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Research Article

Prolonging Shelf-Life of Chinese Water Chestnut by Sodium Alginate

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Abstract: Prolonging shelf-life of fresh-cut Chinese Water Chestnut (CWC) by sodium alginate based on L-Cysteine (L-Cys) was investigated. Browning degree, eating quality and Visible Mold Time (VMT) were evaluated as sensory indexes of shelf-life of fresh-cut CWC. Color difference (ΔE) and Total Soluble Solid (TSS) were evaluated as physicochemical indexes of shelf-life of fresh-cut CWC. The optimal method of prolonging shelf-life of fresh-cut CWC was as follows: 24 pieces of fresh-cut CWC were treated for 45 min by 400 ml 0.4% L-Cys and 0.6% sodium alginate blending solution and stored at 4°C. Shelf-life of fresh-cut CWC treated by the optimal method was longer 10 d than that of fresh-cut CWC treated by L-Cys only. Sodium alginate crosslinked by $CaCl_2$ shortened shelf-life of fresh-cut CWC. Sodium alginate plasticized by glycerin almost had no effect on shelf-life of fresh-cut CWC.

Keywords: Browning degree, Chinese water chestnut, eating quality, shelf-life, sodium alginate

INTRODUCTION

Chinese Water Chestnut (CWC) is an important medical and edible plant food. People prefer to eat fresh-cut CWC because of its convenience and sweetness (You *et al*., 2012). Fresh-cut CWC rots very easy because of removing the peel and cutting. Further, enzymatic browning happens on the surface of fresh-cut CWC very easy because it is in touch with O_2 (Peng *et al*., 2008). These factors shorten shelf-life of fresh-cut CWC greatly. On the basis of predecessor, Li *et al*. (2017) used L-cysteine (L-Cys) to prolong shelf-life of fresh-cut CWC and obtained better results.

Edible coating also can prolong shelf-life of fresh-cut fruit and vegetable except antioxidant. Sodium alginate is one of edible coating used widely. Rojas-Graü *et al*. (2007a) prolonged shelf-life of fresh-cut apples by sodium alginate and apple puree. Rojas-Graü *et al*. (2007b) prolonged shelf-life of fresh-cut apples by sodium alginate and gellan. Sipahi *et al*. (2013) prolonged shelf-life of fresh-cut watermelon by sodium alginate. Robles-Sánchez *et al*. (2013) prolonged shelf-life of fresh-cut Kent mangoes by sodium alginate. Guerreiro *et al*. (2015) prolonged shelf-life of arbutus by sodium alginate. They plasticized sodium alginate by glycerin and crosslinked sodium alginate by $CaCl_2$ in order to gain better effect.

Based on prolonging shelf-life of fresh-cut CWC by L-Cys, we want to prolong its shelf-life by sodium alginate. Is the effect of which method better, L-Cys and sodium alginate treating separately or blending treating？ Do sodium alginate plasticized by glycerin and crosslinked by $CaCl_2$ contribute to prolong shelf-life of fresh CWC? To the best of our knowledge, nobody research these questions specifically. The object of the study is to confirm:

- Which method will prolong shelf-life of fresh-cut CWC longer, L-Cys and sodium alginate treating separately or blending treating?
- Do sodium alginate plasticized by glycerin and crosslinked by $CaCl_2$ contribute to prolong shelf-life of fresh CWC? The evaluation indexes of shelf-life include sensory indexes and physicochemical indexes. Sensory indexes of shelf-

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life include browning degree, eating quality and Visible Mold Time (VMT) (Mastromatteo *et al*., 2011). Physicochemical indexes of shelf-life include color difference (ΔE) (Ghidelli *et al*., 2013a, 2013b) and Total Soluble Solids (TSS) (Pen and Jiang, 2003).

MATERIALS AND METHODS

Materials: CWC was obtained from a commercial market at Huangshi and selected for uniformity and size. Any bruised or diseased fruits were discarded. Other reagents were analytical grade.

