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Original Research Article

Effect of Post-Harvest Chemical Treatments on Physico-Chemical Quality and Shelf Life of Custard Apple (*Annona squamosa* L.) During Storage

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Keywords

Chemical treatment, Physico-chemical Quality, *Annona squamosa*

A B S T R A C T

A laboratory experimental study was conducted on "Effect of post-harvest chemical treatments on physico-chemical quality and shelf life of custard apple (*Annona squamosa* L.) during storage'' at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani and framed in Complete Randomized design (CRD). Custard apple fruits were harvested at physiological stage of maturity. Fruits were graded, washed and dried under fan. After that fruits were treated with 1-Methylcyclopropene (1-MCP) at two concentrations 100ppb and 200ppb for 24 h duration and coated with Chitosan-1% and wax. Treated fruits were subsequently packed in corrugated fibre board boxes and stored at ambient temperature. The results emerged out indicates that the combined application of 1-Methylcyclopropene 200ppb and chitosan 1% as a post-harvest tool may be integrated in to the supply chain management of custard apple fruit, to inhibited fruit ripening and extend shelf life and maintain quality of custard apple fruit during storage.

Introduction

Custard apple (*Annona squamosa* L.) is one of the finest fruit gifted to India by Tropical America. Custard Apple is also known as Sugar Apple. Custard apples are climacteric and have a very short storage life due to their fast ripening after harvest.

The fruit is an excellent source of energy as it high in carbohydrate. The fruit contains vitamins-C and minerals such as calcium, phosphorus potassium.

Area under custard apple is reported to be about 53,000 ha in India. Andhra Pradesh is the major custard apple growing state along with Tamil Nadu, Orissa, Assam, Uttar Pradesh, Bihar and Rajasthan, which produce nearly, 75,000 tonnes of fruits.

Custard apple is one of the most delicious and highly perishable fruit. It has its delightful taste, flavor, moderate price in markets and a high nutritional status. Overall the importance of fruits in domestic and export market as a fresh fruits and processed products. Under ordinary condition, fruits can keep well only for 3-4 days after harvest. The physiological changes in fruit occur continuously after harvest.

The major and foremost constraints of custard apple processing are development of bitterness and change in colour. Heating of pulp beyond 65^{o} C impairs pulp flavor considerably and often results in the development of bitterness and unpleasant repulsive off flavor in the pulp. Changes in colour are due to PPO compound.

Considering these are the major constraints, custard apples have to be disposed off in local market. Glut in market leads to lower prices. If fruits are preserved in the form of pulp during seasonal glut, it will help in better utilization of custard apple fruits. Hence, the present study was undertaken on postharvest handling of custard apple through different post-harvest treatments and processing of custard apple with following objectives:

Materials and Methods

The present study was carried out in the Department of Horticulture, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during 2015-16. Select Custard apple fruits of matured green stage were subjected to uniform size, colour and free from injuries were selected for the study.

The clean dried fruits were washed then divided into main lots each containing 15 fruits and subjected to various treatments, i.e. T1-1-MCP-100 ppb; T_{2}-1-MCP - 200 ppb; T3-Putrescine – 1 mM T_4 -Paraffin Wax; T_5-Chitosan - 1%; $T_{6;}$ 1-MCP -100 ppb + Putrescine – 1 mM; T7-1-MCP – 100 ppb + Paraffin Wax; T8-1-MCP – 100 ppb + Chitosan - 1 %; T_9 -1-MCP - 200 ppb + Putrescine – 1 mM; T_{10} -1-MCP - 200 ppb + Paraffin Wax; T_{11} -1-MCP - 200 ppb + Chitosan -1 %; T_{12} -Putrescine – 1 mM + Paraffin Wax; T_{13} -Putrescine – 1 mM + Chitosan -1%; T_{14} -Paraffin Wax + Chitosan - 1% and T_{15} –Control. Each treatment was replicated thrice (3 replication). Treated fruit were packed in CFB boxes and stored in ambient temperature and record PLW, Fruit decying percentage and biochemical parameter.

