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Effect of postharvest application of chemical elicitors on quality attributes and shelf-life of papaya (*Carica papaya* L.)

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Abstract
The effect of chemical Elicitors *viz.* salicylic acid (2 mM, 3 mM), chitosan (1%, 2%), oxalic acid (10 mM, 20 mM), calcium chloride (2%, 3%) and brassinosteroid (0.1%) on quality attributes and shelf life of papaya cv. Red Lady was investigated. The fruits were harvested at mature green stage with 1 or 2 yellow streaks on the surface, are brought to laboratory and treated with respective elicitor molecules. Further, they are stored at ambient condition and various physiological, physico-chemical properties were analyzed. On 9th day of storage, the papaya fruits treated with chitosan at 1% (T_3) exhibited minimum physiological loss in weight (PLW) (13.40%), decreased respiration rate (11.55 ml CO_2/Kg), with higher fruit firmness (41.88 N), total soluble solids (12.13%), titratable acidity (0.25%), β carotene content (1.89 mg/100g), lowered instrumental colour values *i.e*., L* (59.00), a* (13.65) and b* (50.48). In addition chitosan (1%) treated papaya fruits also exhibited minimum Percent disease index (PDI) (13.33%), higher overall organoleptic acceptability (6.94/9.00) with maximum shelf life of 8.33 days.

Keywords: Papaya, salicylic acid, chitosan, calcium chloride, oxalic acid, brassinosteroid, shelf life

Introduction
Papaya (*Carica papaya* L.) is commercial fruit crop of India, with an area of 1,33,000 ha and production of 56,99,000 tonnes. India exports the fruits to the United Kingdom, Netherlands, Thailand *etc*., and states such as Andhra Pradesh, Gujarat and Karnataka are the leading producers of papaya in India (Anon, 2020) [5]. The fruit is also a good source of nutrition; fresh papaya fruit provides 179–208 KJ of energy, 0.47–0.83 g protein, 0.50–2.10 g fiber and 0.10–0.30 g fat per 100 g fresh weight. The fruit is also a good source of vitamin A, vitamin C, minerals like magnesium (Mg), potassium (K), boron (B), calcium (Ca) and copper (Cu) (Sivakumar and Wall, 2013) [33]. It is a climacteric fruit with maximum respiration rate and ethylene production during ripening (Ding *et al*., 2019) [12]. These physiological events leads to rapid loss in fruit firmness, deterioration of fruit quality and development of diseases, which dramatically reduces the shelf life (Paull *et al*., 1997) [27] leading to post harvest loss.

Exogenous application of chemical elicitors is reported to stimulate physiological adaptations and defensive responses in plants (Baenas *et al*., 2014) [9]. The mechanism by which elicitors exert their effects involves triggering the synthesis of phytochemical compounds, enhancing the production of particular antioxidant enzymes and reducing the production of ethylene in vegetables and fruits (Xylia *et al*., 2021) [38]. In this investigation various chemical elicitors such as, salicylic acid, chitosan, oxalic acid, calcium and brassinosteroid were used. Chitosan is the most widely known elicitor due to its antimicrobial, eliciting and film-forming properties (Maan *et al*., 2021) [23]. Numerous pre and postharvest studies have indicated the positive effects of chitosan application on the quality and shelf life of several fruit crops (Ahmed *et al*., 2021) [2]. SA is endogenous signal molecule, regulates the stress responses. Pre/post-harvest treatment of fruits and vegetables with SA can dramatically enhance the quality, shelf life and prevent deterioration (Ahmed *et al*., 2021) [2]. The use of Ca during post-harvest period maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism which intern leads to extending storage life of fresh fruits. Calcium has been reported to play a vital role in retarding tissue softening and delaying ripening (Atia *et al*., 2018) [7]. Brassinosteroids were found to be effective in maintaining various quality attributes of different horticultural crops (Aghdam *et al*., 2016) [1].

In this regard an experiment is conducted with an objective of elucidating the effect of these chemical elicitors on quality attributes and shelf-life of papaya fruits under ambient storage condition.

Material and Methods

An experiment on effect of postharvest application of chemical elicitors on quality attributes and shelf-life of papaya (*Carica papaya* L.) was carried out during 2019-21 at Department of Post-Harvest Technology, College of Horticulture, Bagalkot (UHS, Bagalkot), Karnataka.

Plant material

Mature-green papaya fruit (green with 1 or 2 yellow streaks) were obtained from a local commercial field of Bagalkot district, Karnataka. The cultivar 'Red Lady' fruit of uniform size, shape and maturity and free from any indication of mechanical injury, insect or pathogenic infection, were selected for the experiment.

Application of treatments

The papaya fruits were treated with respective elicitor molecule solution supplemented with 0.01% (v/v) Tween 80 sticker solution using a hand sprayer until, fruit were wet to runoff. Chitosan forms a gel, the fruits were dipped in the chitosan solution for 1 minute to facilitate the chitosan adherence to the entire fruit surface to generate a uniform film (Petriccione *et al*., 2015) [28]. After treatment, the fruits were air-dried for 30 minutes at room temperature and stored under ambient condition for further analysis of physiological and physico-chemical properties.