Evaluation of shelf-life:

Sensory indexes: Sensory indexes of shelf-life of fresh-cut CWC include browning degree, eating quality and VMT.

Browning degree was evaluated with a visual scale: 0 = No browning; 1 = Browning spots; 2 = Slight browning (browning area＜1/5); 3 = Moderate browning (browning area between 1/5 and 1/3); 4 = Moderate-serious browning (browning area between 1/3 and 1/2); and 5 = Serious browning (browning area＞1/2). A sample was considered to be unacceptable for marketing and its storage was terminated when its browning degree was above 2 (Peng *et al*., 2008).

Eating quality was evaluated with a tasting scale: 9 = Excellent, just sliced; 7 = Very good; 5 = Good; 3 = Fair, limit of marketability; and 1 = Poor, inedible, limit of usability. A sample was considered to be unacceptable for marketing and its storage was terminated when its eating quality was below 5 (Ghidelli *et al*., 2013a).

VMT was the time from beginning to the moment that the mold were observed at first during storage. For security reasons, a sample was considered to be unacceptable for marketing and its storage was terminated as soon as its visible mold were observed (Mastromatteo *et al*., 2011).

Sensory evaluation was carried out by 6 authors, who have a great deal of experiences in sensory evaluation of plant food. The samples were coded and presented to every judge in random order. The judges observed visual mold and recorded the time when the mold were observed at first. Then the judges evaluated browning degree. The judges gargled with distilled water before evaluating eating quality of every sample. Afterwards the judges tasted and graded every sample one by one. A sample was considered to be unacceptable for marketing and its storage was terminated when one of its browning degree, eating quality and VMT was unacceptable for marketing (Mastromatteo *et al*., 2011; Peng and Jiang, 2006).

Physicochemical indexes: Increasing of browning degree of fresh-cut CWC was in accordance with increasing of ΔE of fresh-cut CWC. ΔE was measured with a portable colorimeter. Each measurement was taken randomly at three different locations of each slice. The end value of ΔE of each fresh-cut CWC sample was mean of 18 measurement values (Ghidelli *et al*., 2013b).

Decreasing of TSS of fresh-cut CWC was in accordance with declining of eating quality of fresh-cut CWC during storage. Tissue (2 g) from 12 slices was homogenized in a grinder and then centrifuged for 20 min at 15000 g. The supernatant was collected to measure TSS by a hand refractometer (Pen and Jiang, 2003). The measurement was repeated three times.

Orthogonal experiment: The factors and levels of the orthogonal experiment were list in Table 1. The scheme of the orthogonal experiment was list in Table 2.

Sample preparation: CWC was washed and peeled and cut into 2~3 mm thick slices with a sharp stainless knife. The prepared slices were surface-sterilized by immersing in 0.1% (v/v) NaClO solution for 10 min and air-dried for 30 min.

24 pieces of fresh-cut CWC were soaked in 400 mL treating solution. The samples were air-dried for 10 min after every soaking treating. The samples treated with 0.4% L-Cys solution only was used as a control. These slices were placed into a stainless dish. Each sample was consisting of three dishes. 6 slices were placed in two of the three dishes respectively and they were used to determine browning degree, eating quality, VMT and ΔE. 12 slices were placed in the third dish and it was used to determine TSS. These dishes were over-wrapped with plastic films and the film was additionally perforated with a needle in order to ensure that the gas composition within the package remained near ambient concentrations and to study the effect of

Table 1: Factors and levels of the orthogonal experiment

	Levels	
Factors	1	2
A (Treating method of L-Cys and sodium alginate)[a]	Treating separately	Blending treating
B (If sodium alginate was plasticized by glycerin)[b]	Plasticized by glycerin	Not plasticized by glycerin
C (If sodium alginate was crosslinked by $CaCl_2$)[c]	Crosslinked by $CaCl_2$	Not crosslinked by $CaCl_2$

