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Storage life improvement of custard apple (*Annona squamosa* L.) fruits *cv* 'Balanagar' by postharvest application of antioxidants

A. Venkatram[1]* and A. Bhagwan[2]

[1]*College of Horticulture, Rajendranagar, Dr. Y.S.R. Horticultural University, Hyderabad - 500030, A.P, India.*
[2]*Fruit Research Station, Sangareddy, Medak - 502110, A.P, India. *E-mail: venkatramambotu@gmail.com*

Abstract

The effect of postharvest application of various concentrations of antioxidants [500, 1000 ppm of sodium benzoate (SB) and ascorbic acid (AA) and 50, 100 ppm of benzyl adenine (BA)] on storage life of custard apple (*Annona squamos*a L.) fruits of cv 'Balanagar', stored at 15±1˚C, was studied at Fruit Research Station, Sangareddy, A.P., India. Various physico-chemical parameters like physiological loss in weight (PLW), firmness, spoilage, ripening, days taken for ripening, storage life, total soluble solids (TSS) and ascorbic acid were estimated at an interval of 2 days during storage. Fruits treated with BA (100 ppm) recorded the lower PLW than untreated fruits. The highest firmness was recorded in fruits treated with BA (100 ppm), whereas maximum days taken for ripening was recorded with BA (50 and 100 ppm) and SB 500 ppm. Fruits treated with BA (100 ppm) or SB (500 ppm) or AA (1000 ppm) recorded lower spoilage and correspondingly increased the storage life up to 11, 10.5 and 10 days, respectively, whereas, untreated fruits recorded a storage life of 8.5 days only. The lowest TSS and the highest ascorbic acid were recorded with fruits treated with BA (100 ppm), whereas untreated fruits recorded highest TSS and the lowest ascorbic acid. From the present investigation, it can be concluded that postharvest application of BA (100 or 50 ppm) increases the storage life of custard apple by 29.41 per cent (2.5 days) over untreated fruits.

Key words: Antioxidants, custard apple, firmness, ripening, storage life, total soluble solids

Introduction

Custard apple (*Annona squamosa* L.), belongs to family annonaceae, is an arid zone fruit grown in India. Out of 100 species of *Annona,* only custard apple, cherimoya, soursop, bullock's heart and atemoya are of major commercial importance. Of these, custard apple (synonyms: *Sithaphal*, *Sharifa*, Sugar apple, Sweetsop) is the most popular and widely used dessert fruit having higher production efficiency. The plants are hardy, drought resistant and can thrive well on marginal and neglected soils with minimum inputs (Rajput, 1985). It is considered as one of the delicious table fruit and is valued mainly for its sweet, mild flavoured pulp. The fruit is botanically referred as syncarpium an aggregate of fruitlets, each pocessing edible fleshy mass of soft, juicy and granular textured pulp surrounding a non-edible black seed. Custard apple is a climacteric fruit, starts ripening soon after detached from the tree and highly perishable with short shelf life of 1 to 2 days after ripening (Wills *et al.*, 2001). The steady increase in area and production of custard apple in India has enhanced the fruit flow into the markets, which most of the time leads to glut in the markets (Jalikop, 2006). The lack of information on the postharvest handling of this highly perishable fruit has resulted in huge losses.

Extension of storage life in custard apple even for a day or two will go a long way in increasing the shelf life and thus making it much easier to handle the fruit. The normal ripening of custard apple recorded at a temperature of 15 to 30˚C (Broughton and Tan, 1979), but the safe range is 15 to 20˚C, with maximum shelf life at 15˚C (Vishnu Prasanna *et al.*, 2000). The shelf life of custard apple can be increased up to 11 days when treated with waxol + $KMnO_4$ + individual wrapping by polyfilm and NAA + individual wrapping by polyfilm in cool chamber (Kamthe *et al.*, 2005) and up to 7 days when treated with waxol + $KMnO_4$ or waxol + NAA 30 ppm and packed in individual wrapping polyfilm of 75 gauge at ambient storage conditions as against 4 days in untreated and unpacked fruits (Masalkar and Garande, 2005). Application of edible coating material like sago, arrowroot and waxol 10% to custard apple fruits resulted in increase in shelf life by 5 to 8 days when compared to untreated fruits (Jholgiker and Reddy, 2007).

