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RESEARCH ARTICLE

Application of Edible Coating to Extend Shelf Life of Custard Apple (*Annona Squamosa*) Fruit during Storage

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Abstract

Custard apple (*Annona squamosa* L.) is a climacteric fruit and highly perishable in nature. The fruit is well known for its sweet taste, specific flavour, and pleasant, aromatic creamy pulp. The fresh fruit pulp contains high nutritional value such as protein, carbohydrate, sugar, vitamin and mineral. Edible coatings are widely used for extension of shelf life of fruits and vegetables by reduction of moisture loss and gas exchange as well as reduction of the physiological disorders. The main problem of postharvest losses associated with custard apples is rapid loss of firmness. The objective of the present study was to identify the effect of different xanthan gum concentrations (1%, 2%, 3%, 4%, 5%) and storage temperature (8 ^{o}C, 12 ^{o}C, 16 ^{o}C, 20 ^{o}C) to the weight loss, firmness, total soluble sugar and ascorbic acid in custard apple (*Annona squamosa*) fruits during preservation. Moreover, shelf life (0 day, 7 days, 14 days, 21 days and 28 days) of custard apple (*Annona squamosa*) fruit in storage also clarified. Results demonstrated that xanthan gum 4% and storage temperature 8 ^{o}C could maintain custard apple (*Annona squamosa*) fruit quality for 28 days without any deterioration. This is an opportunity to develop value-added products reducing the postharvest losses, improving nutritional value and generating additional revenue for custard apple growers.

Keywords: *Custard apple, Xanthan gum, Coating, Firmness, Shelf life, Preservation.*

Introduction

Annona squamosa L. belongs to the *Annonaceae* family. *Annona squamosa* is a small, semi-deciduous tree, 3-7 m in height, with a broad, open crown or irregularly spreading branches, bark light brown with visible leaf scars and smoothish to slightly fissured into plates, inner bark light yellow and slightly bitter, twigs become brown with light brown dots [1].

The inter-areole space widens, the fruit turn creamy-white. The round or heart-shaped greenish yellow, ripened aggregate fruit is pendulous on a thickened stalk, 5 cm to 10 cm in diameter with many round protuberances and covered with a powdery bloom. The pulp is white-tinged yellow, edible and sweetly aromatic. It has a thick, creamy-white layer of custard like, somewhat granular, flesh beneath the skin surrounding the concolorous moderately juicy segments [2]. The fruits of this tree are consumed mainly *in natura* or as ingredients in juices and desserts.

The pulp of *A. squamosa* L. is considered rich in calorie content, with high levels of total sugars, vitamin C and vitamin B complex, and some minerals [3]. Custard apple is a nutritionally balanced food which constitutes protein, fiber, minerals, vitamins, energy and very little fat [4].

Custard apple is an ideal source of energy so it helps replenish one's energy levels. This aids combat exhaustion and reduce muscle weakness [5].Various studies have been reported as an antibacterial, antidiabetic, antitumor, anti-malarial, anthelmintic, anti-genotoxic potential and hepatoprotective activity.

The crude extracts of different parts and pure isolated phytoconstituents of its fruits was reported to acquire anti-diabetic, antiviral, antioxidant activity, respiratory stimulant, during pregnancy and diuretics properties, very useful for the improvement of the immune system, nervous system and also for the development of the brain in the fetus [6, 9]. The fruit has pleasant texture and flavour and is sweet with slight acidity [10].

Ripening of custard apple was carried out in crates covered with leaves, cartoon boxes and modified household refrigerator. Household refrigerator was modified to maintain uniform temperature and relative humidity by fitting air circulation tank and hanging wet cloth. Ripening of custard apple fruit at low temperature can delay the ripening of custard apple fruit though ripening percentage of fruit in modified refrigerator was less, it delay the ripening of fruit. Custard apple is the rich source of nutrients but it has short storage life and having a great demand in the market. Custard apple ripens within four days after harvest [11].

