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Effect of Postharvest Treatments on Physiological, Chemical, Microbial and Sensory Qualities of Fruits of Papaya Variety Surya

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ABSTRACT

Background: Papaya is a climacteric fruit which is highly perishable due to rapid ripening and softening and susceptibility to biotic or abiotic stresses, resulting in large losses during storage. Traditionally, people resort to the application of synthetic chemical fungicides on to the crop plant and to the fruits during storage, to control the anthracnose caused by the fungus *Colletotrichum gloeosporioides* on fruits. But their repeated use has caused resistance in microorganisms and toxicity for humans. Hence, nowadays there has been increasing interest in using natural alternatives instead of chemical treatment.

Methods: Fruits of papaya variety Surya collected at fully mature green stage were subjected to different postharvest management practices namely precooling, surface sanitization, treatment with chitosan and were packaged in corrugated fibre board boxes and stored till the end of shelf life under ambient condition. Untreated fruits (control) were also used in the study.

Result: Fruits coated with chitosan (1%) registered an improved shelf life of 6.33 days as against 4.33 days in control in ambient storage and it further improved the sensory score for all the organoleptic parameters, after six days of storage. 1% chitosan coating also reported significantly lowest physiological loss in weight (3.51 %), ion leakage (60.47%), total soluble solids (12.13 °Brix), total carotenoids (2.34 mg $100g^{-1}$), total sugar (7.26%) and reducing sugar (6.34%) and least disease index (16.67%), bacterial count (22.33 cfu/ml $\times 10^6$) and fungal count (7.33 cfu/ml $\times 10^3$) after three days of storage when compared with control.

Key words: *Carica papaya* L., Chitosan, Precooling, Surface sanitization.

INTRODUCTION

Papaya (*Carica papaya* L.) is one of the most commonly cultivated tropical fruit crop, which gained popularity due to its nutraceutical properties. India with an area of 139000 hectares and production of 5831000 MT is the leading producer of papaya in the world (NHB, 2019). Post harvest losses of papaya fruits is reported to be 40-60% of the total production (Prasad and Paul, 2021). Postharvest diseases mainly anthracnose caused by *Colletotrichum gloeosporioides* is the major cause for postharvest losses of papaya fruits during storage and transportation (Maeda and Nelson, 2014). Therefore, developing a suitable technology for prolonging the storage life of papaya, which can help both in domestic as well as international trade is the need of the hour. In recent times, a lot of attention has been received for the adoption of different postharvest practices and use of biologically active natural products rather than synthetic fungicides for curbing decay and lengthening the shelf life of fruits (Ayon-Reyna *et al*., 2017). Precooling or hydrocooling is the prompt cooling of the commodity immediately after harvest, for removal of field heat which will indirectly help improve the shelf life because, it is found that high field heat predisposes harvested fruits to moisture loss due to continuing physiological processes. Hardenburg *et al*. (1986) reported precooling as the first step of temperature management for fruits and suggested it as the first and most crucial line of defense in slowing biological processes to maintain the quality of fruits. According to Nishijima (1994) sodium hypochlorite was found to be safe to use in a five minute dip at 8,000 ppm for papaya fruits instead of mancozeb for the prevention of major postharvest disease as well as blight caused by *Phytophthora palmivora*. Studies on use of bio waxes on papaya revealed significant changes in peel colour, firmness, internal CO_2 concentration and respiration rate in all bio-wax coated fruits without affecting its organoleptic characteristics. Chitosan is one such natural coating and recent research pointed that chitosan treated fruits registered a reduced deterioration index compared to the control without significantly affecting the physicochemical properties of fruits. Singh *et al*. (2018) reported that chitosan has high

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antimicrobial activity against a wide range of pathogenic and spoilage microorganisms, including fungi and bacteria.