Antioxidants are the molecules that are capable of showing or preventing the oxidation of other molecules. These are reducing agents which prevent oxidation reaction by scavenging reactive oxygen species before they can damage the cells (Halliwell and Gutreridge, 1989). Several reports have shown that postharvest application of antioxidants like benzyl adenine (BA), sodium benzoate (SB) and ascorbic acid (AA) were effective in reducing loss in weight and spoilage and increasing the storage period of many fruits. Postharvest application of BA ppm and 50 ppm increased the shelf life of mango by 20 and 18.66 days, respectively (Ahmed, 1998). Application of BA 100 ppm improved the shelf life in papaya up to 11.33 days (Ravikiran Reddy, 2007). Jayachandran *et al.* (2007) reported that the postharvest application of BA at 25 or 50 ppm extended shelf life by 7 days over untreated guava fruits. Padmalatha (1993) found that in grapes, the postharvest application of SB 500 and AA 1000 ppm gave the best result by effectively reducing the loss in weight and subsequently increase the shelf life. Bhagwan (1994) reported that postharvest application of SB 500 ppm and waxol 4 % extended the shelf life of banana cv. Robusta at 20 ˚C and zero energy cool chamber. Such information on custard apple is scanty, therefore, the present investigation was carried out to study the postharvest application of antioxidants for enhancing storage life of custard apple 'Balanagar' fruits stored at 15±1˚C.

Materials and methods

The experiment was carried out during the year 2009-11 at Fruit Research Station, Sangareddy, Medak district, Dr. Y.S.R. Horticultural University, A.P., India. Custard apple 'Balanagar' fruits of uniform size, firm, free from disease and injuries were harvested at the light green fruit colour, yellowish white colour between the carpels and initiation of cracking of the skin between the carpels and brought to the laboratory. The fruits were cleaned in running tap water to remove the adhering dirt material and then allowed to dry in shade. The fruits were surface disinfected with 0.1% (w/v) bavistin solution for 2 min. The fruits were then dipped in the antioxidants solutions for 10 minutes. The treatments included: sodium benzoate (SB) 500 ppm, SB 1000 ppm, ascorbic acid (AA) 500 ppm, AA 1000 ppm, benzyl adenine (BA) 50 ppm, BA 100 ppm and untreated fruits. After the treatment the moisture on the surface of the fruits were dried and the fruits were stored at a temperature of 15±1˚C in horizontal racks. The physico-chemical parameters like physiological loss in weight (PLW), firmness, spoilage, ripening, days taken for ripening, storage life, total soluble solids (TSS) and ascorbic acid were estimated at an interval of 2 days during storage.

The weight of the fruits in each replication was recorded on every second day and subtracted from the initial weight. The loss of weight in relation to initial weight was calculated and expressed as percentage. A table top penetrometer was used to record the firmness of the fruits and obtained direct readings in kg cm^{-2}. Ripening was judged by the development of whitish yellow colour between the aereoles, light green colur of aereoles, softening and characteristic odour. The number of fruits ripened on each date of sampling was counted and ripening percentages were worked out. The days taken for ripening was determined by the stage wherein more than 50% of the stored fruits became ripen. The spoilage of fruits was determined based on visual observations like shriveling, fungal infection and subsequent rotting, over ripening and subsequent splitting, browning and discolouration of fruits. Number of fruits spoiled in a replication was counted and expressed as spoilage percentage. The stage wherein more than 50% of the stored fruits became unfit for consumption was considered as end of storage life and expressed as mean number of days. The TSS (^{o}Brix) of custard apple pulp recorded by using hand refractometer. Ascorbic acid content of pulp was determined by 2, 6-dichlorophenol indophenol titration method (Ranganna, 1986). The experiment was conducted in completely randomized design with factorial concept and each treatment replicated thrice. The data were subjected to statistical analysis as per the procedure outlined by Panse and Sukhatme (1985).