Treatment details

T_1: Salicylic acid at 2 mM
T_2: Salicylic acid at 3 mM
T_3: Chitosan at 1%
T_4: Chitosan at 2%
T_5: Oxalic acid at 10 mM
T_6: Oxalic acid at 20 mM
T_7: CaCl2 at 2%
T_8: CaCl2 at 3%
T_9: Brassinosteroid at 0.1%
T_{10}: Control

Determination of physiological parameter

Respiration rate

Respiration rate was measured with a CO_2 gas analyzer (Make: Quantek Instruments, Model: 902 D Dual Trak) following the static method. The papaya fruits were weighed and placed in a hermetically sealed container for 45 minutes. At the end of the incubation period, the gas sample was drawn from the headspace using a gas-tight syringe and injected into the CO_2 gas analyzer. The time allowed for a change in CO_2 gas concentration in the headspace of the sample container was recorded in an hour and respiration rate is calculated using the formula,

$$\text{Rate of respiration (ml } CO_2\text{/kg/h)} = \frac{CO_2 \text{ concentration} \times \text{volume of the container (ml)}}{100 \times \text{weight of the tissue (kg)} \times \text{time (h)}}$$

Determination of physical parameter

Physiological weight loss

For determining the physiological weight loss, four fruits in each replication for each treatment were marked before storage, and weighed using an electronic balance. The same fruits were weighed at the beginning of the experiment and at subsequent storage interval. The physiological loss in weight (PLW) and was calculated using formula and results were expressed as the percentage loss of initial weight.

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

Fruit firmness: The fruit firmness was measured by the TAXT plus texture analyzer (Make: Stable Micro System, Model: Texture Export Version 1.22). Four fruits in each replication were measured. The compression force was measured at the maximum peak of the recorded force on the chart and expressed in Newton (N).

Peel colour

The peel colour of the fruit was determined using a Lovibond colour meter. The peel colour determination was expressed in chromaticity values of L*, a* and b*.

Percent disease index (PDI)

Disease intensity in different treatments was scored using a 0-4 scale (Pramod *et al*., 2007) [30].

Extent of infection	Severity grade
No infection	0
0.10-25.0% fruit surface infected	1
25.10-50.0% fruit surface infected	2
50.10-75.0% fruit surface infected	3

Percent disease index was calculated by using the formula given by Wheeler (1969) [36],

$$\text{PDI} = \frac{\text{Sum of all disease rating X 100}}{\text{Total number of ratings X Maximum disease grade}}$$

Shelf life

The shelf life of treated fruits was determined based on visual appearance and the extent of ripening. The over ripen, soft and rotten fruits were considered to be the end shelf life and is expressed in days.

Determination of chemical parameter

During storage, the total soluble solid was measured by using digital refractrometer. Titratable acidity (%) was determined by the titration method (Ranganna, 1986) [32]. Beta carotene (mg/100 gm^{-1}) was determined by method followed by Ranganna (1986) [32].

Sensory evaluation

The sensory evaluation was done for the ripe fruits using nine-point hedonic scale for colour and appearance of fruit surface, colour and appearance of flesh, firmness, taste and flavor and overall acceptability of chemical elicitor treated papaya fruit was determined. The sensory evaluation panel consist of semi-trained judges *i.e*. teachers and post-graduate students of College of Horticulture, Bagalkot.

Statistical analysis

The data obtained in this experiment was subjected to statistical analysis by ANOVA for a completely randomized design (CRD) with 3 replications. Statistical analysis was performed using Web Agri Stat Package (WASP) Version 2 (Jangam and Thali, 2010) [19]. The level of significance used in the F and t-test was p=0.01.

Results and Discussion

Effect of post-harvest application of chemical elicitors on physiological attributes of papaya

Respiration rate

Papaya fruits exhibited a gradual increase in respiration rate with prolonged storage of 9 days. Significantly decrease in respiration rate was observed in papaya fruits treated with chitosan @ 1% (11.55 ml CO_2/Kg) (T_3) and salicylic acid @ 2 mM (11.84 ml CO_2/Kg) (T_1) in comparison to control (T_{10}) (23.19 ml CO_2/Kg) fruits on 9th day of storage (Table 1). This might be due to the effect of SA in decreasing the respiration rate and is probably due to its negative effect on ACC (1-amino-cyclopropane-1-carboxylic acid), polygalacturonase (PG), pectin methylesterase (PME), cellulase and antioxidant enzymes, leading to decrease in ethylene production (Mohammadreza and Morteza, 2013) [25]. Chitosan possess film-forming ability this might have possessed the selective permeability for the exchange of gaseous such as C_2H_4, CO_2 and O_2 (Xianghong *et al*., 2008) [37]. The enhanced rate of respiration in control (T_{10}) fruits might possibly due their active metabolic activity in terms of enhanced ripening.