Results and Discussion

The effect of 1-Methylcyclopropene, Chitosan, Putrescine and paraffin wax coating at ambient temperature on rate of changes of physiological loss in weight is presented in Table 1. The physiological loss in weight of fruits was found to increase with the advancement of storage period irrespective of treatments. At 3rd day of storage, there were no PLW was found in T_7, T_{10} and T_{14} treatments. Significantly lowest physiological loss in weight was recorded in treatment T_7 (0.05%) and T_{10} (0.05%) over rest of the treatments except treatment T_{14} (0.08%) which was at par with treatment T_7 and T_{10}, while highest PLW was recorded in treatment T_{15} (12.53%) during 6th day of storage. During the 15th day of observation, the treatment T_{10} (8.23%) was registered a lower PLW which was at par with T_7 (8.65%) and T_5 (9.09%). The higher PLW was shown in treatment T_{11} (13.94%). Least physiological loss in weight (PLW) was found in treatment T_{10} (1-MCP 200 ppb + wax), T_7 (1-MCP 100ppb + wax) and T_{11} (1-MCP 200ppb + Chitosan 1%) during storage.

The effect of various treatments on percentage of decay incidence is presented in Table 2. At 3rd day of storage of custard apple fruits decay incidence was not found in all treatments. At 6th day of storage also decay incidence was not found in treatments T_{10} and T_{11} and T_{14}. At 6th day of storage, lowest decay incidence was found in treatment T_{13} (0.11%) and T_8 (0.14%) followed by in treatments T_7 (0.66%) and T_5 (1.17%). The highest (11.40%) rate of decay was recorded in treatment T_{15}. There was no decay incidence found in treatments $T_{14.}$ At 12th days of storage, the rate of decay incidence was increasing significantly with the advancement of time under the storage period. On 15th day of storage, maximum decay incidence (13.01%) was recorded in treatments T_4 and minimum decay was recorded in treatment T_{14} (7.85%) over rest of the treatment except treatments T_{11} (8.11%) which was at par with treatment T_{10} (8.21), T_8 (8.53%) and T_7 (8.67%). The minimum decay incidence was found in treatment T_{14} (Wax + chitosan 1%) and T_{11} (1-MCP 200ppb + Chitosan 1%) during storage.

The effect of 1-MCP and Chitosan coating and the days of storage on total soluble solids, the results have revealed (Table 3) that the value of total soluble solids was not significantly increased by the various treatments and the days of storage. Whereas the maximum total soluble solids was observed in treatments T_{15} (29.74%) and minimum total soluble solids was observed in treatments T_9 (23.02%) and T_{11} (22.025) during the 6th day of storage. At 12th days of storage, the rate of total soluble solids was increasing slightly with the advancement of time under the storage period. At the 15th day of storage the maximum total soluble solids was recorded in treatments T_3 (29.70%) and T_5 (29.33%).

The effects of various treatments on titratable acidity of custard apple during storage are presented in Table 4. The results showed that the titratable acidity was found stable during the initial days of storage. The titratable acidity decreased significantly along with increased storage time in both treated and untreated fruits but, this decline was less fast in treated fruits than untreated fruits. Higher titratable acidity was recorded in T_3 (putercine-1mM), T_5 (Chitosan – 1%) and lower titratable acidity recorded in T_{10} (1-MCP-100ppb +Wax) and T_{11} (1- MCP 200ppb + Chitosan 1%) during storage. These results agreed with those reported by El-Ghaouth *et al.,* (1991) and Garcia *et al.,* (1989)

The effect of various treatments and the days of storage on total sugars content of custard apple fruit is presented in Table 5.

The obtained results have revealed that the value of total sugars content was significantly increased by the various treatments. It is an inversely proportional to the days of storage period. Highest total sugars, total sugar content was found in T_3 (Putrescine 1mM) and T_5 (Chitosan 1%) in stored fruits.

Effect of post-harvest treatments on the ascorbic acid content in custard apple fruits during storage is presented in Table 6. The ascorbic acid of fruits was found to increase with the advancement of storage period irrespective of treatments.

Higher ascorbic acid was observed in T_{10} (1-MCP 200ppb + chitosan1%), and lower is found in T_3 (Putrescine -1mM) during storage.