MATERIALS AND METHODS

Papaya variety Surya was raised at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala according to the Kerala Agricultural University, Package of Practices for studying the extension of shelf life during 2019-2020. Fruits were collected at the fully mature green stage, subjected to different postharvest management practices, packaged in Corrugated Fibre Board (CFB) boxes and stored under ambient conditions till the end of shelf life. Precooling (hydro cooling) (T_1), surface sanitization with 150 ppm sodium hypochlorite (T_2), external coating with 1% chitosan (T_3) and untreated fruits-control (T_4) were the postharvest management practices resorted in the study which followed a Completely Radomized Block design. Observations on changes in physiological quality, chemical quality, microbial quality and sensory quality were recorded at three days interval till the end of shelf life.

Physiological quality

Shelf life

Shelf life of papaya fruits as influenced by different postharvest treatments was calculated by counting the days required to ripe fully along with retaining optimum marketing and eating qualities.

Physiological loss in weight (PLW)

PLW was calculated on the initial weight basis as suggested by Srivastava and Tandon (1968) at three days interval and expressed as percentage.

$$\text{PLW} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Ion leakage (%)

The uniform sized fruit pieces were made into thin slices, immersed in 100 ml distilled water for three hours and absorbance was read in UV spectrophotometer at 273 nm. The immersed slices were heated in water bath at 100°C for 20 minutes, filtered, filtrate was made upto 100 ml and the absorbance was read in UV spectrophotometer at 273 nm. The loss of membrane integrity was expressed in per cent ion leakage. Percent leakage was calculated using the formula given below and were expressed in percentage (Amith, 2012):

Per cent leakage =

$$\frac{\text{Initial absorbance of bathing medium}}{\text{Final absorbance of bathing medium}} \times \text{Dilution factor}$$

Chemical quality

Total soluble solids

TSS of the fruit pulp was measured using a hand refractometer (Erma) (range 0-32 °Brix) expressed in degree brix (AOAC, 1980).

Titratable acidity

The titrable acidity was estimated by titrating with 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator and expressed as per cent of citric acid. A known weight of fruit was ground using distilled water and made upto 100 ml in a standard flask. An aliquot of 10 ml from this was titrated against 0.1 N NaOH (Ranganna, 1997).

Acidity =

$$\frac{\text{Normality} \times \text{Titre value} \times \text{Equivalent weight} \times \text{Volume made up}}{\text{Weight of sample} \times \text{Aliquot of sample} \times 1000} \times 100$$

Total carotenoids

Determination of total carotenoids was done by extraction with acetone and petroleum ether. The colour was measured at 452 nm using petroleum ether as blank in spectrophotometer. Total carotenoids were expressed as µg 100 g^{-1} of material (Ranganna, 1997).

Total carotenoids (µg 100 g^{-1}) =

$$\frac{3.857 \times \text{Optical density} \times \text{Volume made up}}{\text{Weight of the sample}} \times 100$$

Total sugars

Total sugars was determined according to the procedure described by Ranganna (1997) using Fehling's solution and expressed as gram of sucrose per 100 grams of pulp.

Reducing sugars

Reducing sugars was determined according to the procedure described by Ranganna (1997) using Fehling's solution and expressed as gram of glucose and fructose per 100 grams of pulp.

Microbial quality

Percentage disease index

Papaya fruits subjected to different postharvest management practices were visually observed for fruit rots. The number of fruits infected or spoiled was recorded periodically to assess the effect of treatments on retarding fruit spoilage. It was reported as percentage disease index and was calculated by the following formula (Marpudi *et al*., 2011).

Percentage disease index =

$$\frac{(0\times a) + (1\times b) + (2\times c) + (3\times d) + (4\times e) + (5\times f)}{a + b + c + d + e + f} \times \frac{100}{X}$$

Where,

0, 1, 2, 3, 4, 5 = Infection categories.

0 - No lesions (No disease symptoms).

1 - 5 to ≤15 per cent disease symptoms (Spot first appearing).

2 - ≥16 to ≤25 per cent disease symptoms (Spots increasing in size and number).

3 - ≥26 to ≤50 per cent disease symptoms (Small to large brownish sunken spots with slight to moderate mycelium growth).

