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Bhanushree LS
M. Sc (PHT) student, Department of Postharvest Technology, College of Horticulture, UHS Campus, Bengaluru, Karnataka, India

Vasudeva KR
Associate Professor and Head, Department of Postharvest Technology, College of Horticulture, UHS Campus, Bengaluru, Karnataka, India

Suresha GJ
Assistant Professor, Department of Postharvest Technology, College of Horticulture, UHS Campus, Bengaluru, Karnataka, India

Sadananda GK
Assistant Professor, Department of Postharvest Technology, College of Horticulture, UHS Campus, Bengaluru, Karnataka, India

Mohamad Tayeebulla H
Ph. D Scholar, Department of Postharvest Technology, College of Horticulture, UHS Campus, Bengaluru, Karnataka, India

Halesh GK
Assistant Professor, Department of Biotechnology and Crop Improvement, College of Horticulture, UHS Campus, Bengaluru, Karnataka, India

Correspondence
Vasudeva KR
Associate Professor and Head, Department of Postharvest Technology, College of Horticulture, UHS Campus, Bengaluru, Karnataka, India

Influence of chitosan on postharvest behavior of papaya (*Carica papaya* L.) Fruits under different storage conditions

Bhanushree LS, Vasudeva KR, Suresha GJ, Sadananda GK, Mohamad Tayeebulla H and Halesh GK

Abstract

Papaya (*Carica papaya* L.) fruit is highly perishable in nature due to high physiological processes and microbial decay. Harvest and postharvest losses of papaya is reported to be 7.36%. Chitosan is an edible and biologically safe preservative coating. The experiments were carried out independently to record the influence of postharvest dip treatment of chitosan on papaya fruits stored at ambient (28±1ºC) and cold storage (12±1ºC). Papaya fruits harvested at Stage 2 (Appearance of yellow streak) were treated with chitosan concentrations from 0.5 to 3 per cent. Among the treatments, the fruits treated with chitosan at 3 per cent recorded minimum physicochemical processes and decay and retained maximum sensory quality under both storage conditions. The chitosan treated fruits showed significantly higher storage life of 9 and 23days in ambient and cold storage, respectively compared to control (7days in ambient and 18 days in cold storage).

Keywords: papaya, chitosan, shelf life, physicochemical changes

Introduction

Papaya fruit being climacteric and perishable in nature, has low shelf life hence harvest and postharvest losses are reported together 7.36 per cent wherein, the farm operation, storage and transportation losses together account for 5.06, 2.28 and 1.13 per cent, respectively. (Anon, 2007) [2].

The major constraint that hinder the expansion of export of papaya fruit are short storage life, susceptibility to postharvest diseases, high shipment cost and pesticides residues. Postharvest fruit decay is a major constraint in post harvest handling causing decreases in both quantity and quality of produce. Major postharvest losses are due to pathogenic microorganisms, which can infect fruit through wounds or latent infections during the pre-harvest period. Among the postharvest pathogens, fungal diseases are one of the major causes of fruit decay as they account for 80-90 % of all losses (Gullino, 1995) [6]. Papaya ripens rapidly after harvesting, through elevation of ethylene and increased respiratory rate.

Many new chemical and physical processes have been tested on fruit and vegetables, including papaya for improving their quality and safety. Natural preservatives, such as chitosan, are promising approaches among the treatments. Chitosan is mainly found in the exoskeletons of crustaceans and is classified as a “generally recognized as safe” (GRAS) material. Chitosan is a versatile biopolymer, which exhibits antimicrobial activity against a range of food borne microorganisms and consequently has attracted attention as a potential preservative. Chitosan has a broad range of applications in the food industry, one of which is its application as an edible coating material. The chitosan coating creates a semi-permeable barrier that can reduce water loss and alter the natural exchange of gases between the fruit and the external atmosphere, thereby reducing respiration, slowing senescence in fruit and vegetables, and inhibiting microbial decay. The mechanical properties of chitosan polymer also contribute to the protection of fruit from physical damage. Chitosan coatings have been found to be effective in microbial control and in preserving quality in many vegetables and fruits such as table grapes and mushrooms (Gao *et al.*, 2013) [5].