The effect of post-harvest treatments on the rate of respiration of custard apple fruit is presented in Table 7. There was a gradual increase in the rate of respiration. There were least respiration rate was found with T_3 (Putrescine 1mM), T_5 (Chitosan - 1%) during storage.

The effect of post-harvest treatments on the ethylene evolution of custard apple is presented in Table 8. There was a gradual decrease in the rate of ethylene evolution.

At initial day, higher ethylene evolution was recorded in treatment T_{14} (11.83ppm) while minimum ethylene evolution was recorded in treatment T_1 (11.22 ppm). On 15th day of storage, lower ethylene evolution rate was observed in treatment T_3 (6.90 ppm), while highest ethylene evolution was recorded in treatment in T_{10} (9.87 ppm).

Table.1 Effect of post-harvest treatments on physiological loss in eight (%) of Custard apple fruit during storage

Treatment	Storage Days					
	0	**3**	**6**	**9**	**12**	**15**
T1	0.00	0.05	0.16	5.18	10.27	12.46
T2	00.0	0.05	0.14	4.62	9.47	11.81
T3	0.00	0.04	0.12	3.76	8.63	11.01
T4	0.00	0.01	0.07	2.50	4.90	9.09
T5	0.00	0.06	0.17	5.29	10.39	12.59
T6	0.00	0.03	0.10	3.59	7.76	10.27
T7	0.00	0.00	0.05	1.94	4.09	8.65
T8	0.00	0.07	0.18	5.93	11.77	12.80
T9	0.00	0.02	0.09	3.21	6.69	9.89
T10	0.00	0.00	0.05	1.49	3.17	8.23
T11	0.00	0.07	0.20	6.18	12.37	13.94
T12	0.00	0.01	0.07	2.86	5.53	9.27
T13	0.00	0.04	0.11	3.53	7.90	10.49
T14	0.00	0.00	0.08	2.97	5.70	9.51
T15	0.00	5.56	12.53	-	-	-
S.E. ±	NS	0.22	050	0.04	0.17	0.86
C.D. @ 5 %	NS	0.67	1.52	0.12	0.51	2.58

Table.2 Effect of post-harvest treatments on decaying percentage of Custard apple fruit during storage

Treatment	Storage Days					
	0	**3**	**6**	**9**	**12**	**15**
T1	0.00	0.00	3.46	7.41	9.07	11.96
T2	00.0	00.0	3.25	6.55	8.21	11.09
T3	0.00	0.00	3.63	7.62	9.28	12.17
T4	0.00	0.00	4.07	8.46	10.12	13.01
T5	0.00	0.00	1.17	5.12	6.77	9.66
T6	0.00	0.00	4.06	8.05	9.70	12.59
T7	0.00	0.00	0.66	4.13	5.78	8.67
T8	0.00	0.00	0.14	3.76	5.65	8.53
T9	0.00	0.00	3.70	7.98	9.64	12.53
T10	0.00	0.00	0.00	3.67	5.33	8.21
T11	0.00	0.00	0.00	3.56	5.22	8.11
T12	0.00	0.00	2.57	5.87	7.53	10.42
T13	0.00	0.00	0.11	3.60	5.50	8.39
T14	0.00	0.00	0.00	3.30	4.96	7.84
T15	0.00	0.00	11.40	-	-	-
S.E. ±	NS	NS	0.62	0.60	0.68	0.74
C.D. @ 5 %	NS	NS	1.88	1.81	2.05	2.24

Table.3 Effect of post-harvest treatments on total soluble solids (%) of Custard apple fruits during storage