4 - ≥51 to ≤75 per cent disease symptoms (Large spots with wide spread mycelium growth, fruit is partially or completely rotten).

5 - ≥75 per cent disease symptoms.

a, b, c, d, e and f = Number of fruits that fall into the infection categories.

X = Maximum number of infection categories.

Microbial load

The enumeration of microbial load in pre and post treated sample was carried out by serial dilution technique. Nutrient agar and Martin's Rose Bengal agar medium were used for enumeration of bacterial and fungal population of the fruit surfaces respectively.

No. of colony forming units (cfu)/ml of the sample =

$$\frac{\text{Total number of colony formed} \times \text{Dilution factor}}{\text{Aliquot plated}}$$

Sensory quality

The fruits were assessed using a nine point hedonic scale to evaluate the appearance, colour, flavour, texture, taste, after taste and overall acceptability by a panel of 15 semi trained judges.

Statistical analysis

The data was analysed statistically by applying the techniques of analysis of variance (Panse and Sukhatme, 1985). For organoleptic test, Kruskal Wallis test was performed and the mean rank scores were taken to differentiate the best treatment.

RESULTS AND DISCUSSION

Physiological quality

Shelf life

The effect of different postharvest treatments on shelf life of papaya variety Surya fruits packaged in CFB boxes and stored under ambient conditions is depicted in Table 1 and they differed significantly. External coating with 1% chitosan (T_3) registered a shelf life of 6.33 days. Precooling (hydro cooling) (T_1) and surface sanitization with 150 ppm sodium hypochlorite (T_2) gave a shelf life of 5.67 days and 5.00 days respectively. Significantly lowest shelf life of 4.33 days was observed in control (T_4). External coating with 1% chitosan helped in forming an excellent film over the produce which retards the respiration rate and also helped in maintaining the optimum quality and prolonged shelf life of fruits in T_3. Ali *et al*. (2011) elaborated the commercial application of chitosan as a promising edible coating for extending the storage life of the papaya cv. Eksotika.

Physiological loss in weight (PLW)

Significant difference in physiological loss in weight was found among fruits provided with different postharvest treatments during storage compared to control (Table 1). Lowest PLW (3.51 %) was noticed in fruits externally coated with 1% chitosan (T_3) and highest PLW (7.54%) was noticed in control (T_4) after three days of storage. Paull and Chen (1989) observed that chitosan coating has the capability to develop a film on fruit surface and thereby provides a barrier against diffusion of moisture through stomata, contributing towards reduced weight loss. This might have also contributed to the reduced weight loss in T_3. Ali *et al*. (2011) reported reduced weight loss in chitosan coated papaya fruit during storage compared to the control.

Ion leakage (%)

Fruits externally coated with 1% chitosan (T_3) had least percent leakage (60.47) which was significantly different over other treatments and control sample (T_4) recorded highest per cent leakage (90.25%), after three days of storage (Table 1). According to Parker and Maalekuu (2013) there is a very high and positive correlation with membrane ion leakage and high water loss rate. The higher percent ion leakage in control might be due to the loss of physical integrity of cellular membrane leading to the loss of ion and unrestricted travel of fluids within cellular compartments, a condition deleterious to fruits (Maalekuu *et al*., 2004).

Chemical quality

Total soluble solids

TSS content of papaya fruits increased in all the treatments during storage and varied significantly among each

Table 1: Effect of postharvest management practices on shelf life, physiological loss in weight, ion leakage and total soluble solids of papaya variety Surya fruits.

Treatments	Shelf life (days)	Physiological loss in weight (%)			Ion leakage (%)			TSS (°Brix)		
		Initial (0 DAS)	3 DAS	6 DAS	Initial (0 DAS)	3 DAS	6 DAS	Initial (0 DAS)	3 DAS	6 DAS
T_1	5.67	0.00	4.48 (2.12)	-	11.37	64.39	-	8.07	11.80	-
T_2	5		5.75 (2.40)	-	11.04	81.07	-	8.37	12.70	-
T_3	6.33		3.51 (1.87)	6.80	11.21	60.47	92.24	7.83	12.13	14.33
T_4	4.33		7.54 (2.75)	-	11.37	90.25	-	8.03	13.23	-
SEm (±)	0.29	-	0.20 (0.04)	-	0.29	1.25	-	0.14	0.25	-
CD (5%)	0.94	-	0.66 (0.14)	-	NS	4.09	-	NS	0.81	-

DAS: Days after storage.

