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RESEARCH ARTICLE

Feasibility of Composite Edible Coating Derived from Chitosan and Carboxymethyl Cellulose on Star Apple Quality during Post-harvest Preservation

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Abstract

Star apple (*Chrysophyllum cainito*) is well known as non climacteric fruit with high antioxidant capacity, high nutritional and health benefit. Its pulp is very sweet with glucose as the main sugar. This fruit has a short shelf life due to its perishable nature. Edible coatings have been extensively applied in the fruit preservation as an alternative method to preserve foodstuffs, improve shelf life and control loss of firmness and moisture in fresh fruits. Hence, purpose of this research penetrated on the efficiency of composited edible coating film prepared from chitosan and carboxymetyl cellulose (CMC) in different formulas to preserve star apple fruit. Weight loss (%), firmness (N), total soluble solid (°Brix), and vitamin C were the key indicators used to monitor during 15 days of preservation. After chitosan-CMC coating, the weight loss rate was restrained, and higher firmness, total soluble solid, and vitamin C were reserved. Our finding revealed that chitosan 2.0% combined with CMC 1.0% was appropriate for extending self-life of this valuable fruit. There has been a great demand of emerging fruit packaging from chitosan-CMC composited coating as antibacterial and barrier film. Composited chitosan-CMC coating would have wide prospect in the preservation of other post-harvest fruits and vegetables.

Keywords: *Chrysophyllum cainito, Chitosan, CMC, Coating, Weight loss, Firmness, Soluble solid, Vitamin C.*

Introduction

Milk fruit or star apple (*Chrysophyllum cainito*) is commonly round with a smooth and waxy skin [1]. The star apple fruits are delicious as a fresh dessert fruit. The pulp is white or creamy white, with numerous small, shiny, dark brown seeds embedded in it. The sweet pulpy fruit is an excellent source of Vitamin C; iron [2]. *Chrysophyllum cainito* holds great potentials as an antimicrobial agent for chemotherapeutic medicine and it is a rich source of nutrient and phytochemicals [3]. The fruit is very susceptible to water loss so they are easily shrinkage and fruit softening during storage, resulting in the decrease of their commodity value.

The major postharvest losses of star apples are due to fungal infection, physiological disorders, and physical injuries[4].Edible coating can be utilized to prevent perishable fruits from deterioration by retarding respiration rate, supporting a selective barrier to moisture, oxygen, and carbon dioxide, improving firmness, maintaining volatile aroma components, and limiting microbial proliferation [5]. Chitosan is edible coating which is a safe, biodegradable and non-toxic substance derived from chitin shells of crustaceans [6].Chitosan has certain solubility in acetic acid and hydrochloric acid, which leads to the film-forming ability.

It's considered as an antifungal agent that can control postharvest diseases [7, 8].Carboxymethyl cellulose (CMC) is modified cellulose derived from its carboxymethylation. CMC has an excellent film-forming ability, is biodegradable, and has low toxicity [9]. Moreover, it has strong hydrophilicity and a durable internal network structure [10]. It is odorless, tasteless and nontoxic, bears 4 to 5.5% moisture and pH value about 6 to 8.5 [11]. Chitosan is known to be unstable in acidic conditions, and it has fairly low mechanical strength [12].The combination of CMC and chitosan significantly influenced coating characteristics.

Increased chitosan concentrations reduced the film's amorphous character by increasing its crystalline structure [13].The chitosan/carboxymethyl cellulose film prepared via electrostatic interactions proved to increase the shelf life of cheese and wheat bread [14, 15]. Carboxy methyl cellulose and corn starch can extend the shelf life of cucumber during storage for 7 weeks [16]. The efficacy of an edible bilayer coating comprising carboxymethyl cellulose (CMC) and chitosan in preserving postharvest quality of various citrus fruit was evaluated [17]. Banana fruits were coated with solutions of CMC and tannin, natural biodegradable polymers for food preservation withstanding the temperature and stresses [18].