Effect of post-harvest application of chemical elicitors on physical attributes of papaya

Physiological loss of weight

Physiological loss of weight appeared to be the major determinant of storage life and quality of papaya fruit. Effect of chemical elicitors was found to influence significantly to PLW of papaya at all the successive stages of storage. The chitosan at 1% (T_3) (13.40%) and salicylic acid at 2 mM (T_1) (14.52%) reduced the weight loss of papaya fruit compared to control (T_{10}) (21.13%) at 9 DAS (Table 1). This could be possibly due to declined rate of respiration and transpiration in SA and chitosan treated fruits. SA can decrease the respiration rate and fruit weight loss by stomata closing (Zheng and Zhang, 2004) [42]. Chitosan possess the film-forming ability, known to possess the moisture barrier property during storage. It creates modified atmosphere around the produce and may possesses a selective permeability for C_2H_4, CO_2 and O_2 gaseous. These functions of chitosan might have decreased the fruit respiration, resulting in reduced weight loss (Xianghong *et al*., 2008) [37]. The enhanced PLW of control fruits might be due to their active metabolism in terms of respiration and transpiration.

Fruit firmness

Fruit firmness is a major attributes governing the post-harvest life and quality of fruit. Chemical elicitors had significantly reduced the loss in fruit firmness of papaya fruit during storage. The maximum retention in firmness was obtained in papaya fruits of treatment T_3 (Chitosan1%) (41.88 N), T_4 (Chitosan 2%) (40.94 N), T_7 ($CaCl_2$ at 2%) (40.61 N), T_8 ($CaCl_2$ at 3%) (41.36 N), T_1 (SA at 2 mM) (41.26 N) and T_2 (SA at 3 mM) (41.35 N) in comparison to control (T_{10}) (10.12 N) fruits at 9 DAS (Table 1). Fruit softening is due to deterioration in the cell structure, the cell wall composition and the intracellular materials. It is a biochemical process involving the hydrolysis of pectin and starch by enzymes, such as wall hydrolases. The initial softening of papaya is characterised by an increased solubility of the cell wall pectin and the softening of pectin. The maintenance of firmness in the fruits treated with 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 during storage (Ali *et al*., 2011) [4]. Similar results were noticed in strawberries, raspberries, tomatoes, peaches and papayas (Bautista *et al.*, 2003) [10]. SA could possibly decreases the ethylene production, inhibits cell wall and membrane degrading enzymes such as polygalacturonase (PG), lipoxygenase (LOX), cellulase and pectin methylesterase (PME) might have lead to reduced rate of fruit softening (Zhang *et al*., 2003) [41]. The calcium ions may probably impact tissue firmness by contributing to enhanced membrane integrity (Mignani *et al*., 1995) [24]. The declined firmness of control papaya fruits might be due to enhanced rate of respiration and transpiration, which ultimately leads to reduced fruit firmness.

Peel colour (L*, a*, b* values)

Colour is one of the major visual attributes of papaya. The change in colour from green to yellow continued over the storage period.

Lightness (L*) values: Papaya fruits of treatment T_3 (Chitosan @ 1%) (59.00), T_4 (Chitosan @ 2%) (57.70), T_1 (SA @ 2 mM) (60.32) and T_2 (SA @ 3 mM) (60.16) had recorded lower values for lightness compared to the control (T_{10}) fruits (61.72) on 9th day of storage.

Redness (a*) values: Papaya fruits treated with chitosan @ 2% (T_4) (13.28), chitosan @ 1% (T_3) (13.65), SA @ 2 mM (T_1) (14.28) and SA @ 3 mM (T_2) (13.77) recorded lower values a* value compared to the untreated (T_{10}) fruits (18.87) on 9th day of storage.

Yellowness (b*) values: Fruits treated with chitosan @ 2% (T_4) (50.16), chitosan @ 1% (T_3) (50.48), SA @ 2 mM (T_1) (50.52) and SA @ 3 mM (T_2) (51.34) exhibited lowered b* value compared to the control (T_{10}) fruits (60.90) on 9th day of storage.

The lower L*, a*, b* values recorded (Table 2) by SA and chitosan coatings indicate the delay in fruit colour change, this could be due to the effect of SA and chitosan film coating, which might have reduced the moisture transfer, restricted oxygen uptake, reduced rate of respiration, retarded the ethylene production and discoloration of fruit. Similar results were obtained by Chávez-Sánchez *et al*. (2013) [11] papaya cv. Maradol and by Hundtoft and Akamine (1971) [18] in papaya cv. Solo.