Values in bracket are square root transformed values.

treatment after three days of storage in the present study (Table 1). Untreated fruits sample (T_4) stored in CFB box had highest TSS (13.23°Brix) after three days of storage, whereas lowest TSS (12.13°Brix) was found in fruits externally coated with 1% chitosan (T_3). Breakdown of starch and polysaccharides into simple sugars during ripening contributes to the increment in the TSS during storage. Therefore the higher TSS observed in T_4 after three days of storage indicates that ripening was hastened in untreated fruits, whereas external coating with 1% chitosan delayed the ripening in T_3, which is proved by the lowest TSS after three days of storage. The effect of chitosan in reducing the TSS of papaya fruit was probably due to the slowing down of respiration and metabolic activity, hence retarding the ripening process. It is well documented that the filmogenic property of chitosan results in an excellent semi-permeable film around the fruit, modifying the internal atmosphere by reducing O_2 and/or elevating CO_2 and suppressing ethylene evolution (Dong *et al*., 2004). A suppressed respiration rate also slows down the synthesis and the use of metabolites, resulting in lower TSS due to the slower hydrolysis of carbohydrates to sugars (Rohani *et al*., 1997).

Titratable acidity

In the present study it was found that titratable acidity of papaya fruits decreases with increasing storage time in all the treatments (Table 2). The decrease in acidity during storage is attributed to the utilisation of acids in respiration process and conversion to sugars which demonstrates the fruit ripening. Lowest acidity (0.16%) was noticed in T_4 (control) after three days of storage, whereas papaya fruits subjected to external coating with 1% chitosan (T_3) recorded highest acidity after three days of storage (0.22%). Ali *et al*. (2011) opined that in chitosan coated fruits of papaya cv. Eksotika, the titratable acidity declined throughout the storage period though at a slower rate, as compared to the control.

Total carotenoids

Significant variation in total carotenoid content was noticed in fruits of papaya variety Surya subjected to different postharvest treatments after three days of storage (Table 2). Highest total carotenoid content (2.70 mg 100 g^{-1}) was recorded in control (T_4) and lowest (2.34 mg 100 g^{-1}) being in fruits externally coated with 1% chitosan (T_3). Petriccione *et al*. (2015) noticed that chitosan treatment delayed the senescence rate and consequently there was a delay in increase in carotenoid content throughout the storage in loquat (*Eriobotrya japonica* Lindl.) fruits compared to control.

Total sugars

Untreated fruits (control - T_4) recorded significantly higher percent of total sugars (9.40%) at three days after storage and lowest total sugar content (7.26%) was recorded in fruits externally coated with 1% chitosan (T_3) (Table 2). Higher percent of total sugars in untreated fruits (control - T_4) is due to rapid increase in respiration rate. The rate of increase

Table 2: Effect of postharvest management practices on titratable acidity, total carotenoids, total sugars and reducing sugars content of papaya variety Surya fruits.

Treatments	Titratable acidity (%)			Total carotenoids (mg 100g^{-1})			Total sugars (%)			Reducing sugars (%)		
	Initial (0 DAS)	3 DAS	6 DAS	Initial (0 DAS)	3 DAS	6 DAS	Initial (0 DAS)	3 DAS	6 DAS	Initial (0 DAS)	3 DAS	6 DAS
T_1	0.29	0.19	-	0.98	2.50	-	5.03	8.58	-	4.14	7.52	-
T_2	0.30	0.19	-	1.15	2.55	-	5.08	8.94	-	4.53	7.59	-
T_3	0.29	0.22	0.14	1.29	2.34	2.77	4.75	7.26	9.88	4.16	6.34	8.63
T_4	0.30	0.16	-	1.12	2.70	-	4.99	9.40	-	4.48	8.16	-
SEm (±)	0.00	0.00	-	0.07	0.03	-	0.07	0.27	-	0.06	0.28	-
CD (5%)	NS	0.01	-	NS	0.11	-	NS	0.89	-	NS	0.91	-