Treatment	Storage Days					
	0	**3**	**6**	**9**	**12**	**15**
T1	22.33	24.00	27.88	28.23	28.35	28.49
T2	21.33	23.67	27.55	27.90	28.02	28.16
T3	21.00	25.00	29.09	29.44	29.56	29.70
T4	21.00	21.33	28.44	28.79	28.91	29.05
T5	21.00	24.33	28.72	29.07	29.19	29.33
T6	22.33	22.67	23.35	23.70	23.82	23.96
T7	21.67	21.67	22.68	23.03	23.15	23.29
T8	21.00	21.00	22.35	22.70	22.82	22.96
T9	22.00	22.00	23.02	23.37	23.49	23.63
T10	20.67	20.67	21.35	21.70	21.82	21.96
T11	21.00	21.00	22.02	22.37	22.49	22.63
T12	21.67	23.00	27.12	27.47	27.59	27.73
T13	21.00	23.33	27.22	27.57	27.69	27.83
T14	21.33	22.74	24.35	24.70	24.82	24.96
T15	21.00	21.33	29.74	-	-	-
S.E. ±	0.22	0.47	0.60	0.62	0.62	0.59
C.D. @ 5 %	0.69	1.42	1.81	1.88	1.86	1.79

Table.4 Effect of post-harvest treatments on acidity (%) of custard apple fruits during storage

Treatment	Storage Days					
	0	**3**	**6**	**9**	**12**	**15**
T1	0.22	0.21	0.20	0.18	0.17	0.16
T2	0.23	0.20	0.20	0.18	0.17	0.16
T3	0.20	0.22	0.21	0.19	0.18	0.17
T4	0.22	0.21	0.20	0.17	0.16	0.15
T5	0.21	0.21	0.21	0.19	0.18	0.17
T6	0.22	0.19	0.18	0.16	0.15	0.14
T7	0.21	0.18	0.17	0.15	0.14	0.13
T8	0.22	0.17	0.16	0.13	0.12	0.11
T9	0.22	0.18	0.17	0.15	0.14	0.13
T10	0.22	0.15	0.14	0.12	0.11	0.10
T11	0.20	0.15	0.14	0.13	0.11	0.10
T12	0.20	0.19	0.18	0.16	0.15	0.14
T13	0.21	0.20	0.19	0.17	0.16	0.15
T14	0.22	0.19	0.18	0.15	0.14	0.13
T15	0.23	0.23	0.22	-	-	-
S.E. ±	0.002	0.002	0.09	0.09	0.09	0.10
C.D. @ 5 %	0.007	0.006	0.28	0.28	0.29	0.31

Table.5 Effect of post-harvest treatments on total sugars (%) of custard apple fruit during storage

Treatment	Storage Days					
	0	**3**	**6**	**9**	**12**	**15**
T1	11.98	14.45	16.58	18.90	20.29	22.41
T2	11.84	14.02	16.12	18.44	19.83	21.95
T3	11.25	14.93	17.21	19.53	20.92	23.04
T4	12.05	14.61	16.78	19.10	20.49	22.61
T5	12.03	14.75	16.99	19.31	20.70	22.82
T6	12.03	13.35	15.20	17.52	18.91	21.03
T7	11.97	12.83	14.48	16.80	18.19	20.31
T8	11.98	12.62	14.19	16.51	17.90	20.02
T9	11.89	13.16	14.91	17.23	18.62	20.74
T10	11.95	12.74	13.74	16.06	17.45	19.57
T11	11.72	12.66	13.95	16.27	17.66	19.78
T12	11.91	13.91	15.89	18.21	19.60	21.72
T13	11.97	14.00	16.05	18.37	19.76	21.88
T14	11.91	13.65	15.57	17.89	19.28	21.40
T15	12.26	16.13	21.35	-	-	-
S.E. ±	0.12	0.54	0.50	0.46	0.44	0.41
C.D. @ 5 %	0.38	1.62	1.51	1.38	1.32	1.25

Table.6 Effect of post-harvest treatments on ascorbic acid (mg/100gm) content in custard apple fruit during storage