Percent Disease Index (%)

Papaya fruits coated with chitosan @ 1% (T_3) (13.33%), SA @ 2 mM (T_1) (30.00%) and SA @ 3 mM (33.33%) recorded lower PDI compared control (93.33%) (Table 3). This might be due to exogenous application of SA to fruits and vegetables could enhance resistance to pathogens and control postharvest decay (Babalar *et al*., 2007) [8]. Plants protect themselves against the pathogen attacks by activating defense mechanisms such as local acquired resistance (LAR) and systemic acquired resistance (SAR) (Vlot *et al*., 2009) [35]. Salicylates are a major component in the signal transduction pathways of plants playing an important role in disease resistance (Park *et al*., 2007) [26]. The chitosan coating might have formed a protective barrier on the fruit surface, brought reduced growth and development of decay-causing pathogen (Dutta *et al*., 2009) [14]. It can halt the growth of the pathogen, induces marked morphological changes, structural alterations and molecular disorganization of the fungal cells (AitBarka *et al*., 2004) [3]. In addition, it impairs the production of fungal virulence factors such as cell wall degrading enzymes (polygalacturonase, pectate lyase and cellulose), organic acids (oxalic and fumaric acids), host-specific toxins and can enhance phenylalanine ammonia-lyase, chitinase and β-1,3-glucanase activities of the fruits as compared with the untreated fruits (Zhang and Quantick, 1998) [40]. Maximum decay found in control (T_{10}) fruits might possibly due to reduced natural defense response, which might had made the fruits susceptible to the decay-causing pathogen.

Shelf Life

The maximum shelf life of 8.33 days was recorded in papaya fruits treated with chitosan (1%) (T_3) in comparison to control (T_{10}) which had possessed shelf life of 6.00 days (Table 3). This might possibly because of the minimum PLW, decreased disease incidence and retention of maximum fruit firmness and other quality attributes. The minimum shelf life of control (T_{10}) fruits may possibly due to uncontrolled ripening and enhanced rate of senescence of papaya fruits with prolonged storage. Similar results have reported in green asparagus (Qiu *et al*., 2013) [31], blueberries (Sun *et al*., 2014) [34], guava fruits (Krishna and Rao, 2014).

Sensory evaluation

The papaya fruits treated with chitosan @ 1.00% (T_3) coating had a gloss and no wrinkles, therefore had scored highest of 6.93 for surface colour, 6.70 for pulp colour, 7.10 for texture, 7.00 for taste-flavor and 6.94 for overall acceptability at 9 DAS (Table 4). This may be due to the effect of chitosan on retaining the colour (L*, a*, b*), firmness, TA, TSS *etc*. quality attributes, with minimum decay incidence. The untreated fruits (T_{10}) had lost their shelf life of 6 days and thereafter begin to decompose. Therefore these fruits were not presented to the panelists for sensory evaluation. Similar results were reported by papaya (Asgar *et al.,* 2011) [6], strawberry (Pilar *et al.*, 2008) [29].

Effect of post harvest application of chemical elicitors on chemical attributes of papaya

Total soluble solids: A gradual increase followed by decrease in total soluble solids (TSS) content of papaya fruits was observed during storage (Table 5). Papaya fruits of treatment T_3 (Chitosan at 1%) (12.13%), T_4 (Chitosan at 2%) (12.10%), T_1 (SA at 2 mM) (12.10%), T_2 (SA at 3 mM) (12.07%) and T_9 (Brassinosteroid at 0.1%) (12.07%) had recorded significantly higher TSS compared to control (T_{10}) (11.03%) papaya fruits at 9th days after storage.

The effect of chitosan in retaining 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 (Ali *et al.*, 2011) [4]. A suppressed respiration rate also slows down the synthesis and the use of metabolites, resulting in lower SSC due to the slower hydrolysis of carbohydrates to sugars. Similar results have been reported in papaya (Ali *et al.*, 2011) [4], bell pepper (Gholamipour *et al*., 2010) [15], litchi (Yueming *et al*., 2005) [39], mango and banana (Bautista *et al.*, 2006) [10]. Salicylic acid might possibly decrease the ethylene production and activity of sucrose phosphate synthase enzyme leading to reduced sucrose synthesis. It decreases the levels of invertase and reducing sugar contents along with preventing the activity of cell wall degrading enzymes and consequently dramatic increase in TSS content. Postharvest application of brassinosteroid, might had delayed the degradation of starch and activities of neutral invertase, acid invertase, sucrose synthase, sucrose phosphate synthase, fructokinase, hexokinase enzymes, suppression of activities of these enzymes subsequently lead to a decreased increase in glucose, sucrose and fructose contents. Therefore, could have reduced the rapid increase in the TSS content of fruit. Similar results have been reported in Kiwi fruit (Lu *et al.*, 2019). [22] The decreased TSS of control papaya fruits might be possibly due to uncontrolled ripening and respiration.

Titratable acidity

The titratable acidity (TA) values decreased with storage time irrespective of the treatment imposed. The highest levels of TA were recorded in papaya fruits of the treatment T_3 (Chitosan at 1%) (0.25%), T_1 (Salicylic acid at 2 mM) (0.22%), T_4 (Chitosan at 2%) (0.20%), and T_2 (Salicylic acid at 3 mM) (0.20%) compared to control (T_{10}) (0.09%) at 9 DAS (Table 5). The chitosan coating may probably unable to modify the internal atmosphere of the fruit to prevent the loss in TA contents (Ali *et al*., 2011) [4]. The contents of organic acids in fruits are mainly dependent on the activities of their synthetic and hydrolytic enzymes; SA treatment probably regulates the activities of these enzymes (Ding *et al*., 2007), thereby reduces the loss of organic acids. The reduced TA in untreated fruits could possibly due to an enhanced rate of respiration.