of total sugar was found to be normal in T_3 due to slow degradation of polysaccharides to sugars and gradual buildup of sugars concomitant with reduced utilization of sugars as substrates during respiration.

Reducing sugars

The amount of reducing sugars in fruits showed an upward trend with the advancement of storage period (Table 2). Highest reducing sugar content (8.16 %) was noticed in T_4 (control) after three days of storage. Lowest reducing sugar content (6.34 %) was observed in fruits externally coated with 1% chitosan (T_3). This slow buildup of reducing sugar was achieved by the reduced utilization of sugars in respiration.

Microbial quality

Percentage disease index

Number of fruits infected with anthracnose showed significant difference among treatments in the present study. Lowest disease incidence (16.67 %) was observed in fruits externally coated with 1% chitosan (T_3) and higher per cent of lesions (38.89 %) was observed in control (T_4) after three days of storage (Table 3). Eryani-Raqeeb *et al*. (2009) reported that chitosan controlled the disease incidence in papaya cv. Eksotika. Shiekh *et al.* (2013) attributed natural antimicrobial activity of chitosan responsible for delayed fruit deterioration in commodities by inhibiting the growth of microorganisms.

Microbial load

Fruits subjected to different postharvest treatments recorded significantly lower bacterial and fungal count after three days of storage compared to untreated fruits (control) (Table 3). Lowest bacterial and fungal count (22.33 cfu/ml $\times$ 10^6 and 7.33 cfu/ml $\times$ 10^3) was witnessed in fruits coated with 1% chitosan and highest microbial load of 89.33 cfu/ml $\times$ 10^6 bacterial count and 22.33 cfu/ml $\times$ 10^3 fungal count was witnessed in control (T_4) after three days of storage. Minh *et al*. (2019) documented that chitosan coating effectively inhibited the growth of microorganisms on soursop. Youwei and Yinzhe (2013) opined that chitosan coating had preventive effect against microbes and can reduce decay.

Sensory quality

Effect of different postharvest treatments on sensory parameters of papaya variety Surya fruits after three days of storage is shown in Table 4. The mean scores of appearance (8.47), colour (7.60), flavour (7.47), texture (7.93), odour (8.07), taste (8.20), after taste (7.93) and overall acceptability (7.93) were highest for untreated fruits - control

Table 3: Effect of postharvest management practices on disease index, bacterial count and fungal count of papaya variety Surya fruits.

Treatments	Disease index (%)			Bacterial count (cfu/ml $\times$ 10^6)			Fungal count (cfu/ml $\times$ 10^3)		
	Initial (0 DAS)	3 DAS	6 DAS	Initial (0 DAS)	3 DAS	6 DAS	Initial (0 DAS)	3 DAS	6 DAS
T_1	0.00	33.33 (35.26)	-	2.67	43.33	-	0.67	13.67	-
T_2		27.78 (31.75)	-	3.33	54.00	-	0.33	14.67	-
T_3		16.67 (24.10)	30.55	2.67	22.33	46.33	0.67	7.33	9.33
T_4		38.89 (38.56)	-	3.67	89.33	-	1.33	22.33	-
SEm (±)	-	1.96 (1.20)	-	0.38	1.22	-	0.31	0.52	-
CD (5%)	-	6.41 (3.92)	-	NS	3.99	-	NS	1.72	

Table 4: Effect of postharvest management practices on sensory qualities of papaya fruit (3 DAS).

