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# Effect of chemicals and growth regulators on post-harvest shelf-life and quality in papaya (*Carica papaya* L.) cv. Red Lady

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## ABSTRACT

**The present investigation on papaya (*Carica papaya* L.) cv. Red Lady was carried out at Horticultural College and Research Institute, Venkataramannagudem, West Godavari district of Andhra Pradesh, during the year 2010-11. The study was carried out using 9 different treatments involving two chemicals calcium nitrate and calcium chloride at 1, 2, 3 and 4% concentration and two growth regulators, viz., $GA_3$ at 75, 100, 150 and 200mg/l, and BA at 100, 125, 150 and 175mg/l concentration conducted separately in a factorial concept of completely randomized design (CRD), with three replications, under laboratory conditions. Physical parameters studied were per cent fruit ripening, physiological loss in weight (PLW), fruit firmness, shelf-life, and, physic-chemical properties studied were: total soluble solids (TSS), total sugars, reducing sugars, acidity, ascorbic acid and Brix:acid ratio. Fruits treated with $CaCl_2$ @ 4% showed significantly low PLW, per cent fruit ripening, and the highest fruit-firmness, shelf-life, lowest total soluble solids, total sugars, reducing sugars, Brix:acid ratio, and highest acidity and ascorbic acid content, which were on par with $CaCl_2$ @ 2% application. Fruits treated with $GA_3$ @ 100mg/l also exhibited similar results for these parameters. It was concluded that $CaCl_2$ @ 4 % had a beneficial impact on shelf-life of papaya fruits upto 10.67 days without any loss in either physical or physic-chemical properties. Similarly, application of growth regulators such as $GA_3$ and BA @100mg/l significantly increased shelf-life of papaya fruits upto 12 days and 11 days, respectively, while showing the best physical and physico-chemical properties.**

**Key words:** Papaya, PLW, GA, BA, calcium chloride, fruit firmness, total soluble solids

## INTRODUTION

Papaya (C*arica papaya* L.) has gained popularity in recent years because of ease of its cultivation, quick returns and adaptability to diverse soil and climatic conditions. Moreover, papaya fruits are delicious and commercially important because of their high nutritive and medicinal value. Papaya is cultivated in India in an area of 96,000ha, with production of 39,13,000t. In Andhra Pradesh, the crop is grown in an area of 18,759ha, with production of 15,00,720t (NHB Database, 2010). A new papaya cultivar, Red Lady, introduced from Taiwan has replaced traditional varieties like Coimbatore Selections, Coorg Honey Dew and Pusa Selections because of its high productivity, red colour flesh and gynodioecious nature. Papaya is a highly perishable fruit and can be stored only for four days at room temperature. Post-harvest losses in papaya up to 75 and 90 per cent have been reported in India and Costa Rica (Cerdaz and Seenz, 1993). Storage of papaya fruits at low temperature is limited, as, these are susceptible to chilling injury. However, experimental evidence has revealed that post-harvest treatment of fruits, in general, with various ripening retardants like wax emulsion, gibberellins, calcium chloride, benzyl adenine and spermine, improved shelf-life and quality of fruits and vegetables (Mehta *et al*, 1986; Padhmanabhan *et al*, 1994; Bhagwan, 1998). Salts of calcium have been shown to inhibit ethylene production and, thus, delay ripening (Al-Ani and Richardson, 1985). Fruits treatment with calcium prevented post-harvest losses in ber and pear (Siddiqui and Gupta, 1988). In addition to this, a few growth regulators are believed to promote shelf-life of papaya fruits. It is suggested that $GA_3$ @100mg/l significantly suppresses succinate activity of malate dehydrogenase during post-harvest ripening of papaya and, thus, retards ripening (Mehta *et al*, 1986). Hence, the present investigation was undertaken to study the effect of some chemicals and growth regulators on quality, shelf-life

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and storage of fruit of papaya cv. Red Lady under local agro-climatic conditions.

## MATERIAL AND METHODS

The present investigation was carried out at Department of Post Harvest Technology, Horticultural College and Research Institute, Venkataramannagudem, near Tadepalligudem, APHU, West Godavari district (A.P.) during the year 2010-11. Fruits at full maturity (characterized by all-green and without any yellow or red colour development) were considered. For each treatment, ten good fruits, free from pests and diseases, were selected and subjected to treatment with chemicals and growth regulators in both the experiments. Chemicals of analytical grade, viz., calcium chloride ($CaCl_2$) and calcium nitrate ($CaNO_3$) @ 1%, 2%, 3% and 4%, and growth regulators, viz., gibberellic acid (GA) @75mg/l, 100mg/l, 150 mg/l, and 200 mg/l, and, benzyl adenine (BA) @ 100mg/l, 125mg/l, 150mg/l and 175mg/l, and Control (water treatment) were used. After application of chemicals, all the fruits were wrapped in newspaper for storage studies. Observations on physical and physico-chemical parameters were recorded at 0, 3$^{rd}$, 6$^{th}$, 9$^{th}$ and 12$^{th}$ day after chemical application. Physical parameters studied included physiological loss in weight (PLW), per cent fruit ripening, fruit firmness (kg cm$^{-2}$), shelf-life (days); physico-chemical parameters included total soluble solids -TSS (%), total sugars (%), reducing sugars (%), acidity (%), ascorbic acid (mg/100 g), and TSS: Acid ratio. The experiment was conducted in completely randomized design with factorial concept and two factors, viz., chemicals or growth regulators (Factor-1) and storage period (Factor-2), with 9 treatments replicated thrice. Data were subjected to statistical analysis as per Panse and Sukhatme (1985).