β Carotene content (mg/100 g)

On 9th day of storage significantly higher β carotene content was recorded in papaya fruit of treatment T_3 (Chitosan at 1%) (1.89 mg/100 g) was on par with T_4 (Chitosan at 2%) (1.88 mg/100 g), T_2 (SA at 3 mM) (1.88 mg/100 g) and T_1 (SA at 2 mM) (1.85 mg/100 g) compared to T_{10} (Control) (1.38 mg/100 g) (Table 5). This could possibly due to the delayed senescence rate consequently result in higher β carotene content in SA and chitosan treated papaya fruits. Our results are in line with those of Petriccione *et al.* (2015) [28] in chitosan coated loquat fruit and Kumar *et al.* (2018) [21] in SA treated tomato. The lower β carotene content of untreated (T_{10}) fruits might be due to enhanced rate of senescence of fruit tissue, which leads to loss of cellular integrity and oxidation of cell wall constituents including the β carotene in papaya.

Table 1: Effect of chemical elicitor molecules treatment on changes in respiration rate, physiological loss in weight and fruit firmness of papaya under ambient storage condition

Treatments	Respiration rate (ml CO_2/Kg/h)				Physiological loss of weight (%)				Fruit firmness (N)			
	Initial	4 DAS	6 DAS	9 DAS	1 DAS	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS
T_1- Salicylic acid at 2 mM	5.05	8.27	10.30	11.84	1.43	4.04	9.18	14.52	93.30	85.88	72.94	41.26
T_2- Salicylic acid at 3 mM	5.07	8.85	10.42	12.51	1.44	4.25	9.37	15.17	93.36	87.16	75.88	41.35
T_3 - Chitosan at 1%	5.08	8.26	10.01	11.55	1.42	4.01	8.64	13.40	93.51	86.27	74.34	41.88
T_4 - Chitosan at 2%	5.10	8.94	10.09	13.33	1.57	4.53	10.01	15.34	93.66	86.64	75.82	40.94
T_5 – Oxalic acid at 10 mM	5.08	11.75	13.71	19.16	2.32	5.48	10.81	17.61	93.48	66.76	50.29	15.36
T_6 - Oxalic acid at 20 mM	5.08	12.21	14.35	19.07	2.09	5.24	10.90	18.54	93.31	70.75	55.56	19.45
T_7 - $CaCl_2$ at 2%	5.13	9.68	10.92	14.20	1.72	4.90	11.16	16.03	93.33	85.62	74.07	40.61
T_8 - $CaCl_2$ at 3%	5.07	9.50	10.84	14.25	1.64	4.46	10.84	15.78	93.36	86.46	74.85	41.36
T_9 - Brassinosteroid at 0.1%	5.10	9.59	11.58	13.16	2.07	4.31	10.67	15.50	93.33	79.49	73.28	30.50
T_{10} - Control	5.08	13.25	17.79	23.19	2.81	6.03	12.34	21.13	93.24	67.78	49.21	10.12
Mean	5.08	10.03	12.00	15.23	1.85	4.72	10.39	16.30	93.39	80.28	67.62	32.28
S.Em (±)	0.03	0.05	0.04	0.05	0.01	0.03	0.08	0.02	0.11	0.38	0.37	0.22
CD@1%	NS	0.33	0.29	0.35	0.08	0.19	0.55	0.15	NS	2.62	2.60	1.55

Table 2: Effect of chemical elicitor molecules treatment on changes in peel colour (L*, a* and b*) of papaya under ambient storage condition

Treatments	L*				a*				b*			
	Initial	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS
T_1- Salicylic acid at 2 mM	40.16	44.04	51.74	60.32	-11.45	-8.54	-3.03	14.28	21.18	35.61	41.47	50.52
T_2- Salicylic acid at 3 mM	40.24	45.88	50.69	60.16	-12.05	-8.36	-2.83	13.77	21.00	34.84	40.33	51.34
T_3 - Chitosan at 1%	40.46	45.62	50.18	59.00	-11.74	-9.13	-3.85	13.65	21.36	35.33	40.45	50.48
T_4 - Chitosan at 2%	40.27	45.33	50.06	57.70	-11.94	-9.45	-4.92	13.28	21.37	34.04	40.36	50.16
T_5 – Oxalic acid at 10 mM	40.25	49.08	56.77	61.54	-11.62	-7.32	8.80	18.63	21.83	39.82	46.04	60.49
T_6 - Oxalic acid at 20 mM	40.25	49.59	56.51	61.02	-11.48	-8.08	8.64	18.66	21.39	40.12	46.13	61.28
T_7 - $CaCl_2$ at 2%	40.21	48.23	54.62	61.36	-11.22	-8.20	7.05	18.36	21.45	38.63	43.82	55.26
T_8 - $CaCl_2$ at 3%	40.25	48.68	54.28	60.63	-11.40	-7.85	6.79	17.98	21.50	37.89	43.63	54.49
T_9 - Brassinosteroid at 0.1%	40.20	48.27	53.89	61.07	-11.37	-7.84	7.98	18.16	21.72	38.45	43.46	54.82
T_{10} - Control	40.31	49.23	57.31	61.72	-11.51	-6.87	8.96	18.87	21.35	44.30	50.74	60.90
Mean	40.26	47.40	53.60	60.45	-11.58	-8.16	3.36	16.56	21.42	37.90	43.64	54.97
S.Em (±)	0.03	0.45	0.23	0.20	0.14	0.19	0.09	0.13	NS	0.12	0.19	0.27
CD@1%	NS	3.16	1.63	1.37	NS	1.31	0.64	0.88	NS	0.85	1.34	1.90