Results and discussion

Physiological loss in weight (%): Higher PLW was recorded in untreated fruits (5.02 %) and the lowest in fruits treated with BA 100 ppm (3.12 %), which was on par with SB 1000 ppm and BA 50 ppm (Table 1). The PLW of fruits treated with BA 50 ppm was at par with SB 500 ppm. The PLW increased from 2nd to 12th day and increase was more pronounced from 6th to 8th day of storage. There was significant increase in PLW with successive intervals of storage. The loss in weight in custard apple on storage was earlier reported by Kamble and Chavan (2005). On all the days of storage, fruits treated with antioxidants recorded significantly lower PLW irrespective of their concentration than untreated fruits and the lowest with BA 100 ppm except on 4th, 6th and 8th day of storage. Vishnu Prasanna *et al.* (2000) reported low temperature storage at 15 and 10 ^{o}C reduced the physiological loss in weight in custard apple. The average weight loss during ripening of atemoya fruits was also reported to be less than 10% at different temperatures (Batten, 1990). Postharvest application of BA 100 ppm reduced the PLW to 14.91% in mango fruits (Ahmed, 1998) and 11.53 % in guava with BA 50 ppm (Jayachandran *et al.*, 2007) when compared with untreated controls. Postharvest application of BA 100 ppm, SB 1000 ppm and AA 1000 ppm reduced the PLW in papaya (Ravikiran Reddy, 2007), SB 500 ppm and AA 1000 ppm in grapes (Padmalatha 1993) and SB 500 ppm + 4% waxol in banana cv. Robusta fruits (Bhagwan, 1994).

Firmness (kg cm^{-2}): Significantly higher firmness was recorded in fruits treated with BA 100 ppm (2.23 kg cm^{-2}) and the lowest in untreated fruits (1.25 kg cm^{-2}) (Table 2). The higher firmness was recorded with fruits treated with higher concentration of BA and AA than lower concentration. The firmness of fruits decreased from 0 to 10th day and the decrease was more pronounced from 8th to 10th day of storage. There was significant decrease in firmness of fruits with successive intervals of storage period and fruits treated with BA and AA recorded significantly higher firmness irrespective of their concentrations. Vishnu Prasanna *et al.* (2000) and Bolivar-Fernandez *et al.* (2009) reported that the firmness of ripe fruits of custard apple was the least when stored at 25 and 20 ˚C as compared to those stored at 15 and 10 ˚C. The decrease in firmness might be due to less activity of enzymes at reduced temperatures which are responsible for degradation of cellulose and other pectic substances (Tsay and Wu, 1989). Earlier studies revealed that cherimoya fruit stored at 10 ˚C retained firmness throughout 6 days of storage (Shen *et al.*, 2009). Jayachandran *et al.* (2007) reported high firmness in guava fruits when treated with BA 50 ppm. Similarly, high fruit firmness was recorded by treating sapota 'Kirthibarthi' fruits with ascorbic acid, hydroxyquinone, menadione and aminovinylglycine (Rao and Chundawat, 1982).

Table 1. Effect of postharvest application of antioxidants on PLW (%) of custard apple 'Balanagar' fruits stored at 15±1˚C

Treatments	2ndday	4thday	6thday	8thday	10thday	12thday	Mean
SB 500 ppm	0.28	0.94	2.46	4.39	4.99	6.61	3.27^c
SB 100 ppm	0.27	0.81	2.36	4.19	4.89	6.58	3.20^c
AA 500 ppm	0.30	1.91	2.77	4.88	5.26	8.23	3.89^b
AA 1000 ppm	0.29	1.89	2.69	4.81	5.22	8.12	3.83^b
BA 50 ppm	0.26	0.87	2.37	4.18	4.88	6.55	3.18^c
BA 100 ppm	0.24	1.44	2.49	4.24	4.60	5.74	3.12^{dc}
Untreated	1.09	2.56	3.40	6.75	7.54	8.81	5.02^a
Mean	0.39^f	1.50^e	2.65^d	4.77^c	5.34^b	7.23^a	

LSD (P=0.05)
Days (D)=0.08; Treatments (T)= 0.09; D × T=0.22

Figures with same alphabet did not differ significantly (P=0.05)

Table 2. Effect of postharvest application of antioxidants on firmness (kg cm^{-2}) of custard apple 'Balanagar' fruits stored at 15±1˚C