## RESULTS AND DISCUSSION

### Physical parameters

Papaya is one of the important tropical fruit crops grown in India. Commercial potential of this crop could not be exploited on a large scale due to high perishability of the fruit and poor post-harvest storage facilities. The shelf-life of papaya fruits is relatively short compared to other tropical fruits as a direct consequence of weak cell-wall integrity. Experimental findings revealed that treatment of fruits with $CaCl_2$ @ 4% resulted in delayed ripening (41.52%) and fruits retained their firmness upto the 12$^{th}$ day, which was on par with treatment using $Ca(NO_3)_2$ @ 2% (42.82). This may be attributed to the possibility that high concentrations of externally added calcium inhibited induction of ripening (Ferguson, 1984). Inhibitory effect of calcium on ethylene synthesis, without modifying the capacity to respond to higher concentration of ethylene, helped delay natural ripening (Brady, 1987). Post harvest treatment with $GA_3$ @ 100mg/l also resulted in minimum per cent ripening (34.39) than with rest of the growth regulator treatments. Growth regulators slowed down the ripening process by retarding pre-climacteric respiration rate, thereby postponing their climacteric peaks, compared to untreated Control fruits (58.65). This was also reported by Gautam and Chundawat (1989). $GA_3$, being a growth promoter, is reported to also have an antagonistic effect on ethylene biosynthesis (Diller, 1969) (Table 1).

Fruits treated with $CaCl_2$ @ 4% resulted in best retention of fruit-firmness (6.45) upto the 12$^{th}$ day of observation, followed by the application of $Ca(NO_3)_2$@ 3% (5.75), which was on par fruits treated with $CaCl_2$ @ 3% (5.93). Among all the growth regulators used at different concentrations, fruits treated with $GA_3$ @ 100mg/l recorded the highest firmness (7.92), followed by that at BA @ 150mg/l (6.97) irrespective of the date of observation. The major cause of loss in firmness during ripening is due to dissolution of the cell wall and middle lamella by the action of hydrolyzing enzymes (Hulme, 1958). Breakdown of middle lamella (which holds the cell firmly) is brought about by the action of pectolytic enzymes, mainly, polygalacturonase. The inhibitory effect of $Ca^{2+}$ on the process of softening may have been due to an applicable degree of $Ca^{2+}$ binding during pectin solubilization (Shear, 1975) (Table 1).

As evident from data the lowest PLW (9.61%) was observed with $CaCl_2$ @ 4% which was on par with $Ca(NO_3)_2$ @ 2% (9.74%) than in rest of the treatments. Similarly, treatment of fruits with $GA_3$ @ 100mg/l recorded the lowest PLW (8.84), which was on par with that in BA 150mg/l and was significantly lower than rest of the growth regulator treatments. Highest PLW (13.64%) was observed in Control, which resulted in quick deterioration of fruits. This may be due to the role of calcium on limiting electrolyte breakage attributed to altered membrane permeability (Bangerth, 1979). Jones and Lunt (1970) contended that calcium controlled disintegration of mitochondria, endoplasmic reticulum and cytoplasmic membrane and, thus, helped retard respiration (Table 1).

**Table 1. Effect of post-harvest application of chemicals and growth regulators on per cent fruit ripening, fruit firmness and physiological loss of weight in papaya (*Carica papaya* L.) cv. Red Lady**