Chitosan has been one of the best edible and biologically safe preservative coatings for different types of foods because of its film-forming properties, antimicrobial actions, lack of toxicity, biodegradability and biochemical properties. It has been proven that the chitosan can control numerous pre and postharvest disease of fresh fruits. Chitosan edible coatings extend the shelf life of the fruits and vegetables.

Chitosan coating offers a defensive barrier against bacterial contamination and loss of moisture from the surface of food products, thus extending their shelf life. With limited increase in the concentration of chitosan coating, the beneficial effect of chitosan on postharvest life and quality of the food is enhanced. Papaya, being a climacteric fruit deteriorates rapidly owing to physicochemical changes and microbial spoilage. Hence, there is a need to find an alternative to control postharvest pathogen without compromising the safety of the food. Chitosan is a biological compound that is effective against the pathogenic microorganisms additionally slows down the physiological and biochemical processes ultimately enhancing the quality and safety of the papaya fruits. Hence, it is proposed to test effectiveness of postharvest dip treatments of chitosan on controlling decay, maintaining postharvest quality and shelf life of papaya fruits

Materials and Method

Raw material: Papaya fruits required for the experiment were procured from the papaya orchard located in the out skirts of Bengaluru situated at 35 km from the experimental site. The fruits were carefully chosen from the orchard and manually harvested. The fruits were selected based on the appearance of one or two yellow streaks on the surface of the fruits. After selection, they were brought to the laboratory by wrapping the individual fruits with paper and placed in corrugated fiber boxes (CFB). 'ChitoGro^{TM} GEL' is procured from Everest Biotech, Bengaluru.

Postharvest treatment with chitosan: Fruits were uncovered with papers. Immediately, they were washed with water containing 0.2 per cent sodium hypochlorite and surface air dried under electric fan. The air dried fruits were dipped in the solution of chitosan at 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 per cent for five minutes and one with distilled water which served as control. Then the individual fruits were wrapped with paper and placed in CFB by maintaining 6 fruits per replication. The CFB boxes were placed in ambient storage (28±1^{0}C) and cold storage (12±1^{0}C) to record the quality changes in the fruits.

Storage: Treated fruits were stored under two conditions: cold storage (12±1^{0}C), ambient temperature (28±1^{0}C) and observations were recorded at 6, 12, 18, 23 days and 3, 5, 7, 9 days, respectively.

Physical parameters

Physiological loss in weight (%)

Fruits from each replication were taken to record the physiological loss in weight (PLW). The weight of the fruits was recorded using electronic weighing balance (Model: Essae, DS-852, Teraoaka Ltd.) before storage. Thereafter, the weights were recorded regularly during storage and the cumulative PLW was calculated with the standard formula and expressed as per cent physiological loss in weight.

Firmness

Firmness is evaluated using a texture analyzer (TAHD+, Stable Microsystems, UK) equipped with a 50kg load cell. The analyzer was linked to a computer that recorded data via a software program called Texture Expert (version 1.22, Stable Micro Systems, UK). Firmness evaluation was carried out by taking whole fruit with skin and penetrating it with a 2 mm diameter cylindrical needle at a speed of 0.5mm/s with automatic return. The downward distance (penetration distance into the fruit) was set at 10mm and pre-test speed and post-test speed were 1mm/s and10mm/s; respectively. Samples were positioned so that the rod penetrated their geometric center at the middle of the fruit in longitudinal axis.