[a] Concentration of L-Cys was 0.4%; Concentration of sodium alginate was 0.6%; If treating separately, treating time of L-Cys was 25 min and treating time of sodium alginate was 20 min; If blending treating, treating time was 45 min; [b] Mass ratio: glycerin/sodium alginate = 0.28/1; [c] Concentration of $CaCl_2$ was 0.2%; If crosslinked by $CaCl_2$, crosslinking time was 2 min

Table 2: Scheme and results of the orthogonal experiment

Experiment No.	Factor A	Factor B	Factor C	Shelf life
0(Control)				18
1	1	1	1	12
2	1	1	2	16
3	1	2	1	12
4	1	2	2	18
5	2	1	1	18
6	2	1	2	24
7	2	2	1	16
8	2	2	2	28
K1	58	70	58	
K2	86	74	86	
R	28	4	28	

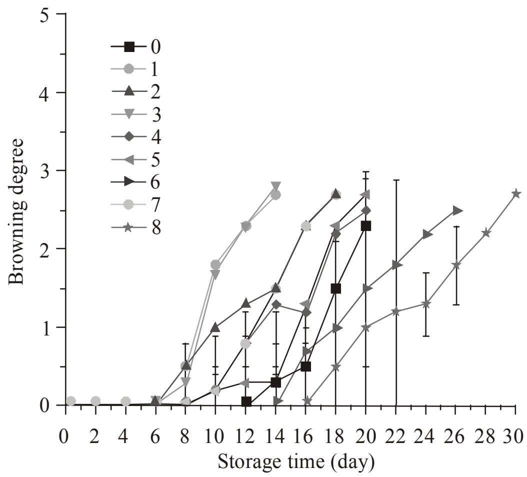

Fig. 1: Browning degree of the samples of the orthogonal experiment denoted 0, control, treated by 0.4% L-Cys; 1, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin and crosslinked by $CaCl_2$; 2, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin; 3, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, crosslinked by $CaCl_2$; 4, treated by 0.4% L-Cys and 0.6% sodium alginate respectively; 5, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin and crosslinked by $CaCl_2$; 6, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin; 7, blending treated by 0.4% L-Cys and 0.6% sodium alginate, crosslinked by $CaCl_2$; 8, blending treated by 0.4% L-Cys and 0.6% sodium alginate

the antioxidant and edible coating only. The above operations were carried out at 10°C in a temperature-controlled room. Then these samples were stored at 4°C in a temperature-controlled room. The evaluations were carried out each two days till the samples can't be accepted by marketing (You *et al*., 2012).

Statistical analysis: Statistical analysis was performed using SPSS 20.0. All data are mean ± standard error.

RESULTS AND DISCUSSION

Browning degree, eating quality, VMT, ΔE and TSS of each sample of the orthogonal experiment were

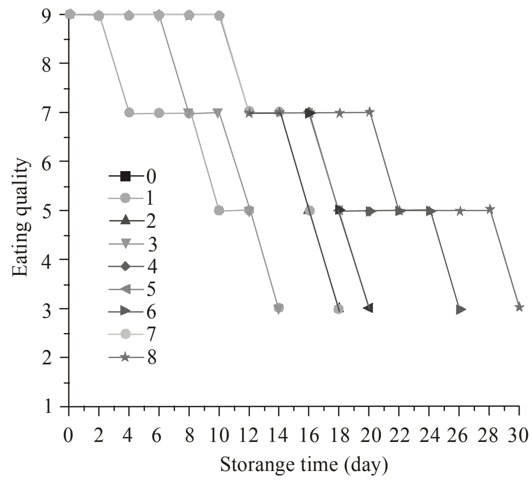

Fig. 2: Eating quality of the samples of the orthogonal experiment denoted 0, control, treated by 0.4% L-Cys; 1, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin and crosslinked by $CaCl_2$; 2, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin; 3, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, crosslinked by $CaCl_2$; 4, treated by 0.4% L-Cys and 0.6% sodium alginate respectively; 5, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin and crosslinked by $CaCl_2$; 6, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin; 7, blending treated by 0.4% L-Cys and 0.6% sodium alginate, crosslinked by $CaCl_2$; 8, blending treated by 0.4% L-Cys and 0.6% sodium alginate

