column indicate significant differences during the storage time ($p < 0.05$).

The NCC/CS composite coatings could extend the shelf life, maintain the color and slow down the biological aging process of the strawberries compared to CS and the control. Therefore, the present results are useful for further development of natural biomaterials that can be widely used for strawberry packaging.

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