| Treatment | Per cent fruit ripening | | | | | Fruit firmness (kg cm$^{-2}$) | | | | | Physiological Loss of Weight (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after treatment | | | | | Days after treatment | | | | | Days after treatment | | | | |
| | 3rd day | 6th day | 9th day | 12th day | Mean | 3rd day | 6th day | 9th day | 12th day | Mean | 3rd day | 6th day | 9th day | 12th day | Mean |
| $CaCl_2$ @ 1% | 14.20 (22.14) | 24.30 (29.53) | 64.50 (53.42) | 94.30 (76.18) | 49.33 (45.32) | 10.20 | 6.06 | 2.33 | 0.92 | 4.88 | 7.87 (16.29) | 11.03 (19.40) | 14.4 (22.30) | 17.97 (25.08) | 12.82 (20.77) |
| $CaCl_2$ @ 2% | 12.40 (20.61) | 22.50 (28.31) | 65.17 (53.82) | 95.00 (77.07) | 48.77 (44.96) | 11.32 | 6.33 | 3.67 | 0.93 | 5.56 | 7.63 (16.03) | 10.67 (19.06) | 12.67 (20.85) | 14.83 (22.65) | 11.45 (19.65) |
| $CaCl_2$ @ 3% | 10.40 (18.81) | 20.50 (26.92) | 64.50 (53.42) | 94.50 (76.42) | 47.48 (43.90) | 11.60 | 7.20 | 3.93 | 1.00 | 5.93 | 6.76 (15.07) | 9.63 (18.08) | 11.4 (19.73) | 13.67 (21.70) | 10.37 (18.64) |
| $CaCl_2$ @ 4% | 8.12 (16.55) | 18.47 (25.45) | 50.17 (45.09) | 89.32 (70.92) | 41.52 (39.50) | 12.27 | 7.87 | 4.60 | 1.07 | 6.45 | 5.57 (13.65) | 8.03 (16.46) | 11.27 (19.61) | 13.55 (21.60) | 9.61 (17.83) |
| $Ca(NO_3)_2$ @ 1% | 11.40 (19.73) | 21.5 (27.62) | 62.17 (52.03) | 94.20 (76.06) | 47.32 (43.86) | 11.60 | 6.33 | 2.93 | 1.00 | 5.47 | 7.63 (16.03) | 10.67 (19.06) | 12.67 (20.85) | 14.83 (22.65) | 11.45 (19.65) |
| $Ca(NO_3)_2$ @ 2 % | 8.10 (16.53) | 19.52 (26.22) | 52.43 (46.39) | 91.21 (72.75) | 42.82 (40.47) | 11.73 | 6.13 | 4.00 | 1.13 | 5.75 | 5.87 (14.02) | 9.27 (17.72) | 11.01 (19.38) | 12.80 (20.96) | 9.74 (18.02) |
| $Ca(NO_3)_2$ @ 3% | 13.40 (21.47) | 23.5 (28.99) | 64.17 (53.22) | 94.30 (76.18) | 48.84 (44.96) | 11.40 | 7.20 | 3.67 | 0.93 | 5.80 | 6.30 (14.54) | 9.57 (18.02) | 11.76 (20.05) | 13.40 (21.47) | 10.26 (18.52) |
| $Ca(NO_3)_2$ @ 4% | 15.17 (22.92) | 25.17 (30.11) | 67.67 (55.34) | 98.20 (82.28) | 51.55 (47.66) | 10.87 | 6.02 | 3.00 | 1.00 | 5.22 | 7.76 (16.17) | 10.9 (19.28) | 12.6 (20.79) | 15.03 (22.81) | 11.57 (19.76) |
| Control | 15.40 (23.10) | 25.5 (30.33) | 82.53 (65.28) | 99.55 (86.14) | 55.75 (51.22) | 9.60 | 4.13 | 1.77 | 0.93 | 4.10 | 7.97 (16.40) | 11.57 (19.88) | 16.27 (23.79) | 18.73 (25.64) | 13.64 (21.43) |
| Mean | 11.80 (20.21) | 22.08 (22.26) | 63.60 (53.12) | 94.54 (77.11) | | 11.18 | 6.36 | 3.32 | 0.99 | | 7.04 (15.36) | 10.15 (18.55) | 12.26 (20.82) | 14.98 (22.73) | |
| | F test | SE.d | CD (*P=0.05*) | | | F test | SE.d | CD (*P=0.05*) | | | F test | SE.d | CD (*P=0.05*) | | |
| Chemical (C) | * | 0.92 | 2.13 | | | * | 0.04 | 0.07 | | | * | 0.09 | 0.17 | | |
| Storage period (S) | * | 0.71 | 1.65 | | | * | 0.03 | 0.06 | | | * | 0.07 | 0.13 | | |
| Interaction C x S | * | 0.61 | 3.7 | | | * | 0.07 | 0.14 | | | * | 0.17 | 0.24 | | |
| $GA_3$ @75mg/l | 11.41 (19.74) | 21.50 (27.62) | 63.17 (52.63) | 95.2 (77.34) | 47.82 ( 44.33) | 11.28 | 6.29 | 4.13 | 1.8 | 5.88 | 5.80 (13.93) | 10.57 (18.97) | 12.00 (20.27) | 14.6 (22.46) | 10.74 (18.91) |
| $GA_3$ @100mg/l | 8.84 (17.30) | 19.33 (26.08) | 57.26 (49.17) | 72.12 (58.12) | 39.39 (37.67) | 13.4 | 8.8 | 6.13 | 3.33 | 7.92 | 4.87 (12.75) | 8.03 (16.46) | 10.40 (18.81) | 12.07 (20.33) | 8.84 (17.09) |
| $GA_3$ @150mg/l | 12.23 (20.47) | 22.33 (28.20) | 60.17 (50.86) | 77.20 (61.47) | 42.98 (40.25) | 12.27 | 8.07 | 4.87 | 1.6 | 6.7 | 5.33 (13.35) | 9.37 (17.82) | 10.90 (19.28) | 12.63 (20.82) | 9.56 (17.82) |
| $GA_3$ @200mg/l | 15.40 (23.10) | 25.50 (30.33) | 64.5 (53.42) | 98.20 (82.28) | 50.90 (47.28) | 7.28 | 6.28 | 2.93 | 1.3 | 4.47 | 5.57 (13.65) | 8.89 (17.35) | 11.07 (19.43) | 12.03 (20.29) | 8.89 (17.68) |
| BA @ 100mg/l | 12.20 (20.44) | 22.33 (28.20) | 64.17 (53.23) | 94.20 (76.06) | 48.23 (44.48) | 11.73 | 6.13 | 4 | 1.23 | 5.77 | 5.67 (13.77) | 9.27 (12.72) | 11.57 (19.88) | 13.13 (21.24) | 9.91 (18.16) |
| BA @ 125mg/l | 13.17 (21.28) | 23.17 (28.77) | 64.15 (53.21) | 94.30 (76.18) | 48.70 (44.86) | 12.13 | 7.33 | 4.47 | 1.6 | 6.38 | 5.87 (14.02) | 9.73 (18.17) | 12.50 (20.70) | 15.03 (22.81) | 10.78 (18.93) |
| BA @ 150mg/l | 11.41 (19.74) | 21.45 (27.59) | 57.38 (49.24) | 77.20 (61.47) | 41.86 (39.51) | 12.27 | 8.13 | 5.67 | 1.8 | 6.97 | 4.53 (12.29) | 8.30 (16.74) | 10.43 (18.84) | 12.13 (20.38) | 8.85 (17.06) |
| BA @ 175mg/l | 15.30 (23.02) | 24.33 (29.55) | 64.25 (53.27) | 95.15 (77.27) | 49.76 (45.78) | 11.6 | 8.07 | 4.93 | 1.47 | 6.52 | 5.70 (13.81) | 9.13 (17.59) | 12.40 (20.62) | 13.76 (21.77) | 10.24 (18.45) |
| Control | 30.40 (33.46) | 40.50 (39.52) | 64.50 (53.42) | 99.2 (84.86) | 58.65 (52.82) | 11.6 | 7.07 | 2.8 | 1.2 | 5.67 | 7.76 (16.17) | 10.90 (19.28) | 12.60 (20.79) | 15.1 (22.86) | 11.59 (19.78) |
| Mean | 14.48 (22.06) | 24.49 (29.54) | 62.17 (52.05) | 89.20 (72.78) | | 11.51 | 7.35 | 4.44 | 1.66 | | 5.42 (13.75) | 9.16 (17.79) | 11.28 (19.85) | 12.67 (21.44) | |
| | F test | SE.d | CD (*P=0.05*) | | | F test | SE.d | CD (*P=0.05*) | | | F test | SE.d | CD (*P=0.05*) | | |
| Growth regulators (G) | * | 0.90 | 2.10 | | | * | 0.06 | 0.09 | | | * | 0.10 | 0.18 | | |
| Storage period (S) | * | 0.68 | 1.65 | | | * | 0.50 | 0.08 | | | * | 0.09 | 0.15 | | |
| Interaction G x S | * | 0.57 | 2.80 | | | * | 0.80 | 0.20 | | | * | 0.19 | 0.26 | | |