CMC and Gum arabic coatings can increase longer the shelf life of sugar apple fruit than these untreated samples [19].The influence of different edible coatings including aloe vera gel (AV) (33 and 50% v/v), carboxymethyl cellulose (CMC) and pectin (1, 1.5 and 2% w/v) was studied on fresh jujube quality during 40 days of refrigerated storage at 4 °C [20]. The effect of carboxymethyl cellulose (CMC), chitosan, CMC + glucomannan, chitosan + glucomannan as edible coating in storage of mango fruits was examined [21]. Edible coating chitosan and calcium gluconate maintained fruit quality and marketability of Guava (*Psidium guajava*) fruits during storage [22]. An investigation on coating of star apples by using agar/glycerol was investigated. Star apples which were coated with 2.75% agar and 6.8% glycerol still maintained good quality until 30 days of preservation [23].

Nguyen Phuoc Minh et al [21] used chitosan as edible coating on storage of star apple (*Chrysophyllum Cainino*) fruit. Chitosan and carboxymethyl cellulose as edible coating was significantly effective at inhibiting the loss of fruit firmness and aroma volatiles of strawberry, with little effect on the total soluble solids and total acidity contents [24].There was not any research mentioned to the combination of chitosan and CMC as composited edible coating for preservation of star apple fruit. Objective of our study focused on different concentrations of chitosan and CMC to formulate the suitable coating film to maitain quality of star apple fruit during 15 days of storage.

Materials and Method

Material

Star apple fruits were harvested from Ke Sach district, Soc Trang province, Vietnam. After collecting, they must be conveyed to laboratory for experiments. They were subjected to air blowing to remove foreign matter and then coated by the available chitosan-CMC mixture. Chitosan, CMC, glycerol and acetic acid were purchased from Sigma-Aldrich. Chitosan was dissolved in 1.0% (v/v) acetic acid. CMC was dissolved in distilled water. Glycerol was added mL to CMC solution as plasticizer at 0.5 g per 100 mL.

Researching Procedure

The coating formulation was set for 5 different coating treatments with respective formulas as follows: Chitosan 0.5%: CMC 2.5%; Chitosan 1.0%: CMC 2.0%; Chitosan 1.5%: CMC 1.5%; Chitosan 2.0%: CMC 1.0%; Chitosan 2.5%; CMC 0.5%. Fruits were dipped prior into chitosan solution for 20 s and then permitted to dry for one hour at normal ambient temperature, followed by layer by layer encapsulating with CMC solution, and then dried for one hour at ambient temperature on a tray. The 3rd, 6th, 9th, 12th, and 15th observational days were carefully monitored by validation of weight loss (%), firmness (N), total soluble solid (^{o}Brix), vitamin C (mg/100g)

Physico-chemical and Statistical Analysis

Weight losses (%) were determined by comparing weight of samples before and after the storage period.

Firmness (N) was measured by penetrometer as the maximum penetration force (N) reached during tissue breakage. Total soluble solid (°Brix) were measured by hand-held refractometer. Vitamin C (mg/100g) was evaluated by using 2, 5-6 dicholorophenol indophenols' method described by A.O.A.C (1994). The experiments were run in triplicate with three different lots of samples. Statistical analysis was performed by the Statgraphics Centurion XVI.

Result & Discussion

Weight Loss (%) of the Monitored Star Apple Fruits Coated by chitosan and CMC during Preservation

Respiration rate is one of the major factors contributing to postharvest losses of fruit [25].Weight losses (%) of treated and non-treated samples were carefully monitored within 15 days of storage. Our results revealed that star apple fruits coated by chitosan 2.0% + CMC 1.0% showed the lowest weight loss (%).

Table 1: Weight loss (%) of the monitored star apple fruits coated by chitosan and CMC during preservation

Storage days	3	6	9	12	15
Control (acetic acid 1.0%)	$2.19±0.05^{a}$	$3.85±0.01^{a}$	$5.89±0.05^{a}$	$8.15±0.01^{a}$	$9.28±0.02^{a}$
Chitosan 0.5%: CMC 2.5%	$1.05±0.00^{b}$	$1.39±0.05^{b}$	$1.97±0.04^{b}$	$2.39±0.04^{b}$	$4.04±0.01^{b}$
Chitosan 1.0%: CMC 2.0%	$0.98±0.03^{bc}$	$1.27±0.02^{bc}$	$1.46±0.00^{bc}$	$1.84±0.03^{bc}$	$2.07±0.02^{c}$
Chitosan 1.5%: CMC 1.5%	$0.75±0.01^{c}$	$0.96±0.01^{c}$	$1.14±0.02^{c}$	$1.92±0.01^{c}$	$1.98±0.03^{cd}$
Chitosan 2.0%: CMC 1.0%	$0.47±0.02^{d}$	$0.63±0.03^{cd}$	$0.71±0.04^{cd}$	$0.85±0.02^{cd}$	$1.31±0.01^{d}$
Chitosan 2.5%: CMC 0.5%	$0.45±0.03^{d}$	$0.54±0.02^{d}$	$0.69±0.02^{d}$	$0.74±0.00^{d}$	$0.98±0.04^{e}$