Table 3: Effect of chemical elicitor molecules treatment on changes in overall acceptability, shelf-life and Percent disease index of papaya under ambient storage condition

Treatments	Percent Disease Index (%)	Shelf-life (Days)
T_1- Salicylic acid at 2 mM	30.00	8.00
T_2- Salicylic acid at 3 mM	33.33	8.00
T_3 - Chitosan at 1%	13.33	8.33
T_4 - Chitosan at 2%	50.00	8.00
T_5 – Oxalic acid at 10 mM	60.00	7.67
T_6 - Oxalic acid at 20 mM	53.33	7.67
T_7 - $CaCl_2$ at 2%	46.67	8.00
T_8 - $CaCl_2$ at 3%	43.33	8.00
T_9 - Brassinosteroid at 0.1%	50.00	8.00
T_{10} - Control	93.33	6.33
Mean	47.33	7.80
S.Em (±)	4.08	0.12
CD@1%	28.45	0.85

Table 4: Effect of chemical elicitors treatment on changes in organoleptic properties of papaya under ambient storage condition (9 DAS)

Treatments	Surface Colour	Pulp Colour	Texture	Taste and Flavour	Overall acceptability
T_1- Salicylic acid at 2 mM	6.88	6.50	6.97	7.00	6.80
T_2- Salicylic acid at 3 mM	6.75	6.33	6.93	6.87	6.66
T_3 - Chitosan at 1%	6.93	6.70	7.10	7.00	6.94
T_4 - Chitosan at 2%	6.73	6.38	7.00	6.87	6.75
T_5 – Oxalic acid at 10 mM	5.87	5.53	5.93	5.93	5.81
T_6 - Oxalic acid at 20 mM	5.93	5.67	5.67	5.67	5.74
T_7 - $CaCl_2$ at 2%	6.73	6.25	6.73	6.60	6.68
T_8 - $CaCl_2$ at 3%	6.77	6.25	6.67	6.43	6.53
T_9 - Brassinosteroid at 0.1%	6.60	6.30	6.70	6.62	6.56
T_{10} - Control	*	*	*	*	*
Mean	5.92	5.59	5.97	5.90	5.85
S.Em (±)	0.05	0.04	0.06	0.07	0.05
CD@1%	0.35	0.29	0.41	0.47	0.32

Note: * - not fit for marketing

Table 5: Effect of chemical elicitor molecules treatment on changes in titrable acidity, total soluble solids and β carotene content of papaya under ambient storage condition

Treatments	Total soluble solids (%)				Titrable acidity (%)				β carotene content (mg/100 g)			
	Initial	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS	Initial	4 DAS	6 DAS	9 DAS
T_1- Salicylic acid at 2 mM	7.23	10.40	11.50	12.10	0.44	0.36	0.33	0.22	0.48	0.96	1.56	1.85
T_2- Salicylic acid at 3 mM	7.23	10.03	11.27	12.07	0.42	0.35	0.32	0.20	0.49	0.93	1.38	1.88
T_3 - Chitosan at 1%	7.23	10.40	11.73	12.13	0.44	0.38	0.35	0.25	0.48	1.04	1.78	1.89
T_4 - Chitosan at 2%	7.23	10.57	11.90	12.10	0.44	0.36	0.33	0.20	0.48	0.97	1.75	1.88
T_5 – Oxalic acid at 10 mM	7.27	11.50	12.03	11.60	0.42	0.30	0.28	0.12	0.49	1.05	1.80	1.62
T_6 - Oxalic acid at 20 mM	7.27	11.57	12.37	11.47	0.42	0.31	0.25	0.09	0.48	1.13	1.84	1.65
T_7 - $CaCl_2$ at 2%	7.27	10.73	11.73	11.30	0.43	0.33	0.28	0.12	0.48	1.01	1.70	1.60
T_8 - $CaCl_2$ at 3%	7.23	10.60	11.60	11.50	0.42	0.35	0.32	0.13	0.48	1.02	1.72	1.75
T_9 - Brassinosteroid at 0.1%	7.27	11.63	12.10	12.07	0.42	0.33	0.26	0.13	0.48	1.17	1.70	1.78
T_{10} - Control	7.23	11.30	12.03	11.03	0.43	0.27	0.23	0.09	0.47	1.59	1.82	1.38
Mean	7.25	10.87	11.83	11.74	0.43	0.33	0.30	0.16	0.48	1.09	1.71	1.73
S.Em (±)	0.04	0.06	0.06	0.05	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01
CD@1%	NS	0.41	0.39	0.37	NS	0.06	0.07	0.05	NS	0.13	0.08	0.11