Colour (*L*a*b**) values

The colour of the papaya fruits was measured using a Lovibond colour meter (Lovibond LC 100, Portable). The instrument was calibrated using the black and white tiles slide provided. The *L** indicates lightness co-efficient and it ranges from 0-100 (black to white), *a** and *b** indicates the colour ranges from green to red and blue to yellow from negative to positive on the horizontal and vertical axes respectively, C (chroma) and h^0 (hue angle). From these *L**, *a** and *b** values, the total colour change (ΔE) is calculated using the following formula:

$$Total\ Colour\ Change(\Delta E) = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2}$$

Where L_0, a_0 and b_0 are initial values. *L*, *a* and *b* are final values

Moisture (%)

Two or five grams of fruit pulp sample was taken and cut in to small pieces and placed in Sartorius electronic moisture analyzer (Model: MA 35) and the direct reading was noted down from the instrument screen and expressed in per cent.

Sensory evaluation (9-point hedonic scale)

Organoleptic evaluation of papaya fruits was conducted on the basis of colour, flavour, texture, taste and overall acceptability by a panel of ten judges using a nine-point hedonic scale as laid out by Ranganna (1997) [13].

Results and Discussions

Physiological loss in weight

Physiological loss in weight is one of the important economic parameter that decides the shelf life even if fruit is free from physical and microbial abuse. The physiological weight loss of papaya fruits increased in the storage. There was a significant difference among the treatments as affected by the coating of different concentrations of chitosan. In both the storage conditions, the untreated fruits lost maximum weight of 9.90 per cent at ambient storage and 8.97 per cent at cold storage, respectively during 7 and 18 days of storage. While, fruits coated with 3 per cent chitosan lost minimum weight of 5.1 per cent at ambient and 4.5 per cent at cold storage during 9 and 23 days of storage, respectively. Ali *et al.* (2011) [1] reported PLW of papaya fruits treated with chitosan recorded less loss in weight and no major evidence of shriveling in the fruits. However, per cent increase in weight loss was more pronounced in control due to high rate of transpiration and respiration. The chitosan coating known to prevent the loss of the water from fruits and responsible for determining the rate of water vapour transfer from inside to the outside atmosphere. Similar results of reduced weight loss and delayed ripening have been reported in papaya (Ali *et al.*, 2011) [1], bell pepper (Nyanjage *et al.*, 2005) [10], grapes (Juan *et al.*, 2005) [7], sweet cherry (Martienez *et al.*, 2006) and tomato (Padmini, 2006) [11].

Table 1: Effect of different concentrations of chitosan on physiological loss in weight (%) of papaya var. Red Lady fruits during storage at ambient and cold storage

Treatment details	Storage Days (D)							
	Ambient storage (28±1ºC)				Cold storage (12±1ºC)			
	3 D	5 D	7 D	9 D	6 D	12 D	18 D	23 D
T_1- Control	2.51	4.72	9.90	---	5.73	6.15	8.97	---
T_2- Chitosan @ 0.5 %	2.99	4.31	7.24	10.07	4.07	5.09	7.67	10.23
T_3- Chitosan @ 1.0 %	3.23	4.53	5.64	8.33	2.47	3.80	4.57	7.67
T_4- Chitosan @ 1.5 %	3.20	4.30	7.24	8.67	2.55	3.76	4.60	8.03
T_5- Chitosan @ 2.0 %	3.47	4.83	7.48	8.03	2.58	3.56	4.10	7.07
T_6- Chitosan @ 2.5 %	2.63	3.67	5.24	5.83	2.43	3.14	4.53	5.17
T_7- Chitosan @ 3.0 %	1.00	2.50	3.20	5.10	1.20	2.70	3.90	4.50
SEm±	0.381	0.458	1.675	0.964	0.367	0.200	0.545	0.152
CD @1%	1.52	1.37	5.02	2.89	1.10	0.68	1.63	0.45

D: No. of days Average weight of individual fruit (g): 758: Treatment terminated

Firmness

Fruit firmness is one of the most crucial factors in determining the postharvest quality of fruits (Shear, 1975). The untreated fruits recorded minimum firmness of 47.19 g at ambient storage and 41.00 g at cold storage, respectively during 7 and 18 days of storage. While fruits coated with 3 per cent chitosan had highest firmness of 639g at ambient storage and 591g at cold storage during 9 and 23 days of storage, respectively.