list in Fig. 1 to 5 respectively. The results of the orthogonal experiment were list in Table 2. The optimal method of prolonging shelf-life of fresh-cut CWC was as follows: 24 pieces of fresh-cut CWC were treated for 45 min by 400 mL 0.4% L-Cys and 0.6% sodium alginate blending solution. Sodium alginate plasticized by glycerin almost had no effect on shelf-life of fresh-cut CWC. Sodium alginate cross-linked by $CaCl_2$shortened shelf-life of fresh-cut CWC. Shelf-life of fresh-cut CWC treated by the optimal method was 28 d. Shelf-life of fresh-cut CWC treated by 0.4% L-Cys was 18 d only. According to range analysis, the effect of sodium alginate on shelf-life of fresh-cut CWC was greater than that of sodium alginate plasticized by glycerin; The effect of sodium alginate crosslinked by $CaCl_2$ was greater than that of sodium alginate plasticized by glycerin. Whether sodium alginate plasticized by glycerin almost did not affect shelf-life of fresh-cut CWC.

If other things being equal, blending treating of L-Cys and sodium alginate prolonged shelf-life of fresh-cut CWC much longer than the treating separately and the result was consist with previous works (Robles-Sánchez *et al*., 2013). The positive and negative ions of

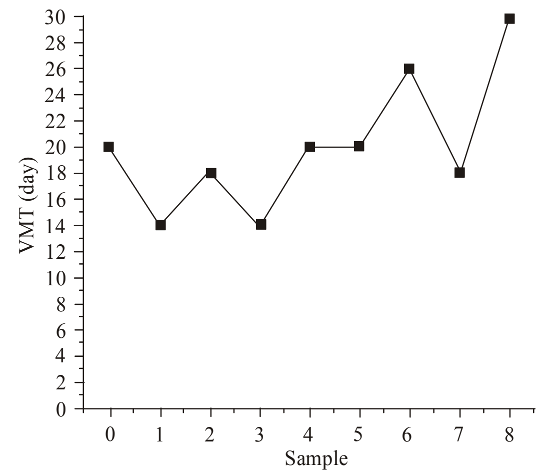

Fig. 3: VMT of the samples of the orthogonal experiment denoted 0 sample, control, treated by 0.4% L-Cys; 1 sample, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin and crosslinked by $CaCl_2$; 2 sample, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin; 3 sample, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, crosslinked by $CaCl_2$; 4 sample, treated by 0.4% L-Cys and 0.6% sodium alginate respectively; 5 sample, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin and crosslinked by $CaCl_2$; 6 sample, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin; 7sample , blending treated by 0.4% L-Cys and 0.6% sodium alginate, crosslinked by $CaCl_2$; 8 sample, blending treated by 0.4% L-Cys and 0.6% sodium alginate