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%)

Respiration rate is one of the major factors contributing to postharvest losses of fruit [25].After weight loss, the firmness of fruits and vegetables become soft from crisp. Their taste decreases, and their resistant ability against physical and microbial pathogen also come down [26].Chitosan-CMC coating can restrain the transpiration, and then more water is reserved.

Firmness of the Monitored Star Apple Fruits Coated by chitosan and CMC during Preservation

The firmness of fruits is closely associated with acceptability levels of the fruits. Firmness (N) of treated and non-treated samples was carefully monitored within 15 days of storage. Our results revealed that star apple fruits coated by chitosan 2.0% + CMC 1.0% still maintained their firmness until the 12th day of preservation.

Table 2: Firmness (N) of the monitored star apple fruits coated by chitosan and CMC during preservation

Storage days	**3**	**6**	**9**	**12**	**15**
Control (acetic acid 1.0%)	$1.09±0.01^{d}$	$1.02±0.02^{d}$	$0.85±0.00^{d}$	$0.61±0.01^{d}$	$0.42±0.01^{d}$
Chitosan 0.5%: CMC 2.5%	$2.71±0.00^{c}$	$2.61±0.01^{c}$	$2.52±0.00^{c}$	$2.22±0.03^{c}$	$1.41±0.02^{c}$
Chitosan 1.0%: CMC 2.0%	$3.02±0.04^{bc}$	$2.90±0.04^{bc}$	$2.74±0.01^{bc}$	$2.51±0.04^{bc}$	$1.82±0.03^{bc}$
Chitosan 1.5%: CMC 1.5%	$3.25±0.00^{b}$	$3.17±0.03^{b}$	$3.03±0.02^{b}$	$2.84±0.03^{b}$	$2.34±0.04^{b}$
Chitosan 2.0%: CMC 1.0%	$3.41±0.03^{ab}$	$3.29±0.02^{ab}$	$3.19±0.04^{ab}$	$2.96±0.01^{ab}$	$2.83±0.00^{ab}$
Chitosan 2.5%: CMC 0.5%	$3.72±0.01^{a}$	$3.54±0.01^{a}$	$3.23±0.01^{a}$	$3.04±0.02^{a}$	$2.72±0.02^{a}$

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%)

Firmness is one of key factors represented for fruit quality. Once post-harvest fruits become soft during storage duration, their crisp property gradually decreases and then disappears. Their firmness will decrease due to water evaporation, pectin degradation, nutrient consumption [27]. CMC/chitosan bilayer coating slightly increased fruit firmness, especially of oranges and grapefruit [17]. After coating with chitosan on the surface of post-harvest fruit and vegetable, the respiration rate and weight loss rate are restrained, and higher firmness is remained [28].

Total Soluble Solid of the Monitored Star Apple Fruits Coated by Chitosan and CMC during Preservation

Total soluble solid (°Brix) of treated and non-treated samples were carefully monitored within 15 days of storage.

Our results revealed that star apple fruits coated by chitosan 2.0% + CMC 1.0% still maintained their soluble solid until the 15th day of preservation.