Values in parentheses are arcsine transformed

**Table 2. Effect of postharvest application of chemicals and growth regulators on shelf life (in days) in papaya cv. Red Lady**

| Treatment | Shelf life (in days) | Treatment | Shelf life (in days) |
|---|---|---|---|
| $CaCl_2$ @ 1% | 9.00 | $GA_3$@75ppm | 11.33 |
| $CaCl_2$ @ 2% | 9.67 | $GA_3$@100ppm | 12.00 |
| $CaCl_2$ @ 3% | 9.33 | $GA_3$@150ppm | 11.67 |
| $CaCl_2$ @ 4% | 10.67 | $GA_3$@200ppm | 10.67 |
| $Ca(NO_3)_2$ @ 1% | 9.00 | BA@100ppm | 11.00 |
| $Ca(NO_3)_2$ @ 2% | 10.50 | BA@125ppm | 10.00 |
| $Ca(NO_3)_2$ @ 3% | 8.25 | BA@150ppm | 9.33 |
| $Ca(NO_3)_2$ @ 4% | 9.33 | BA@175ppm | 10.33 |
| Control | 7.33 | Control | 8.67 |
| Mean | 9.34 | Mean | 10.56 |
| S.Ed | 0.39 | S.Ed | 0.20 |
| CD *(P=0.05)* | 0.83 | CD *(P=0.05)* | 0.44 |

Fruits treated with $CaCl_2$ @ 4% recorded the highest shelf-life (10.67 days) over other treatments, and was on par with $Ca(NO_3)_2$ @ 2% application (10.50 days). Among the growth regulators applied, significantly higher shelf-life was recorded with $GA_3$ @100mg/l (12 days), followed by $GA_3$ @ 150mg/l (11.67 days) than in rest of the treatments. Further, in both the cases, untreated fruits resulted in the lowest shelf-life (7.33 and 8.67, respectively) (Table 2). The most important physiological effect of $GA_3$ is that it influences oxidative or peroxidative enzyme activity by increasing production of oxidative inhibitors (such as polyhydroxy cinnamic acids) in large quantities. This may have helped extend shelf-life of the fruits, as stated by Frenkel and Dyck (1973).

## Physico-chemical parameters

The lowest per-cent reducing sugars (7.51) was observed with $CaCl_2$ @ 4% whereas, the highest per cent (8.65) was seen in untreated fruits. Similarly, fruits treated with $GA_3$ @ 100mg/l resulted in lowest amounts of reducing sugars (6.78%) compared to that in the remaining treatments. Fruits treated with $CaCl_2$ @ 4% resulted in lowest (10.48%) total sugars than that in rest of the treatments; whereas, highest per cent total sugars (13.31) was observed in untreated fruits (Table 3). In the Control, total soluble solids (TSS) increased during ripening due to enzymatic conversion of starch to simple sugars (Hussain *et al*, 2008). However, reduction in the TSS of calcium-treated papaya may have been due to inhibition or retardation of conversion of starch to simple sugars (which slows down electrolytic breakage and metabolic activity, thereby retarding ripening (Izumi and Watada, 1994; Agar *et al,* 1999).