Table 2: Effect of different concentrations of chitosan on firmness (g) of papaya var. Red Lady fruits during storage at ambient and cold storage

Treatment details	Storage Days (D)							
	Ambient storage (28±1ºC)				Cold storage (12±1ºC)			
	3 D	5 D	7 D	9 D	6 D	12 D	18 D	23 D
T_1- Control	327.33	64.00	47.19	---	251.67	99.33	41.00	---
T_2- Chitosan @ 0.5 %	344.67	246.21	118.33	51.67	377.33	250.33	154.33	54.00
T_3- Chitosan @ 1.0 %	672.00	382.33	204.00	55.08	457.00	293.33	192.00	59.00
T_4- Chitosan @ 1.5 %	701.67	406.67	331.67	249.00	501.33	330.00	204.00	85.00
T_5- Chitosan @ 2.0 %	744.67	630.33	501.67	321.67	756.33	501.33	339.33	112.33
T_6- Chitosan @ 2.5 %	809.67	703.33	619.00	306.67	890.00	750.33	553.33	352.00
T_7- Chitosan @ 3.0 %	879.00	766.67	639.00	541.33	938.00	801.33	688.33	591.33
SEm±	0.942	0.899	0.950	0.814	0.908	0.845	0.908	0.890
CD @1%	2.82	2.69	2.85	2.44	2.72	2.53	2.72	2.67

D: No. of days Initial firmness of fruit (g): 986, Treatment terminated

In the present study softening of papaya fruits was remarkably delayed with chitosan treatment during storage at all the concentrations tried but lower firmness loss was seen in fruits treated with chitosan @ 3 per cent (T_7), chitosan @ 2.5 per cent (T_6) and chitosan @ 2.0 per cent (T_5). The lesser loss in firmness may be due to the film forming properties of chitosan which reduces the ripening rate, hence, softening of fruit were minimum. This is mainly due to the retardation of ripening process in the chitosan treated fruits. It could be attributed to the ability of chitosan coating to modify the respiration, transpiration and reduction in ethylene production rate that maintains the turgidity of tissues. On the other hand, chitosan coatings cover the cuticle and lenticels, thereby reducing respiration and other ripening processes during storage. Similar results have been reported in papaya (Ali *et al.*, 2011) [1], banana (Balasooriya *et al.*, 2006) [3] and bell pepper (Mustafa and Kenan, 2010).

Colour values

Papaya fruits treated with chitosan were recorded upto 48.15 % lesser change in colour than untreated fruits was evident from the colour (*L*, *a* and *b*) values at the end of storage. During ripening, the fruits undergo biochemical, physiological and structural changes leading to increase in TSS, pulp softening and change in coloration. The green colour is due to the presence of chlorophyll, which is a magnesium-organic complex, change in coloration which is the visual symptom of ripening, as fruits ripen chlorophyll degradation takes place and senescence begins, which is an irreversible process. The principal agents responsible for this degradation are pH changes i.e., mainly due to leakage of organic acids from vacuoles, oxidative system and enzyme chlorophyllase. Loss of colour depends on one or all of these factors acting in sequence to destroy the chlorophyll structure. In the present experiment total change in peel colour value of was higher in untreated (T_1) fruits and reached the highest change in peel colour of 47.61 (ambient storage) and 44.08 (cold storage) on 9 and 23 days after storage, respectively. While the lowest change in peel colour was recorded in papaya fruits coated with chitosan at 3.0 % had 21.51 (ambient storage) and 21.22 (cold storage) during 9 and 23 days of storage, respectively. Our findings are in agreement with report published in papaya fruits treated with chitosan recorded minimum loss of chlorophyll in the peel (Reboucas *et al.*, 2013) [14]. Variation of peel colour in papaya as a reference of maturation stage is also explained by Fonseca *et al*. (2007) [4] and Sancho *et al*. (2010) [15].

Table 3: Effect of different concentrations of chitosan on total change in peel colour (∆E) of papaya *var*. Red Lady during different storage.