Conclusion
It is concluded that the post-harvest application of chemical elicitor chitosan @ 1% can extends the shelf life of papaya fruits with better quality traits. The papaya fruits treated with chitosan @ 1% can reduce respiration rate, physiological loss in weight, Percent disease index, with retention of quality parameters such as, fruit firmness, total soluble solids, titratable acidity, β carotene content, instrumental colour values (L*,a*,b*), higher overall organoleptic acceptability.

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References
1. Aghdam MS, Babalar M, Sarcheshmeh MAA. Impact of brassinosteroids on postharvest physiology of fruits and vegetables. In: Siddiqui, M.W. (ed.). Eco-Friendly Technology for Postharvest Produce Quality, Academic Press; c2016. p. 203-218.
2. Ahmed ZFR, Al Shaibani FYY, Kaur N, Maqsood S, Schmeda-Hirschmann G. Improving fruit quality, bioactive compounds, and storage life of date palm (*Phoenix dactylifera* L., cv. Barhi) using natural elicitors. Horticulturae. 2021;7:293.
3. AitBarka E, Eullaffroy P, Cle´ment C, Vernet G. Chitosan improves development, and protects *Vitis vinifera* L. against *Botrytis cinerea*. Plant cell reports. 2004;22:608-614.
4. Ali A, Muhammad MTM, Sijam K, Siddiqui Y. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. Food Chemistry. 2011;124:620-26.
5. Anonymous. Indian Horticulture Database, National Horticulture Board; c2020.
6. Asgar A, Mahmud TMM, Kamaruzaman S, Yasmeen S. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. Food chem. 2011;124:620-626.
7. Atia A, Abdelkarim D, Younis M, Alhamdan A. Effects of calcium chloride and salicylic acid postharvest treatments on the quality of Khalal Barhi dates at different ripening levels during cold storage. Journal of Food Measurement and Characterization. 2018;12:1156-1166.
8. Babalar M, Asghari M, Talaei A, Khosroshahi A. Effect of pre and postharvest salicylic acid treatment on ethylene production, fungal decay and overall quality of 'Selva' strawberry fruit. Food Chemistry. 2007;105:449-453.
9. Baenas N, Gariıa-Viguera C, Moreno DA. Elicitation: A tool for enriching the bioactive composition of foods. Molecules. 2014;19:13541-13563.
10. Bautista S, Hernández AN, Velázquez MG, Hernández M, Aitbarka E, Bosquez E, *et al*. Chitosan as a potential natural compound to control pre and postharvest diseases of horticultural commodities. Crop Protection. 2006;25(2):108-118.
11. Chávez-Sánchez I, Carrillo-López A, Vega-García M, Yahia EM. The effect of antifungal hot-water treatments on papaya postharvest quality and activity of pectin methylesterase and polygalacturonase. J Food Technol. 2013;50(1):101-107.
12. Ding X, Zhu X, Ye L, Xiao S, Wu Z, Chen W, *et al*. The interaction of CpEBF1 with CpMADSs is involved in cell wall degradation during papaya fruit ripening. Horticulture Research. 2019;6:13.
13. Ding ZS, Tian SP, Zheng XL, Zhou ZW, Xu Y. Response of reactive oxygen metabolism and quality in mango fruit to exogenous oxalic acid or salicylic acid under chilling temperature stress. *Physiologia Plantarum*. 2007;130:112-121.
14. Dutta PK, Tripathi S, Mehrotra GK, Dutta J. Perspectives for chitosan based antimicrobial films in food applications. Food Chemistry. 2009;114(4):1173-1182.
15. Gholamipour F, Kamari S, Ghasemnezhad M, Ghazvini RF. Effect of chitosan coating on weight loss and postharvest quality of green pepper (*Capsicum annum* L.) fruits. Acta Horticulturae; c2010. p. 877.
16. Han C, Zhao Y, Leonard SW, Traber MG. Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (*Fragaria × ananassa*) and raspberries (*Rubus ideaus*). Postharvest Biology and Technology. 2004;33(1):67-78.
17. Hernández-Muñoz P, Almenar E, Ocio MJ, Gavara R. Effect of calcium dips and chitosan coating on postharvest life of strawberries (*Fragaria × ananassa*). Postharvest Biology and Technology. 2006;39:247-253.
18. Hundtoft EB, Akamine EK. Establishing the effects of