Treatments	0 day	2nd day	4th day	6th day	8th day	10th day	Mean
SB 500 ppm	2.85	2.80	2.50	2.10	1.70	0.60	2.09b
SB 100 ppm	2.85	2.60	2.30	1.90	1.50	0.40	1.92d
AA 500 ppm	2.85	2.50	2.20	1.80	1.40	0.30	1.84e
AA 1000 ppm	2.85	2.69	2.39	1.99	1.59	0.49	2.00c
BA 50 ppm	2.85	2.85	2.55	2.15	1.75	0.65	2.13b
BA 100 ppm	2.85	2.85	2.70	2.30	1.90	0.80	2.23a
Untreated	2.85	2.15	1.85	0.55	0.10	0.00	1.25f
Mean	2.85a	2.63b	2.35c	1.82d	1.42e	0.46f	

LSD (P=0.05)
Days (D)=0.06; Treatments (T)= 0.06; D × T=0.16

Figures with same alphabet did not differ significantly (P=0.05)

Ripening (%): Significantly, highest ripening was recorded in untreated fruits (50.00), which was on par with fruits treated with AA 500 ppm (45.00 %) and the lowest (27.50 %) in fruits treated with BA at both concentrations (50 and 100 ppm) and SB 500 ppm (Table 3). The ripening of fruits treated with AA 1000 ppm was at par with SB 1000 ppm. The ripening increased from 4th to 10th day of storage and the increase was more pronounced from 8th to 10th day of storage Antioxidant like SB, AA reduce ethylene production and respiration by hindering the probable free radical mediated 1-amino cyclopropene-1-carboxylic acid to ethylene pathway of ethylene production (Apelbaum *et al.*, 1981). Similarly, banana cv. Robusta fruits treated with SB 500 ppm and 4% waxol exhibited delayed ripening (Bhagwan, 1994). Postharvest application of SB 1000 ppm recorded lowest ripening in mango (Vanajalatha, 2001) and guava (Jayachandran *et al.*, 2007).

Spoilage (%): The fruits treated with antioxidants recorded significantly lower spoilage (Table 4) irrespective of their concentrations. Higher spoilage was recorded in untreated fruits (80.00 %) and the lowest (52.50 %) in fruits treated with BA with both concentrations (50 and 100 ppm), which was on par with SB 500 ppm. The spoilage of fruits increased from 8th to 14th day and increase was more pronounced from 10th to 12th day of storage. There was significant increase in spoilage of fruits with any treatment on successive intervals of storage period. Fruits treated with antioxidants recorded significantly lower spoilage irrespective of their concentrations. Higher spoilage was recorded in untreated fruits and the lowest in fruits treated with BA at both concentrations (50 and 100 ppm), which is on par with SB 500 ppm. BA, besides being an antioxidant is a potent free radical scavenger also. Low spoilage has been reported in mango fruits treated with SB 1000 ppm after 16 days of storage (Vanajalatha, 2001), guava fruits treated with BA 50 ppm (Jayachandran *et al.*, 2007), in grape, 'Thompson seedless' treated with SB 1000 ppm and stored at room temperature (Padmavathi and Reddy, 2003) and papaya where spoilage was delayed due to BA 100 ppm treatemnt (Ravikiran Reddy, 2007).

Table 3. Effect of postharvest application of antioxidants on ripening (%) of custard apple 'Balanagar' fruits stored at 15±1˚C

Treatments	4th day	6th day	8th day	10th day	Mean
SB 500 ppm	0.00	10.00	30.00	70.00	27.50c
SB 100 ppm	10.00	20.00	40.00	80.00	37.50b
AA 500 ppm	10.00	30.00	50.00	90.00	45.00a
AA 1000 ppm	0.00	20.00	40.00	80.00	35.00b
BA 50 ppm	0.00	10.00	30.00	70.00	27.50c
BA 100 ppm	0.00	10.00	30.00	70.00	27.50c
Untreated	10.00	30.00	60.00	100.00	50.00a
Mean	4.29d	18.57c	40.00b	80.00a	

LSD (P=0.05)
Days (D)= 0.40; Treatments (T)=0.37; D × T= 1.06

Figures with same alphabet did not differ significantly (P=0.05)

Days taken for ripening: The days taken for ripening was maximum (9 days) in fruits treated with BA 50 ppm or BA 100 ppm or SB 500 ppm and minimum in untreated fruits (7.33) (Table 5). The days taken for ripening of fruits treated with AA 1000 ppm and SB 1000 ppm was equal (8.5 days). Benzyl adenine was found to delay ripening in papaya (Ravikiran Reddy, 2007), guava (Jayachandran *et al.*, 2007) and grapes (Padmavathi and Reddy, 2003).