It is full of vitamin C anti-oxidants, which helps to combat many diseases and also enhances the immune system. Eating custard apple is helpful in curing many diseases and disorders. The fruit is good for heart, skin and bone and maintains blood pressure. Custard apple is also helpful in curing of boils, ulcers and gum related problems. The leaves of this fruit work against cancer, bark can be used in case of toothache, and gum pain.

However, the most important advantages of custard apple are healthy heart, beneficial in pregnancy, improve eye vision, cure arthritis, fighting fatigue and protects against anaemia [2]. There were several studies mentioned to custard apple (*Annona squamosa*) processing and preservation. Custard apple pulp, when exposed to air, turns pink due to peroxidase activity and becomes bitter when heated above 55°, which renders preservation by heat treatment inapplicable.

To preserve the pulp, it is necessary to add 1% of citric acid together with 0.1% of sodium benzoate, while addition of 50–100 p.p.m. of sulphur dioxide checks the pink discoloration due to enzymic activity [12].

A study was to evaluate the potential of custard apple (*Annona squamosa* L.) in the production of a beverage fermented using *Saccharomyces cerevisiae* yeast and assess the antioxidant capacity, total phenolic content and DNA damage-protecting activity of custard apple fruit [13]. Processing the pulps of ripe fruits to add value to these fruits, jams, nectar, and juice have been developed [14, 15]. Postharvest application of benzyl adenine (100 or 50 ppm) increases the storage life of custard apple by 29.41 per cent (2.5 days) over untreated fruits [16].

A study evaluatedthe effect of carboxyl methyl cellulose (CMC) and gum arabic (G) that are used to make the edible coatings to extend the shelf-life of raw sugar apple fruits [17]. The objective of the present study was to identify the effect of different xanthan gum concentrations (1%, 2%, 3%, 4%, 5%) and storage temperature (8 ^{o}C, 12 ^{o}C, 16 ^{o}C, 20 ^{o}C) to the weight loss, firmness, total soluble sugar and ascorbic acid in custard apple (*Annona squamosa*) fruits during preservation. Moreover, shelf life (0 day, 7 days, 14 days, 21 days and 28 days) of custard apple (*Annona squamosa*) fruit in storage also clarified.

Materials and Method

Materials

We collected custard apple (*Annona squamosa*) fruits in Hau Giang province, Vietnam. They were cultivated following VietGAP to ensure food safety. After harvesting, collected nuts were stored at a temperature of 20˚C and they were conveyed to laboratory within 8 hours for experiments.

These fruits were tumbled thoroughly under turbulent moving to remove dirt, dust and adhered unwanted material. Beside custard apple we also used other materials during the research such as xanthan gum, ethyl alcohol, propylene glycol. Lab utensils and equipments included digital weight balance, penetrometer, refractometer, biuret, and refrigerator.

Figure 1: Custard apple (*Annona squamosa*) fruit

Methods

Preparation of Edible Coatings

Xanthan gum (1%, 2%, 3%, 4%, 5%) was prepared by dissolving 2.0g, 4.0g, 6.0 g, 8.0g, 10.0g of xanthan gum powder in 200 ml of water ethyl alcohol mixture (3:1) at 80 ^{o}C and stirred for 10 min using magnetic stirrer. Ethyl alcohol was added in order to reduce drying time and obtain a transparent and shiny coating. 2% volume of propylene glycol was also added in the formulation as plasticizer. Custard apple (*Annona squamosa*) fruits were dipped in the film forming dispersions for 1min. After that, they were hung up and dried at room temperature with natural convection for 2-3 h and then stored in refrigerator for further experiments.

Fruit Quality Assessments

The physical and chemical compositions including weight loss (%), firmness (N), total soluble solid (^{o}Brix), and ascorbic acid (mg/ml) in fresh and coated custard apple (*Annona squamosa*) were analyzed.

Weight loss (%): To evaluate weight loss, separate samples in 3 replicates of each treatment were used. The same samples were evaluated for weight loss each time at weekly intervals until the end of experiment. Weight loss was determined by the following formula: Weight loss (%) = [(A−B)/A] x 100 where A indicates the fruit weight at the time of harvest and B indicates the fruit weight after storage intervals (A.O.A.C., 1994).