Treatment	Storage Days					
	0	**3**	**6**	**9**	**12**	**15**
T1	27.45	29.18	29.60	29.92	30.33	31.38
T2	28.17	31.81	32.23	32.55	32.96	34.01
T3	24.03	24.32	24.74	25.06	25.47	26.52
T4	26.93	26.87	27.29	27.61	28.02	29.07
T5	24.86	25.15	25.57	25.89	26.30	27.35
T6	32.56	33.64	34.06	34.38	34.79	35.84
T7	31.92	34.33	35.43	35.75	36.16	37.21
T8	32.32	34.81	36.06	36.38	36.79	40.06
T9	32.35	33.76	34.87	35.19	35.60	36.65
T10	33.95	36.59	38.93	39.25	39.66	41.00
T11	33.03	35.42	37.20	37.52	37.93	40.25
T12	32.63	33.22	34.24	34.56	34.97	36.02
T13	31.22	32.41	33.36	33.68	34.09	35.14
T14	32.25	33.47	34.55	34.87	35.28	36.33
T15	24.02	36.10	42.00	-	-	-
S.E. ±	0.31	0.06	0.07	0.05	0.05	0.05
C.D. @ 5 %	0.97	0.18	0.21	0.17	0.17	0.16

Table.7 Effect of post-harvest treatments on rate of respiration (ml CO_2 kg^{-1} h^{-1}) of custard apple fruit during storage

Treatment	Storage Days					
	0	3	6	9	12	15
T1	26.25	22.40	20.58	19.26	17.24	16.01
T2	25.47	22.79	21.10	19.78	17.76	16.53
T3	25.16	20.93	18.61	17.29	15.27	14.04
T4	25.59	21.90	19.94	18.62	16.60	15.37
T5	24.83	20.88	18.79	17.47	15.45	14.22
T6	24.81	24.10	23.44	22.12	20.10	18.87
T7	25.01	24.50	23.88	22.56	20.54	19.31
T8	25.14	24.72	24.23	22.91	20.89	19.66
T9	25.07	24.38	23.56	22.24	20.22	18.99
T10	25.45	25.22	25.01	23.69	21.67	20.44
T11	25.45	25.10	24.75	23.43	21.41	20.18
T12	24.66	23.37	22.02	20.70	18.68	17.45
T13	24.92	23.00	21.38	20.06	18.04	16.81
T14	24.56	23.60	22.51	21.19	19.17	17.94
T15	25.58	17.23	12.25	-	-	-
S.E. ±	0.26	0.04	0.05	0.05	0.05	0.05
C.D. @ 5 %	0.82	0.14	0.15	0.16	0.16	0.17

Table.8 Effect of post-harvest treatments on ethylene evolution rate (ppm) of custard apple fruit during storage

Treatment	Storage Days					
	0	3	6	9	12	15
T1	11.22	9.98	9.69	8.84	8.42	8.14
T2	11.25	10.19	9.93	9.08	8.66	8.38
T3	11.49	8.84	8.45	7.60	7.18	6.90
T4	11.47	9.79	9.49	8.64	8.22	7.94
T5	11.59	9.61	9.30	8.45	8.03	7.75
T6	11.33	10.69	10.55	9.70	9.28	9.00
T7	11.26	10.93	10.81	9.96	9.54	9.26
T8	11.26	10.96	10.66	9.81	9.39	9.11
T9	11.51	10.91	10.78	9.93	9.51	9.23
T10	11.64	11.42	11.42	10.57	10.15	9.87
T11	11.25	11.00	11.00	10.15	9.73	9.45
T12	11.52	10.62	10.41	9.56	9.14	8.86
T13	11.77	10.51	10.28	9.43	9.01	8.73
T14	11.83	10.64	10.48	9.63	9.21	8.93
T15	11.45	6.80	4.26	-	-	-
S.E. ±	0.12	0.02	0.005	0.02	0.02	0.02
C.D. @ 5 %	0.36	0.07	0.016	0.06	0.07	0.06

Table.9 Effect of post-harvest treatments on shelf life (days) of custard apple fruit during storage

Treatments	**Days**
T_1 -1-MCP-100 ppb	12.46
T_2-1-MCP - 200 ppb	12.18
T_3-Putrescine – 1 mM	11.80
T_4-Paraffin wax	11.27
T_5-Chitosan - 1%	10.05
T_6-1-MCP -100 ppb + Putrescine – 1 mM	13.41
T_7-1-MCP – 100 ppb + Paraffin wax	14.22
T_8-1-MCP – 100 ppb + Chitosan - 1 %	15.15
T_9-1-MCP - 200 ppb + Putrescine – 1 mM	13.34
T_{10}-1-MCP - 200 ppb + Paraffin wax	13.82
T_{11}-1-MCP - 200 ppb + Chitosan -1 %	14.83
T_{12}- Putrescine – 1 mM + Paraffin wax	12.52
T_{13}- Putrescine – 1 mM + Chitosan -1%	13.07
T_{14}-Paraffin wax + Chitosan - 1%	11.27
T_{15}-Control	4.60
S.E. ±	0.04
C.D. @ 5 %	0.12