Total soluble solids (TSS) in papaya fruits increased with an increase in storage period from the 3$^{rd}$ day (10.60°B) to the 9$^{th}$ day (13.56°B) and, thereafter, decreased until the 12$^{th}$ day (12.40°B) with application of chemicals at different days of storage. Further, mean TSS of fruits with use of various growth regulators also increased from the 3$^{rd}$ day (8.37°B) to the 9$^{th}$ day (14.33°B). Thereafter, it decreased until the 12$^{th}$ day (12.07°B). The increase in TSS may be attributed mainly to conversion of starch and other polysaccharides to soluble forms of the sugars (Mukherjee and Dutta, 1967). Rate of increase in TSS content was slow in fruits treated with $CaCl_2$ @ 4% (10.91°B) and $GA_3$ 100mg/l (11.14°B) compared to the Control fruits (13°B). In fruits showing higher shelf-life, TSS decreased at a slower rate. Further, among growth regulators, fruits treated with $GA_3$ @ 100mg/l had lower TSS (11.14°B) indicating that the ripening process slowed down. These findings are in conformity with those of Kumbhar and Desai (1986) in sapota.

Highest titratable acidity (0.30%) was observed in fruits treated with $CaCl_2$ @ 4% and lowest (0.19%) was observed in the untreated fruits. Similarly, fruits treated with $GA_3$ @ 100mg/l recorded highest (0.26%) titrable acidity than the rest of the treated fruits. Acidity decreased gradually from the 3$^{rd}$ day to the 12$^{th}$ day in all the treatments (Table 4). Decline in acidity can be attributed to a decrease in citric acid content during storage, as reported by Medlicott and Thompson (1985). There was a continuous decrease in acidity of papaya fruits with progressive storage period, as was utilization of organic acids during respiration (Singh *et al*, 1954).

Ascorbic acid content of papaya fruits treated with $CaCl_2$ @ 4% recorded the highest values (48.60 mg/100g fresh weight), whereas, fruits treated with $Ca(NO_3)_2$ @ 2% recorded a value of 47.33 which was on a par with the former, but higher than that in Control (41.00). Similarly, fruits treated with $GA_3$ 100mg/l resulted in highest (42.67) ascorbic acid content than fruits treated with rest of the growth regulators. Untreated fruits recorded the lowest value for this (34.14) (Table 4). TSS:acid ratio of papaya fruits treated with $CaCl_2$ @ 4% was the lowest (55.48), whereas, the highest ratio (79.35) was observed in untreated fruits. This may be due to a slow hydrolysis of starch to sugars, and, a gradual build-up of sugars in calcium-treated fruits.

**Table 3. Effect of post-harvest application of chemicals and growth regulators on reducing sugars, total sugars and total soluble solids in papaya cv. Red Lady**