Treatment details	Total Change in Peel Colour (∆E)							
	Ambient storage (28±1ºC)				Cold storage (12±1ºC)			
	3 D	5 D	7 D	9 D	6 D	12 D	18 D	23 D
T_1- Control	0.00	27.33	39.17	47.61	0.00	28.03	35.37	44.08
T_2- Chitosan @ 0.5 %	0.00	12.41	28.65	37.15	0.00	22.11	32.78	37.41
T_3- Chitosan @ 1.0 %	0.00	24.40	29.78	34.65	0.00	21.64	27.00	37.15
T_4- Chitosan @ 1.5 %	0.00	24.00	39.08	44.29	0.00	23.59	32.57	41.30
T_5- Chitosan @ 2.0 %	0.00	17.15	20.47	26.55	0.00	11.47	17.18	27.14
T_6- Chitosan @ 2.5 %	0.00	8.70	14.40	22.01	0.00	7.13	13.72	22.91
T_7- Chitosan @ 3.0 %	0.00	3.94	9.10	21.52	0.00	7.71	14.09	21.23

D: No. of days, Initial *b** value: 8.56, Treatment terminated

The slower pigmentation may be due to coating of chitosan in combination with low temperature storage could have delayed the degradation of chlorophyll and reduced the softening of papaya fruits by maintaining the high humidity in the vicinity of the fruits. It may be also due to reduced rate of respiration and decreased activities as created by low temperature storage. Higher loss in green colour at ambient temperatures may be caused by increased breakdown of chlorophyll and synthesis of β-carotene and lycopene pigments, which occur during ripening. In addition, chitosan coating resulted in slow rate of respiration and reduced ethylene production, leading to a modified internal atmosphere of the fruit (Ali *et al.*, 2011) [1]. This, in turn delayed the ripening and senescence of the fruit, resulting in reduced colour change. Similar results have been reported in bell pepper (Nyanjage *et al.*, 2005 and Muhammad *et al.*, 2005) [10, 9].

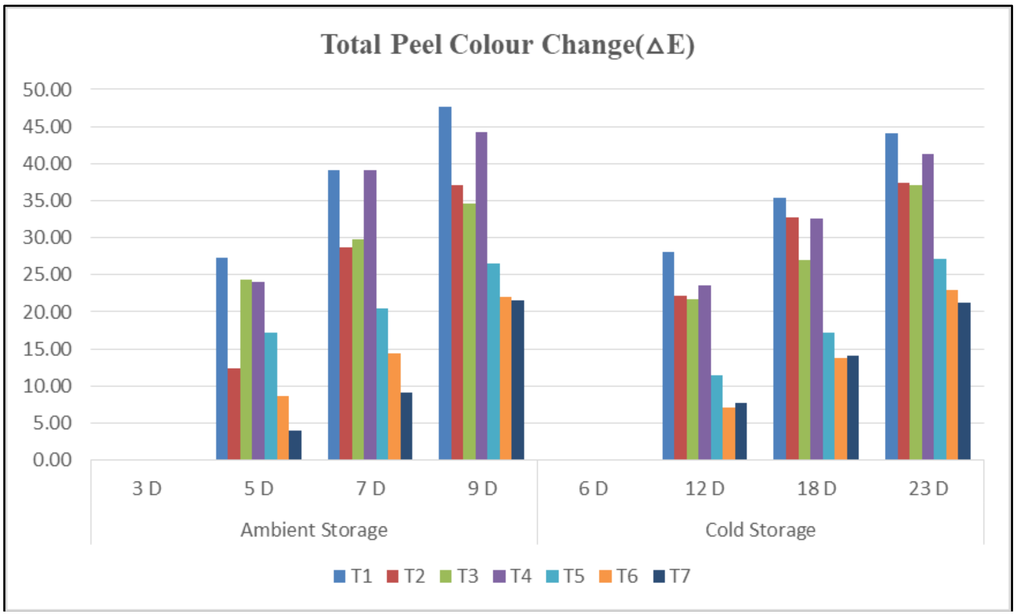

Fig 1: Effect of different concentrations of chitosan on total change in peel colour (∆E) of papaya *var*. Red Lady during different storage

