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The preservation effect of ascorbic acid and calcium chloride modified chitosan coating on fresh-cut apples at room temperature

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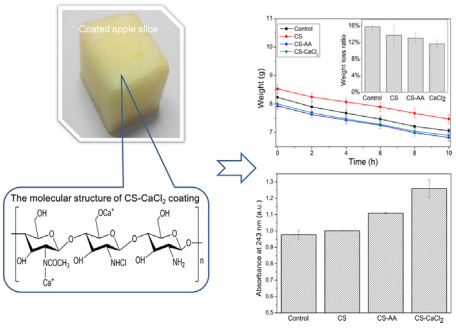
HIGHLIGHTS

- All the coatings possessed the ability to maintain AA content inner apple slices.
- CS-$CaCl_2$ coating was good at anti-browning and quality maintaining.
- CS-$CaCl_2$ coated apples have lower weight loss and higher AA content than CS-AA.

GRAPHICAL ABSTRACT



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ABSTRACT

The consumption of fresh-cut apples has grown rapidly due to consumers' increasing willingness to enjoy prepared and ready-to-eat fruits. But fresh-cut apples tend to experience severe enzymatic browning which discourages people to taste. Chitosan (CS) coating containing ascorbic acid (AA) or calcium chloride ($CaCl_2$) were applied on fresh-cut apples in this work to observe their preservation effects. Their appearance, weight change were evaluated during the storage at room temperature, besides, AA content, soluble solid content were analyzed at the end of storage. CS-$CaCl_2$ coating has better preservation effect than CS-AA coating when they were applied on fresh-cut apples. CS-$CaCl_2$ coating showed lower weight loss and higher AA content of apple slices than CS-AA coating. CS-$CaCl_2$ coating was also good at anti-browning in terms of the appearance of coated apple slices.

1. Introduction

Fruits are good sources of vitamins, minerals and fibers, moreover, they have become an important segment of our daily life. Apple helps improving people's health because of their various nutritional constituents such as vitamins and phenolic compounds [1]. Nowadays, more and more apples are cut into pieces for the convenience of consumers. In food service establishments, school lunch programs and our own house, fresh-cut apples have recently emerged as popular snacks [2]. However, fresh-cut apples are susceptible to be spoiled because of their enzymatic browning. And the most remarkable negative effect of enzymatic browning is the color deterioration which is the main reason of impairing fruit quality and discouraging consumers to purchase fresh-cut apples [3–5]. Thus, it is an urgent task to develop proper methods to reduce the decay of fresh-cut apples and prolong their shelf-life. Nowadays, fresh-cut apples are typically stored under refrigerated conditions to maintain their quality. However, after being stayed in a cold circumstance for a long time, apple slices may suffer from physiological injure. Moreover, this method is costly and

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energy consuming. Edible coatings have become a method that is a potential for the development of high-quality fresh-cut fruits [6,7]. Poverenov et al. reported that the LBL alginate–chitosan coating was found to possess the beneficial properties of both ingredients and antimicrobial activity [8]. The data of Xiao et al. suggested that chitosan incorporated with rosemary improved the antioxidant protection and sensory qualities of fresh-cut pears and showed the antibrowning ability [9]. Qi et al. demonstrated coatings in combination with anti-browning agents (ascorbic acid and $CaCl_2$) effectively retarded enzymatic browning on minimally processed apples during storage and retarded or avoided tissue softening of the apple slices [10].

CS produced by the deacetylation of chitin [11] is cationic, nontoxic, biodegradable, biocompatible and has the film-forming ability as well as antifungal effects on various plant pathogenic bacteria and fungi [12]. In previous studies, CS was used to preserve fruit quality and performed well [13–15]. Employing $CaCl_2$ on the preservation of apples is an important approach to avoid browning with the modified (reduced O_2) atmospheres [16]. Souza et al. [17] represented that adding $CaCl_2$ into CS coating showed good preservation effects on strawberries in terms of firmness, weight loss and microbial growth. It has been reported that AA, a nutrient that is needed for consumers, is effective in controlling enzymatic browning. Tortoe et al. [18] observed moderate anti-browning effects on 'Golden Delicious' apple slices using AA for up to 14 days when apple slices were stored at 4 °C. Son et al. [19] also reported the effect of AA on anti-browning of fresh-cut apples. Non-toxic materials such as AA and calcium source have been proposed as excellent treatments for fresh-cut apples to inhibit enzymatic browning [19–21]. However, these methods have limited success in extending the shelf-life of fresh-cut apples because of low efficiency and off flavors [3,4]. Although CS has great film-forming ability, CS film's fruit preservation effect is relatively low. Thus, this work was undertaken to research the effect of CS coating modified with $CaCl_2$ or AA on prolonging the shelf-life of fresh-cut apples at room temperature.