| Treatment | Reducing sugars (%) | | | | | Totals sugars (%) | | | | | Total Soluble Solids (°Brix) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after treatment | | | | | Days after treatment | | | | | Days after treatment | | | | |
| | 3rd day | 6th day | 9th day | 12th day | Mean | 3rd day | 6th day | 9th day | 12th day | Mean | 3rd day | 6th day | 9th day | 12th day | Mean |
| $CaCl_2$ @ 1% | 5.80 (13.93) | 8.25 (16.69) | 9.97 (18.40) | 7.77 (16.18) | 7.95 (16.30) | 9.05(17.51) | 11.20 (19.55) | 13.47(21.53) | 10.90(19.28) | 11.16(19.47) | 10.69 | 13.43 | 13.65 | 12.68 | 12.61 |
| $CaCl_2$ @ 2% | 5.62 (13.71) | 8.20 (16.64) | 9.63 (18.08) | 7.66 (16.06) | 7.78 (16.12) | 8.45(16.90) | 11.08 (19.44) | 13.43(21.50) | 10.51(18.92) | 10.87(19.19) | 10.6 | 12.76 | 13.55 | 12.65 | 12.39 |
| $CaCl_2$ @ 3% | 5.04 (12.97) | 7.93 (16.35) | 9.60 (18.05) | 7.52 (15.91) | 7.52 (15.82) | 8.31(16.75) | 10.97 (19.34) | 13.30(21.39) | 10.32(18.74) | 10.73(19.05) | 10.51 | 12.54 | 13.54 | 12.34 | 12.23 |
| $CaCl_2$ @ 4% | 5.03 (12.96) | 7.16 (15.52) | 8.70 (17.15) | 7.51 (15.90) | 7.10 (15.38) | 8.30(16.74) | 10.81 (19.19) | 12.25(20.49) | 10.25(18.67) | 10.40(18.77) | 10.4 | 12.04 | 13.05 | 12.15 | 11.91 |
| $Ca(NO_3)_2$ @ 1% | 5.10 (13.05) | 8.60 (17.05) | 9.80 (18.24) | 7.79 (16.21) | 7.82 (16.14) | 8.90 (17.36) | 11.86 (20.14) | 13.22(21.32) | 11.51 (19.83) | 11.37(19.66) | 10.61 | 12.2 | 13.54 | 11.85 | 12.05 |
| $Ca(NO_3)_2$ @ 2% | 5.02 (12.95) | 8.05 (16.48) | 9.63 (18.08) | 7.58 (15.97) | 7.57 (15.87) | 8.60 (17.05 | 11.98 (20.25) | 12.81(20.97) | 11.50(19.82) | 11.22(19.52) | 10.46 | 12.07 | 13.15 | 12.22 | 11.98 |
| $Ca(NO_3)_2$ @ 3% | 5.80 (13.93) | 8.69 (17.14) | 9.85 (18.29) | 7.82 (16.24) | 8.04 (16.40) | 9.40(17.85) | 12.98 (21.12) | 13.34(21.42) | 11.88(20.16) | 11.90(20.14) | 10.45 | 13.32 | 13.68 | 12.22 | 12.42 |
| $Ca(NO_3)_2$ @ 4% | 5.90 (14.06) | 8.80 (17.25) | 10.13 (18.56) | 7.88 (16.30) | 8.18 (16.54) | 9.70 (18.14) | 12.16 (20.41) | 13.38(21.45) | 12.29(20.52) | 11.88(20.13) | 10.65 | 12.5 | 13.72 | 12.5 | 12.34 |
| Control | 6.57 (14.85) | 9.47 (17.92) | 10.56 (18.96) | 7.98 (16.41) | 8.65 (17.03) | 10.50(18.91) | 13.51 (21.56) | 13.86(21.85) | 12.61(20.80) | 12.62(20.78) | 11 | 13.85 | 14.2 | 12.95 | 13 |
| Mean | 5.54 (13.60) | 8.35 (14.95) | 9.76 (16.17) | 7.72 (16.13) | 9.02 (17.47) | 11.83(20.11) | 13.22 (21.32) | 11.31(19.64) | 10.6 12.75 | 13.56 12.4 | | | | | |
| | F test | SE.d | CD (*P=0.05*) | | | F test | SE.d | CD (*P=0.05*) | | | F test | SE.d | CD (*P=0.05*) | | |
| Chemical (C) | * | 0.06 | 0.12 | | | * | 0.11 | 0.34 | | | * | 0.04 | 0.07 | | |
| Storage period (S) | * | 0.05 | 0.10 | | | * | 0.07 | 0.15 | | | * | 0.03 | 0.06 | | |
| Interaction C x S | * | 0.12 | 0.24 | | | * | 0.41 | 0.41 | | | * | 0.07 | 0.14 | | |
| $GA_3$ @75mg/l | 4.53 (12.29) | 7.95 (16.38) | 8.32 (16.76) | 6.85 (15.17) | 6.91 (15.15) | 8.24(16.68) | 11.62 (19.93) | 13.56 (21.60) | 11.54 (19.86) | 11.24(19.52) | 8.25 | 11.87 | 13.53 | 11.57 | 11.31 |
| $GA_3$ @100mg/l | 4.50 (12.25) | 7.81 (16.23) | 8.07 (16.50) | 6.74 (15.05) | 6.78 (15.01) | 7.81(16.23) | 11.50 (19.82) | 13.24 (21.34) | 11.24 (19.59) | 10.95(19.24) | 8.2 | 11.75 | 13.22 | 11.37 | 11.14 |
| $GA_3$ @150mg/l | 4.81 (12.67) | 8.18 (16.62) | 9.11 (17.57) | 7.09 (15.44) | 7.30 (15.57) | 7.87 (16.29) | 12.23 (20.47) | 13.33 (21.41) | 11.18 (19.53) | 11.15(19.43) | 8.29 | 12.24 | 13.76 | 11.43 | 11.43 |
| $GA_3$ @200mg/l | 4.89 (12.77) | 8.27 (16.71) | 9.15 (17.61) | 7.12 (15.47) | 7.36 (15.64) | 8.50 (16.95) | 12.24 (20.48) | 13.74(21.76) | 11.68 (19.98) | 11.54(19.79) | 8.3 | 13.42 | 14.2 | 12.38 | 12.08 |
| BA @ 100mg/l | 5.37 (13.40) | 8.74 (17.19) | 9.65 (18.10) | 7.76 (16.17) | 7.88 (16.22) | 8.30(16.74) | 11.61 (19.92) | 13.02(21.15) | 11.78 (20.07) | 11.18(19.47) | 8.22 | 11.86 | 13.27 | 11.41 | 11.19 |
| BA @ 125mg/l | 5.35 (13.37) | 8.67 (17.12) | 9.64 (18.09) | 7.23 (15.60) | 7.72 (16.04) | 8.27(16.71) | 12.63 (20.82) | 13.65 (21.68) | 11.34 (19.68) | 11.47(19.72) | 8.27 | 13.57 | 15.19 | 12.3 | 12.33 |
| BA @ 150mg/l | 5.24 (13.23) | 7.32 (15.69) | 8.64 (17.09) | 7.01 (15.35) | 7.05 (15.34) | 7.84 (16.26) | 12.34 (20.56) | 13.27(21.36) | 11.28 (19.62) | 11.18(19.45) | 8.28 | 13.59 | 15.2 | 12.37 | 12.36 |
| BA @ 175mg/l | 5.29 (13.30) | 8.56 (17.01) | 9.68 (18.13) | 7.22 (15.59) | 7.69 (16.00) | 8.10 (16.53) | 12.56 (20.75) | 14.02(21.99) | 12.85 (21.00) | 11.88(20.07) | 8.3 | 13.76 | 15.25 | 12.56 | 12.47 |
| Control | 6.23 (14.45) | 9.49 (17.94) | 10.22 (18.64) | 8.78 (17.23) | 8.68 (17.07) | 9.25 (17.70) | 13.56 (21.60) | 15.12(22.88) | 12.98 (21.12) | 12.72(20.82) | 9.26 | 13.81 | 15.37 | 13.2 | 12.91 |
| Mean | 5.13 (13.08) | 8.33 (16.77) | 9.16 (17.61) | 7.33 (15.67) | 8.24 (16.68) | 12.25 (20.48) | 13.66 (21.69) | 11.76(20.05) | 8.37 | 12.87 14.33 | 12.07 | | | | |
| | F test | SE.d | CD (*P=0.05*) | | | F test | SE.d | CD (*P=0.05*) | | | F test | SE.d | CD (*P=0.05*) | | |
| Growth regulators (G) | * | 0.06 | 0.11 | | | * | 0.13 | 0.25 | | | * | 0.06 | 0.08 | | |
| Storage period (S) | | * | 0.04 | | | 0.08 | * | 0.07 | | | 0.21 | * | 0.05 | 0.07 | |
| Interaction G x S | * | 0.11 | 0.22 | | | * | 0.18 | 0.35 | | | * | 0.08 | 0.16 | | |