Firmness (N): Firmness was measured as the maximum penetration force (N) reached during tissue breakage, and determined with a 5 mm diameter flat probe. The penetration depth was 5 mm. Custard apple (*Annona squamosa*) was cut into halves and each half was measured in the central zone.*Total soluble solids (^{o}Brix):* Individual custard apple (*Annona squamosa*) fruit from each of the treatment was grinded in an electric juice extractor for freshly prepared juice. Soluble solids content was measured using T/C hand refractometer in ^{o}Brix.

Ascorbic acid (mg/ml): Ascorbic acid content was measured using 2, 5-6 dicholorophenol indophenols' method described by A.O.A.C (1994).

Effect of Different xanthan Gum Concentrations to Weight Loss, Firmness, Total Soluble Solid, Ascorbic Acid of Custard Apple (Annona squamosa) Fruit

Effect of different xanthan gum concentrations (1%, 2%, 3%, 4%, 5%) to weight loss (%), firmness (N), total soluble solid (^{o}Brix), ascorbic acid (mg/ml) was assessed. All samples were preserved in 8^{o}C for 7 days.

Effect of Storage Temperature to Shelf Life of Custard Apple (Annona squamosa) Fruit

After finding the appropriate xanthan gum coating concentration (%), shelf life of custard apple (*Annona squamosa*) fruit was also evaluated by the effect of different storage temperature. Custard apple (*Annona squamosa*) fruits which were set in trays in were divided into four groups (8 ^{o}C, 12 ^{o}C, 16 ^{o}C and 20 ^{o}C). Weight loss, firmness, total soluble solid, ascorbic acid were assessed during preservation (7days) to demonstrate the appropriate storage temperature.

Shelf-life of Custard Apple (Annona squamosa) Fruit during Preservation

After finding the appropriate xanthan gum concentration, storage temperature; shelf life of custard apple (*Annona squamosa*) fruit during preservation was also evaluated by sampling at different intervals (0, 7, 14, 21, 28 days). Weight loss, firmness, total soluble solid, ascorbic acid were assessed.

Statistical Analysis

The Methods 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 Statgraphics Centurion XVII.

Results & Discussion

Physical and Chemical Characteristics in Fresh Custard Apple (*Annona squamosa*) Fruit

The physical and chemical compositions in fresh custard apple (*Annona squamosa*) fruit were analyzed. Results were mentioned in Table 1.

Table 1: The chemical compositions in fresh custard apple (*Annona squamosa*) fruit

Parameter	Firmness (N)	Total soluble solid (°Brix)	Ascorbic acid (mg/ml)
Value	1843.21±104.3	9.48±0.01	10.35±0.02

Fruit firmness, total soluble solid and ascorbic acid are major attributes that dictates the postharvest life and quality of fruit in general and custard apple (*Annona squamosa*) in particular. According data from one research, the fruit is rich in starch when firm but increases markedly in sugar as it softens. The main sugars are glucose and fructose. The calorific value is high. Custard apple is full of vitamin C anti-oxidants. It is abundant source of dietary fibre, Vitamin A, Vitamin C, Antioxidant, Potassium, magnesium and also contains calcium, Vitamin B6, Copper and Low fat levels, excellent source of Iron [10].

In another research, the results for the chemical composition analysis of custard apple pulp were respectively: moisture (74.6 g.100g-1), total soluble solids (26 0B), total sugar (20.9 g.100g-1), ascorbic acid (32.5 mg.100g-1) with a titrable acidity (0.29 g.100g-1). The mineral content for custard apple pulp were respectively: calcium (642.5 mg.kg-1), potassium (4280.0 mg.kg-1), sodium (627.5 mg.kg-1), magnesium (545 mg.kg-1), iron (28.0 mg.kg-1) etc [18].