post-harvest treatment on fresh market papayas by response surface methodology. J Agric. Eng. Res. 1971;16(4):343-352.
19. Jangam AK, Thali P. ICAR Research Complex for Goa, Ela, Old Goa, Goa (India); c2010. p. 403-402.
20. Krishna KR, Rao DVS. Effect of chitosan coating on the physiochemical characteristics of guava (*Psidium guajava* L.) fruits during storage at room temperature. Indian J Sci. Tech. 2014;7:554-58.
21. Kumar N, Tokas J, Kumar P, Singal HR. Effect of salicylic acid on post-harvest quality of tomato (*Solanum lycopersicon* L.) Fruit. International journal of chemical studies. 2018;6(1):1744-1747.
22. Lu Z, Wang X, Cao M, Li Y, Su J, Gao H. Effect of 24-epibrassinolide on sugar metabolism and delaying postharvest senescence of kiwifruit during ambient storage. Scientia Horticulturae. 2019;253:1-7.
23. Maan AA, Ahmed ZFR, Iqbal Khan MK, Riaz A, Nazir A. Aloe vera gel, an excellent base material for edible films and coatings. Trends in Food Science and Technology. 2021;116:329-341.
24. Mignani I, Greve LC, Ben-Arie R, Stotz HU, Li C, Shakel K, *et al*. The effect of GA and divalent cations on aspects of pectin metabolism and tissue softening in ripening tomato pericarp. Physiologia Plantarum. 1995;93:108-115.
25. Mohammadreza AJ, Morteza OH. Effect of salicylic acid and methylejasmonate on ethylene producing and ethylene forming enzyme activity in peach. Journal of Plant Physiology. 2013;129(1-2):175-180.
26. Park SW, Kaimoyo E, Kumar D, Mosher S, Klessig DF. Methyl salicylate is a critical mobile signal for plant systemic acquired resistance. Science. 2007;318:113-116.
27. Paull RE, Nishijima W, Reyes M, Cavaletto C. Postharvest handling and losses during marketing of papaya (*Carica papaya* L.). Postharvest Biology and Technology. 1997;11:165-179.
28. Petriccione M, de Sanctis F, Pasquariello MS, Mastrobuoni F, Rega P, Scortichini M, *et al*. The effect of chitosan coating on the quality and nutraceutical traits of sweet cherry during postharvest life. Food and Bioprocess Technology. 2015;8:394-408.
29. Pilar H, Eva ADV, Dinoraz V, Rafael G. Effect of chitosan coating combined with postharvest calcium treatment on strawberry (*Fragaria x ananassa*) quality during refrigerated storage. Food Chem. 2008;110:428-435.
30. Pramod O, Swami AP, Srinivas P, Post-harvest diseases of papaya fruit in Coimbatore markets. Ann. Pl. Protec. Sci. 2007;15(1):140-144.
31. Qiu M, Jiang H, Ren G, Huang J, Wang X. Effect of chitosan coatings on postharvest green asparagus quality. Postharvest Biol. Technol. 2013;92:2027-32.
32. Ranganna S. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. Secondedn. Tata McGraw-Hill Pub. Co. New Delhi, India; c1986.
33. Sivakumar D, Wall MM. Papaya Fruit Quality Management during the Postharvest Supply Chain. Food reviews international. 2013;29:24-48.
34. Sun X, Narciso J, Wang Z, Zhou K. Effect of chitosan oil coatings on safety and quality of fresh blueberries. J F. Sci. 2014;10:1750-3841.
35. Vlot AC, Dempsey DA, Klessig DF. Salicylic acid, a multifaceted hormone to combat disease. Annual Review of Phytopathology. 2009;47:177-206.
36. Wheeler BEJ. An Introduction to Plant Diseases, John Wiley and Sons Limited, London; c1969. p. 301.
37. Xianghong M, Li B, Liu J, Tian S. Physiological responses and quality attributes of table grape fruit to chitosan preharvest spray and postharvest coating during storage. Food Chemistry. 2008;106(2):501-508.
38. Xylia P, Chrysargyris A, Ahmed ZFR, Tzortzakis N. Application of rosemary and eucalyptus essential oils and their main component on the preservation of apple and pear fruits. Horticulturae. 2021;7:479.
39. Yueming J, Jianrong L, Weibo J. Effects of chitosan coating on shelf life of cold-stored litchi fruit at ambient temperature. LWT - Food Science and Technology. 2005;38:757-761.
40. Zhang D, Quantick PC. Antifungal effects of chitosan coating on fresh strawberries and raspberries during storage. The Journal of Horticultural Science and Biotechnology. 1998;73:763-767.
41. Zhang Y, Chen K, Zhang S, Ferguson I. The role of salicylic acid in post-harvest ripening of kiwifruit. Postharvest Biology and Technology. 2003;28(1):67-74.
42. Zheng Y, Zhang Q. Effects of Polyamines and Salicylic Acid on Postharvest Storage of 'Ponkan' Mandarin. Acta Horticulturae; c2004. p. 632.