Moisture content

Moisture content of the fruits generally decreases during postharvest since it is a function of transpiration. The moisture content of untreated fruits decreased at faster rate and recorded 86.23 per cent (ambient storage) and 85.00 per cent (cold storage) during 7 and 18 days of storage, respectively. Moisture content of papaya fruits treated with 3 per cent chitosan registered slower decrease and registered highest moisture content of 87.23 per cen tin ambient storage and 88.25 per cent in cold storage during 9 and 23 days of storage, respectively.

As the fruits approaches ripening, the moisture content decreased. However, in chitosan treated fruits, moisture content decreased gradually on ripening till the end of the storage due to delayed ripening process caused by reduced ethylene production. The ability of chitosan coating to modify the respiration, transpiration and reduction in ethylene production rate that maintains the turgidity of tissues and chitosan coatings could be due to their higher antifungal activity and covering of the cuticle and lenticels, thereby reducing infection, respiration and other ripening processes showed slower decrease of moisture compared to the untreated fruits during storage. Similar results have been reported in papaya (Ali *et al.*, 2011) [1], mango (Chein *et al.*, 2007) and banana (Balasooriya *et al.*, 2006) [3].

Sensory evaluation

There were significant changes in sensory evaluation of papaya fruits, as influenced by fruits coated with chitosan. Untreated papaya fruits recorded lesser sensory scores while, chitosan at 3 per cent (T_7) fruits had higher score of overall acceptability of 7.92 (ambient storage) during 7 days of storage and 8.85 (cold storage) during 18 days of storage.

This is due to modified atmosphere condition around the papaya fruits caused by chitosan, which protect the fruits from microorganism decay. Chitosan plays major role in inhibiting the growth of microorganisms in both cold and ambient storage. In addition, chitosan also controls the loss of nutrients and increase the shelf life of papaya fruit, due to its lipid-binding capacity and hypocholesterolemic action. Apart from that higher CO_2 and less O_2 around the fruits, would have helped the fruits to maintain attractive colour, flavour, texture, taste and overall acceptability. The results confirmed the findings in papaya (Ali *et al.*, 2011 and Marupudi *et al.*, 2009) [1, 8], tomato (Padmini, 2006) [11] and litchi (Yueming *et al.*, 2005) [17].

Storage life

Papaya fruits treated with chitosan had shown an extended storage period up to 9 days (ambient storage) and 23 days (cold storage) compared to control fruits. This extension of storage period was due to the delay in the ripening process caused by film forming and antimicrobial properties of chitosan which also delayed the respiration rate during storage. In addition, delay in the loss of green colour and onset of yellowing compared to the control one. Similar results have been reported in papaya (Ali *et al.*, 2011) [1], jujube fruit (Qiuping and Wenshui, 2006).

Table 4: Effect of different concentrations of chitosan on storage life (no. of days) of papaya var. Red Lady of fruits during storage at ambient and cold storage

Treatment	Number of days in ambient condition (28±1^{0}C)	Number of days in cold condition (12±1^{0}C)
T_1- Control	7	18
T_2- Chitosan @ 0.5 %	8	22
T_3- Chitosan @ 1.0 %	8	22
T_4- Chitosan @ 1.5 %	9	22
T_5- Chitosan @ 2.0 %	9	23
T_6- Chitosan @ 2.5 %	9	23
T_7- Chitosan @ 3.0 %	9	23
SEm±	0.109	0.126
CD @1%	0.32	0.37

Conclusion

The storage life of papaya var. Red Lady fruits can be extended with 3 per cent chitosan pre-treated in ambient (8-9 days) and cold storage (22-23 days) condition with reduction in the decay loss. The chitosan treated fruits had shown delayed ripening with retention of higher firmness. Chitosan is a biological compound that is effective against the pathogenic microorganisms additionally slows down the physiological and biochemical processes ultimately enhancing the quality and safety of the papaya fruits.

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