The calorific value of custard apple ranges between 860 to 1140 kcal per kg as compared with 741 kcal per kg of mango [19]. The content of ascorbic acid in custard apple was reported to be in the range of 34 mg to 44 $mg.100g^{-1}$ [20].The content of pectin is almost insignificant in all the varieties of Annona [21]. In another study, custard apple pulp exhibited moisture levels 74.00%, fat 0.39 %, crude fibre 3.30 %, sugars 22.77%, crude protein 2.80 %, and carbohydrates 21.50 %, acidity 0.63% and ash 1.05%. The predominant mineral elements in the custard apple were Ca, Fe, phosphorus, 22.00, 0.43, 25.33 mg/100g respectably. The phytochemical properties revealed that the ascorbic acid and total phenols of custard apple pulp ranged from (52.13, 79.73) mg/100g, respectively. Antioxidant activities were found in custard apple 1815.20 % activity [22].

Effect of Different Xanthan Gum Concentrations to Weight Loss, Firmness, total Soluble Solid, Ascorbic Acid of Custard Apple (*Annona squamosa*) fruit

Effect of different xanthan gum concentrations (1%, 2%, 3%, 4%, 5%) to weight loss (%), firmness (N), total soluble solid (°Brix), ascorbic acid (mg/ml) was assessed. All samples were preserved in 8°C for 7 days. Results were depicted in Table 2.

As clearly shown in Table 2, all edible coatings significantly ($P< 0.05$) retard the changes in custard apple (*Annona squamosa*) weightl loss, firmness, total soluble solid and ascorbic acid as compared to control samples. 4% xanthan gum coating was appropriated for further experiments.

Table 2: Effect of different xanthan gum concentrations to weight loss (%), firmness (N), total soluble solid (°Brix), ascorbic acid (mg/ml) of custard apple (*Annona squamosa*) fruit during preservation (8°C after 7 days)

Xanthan gum **concentration (%)**	**Weight loss (%)**	**Firmness (N)**	**Total soluble solid (°Brix)**	**Ascorbic acid (mg/ml)**
Control	16.40±0.02^{a}	1341.12±110.6^{e}	6.34±0.01^{e}	6.09±0.02^{e}
1	14.13±0.01^{b}	1529.78±109.4^{d}	6.99±0.04^{d}	7.65±0.01^{d}
2	12.35±0.03^{c}	1590.17±110.6^{c}	7.43±0.02^{c}	8.42±0.02^{c}
3	10.21±0.00^{d}	1622.04±111.9^{b}	8.84±0.00^{b}	9.27±0.01^{b}
4	**9.29±0.02^{e}**	**1731.28±103.6^{a}**	**9.28**±0.03^{a}	**10.12**±0.01^{a}
5	9.20±0.01^{e}	1729.75±110.4^{a}	9.30±0.02^{a}	10.16±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 ($\alpha = 5\%$)

Freshly harvested uniform sized custard apple fruits were washed, cleaned and treated with different levels of CaCl2 (1.0, 1.5 and 2.0 %) and Sago (5, 10 and 15 %) and covered with and without wrapping materials (Newspaper and Banana leaves) and stored at ambient temperature. The result revealed that application of sago (10%) + Newspaper wrapping improved the chemical constituents *i.e.* TSS (27.06 o Brix), reducing and total sugars *i.e.* 26.16 %, 31.80 %, respectively while, acidity content (0.22%) was minimum in fruits treated with sago (5 %) + Newspaper wrapping [23].

In another research, application of ascorbic acid 1000 mg/l effective for increasing ascorbic acid while minimum acidity was recorded in control in custard apple fruits under ambient storage condition [24]. In another research, sugar apple fruits were washed, pretreated with ultrasonic and then uncoated or coated by films with 1% of gel at the different ratio of CMC and G. These samples were kept in cold chamber at 100C for 5 weeks. The quality of sugar apples was evaluated through TA, TSA, TSS, firmness, and color as well as the weight loss. The results showed that CMC and G coatings can increase longer the shelf life of sugar apple fruit than these untreated samples. CMC coating had a significant effect on the quality of sugar apple fruits than the CMC combined G coating during cold storage. The weight losses of coating samples reduced slightly and its lower 43.35% and 80.49% to compare with the uncoated sample. TA, TSS, and respiration rate of coated fruits increased slightly and significantly different with uncoated fruit. The color of the uncoated sample (L*, a *, b*) become a darkness and had less greenness than fruit coated. It was concluded that higher CMC and G used as a coating for sugar apple fruits could serve as an alternative to post-harvest chemical treatments [17].