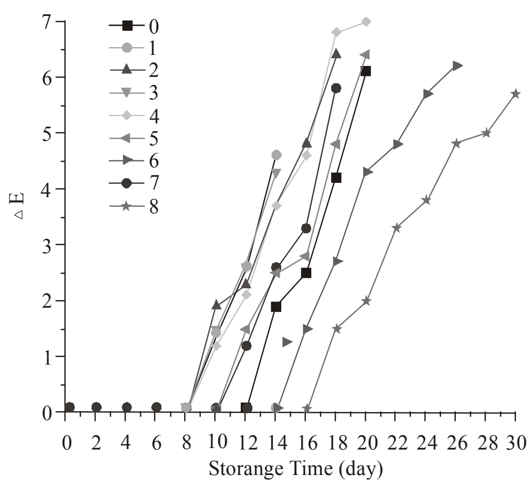

Fig. 4: ∆E of the samples of the orthogonal experiment denoted 0, control, treated by 0.4% L-Cys; 1, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin and crosslinked by $CaCl_2$; 2, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin; 3, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, crosslinked by $CaCl_2$; 4, treated by 0.4% L-Cys and 0.6% sodium alginate respectively; 5, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin and crosslinked by $CaCl_2$; 6, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin; 7, blending treated by 0.4% L-Cys and 0.6% sodium alginate, crosslinked by $CaCl_2$; 8, blending treated by 0.4% L-Cys and 0.6% sodium alginate

L-Cys can be inlayed in sodium alginate edible coating when blending treating. The sodium alginate edible coating inlayed by positive and negative ions of L-Cys can prevent oxygen from entering fresh-cut CWC more effectively than the pure sodium alginate edible coating. So blending treating of L-Cys and sodium alginate can inhibit enzymatic browning more effectively than treating separately.

If other things being equal, sodium alginate cross-linked by $CaCl_2$ shortened shelf-life of fresh-cut CWC and the result was contrary with previous works (Chien *et al*., 2007; Rojas-Graü *et al*., 2008). It maybe be just an accident. Ca^{2+} maybe enhance activity of polyphenol oxidase in CWC and so enzymatic browning increased.

If other things being equal, sodium alginate plasticized by glycerin almost had no effect on shelf-life of fresh-cut CWC and the result was contrary with previous works (Rojas-Graü *et al*., 2007a, 2008). It maybe is not just an accident. Glycerin is more suitable to act as solvent and sweetening agent according to its physical and chemical properties.

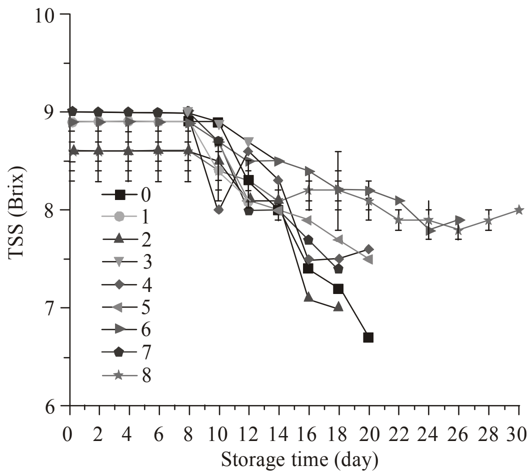

Fig. 5: TSS of the samples of the orthogonal experiment denoted 0, control, treated by 0.4% L-Cys; 1, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin and crosslinked by $CaCl_2$; 2, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, plasticized by glycerin; 3, treated by 0.4% L-Cys and 0.6% sodium alginate respectively, crosslinked by $CaCl_2$; 4, treated by 0.4% L-Cys and 0.6% sodium alginate respectively; 5, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin and crosslinked by $CaCl_2$; 6, blending treated by 0.4% L-Cys and 0.6% sodium alginate, plasticized by glycerin; 7, blending treated by 0.4% L-Cys and 0.6% sodium alginate, crosslinked by $CaCl_2$; 8, blending treated by 0.4% L-Cys and 0.6% sodium alginate

CONCLUSION

Based on prolonging shelf-life of fresh-cut CWC by L-Cys, the optimal method of prolong its shelf-life by sodium alginate further was as follow: 24 pieces of fresh-cut CWC were treated for 45 min by 400 mL 0.4% L-Cys and 0.6% sodium alginate blending solution and stored at 4°C. Shelf-life of fresh-cut CWC treated by the optimal method was longer 10 d than that of fresh-cut CWC treated by L-Cys only. Sodium alginate plasticized by glycerin almost had no effect on shelf-life of fresh-cut CWC. Sodium alginate crosslinked by $CaCl_2$ shortened shelf-life of fresh-cut CWC.

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