Values in parentheses are arcsine transforme

**Table 4. Effect of post-harvest application of chemicals and growth regulators on titrable acidity, ascorbic acid and TSS:Acid ratio in papaya cv. Red Lady**

| Treatment | Titrable acidity (%) | | | | | Ascorbic acid (mg/100g) | | | | | TSS:Acid ratio | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after treatment | | | | | Days after treatment | | | | | Days after treatment | | | | |
| | 3rd day | 6th day | 9th day | 12th day | Mean | 3rd day | 6th day | 9th day | 12th day | Mean | 3rd day | 6th day | 9th day | 12th day | Mean |
| $CaCl_2$ @ 1% | 0.30 (3.14) | 0.23 (2.75) | 0.18 (2.43) | 0.17 (2.36) | 0.22 (2.67) | 34.57 | 46.26 | 54.07 | 34.13 | 42.26 | 39.01 | 70.34 | 85.75 | 97.68 | 73.20 |
| $CaCl_2$ @ 2% | 0.33 (3.29) | 0.29 (3.09) | 0.24 (2.81) | 0.19 (2.50) | 0.26 (2.92) | 35.43 | 46.40 | 54.80 | 35.93 | 43.14 | 38.74 | 66.34 | 83.15 | 95.27 | 70.88 |
| $CaCl_2$ @ 3% | 0.34 (3.34) | 0.31 (3.20) | 0.25 (2.87) | 0.20 (2.56) | 0.28 (2.99) | 36.70 | 47.17 | 56.67 | 39.30 | 44.96 | 36.90 | 48.67 | 74.70 | 91.25 | 62.88 |
| $CaCl_2$ @ 4% | 0.36 (3.44) | 0.32 (3.24) | 0.28 (3.03) | 0.22 (2.69) | 0.30 (3.10) | 38.63 | 55.63 | 57.09 | 43.03 | 48.60 | 27.24 | 42.22 | 69.63 | 82.84 | 55.48 |
| $Ca(NO_3)_2$ @ 1% | 0.23 (2.75) | 0.20 (2.56) | 0.19 (2.50) | 0.13 (2.07) | 0.19 (2.47) | 35.57 | 49.50 | 54.24 | 36.97 | 44.07 | 39.43 | 55.43 | 74.76 | 75.43 | 61.26 |
| $Ca(NO_3)_2$ @ 2 % | 0.30 (3.14) | 0.25 (2.87) | 0.23 (2.75) | 0.19 (2.50) | 0.24 (2.81) | 37.20 | 55.30 | 56.82 | 40.01 | 47.33 | 35.79 | 47.74 | 72.12 | 74.44 | 57.52 |
| $Ca(NO_3)_2$ @ 3% | 0.29 (3.09) | 0.24 (2.81) | 0.22 (2.69) | 0.18 (2.43) | 0.23 (2.75) | 36.50 | 47.17 | 56.57 | 39.30 | 44.89 | 39.56 | 65.96 | 85.54 | 92.62 | 70.92 |
| $Ca(NO_3)_2$ @ 4% | 0.25 (2.87) | 0.22 (2.69) | 0.20 (2.56) | 0.16 (2.29) | 0.21 (2.60) | 34.67 | 46.45 | 53.44 | 35.93 | 42.62 | 41.24 | 70.24 | 86.42 | 97.53 | 73.86 |
| Control | 0.23 (2.75) | 0.20 (2.56) | 0.17 (2.36) | 0.15 (2.22) | 0.19 (2.47) | 33.47 | 46.20 | 52.21 | 32.12 | 41.00 | 50.64 | 79.12 | 87.98 | 99.67 | 79.35 |
| Mean | 0.29 (3.09) | 0.25 (2.86) | 0.22 (2.39) | 0.18 (2.40) | 35.94 | 48.89 | 55.46 | 37.41 | | 38.73 | 60.67 | 80.01 | 89.64 | | |
| | F test | SE.d | CD (*P*=0.05) | | | F test | SE.d | CD (*P*=0.05) | | | F test | SE.d | CD (*P*=0.05) | | |
| Chemical (C) | * | 0.08 | 0.02 | | | * | 0.67 | 1.32 | | | * | 6.38 | 4.59 | | |
| Storage period (S) | * | 0.05 | 0.09 | | | * | 0.37 | 0.74 | | | * | 4.64 | 9.23 | | |
| Interaction C x S | NS | - | - | | | * | 1.17 | 2.34 | | | NS | - | - | | |
| $GA_3$ @ 75mg/l | 0.31 (3.19) | 0.19 (2.50) | 0.16 (2.29) | 0.10 (1.81) | 0.19 (2.45) | 36.50 | 39.25 | 49.38 | 37.93 | 40.77 | 40.33 | 51.22 | 71.02 | 82.75 | 61.33 |
| $GA_3$ @ 100mg/l | 0.33 (3.29) | 0.29 (3.09) | 0.21 (2.62) | 0.19 (2.50) | 0.26 (2.88) | 37.63 | 41.21 | 51.72 | 40.13 | 42.67 | 37.90 | 49.67 | 57.87 | 76.43 | 55.47 |