Table 3: Total soluble solid (°Brix) of the monitored star apple fruits coated by chitosan and CMC during preservation

Storage days	3	6	9	12	15
Control (acetic acid 1.0%)	14.07±0.03^{d}	13.29±0.04^{d}	12.92±0.03^{c}	12.36±0.03^{c}	11.88±0.03^{c}
Chitosan 0.5%: CMC 2.5%	15.81±0.02^{c}	15.72±0.21^{c}	15.15±0.02^{b}	14.83±0.01^{b}	14.43±0.00^{b}
Chitosan 1.0%: CMC 2.0%	16.04±0.01^{b}	15.94±0.00^{b}	15.43±0.03^{ab}	15.02±0.02^{ab}	14.78±0.00^{ab}
Chitosan 1.5%: CMC 1.5%	16.27±0.03^{ab}	16.12±0.01^{ab}	15.76±0.00^{ab}	15.27±0.00^{ab}	15.12±0.02^{ab}
Chitosan 2.0%: CMC 1.0%	16.39±0.02^{a}	16.25±0.03^{a}	16.00±0.02^{a}	15.76±0.04^{a}	15.49±0.01^{a}
Chitosan 2.5%: CMC 0.5%	16.42±0.04^{a}	16.27±0.04^{a}	16.03±0.00^{a}	15.81±0.03^{a}	15.54±0.03^{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%)

According to Isaac Kwabena Asare et al [29].Total soluble solids in pulp of star apple fruit were approximately 11.2°Brix. The reason causing weight loss of post-harvest fruits and vegetables includes transpiration and the substrate consumption of respiration [28].

Vitamin C of the Monitored Star Apple Fruits Coated by Chitosan and CMC During Preservation

According to S. U. Oranusi et al [3].The vitamin C content in pulp of star apple (*Chrysophyllum cainito*) was around 10 mg/100g. Soluble particles may be decomposed as a result of respiration; polyphenol, vitamin C and flavonoid may serve as antioxidant and participate to eliminate free radicals during preservation [30].After coating with chitosan/CMC on the peel of fruit and vegetable, respiration rate decrease, free radicals reduce, and the disease resistance increase. Major nutrients are maintained in maximum level [31].

Vitamin C (mg/100g) of treated and non-treated samples was carefully monitored within 15 days of storage. Our results revealed that star apple fruits coated by chitosan 2.0% + CMC 1.0% still maintained their vitamin C content until the 15th day of preservation.

Table 4: Vitamin C (mg/100g) of the monitored star apple fruits coated by chitosan and CMC during preservation

Storage days	3	6	9	12	15
Control (acetic acid 1.0%)	8.12±0.00^{d}	8.01±0.02^{d}	7.46±0.03^{d}	7.04±0.02^{d}	5.03±0.02^{d}
Chitosan 0.5%: CMC 2.5%	8.81±0.01^{c}	8.62±0.06^{c}	8.41±0.01^{c}	7.82±0.00^{c}	7.64±0.01^{c}
Chitosan 1.0%: CMC 2.0%	8.93±0.00^{bc}	8.75±0.03^{bc}	8.52±0.00^{bc}	8.01±0.03^{bc}	7.90±0.03^{bc}
Chitosan 1.5%: CMC 1.5%	9.02±0.05^{b}	8.84±0.05^{b}	8.68±0.01^{b}	8.23±0.01^{b}	8.02±0.01^{b}
Chitosan 2.0%: CMC 1.0%	9.08±0.04^{ab}	8.95±0.01^{ab}	8.73±0.03^{ab}	8.51±0.02^{ab}	8.17±0.02^{ab}
Chitosan 2.5%: CMC 0.5%	9.13±0.03^{a}	9.04±0.02^{a}	8.97±0.02^{a}	8.72±0.00^{a}	8.41±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%)

Conclusion

In the harvesting time, commercial price of milk fruit goes down very fast because it is very easy to be decomposed and damaged by high respiration rate and harmful pathogen. Carboxymethyl cellulose is a water-soluble polysaccharide with appropriate biodegradable and edible film-forming properties. Chitosan is one of the most abundant biopolymers after cellulose. Chitosan-based materials have been widely executed in different areas by its biological and physical characteristics of biocompatibility, biodegradability, antimicrobial and easy film forming.

The application of edible coating is normally implemented to prepare the chitosan-based thin films on the surface of fruits or encapsulating active polymers on the surfaces for protective goals. Demand of edible and biodegradable coating films has increased recently because it is more evident that non-degradable materials are doing much damage to the environment. The obtained bio-based chitosan/CMC film, with environment friendly attribute, has advantages of low cost and biodegradation. This coating was demonstrated to be a lucrative alternative to plastic materials used in food packaging.

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