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T_1	6.93 (90.13)	7.00 (96.50)	6.73 (87.47)	6.73 (95.87)	6.60 (90.53)	6.27 (81.63)	6.13 (76.80)	6.60 (90.60)	52.99
T_2	7.67 (110.33)	7.00 (94.90)	7.07 (97.40)	7.00 (100.00)	6.93 (102.17)	6.93 (100.83)	6.67 (97.73)	7.07 (100.73)	56.34
T_3	5.73 (47.83)	5.80 (50.80)	5.87 (52.17)	5.60 (48.83)	5.60 (49.17)	5.60 (50.70)	5.60 (52.07)	5.67 (49.73)	45.47
T_4	8.47 (124.53)	7.60 (115.80)	7.47 (114.13)	7.93 (123.13)	8.07 (124.30)	8.20 (125.33)	7.93 (125.07)	7.93 (122.27)	63.60
K W value	83.36	59.42	52.72	76.03	75.53	70.11	63.56	71.80	

χ^2-9.49 (4, 0.05).

Table 5: Effect of postharvest management practices on sensory qualities of papaya fruit (6 DAS).

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T_1	-	-	-	-	-	-	-	-	-
T_2	-	-	-	-	-	-	-	-	-
T_3	8.67	8.40	8.33	8.53	8.33	8.53	8.47	8.87	68.13
T_4	-	-	-	-	-	-	-	-	-
K W value	-	-	-	-	-	-	-	-	-

(T_4) with a total score of 63.60. Minimum total score of 45.47 was observed in fruits externally coated with 1% chitosan (T_3). This indicates that ripening of fruits was hastened in control, which was depicted by the highest sensory scores for all the parameters after three days of storage. Whereas, in all other treatments ripening was delayed due to postharvest management measures adopted.

After six days of storage, mean score for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability were 8.67, 8.40, 8.33, 8.53, 8.33, 8.53, 8.47, 8.87 respectively in fruits externally coated with chitosan (1%) (T_3), with a total score of 68.13 (Table 5). Bhanushree *et al*. (2018) reported higher score of overall acceptability in papaya fruits coated with chitosan after seven days of storage.

CONCLUSION

The present study suggests that chitosan can be used to reduce microbial deterioration, maintain fruit quality and increase the shelf life of fruits of papaya variety Surya under ambient storage.

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Conflict of interest: None.

REFERENCES

Ali, A., Muhammad, M.T M., Sijam, K. and Siddiqui, Y. (2011). Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. Food Chemistry. 124(2): 620-626.

Amith, P.K. (2012). Protocol Development for Fresh Cut Fruits and Fruit Mix Preparation. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 21p.

AOAC [Association of Official Analytical Chemists]. (1980). AOAC home page [online]. Available: http://www.aoac.org/iMIS 15 pROD/AOAC. [18 Jan 2017].

Ayon-Reyna, L.E., Gonzalez-Robles, A., Rendon-Maldonado, J.G., Baez-Flores, M.E., Lopez-Lopez, M.E., Vega-García, M.O. (2017). Application of hydrothermal-calcium chloride treatment to inhibit postharvest anthracnose development in papaya. Postharvest Biology and Technology. 124: 85-90. https://doi.org/10.1016/j.

Bhanushree, L.S., Vasudeva, K.R., Suresha, G.J., Sadananda, G.K., Tayeebulla, M.H. and Halesh, G.K. (2018). Influence of chitosan on postharvest behavior of papaya (*Carica papaya* L.) fruits under different storage conditions. Journal of Pharmacognosy and Phytochemistry. 7(2): 2010-2014.

Dong, H., Cheng, L., Tan, J., Zheng, K. and Jiang, Y. (2004). Effect of chitosan coating on quality and shelf life of peeled litchi fruit. Journal of Food Engineering. 64: 355-358.

Eryani-Raqeeb, A.A., Mahmud, T.M.M., Omar, S.R.S., Zaki, A.R.M. and Eryani, A.R.A.I. (2009). Effects of calcium and chitosan treatments on controlling anthracnose and postharvest quality of papaya (*Carica papaya* L.). International Journal of Agricultural Research. 4(2): 53-68. DOI: 10.3923/ijar.2009.53.68.