2. Materials and methods

2.1. Materials

Ascorbic acid was obtained from Sinopharm Chemical Reagent Co., LTD (Shanghai, China). Calcium chloride (food grade) was purchased from Zhejiang Dacheng Calcium Industry Co., LTD (Zhejiang, China). Phosphate buffer (pH = 8.0) was provided by Jiangsu KeyGen Biotechnology Co., LTD and potassium bromide (KBr) was from Shanghai ShiSiHeWei Chemical Co., LTD. Chitosan (Mw = 590000, D.D: 80–95%) was supplied by Sinopharm Chemical Reagent Co., LTD (Shanghai, China).

2.2. Preparation of apple samples

"Fuji" apples that were uniformity of size, color and ripeness and did not have apparent injury or infection were selected from a local wholesale distributor (Jiangsu, China). Apple were pre-washed in 500 ppm chlorinated water for 2 min to reduce the natural flora, and then they were washed thoroughly with sterile water to remove the residual chlorine. Apples were then cut into apple slices with a sterile sharp knife on a sterile cutting board. Besides, the apple slices that were without peel and core were similar in size and shape (their weight were 8 ± 0.5 g)

2.3. Packaging and storage of fresh-cut apples

Packaging of apple slices was carried out as described in Ref. [22] with some modification. The CS-$CaCl_2$ solution was prepared by mixing 100 mL 4 mg/mL CS solution with 100 mL 4 mg/mL $CaCl_2$ solution. CS-AA solution was prepared in the same way as preparing CS-$CaCl_2$ solution but $CaCl_2$ was took place by AA. Prepared apple slices were randomly divided into two groups and they were then dipped in the 200 mL CS-$CaCl_2$ and CS-AA solution separately for 5 min. Afterwards, the apple slices were drained at room temperature for 2 min and then randomly placed in a 20.7 cm × 14.5 cm melamine tray. The control apple slices were tackled with ultrapure water instead. Images were taken at 0, 2, 4, 6, 8 and 10 h (the drying time of 2 min was set as 0 h) by an optical camera after apple slices had been picked up from their solutions. The tested apple slices were put on a piece of white paper the moment they were being taken photos to exclude the disturbance of other substance.

2.4. Measurement of weight loss

It's assumed that weight loss is entirely corresponded with water loss which is a vital factor of evaluating apple quality. Moreover, the increase of water loss has a great impact on the appearance of apples. To determine the water loss inhibition effect of all the tested coatings, the weight of all the apple slices was individually monitored during the storage time with an analytical balance (Shanghai Precision Scientific Instrument Co., LTD. Shanghai, China) at 0, 2, 4, 6, 8, 10 h.

The weight loss ratio W (%) was expressed as:

$$W(\%) = \frac{m_i - m_t}{m_i} \times 100\%$$

where m_i was the initial weight and m_t was the weight at the end of storage.

2.5. Measurement of AA content

At the end of storage time, apple slices were grinded in 40 mL 0.1 mol/L phosphate buffer with glass mortar. All the substance in the mortar was transferred into a 50 mL centrifuge tube and the volume was adjusted into 50 mL with ultrapure water. After that, the mixture was centrifuged at 12000 rpm for 30 min at 4 °C using laborzentrifugen centrifugal machine (3–30 K, Sigma, Osterode am Harz, Germany) The supernatant was filtered using Whatman No. 1 filter paper. We set apart 20 mL supernatant to measure the soluble solid content. AA content was obtained by the absorbance of the supernatant at 243 nm (A_{243}) according to Refs. [23,24]. The equipment used was a dual beam UV and visible spectrophotometer (a-1900 PC, Shanghai Aoxi Scientific Instrument Co., LTD. Shanghai, China). The result was expressed as the mean of the three replication of the absorbance value.

2.6. Soluble solid content

SSC was conducted at these supernatant samples according to Ref. [25] with some modification using an Abbe refratometer (2WAJ, Shanghai YuGuang Instrument Co., LTD, Shanghai, China). This measurement was processed at room temperature (25 ± 2 °C). SSC was represented as reflective index, meanwhile, ultrapure water was set as the base line of those tested samples' reflective index.

2.7. Fourier transform infrared spectroscopy (FT-IR) analysis

After the experiments stated above, we found that CS-$CaCl_2$ coating showed better anti-browning and quality maintaining ability. Thus, FT-IR analysis of CS-$CaCl_2$ coating was conducted to analysis the possible reasons of its preservation of fresh-cut apples. CS-$CaCl_2$ mixture solution was prepared as stated in 2.3 and three drops of the solution were dipped on a glass. After that, the glass