The effect of treatments on the shelf life of custard apple is presented in Table 9. It was observed that the highest shelf life was observed in treatament T_8 (15.15 days) which was at par with tretement T_{11} (14.83) and T_7 (14.22) whereas lowest shelf life was observed in treatment T_{15} (4.60).

As an expected result, PLW of fruits was altered with treatment applied and use of 1-MCP + Chitosan gave superior results over other treatments with respect to keeping PLW rate low under both the storage conditions. This low PLW of fruits may be attributed to diminished biological activities (respiration, ethylene evolution, inactivation of enzymes and restricted movement of free water). The above findings confirmed with the work done by Jeong *et al.,* (2002).

Since 1-MCP is known to delay senescence by blocking the evolution of ethylene, it there by inhibited fruit softening (Blankenship and Dole, 2003; Jeong *et al.*, 2002). Maximum fruit firmness in Chitosan coated fruits could be attributed to the permeability property of the coating and its effects on the fruits (Buescher, 1979) and provided better way to reduce the evaporation and avoided shrinkage (Medlicott *et al.,* 1987).

In this study it was found that the decay controls of treated custard apple fruits was better as compared to untreated fruits. Chitosan treated fruit inhibited the growth of a wide variety of bacteria and fungi as compared to the control treatments. El-Ghaouth *et al.,* (1991) suggested that chitosan induces chitinase, a defense enzyme (Mauch *et al.,* 1984), which catalyzes the hydrolysis of chitin, a common component of fungal cell walls (Hou *et al.*, 1998). The results suggested that chitosan extend the shelf life, limit the growth of fungi, and decrease the spoilage without affecting on ripening characteristics of fruit (Lam and Diep, 2003). The lower decay in treated fruits may be due to stimulation of some natural defence mechanism included by 1-MCP, in addition to maintaining tissue integrity during storage and ripening.

Decreasing the acidity during storage it demonstrated fruit senescence. Among all treatments showed greater stability in acidity compared to other treatments. The higher levels of titratable acidity in the fruits treated with 1-MCP and Chitosan may be due to protective O_2 barrier or reduction of O_2 supply to the fruit surface which inhibited respiration rate (Jiang and Li 2000). The reduction in acidity may be due to their conversion into sugars and their further utilization in the metabolic processes of the fruit.

Total sugars of the fruit are considered as one of the basic criteria to evaluate the fruit ripening. It is cleared from the results that at the time of harvest the sugars were very low but with the passage of time ripening enhances and ultimately total sugars increased. However, during storage of custard apple fruits total sugars significantly increased in all treatments except control, as storage prolonged the rate of respiration, transpiration and other metabolic changes (Gul *et al.*,1990). Gradual increase in reducing sugars in treated fruits as compared to control treatment might be due to its slow ripening process (Youssef *et al.*, 2002). Maximum amount of reducing sugars in untreated fruits might be due to rapid conversion of starch to sugars as a result of moisture loss and decrease in acidity by physiological changes during storage.

An increase in ethylene production was detected after 10 days in 1-MCP treated fruit. 1-MCP treated fruit showed a decrease in respiration rate compared to untreated fruits. The respiration rate of untreated fruits began to increase after 6 days and reached a maximum after 10 days. The respiration rate of 1-MCP treated fruit did not showed a distinct climacteric peak and initially respiration rate declined, then slightly increased at 2 days of storage. Ethylene production of non-treated custard apple showed the maximum evolution rate occurrence on 6^{th} day. Ethylene evolution of treated fruit was smaller than untreated fruit. The treated fruits had a lower rate of ethylene evolution than other treatments.

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