Storage life (days): The shelf life differed significantly among different antioxidants treated fruits with maximum storage life of 11 days recorded in fruits treated with BA with both concentrations (50 and 100 ppm) (Table 5). However minimum storage life of 8.5 days was recorded in untreated fruits followed by fruits treated with AA with both concentrations (500 and 1000 ppm). The fruits treated with antioxidants recorded significantly higher storage life irrespective of concentration than untreated fruits. Improved storage life by BA may be due to its strong antioxidant as well as free radical scavenger action, which might have delayed the ripening of fruits by reducing and delaying the ethylene production and may be due to inhibition of alternative respiration and also protection from senescence as a cytokinin (Ravikiran Reddy, 2007). BA 50 or 25 ppm has been reported to increase the storage life (7 days) over untreated guava fruits (Jayachandran *et al.*, 2007) and BA 100 ppm recorded the maximum storage life 11.33 days in papaya (Ravikiran Reddy, 2007). Postharvest application of SB 1000 ppm enhanced the shelf life up to 18.97 days in mango (Vanajalatha, 2001).

Table 4. Effect of postharvest application of antioxidants on spoilage (%) of custard apple 'Balanagar' fruits stored at 15±1˚C

Treatments	8th day	10th day	12th day	14th day	Mean
SB 500 ppm	20.00	40.00	80.00	90.00	57.50c
SB 100 ppm	20.00	40.00	90.00	100.00	62.50cb
AA 500 ppm	30.00	50.00	90.00	100.00	67.50b
AA 1000 ppm	30.00	50.00	90.00	100.00	67.50b
BA 50 ppm	20.00	30.00	90.00	90.00	52.50dc
BA 100 ppm	20.00	30.00	70.00	90.00	52.50dc
Untreated	40.00	80.00	70.00	100.00	80.00a
Mean	25.71d	45.71c	100.00	95.71a	

LSD (P=0.05)
Days (D)=4.38; Treatments (T)=5.78; D × T=11.57

Figures with same alphabet did not differ significantly (P=0.05)

Table 5. Effect of postharvest application of antioxidants on days taken for ripening and storage life (days) of custard apple 'Balanagar' fruits stored at 15±1˚C

Treatments	Days taken for ripening	Storage life (days)
SB 500 ppm	9.00[b]	10.50[b]
SB 100 ppm	8.50[c]	10.40[b]
AA 500 ppm	8.00[d]	10.00[c]
AA 1000 ppm	8.50[c]	10.00[c]
BA 50 ppm	9.00[b]	11.00[a]
BA 100 ppm	9.00[b]	11.00[a]
Untreated	7.33[a]	8.50[d]
LSD (*P*=0.05)	0.48	0.35

Figures with same alphabet did not differ significantly (*P*=0.05)

TSS (°Brix): Significantly higher TSS (22.81 °Brix) was recorded in untreated fruits and the lowest (21.00 °Brix) in fruits treated with BA 100 ppm (Table 6). The fruits treated with SB and AA recorded significantly lower TSS irrespective of their concentrations than untreated fruits. The TSS increased from 0 to 10th day and then declined to 23.97 °Brix on 12th day of storage. The increase of TSS was more pronounced from 6th to 8th day of storage. There was significant increase in TSS in all treatments from 0 to 10th day and then declined up to 12th day of storage. The TSS of climacteric fruits increase with progression of ripening (Kumbhar and Desai, 1986) and the increase reaches a peak and then declines in custard apple (Bolivar-Fernandez *et al*., 2009). Further, the lowest TSS in BA 100 in the present study indicates delay in the ripening process which may be due to antioxidant properties of the benzyl adenine. Postharvest application of BA at 100 ppm was found to lower the TSS in mango (Ahmed, 1998) and papaya (Ravikiran Reddy, 2007).