| $GA_3$ @ 150mg/l | 0.32 (3.24) | 0.21 (2.62) | 0.19 (2.50) | 0.14 (2.14) | 0.22 (2.63) | 33.95 | 37.54 | 48.32 | 33.24 | 38.26 | 40.99 | 52.53 | 71.03 | 82.84 | 61.78 |
| $GA_3$ @ 200mg/l | 0.30 (3.14) | 0.20 (2.56) | 0.16 (2.29) | 0.13 (2.07) | 0.20 (2.52) | 32.57 | 36.24 | 45.23 | 32.97 | 36.75 | 41.44 | 53.26 | 75.46 | 85.36 | 63.88 |
| BA @ 100mg/l | 0.25 (2.87) | 0.18 (2.43) | 0.15 (2.22) | 0.12 (1.98) | 0.18 (2.38) | 35.43 | 37.38 | 39.18 | 36.61 | 37.15 | 43.46 | 57.24 | 75.46 | 87.61 | 65.94 |
| BA @ 125mg/l | 0.26 (2.92) | 0.20 (2.56) | 0.18 (2.43) | 0.16 (2.29) | 0.20 (2.55) | 36.80 | 38.67 | 40.21 | 37.36 | 38.26 | 41.33 | 55.23 | 73.26 | 83.62 | 63.36 |
| BA @ 150mg/l | 0.32 (3.24) | 0.27 (2.98) | 0.21 (2.62) | 0.17 (2.36) | 0.24 (2.80) | 38.40 | 39.32 | 41.37 | 38.63 | 39.43 | 37.24 | 50.80 | 59.32 | 76.57 | 55.98 |
| BA @ 175mg/l | 0.31 (3.19) | 0.21 (2.62) | 0.18 (2.43) | 0.13 (2.07) | 0.21 (2.58) | 34.50 | 38.43 | 39.40 | 35.93 | 37.07 | 38.13 | 48.68 | 72.13 | 86.43 | 61.34 |
| Control | 0.24 (2.81) | 0.17 (2.36) | 0.14 (2.14) | 0.10 (1.81) | 0.16 (2.28) | 32.13 | 34.23 | 38.11 | 32.11 | 34.14 | 43.48 | 65.93 | 76.43 | 89.76 | 68.90 |
| Mean | 0.29 (3.10) | 0.21 (2.64) | 0.18 (2.40) | 0.14 (2.12) | 35.32 | 38.36 | 43.66 | 36.10 | | 40.48 | 53.84 | 70.22 | 83.49 | | |
| | F test | SE.d | CD (*P*=0.05) | | | F test | SE.d | CD (*P*=0.05) | | | F test | SE.d | CD (*P*=0.05) | | |
| Growth regulators (G) | * | 0.90 | 2.10 | | | * | 0.67 | 1.32 | | | * | 7.69 | 5.38 | | |
| Storage period (S) | * | 0.68 | 1.65 | | | * | 0.42 | 0.84 | | | * | 3.30 | 8.25 | | |
| Interaction G x S | * | 0.57 | 2.80 | | | * | 1.33 | 2.64 | | | NS | - | - | | |

Values in parentheses are arcsine transformed

Among the growth regulators tested, fruits treated with $GA_3$ @ 100mg/l resulted in lowest TSS:acid ratio (55.47), and untreated fruits had a value of 68.90. TSS:acid ratio of papaya fruits recorded a gradual increase with increasing storage period. The increase in TSS:acid ratio can be attributed to starch breakdown, resulting in free sugars, and, a decline in organic acids due to their consumption during respiration (Ghafir *et al*, 2009). The decline in TSS:acid ratio in calcium-treated papaya may be due to a retardation in TSS levels by calcium but the retention of acidity at high levels (Mahajan *et al,* 2008). Further, a gradual decline in TSS:acid ratio was recorded with increasing $CaCl_2$ concentration. These results are in agreement with findings of Rajkumar *et al* (2005) in papaya and Goud (1979) in sapota.

It is concluded that chemicals such as $CaCl_2$ @ 4% have proved their beneficial impact on shelf-life of papaya fruits upto 10.67 days without any loss in either physical or physico-chemcial properties. Similarly, application of the growth regulator $GA_3$ @ 100mg/l also increased shelf-life in papaya fruits upto 12 days, with the best physical and physico-chemical attributes.

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