Effect of Storage Temperature to Weight Loss, Firmness, Total Soluble Solid, Ascorbic Acid of Custard Apple (*Annona squamosa*) Fruit

After finding the appropriate xanthan gum coating concentration (%), shelf life of custard apple (*Annona squamosa*) fruit was also evaluated by the effect of different storage temperature. Results were elaborated in table 3. Storage temperature for custard apple (*Annona squamosa*) should be 8 ^{o}C which was appropriated for further experiments.

Table 3: Effect of storage temperature to weight loss (%), firmness (N), total soluble solid (^{o}Brix), ascorbic acid (mg/ml) of custard apple (*Annona squamosa*) fruit

Storage temperature (^{o}C)	Weight loss (%)	Firmness (N)	Total soluble solid (^{o}Brix)	Ascorbic acid (mg/ml)
8 ^{o}C	**9.29±0.02^{d}**	**1731.28±103.6^{a}**	**9.28**±0.03^{a}	**10.12**±0.01^{a}
12 ^{o}C	11.44±0.02^{c}	1661.22±107.1^{a}	8.74±0.03^{b}	9.38±0.02^{b}
16 ^{o}C	13.08±0.02^{b}	1539.75±105.9^{a}	8.09±0.01^{bc}	9.01±0.01^{bc}
20 ^{o}C	16.14±0.01^{a}	1411.44±106.5^{a}	7.65±0.00^{c}	8.44±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%)

The pulp can be used as flavouring in ice cream. Between 50-80% of the fruit is edible. The Vitamin C content is appreciable (35-42 mg/100 g). The nutrient value of thiamine, potassium and dietary fiber is also significant [6].

Shelf-life of Custard Apple (*Annona squamosa*) Fruit During Preservation

After finding the appropriate 4% xanthan gum concentration, storage temperature at 8 ^{o}C; shelf life of custard apple (*Annona squamosa*) fruit during preservation also evaluated by sampling in different intervals (0, 7, 14, 21, 28 days). Results were also mentioned in table 4. Quality of custard apple (*Annona squamosa*) fruits which were coated by 4% xanthan gum and stored at 8 ^{o}C was maintained for 28 days without any deterioration.

Table 4: Shelf life of custard apple (*Annona squamosa*) fruit during preservation

Preservation time (days)	Weight loss (%)	Firmness (N)	Total soluble solid (^{o}Brix)	Ascorbic acid (mg/ml)
0	0^{e}	1731.28±103.6^{a}	9.28±0.03^{a}	10.12±0.01^{a}
7	4.18±0.01^{c}	1726.13±105.4^{ab}	9.05±0.01^{ab}	9.95±0.02^{ab}
14	8.69±0.03^{b}	1650.74±103.1^{b}	8.76±0.03^{b}	9.46±0.01^{b}

21	10.04±0.01^{ab}	1611.20±103.1^{bc}	8.30±0.01^{bc}	9.01±0.03^{bc}
28	12.18±0.02^{a}	1525.68±102.7^{c}	8.11±0.00^{c}	8.89±0.01^{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%)

According to one research, except for acidity and ascorbic acid contents which were decreasing during storage ripening, the moisture content, total sugar content, reducing sugar content and sucrose were all increasing as the fruit was ripening while in storage [25].Combined pre-storage treatment of CaCl2 (4%) and wax (1:10) for 5 minutes effectively delayed the ripening changes in sugar apple [26].

Conclusion

Custard apples have been part of human diet for ages due to its nutritional and medicinal values. Custard apple is one of the most delicious and highly perishable fruit. It has its delightful taste, flavour, moderate price in markets and a high nutritional status. Edible coatings are thin films that can be used as a new trend in post-harvest. Edible coatings applied on many products to provide a barrier against external elements and therefore increase shelf life. This research has successfully found out the appropriate conditions for maintaining custard apple (*Annona squamosa*) fruit quality such as xanthan gum coating concentration, storage temperature as well as extending product shelf life. The increase in shelf life of custard apple fruit would, therefore, be an advantage to the growers.

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