Ascorbic acid (mg 100 g^{-1}): Significantly higher ascorbic acid content (42.92 mg 100 g^{-1}) was recorded in fruits treated with BA 100 ppm and the lowest (37.25 mg 100 g^{-1}) in untreated fruits (Table 7). Significantly higher ascorbic acid content was recorded with fruits treated with higher concentration of antioxidants than lower concentration except SB. The ascorbic acid content of fruits increased from 0 to 6th day and then declined by 22.80 mg 100 g^{-1} on 12th day and decrease was more pronounced from 6th to 8th day of storage. On all the days of storage, there was significant increase in ascorbic acid content of fruits with any treatment from 0 to 6th day and then declined up to 12th day. The decline in ascorbic acid during storage may be attributed to conversion of ascorbic acid into dehydroascorbic acid (Guftason and Cooke, 1952). The reduction in ascorbic acid content might be due to the activity of oxidative enzymes during storage. However, the decrease in ascorbic acid content after reaching peak observed in present study may be due to the oxidative reduction of vitamin C in presence of molecular oxygen by ascorbic acid oxidase enzymes (Pruthi *et al*., 1984). The higher ascorbic acid content was also recorded by postharvest application of BA 50 ppm, SB 500 ppm and BA 100 ppm in guava (Jayachandran *et al*., 2007), mango (Vanajalatha, 2001) and papaya (Ravikiran Reddy, 2007), respectively.

Table 6. Effect of postharvest application of antioxidants on TSS (˚Brix) of custard apple 'Balanagar' fruits stored at 15±1˚C

Treatments	2nd day	4th day	6th day	8th day	10th day	12th day	Mean
SB 500 ppm	19.50	20.40	21.30	23.40	23.90	23.60	21.51[c]
SB 100 ppm	19.60	20.30	21.40	23.30	23.80	23.50	21.48[c]
AA 500 ppm	20.80	21.40	22.60	24.40	24.90	24.60	22.45[b]
AA 1000 ppm	20.60	21.60	22.40	24.60	25.10	24.80	22.51[b]
BA 50 ppm	19.00	19.70	20.80	22.70	23.20	23.10	21.27[e]
BA 100 ppm	20.80	19.80	20.70	22.80	23.30	23.00	21.00[d]
Untreated	20.90	21.90	22.80	24.90	25.50	25.20	22.81[a]
Mean	20.17[f]	20.73[e]	21.71[d]	23.73[c]	24.24[a]	23.97[b]	

LSD (*P*=0.05)
Days (D)=0.18; Treatments (T)=0.17; D × T=0.47

At 0 day TSS value was 18.50 °Brix. Figures with same alphabet did not differ significantly (*P*=0.05)

Table 7. Effect of postharvest application of antioxidants on ascorbic acid (mg 100 g^{-1}) of custard apple 'Balanagar' fruits stored at 15±1˚C

Treatments	2nd day	4th day	6th day	8th day	10th day	12th day	Mean
SB 500 ppm	45.20	50.50	51.20	38.50	30.80	22.60	40.07[c]
SB 100 ppm	43.60	50.50	53.30	39.40	29.20	23.50	40.11[c]
AA 500 ppm	42.50	48.20	50.50	37.80	28.50	20.50	38.47[e]
AA 1000 ppm	44.40	47.80	49.43	38.50	30.50	21.30	39.03[d]
BA 50 ppm	48.30	51.50	54.30	40.40	32.30	25.20	41.90[b]
BA 100 ppm	49.20	52.30	56.50	41.30	33.40	26.50	42.92[a]
Untreated	41.50	49.50	49.50	35.50	26.50	20.00	37.25[f]
Mean	44.95[c]	49.61[b]	52.10[a]	38.77[d]	30.17[e]	22.80[f]	

LSD (*P*=0.05)
Days (D)=0.40; Treatments (T)=0.37; D × T=; 1.06

Figures with same alphabet did not differ significantly (*P*=0.05). At 0 day AA was 41.30 mg 100g^{-1}

From the present study, it can be concluded that the postharvest application of BA either at 50 ppm or 100 ppm concentration significantly improved the shelf life of custard apple by 29.41 per cent (2.5 days) over untreated fruits. The benzyl adenine treatment was effective in reducing the physiological loss in weight and retaining the firmness of the fruit by retarding the ripening of the fruit. Benzyl adenine, an antioxidant and free radical scavenger might have effectively reduced the ethylene production and thus delayed the ripening process in the present study. Further, BA was effective in retaining the quality of the fruit in terms of retaining higher ascorbic acid content of the fruit.

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