Hardenburg, R.E., Watada, A.E. and Wang. C.Y. (1986). The Commercial Storage of Fruits, Vegetables and Florist and Nursery Stocks, Agriculture Handbook, U.S. Department of Agriculture, Washington, pp. 14-16.

Maalekuu, K., Elkind, Y., Alkalai, T.S., Shalom, Y. and Fallik, E. (2004). The influence of harvest season and cultivar type on several quality traits and quality stability of three commercial sweet peppers during the harvest period. Advances in Horticultural Sciences. 18: 21-25.

Maeda, C. and Nelson, S. (2014). Anthracnose of papaya in Hawai. Plant Disease. Pp 103.

Marpudi, S.L., Abirami, L.S.S., Pushkala, R. and Srividya, N. (2011). Enhancement of storage life and quality maintenance of papaya fruits using Aloe vera based antimicrobial coating. Indian J. Biotechnol. 10: 83-89.

Minh, N.P., Vo, T.S., Tram, D.N., Nga, N.H., Bang, N.T. and Trinh, M.T.D. (2019). Application of chitosan edible coating for soursop (*Annona muricata*) storage. Journal of Pharmaceutical Science Research. 11(2): 284-288.

NHB [National Horticuture Board]. NHB home page [online]. (2019). Available: http://nhb.gov.in/statistics/areaproductionstatistics.html.

Nishijima, W.T. (1994). Papaya fungicide research update. [on-line]. Available: https://www.ctahr.hawaii.edu/oc/freepubs/pdf/HITAHR_05-08-94_39.pdf [22 Aug 2019].

Panse, V.G. and Sukhatme, P.V. (1985). Statistical Method for Agricultural Workers. Indian Council of Agricultural Research, New Delhi, 347p.

Parker, R. and Maalekuu, B.K. (2013). The effect of harvesting stage on fruit quality and shelf life of four tomato cultivars (*Lycopersicon esculentum* Mill). Agricultural Biology Journal of North America. 4(3): 252-259.

Paull, R.E. and Chen, N.J. (1989). Waxing and plastic wraps influence water loss from papaya fruit during storage and ripening. Journal of American Society of Horticultural Sciences. 114: 937-942.

Petriccione, M., Pasquariello, M.S., Mastrobuoni, F., Zampella, L., Di Patre, D. and Scortichini, M. (2015). Influence of a chitosan coating on the quality and nutraceutical traits of loquat fruit during postharvest life. Scientia Horticulturae. 197: 287-296.

Prasad, K. and Paul, J.R. (2021). Post-harvest losses of papaya and practice for management. Food Science Reports. 2(1): 7-11.

Ranganna, S. (1997). Handbook of Analysis and Quality Control for Fruits and Vegetable Products (3rd Ed.). Tata McGraw and Hill Publication Co. Ltd., New Delhi, 634p.

Rohani, M.Y., Zaipun, M.Z. and Norhayati, M. (1997). Effect of modified atmosphere on the storage life and quality of Eksotika papaya. Journal of Tropical Agriculture and Food Science. 25: 103-113.

Shiekh, R.A., Malik, M.A., Al-Thabaiti, S.A. and Shiekh, M.A. (2013). Chitosan as a novel edible coating for fresh fruits. Food Science and Technology Research. 19: 139-155.

Singh, A., Gairola, K., Upadhyay, V. and Kumar, J. (2018). Chitosan: An elicitor and antimicrobial bio-resource in plant protection. Agricultural Reviews. 39(2): 163-168.

Srivastava, M.P. and Tandon, R.N. (1968). Influence of temperature on botrydiplodia rots of citrus and sapodilla. Indian Phytopathology. 21: 195-197.

Youwei, Y. and Yinzhe, R. (2013). Effect of chitosan coating on preserving character of post-harvest fruit and vegetable: A review. Journal of Food Process Technology. 4(8): 1-3.