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# THE EFFECT OF HEXANAL AND STORAGE CONDITIONS ON POST-HARVEST QUALITY OF PAPAYA (*CARICA PAPAYA* L.) CV. RED LADY

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**ABSTRACT**

The study was conducted on Effect of hexanal and storage conditions on post-harvest quality of papaya cv. Red Lady at College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari district of Andhra Pradesh during 2021-22 and 2022-23. The experiment was conducted in a Factorial Completely Randomized Design (FCRD) with three replications and two factors *viz.*, hexanal treatment at four levels ($P_1$: preharvest spray @ 2% hexanal; $P_2$: pre harvest spray and post-harvest dip @ 2 % hexanal, $P_3$: post-harvest dip @ 2% hexanal and $P_4$: No preharvest spray and post-harvest dip) and two storage conditions ($S_1$: Ambient storage; $S_2$: Cold storage @ 13℃) with eight treatment combinations. Results revealed that maximum titrable acidity, ascorbic acid content, minimum TSS, total sugars, reducing sugars, non-reducing sugars, carotenoids content at 12$^{th}$ day of storage in the hexanal treatments [combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$)], storage conditions [fruits stored under cold storage (13℃)] and their interaction [combined pre and post-harvest treatment of hexanal @ 2% under cold storage condition ($P_2S_2$)].

***Keywords*:** Hexanal, Storage conditions, Post-harvest quality, Papaya.

## Introduction

Among the Caricaceae family, papaya (*Carica papaya* L.) is the most important economic crop. Papaya is domesticated in tropical and sub-tropical regions of the world (Asia, Africa, Oceania, and North America). India is the world's largest producer cultivated in an area of 1.48 lakh ha with an annual production of 58.85 lakh MT followed by Brazil, Mexico, Indonesia and Nigeria. Papaya, containing about 89.7% water, is a highly perishable fruit. Huge post-harvest losses, estimated at over 50%, are one of the key challenges to the continued production and marketing of this thin-skinned fruit. Papaya ripens and softens over a very short period of time, usually three days, predisposing the fruit to physical damage and phyto-pathogen invasions. Pre-treatments and storage are the two vital wings of post-harvest handling of these perishable commodities. The objective of successful storage is to delay the ripening process, retard the biochemical changes, reduce the microbial growth and finally enhance the shelf life of the fruit. A new formulation based on hexanal, a six-carbon aldehyde naturally found in fruits, is associated with the characteristic green flavour has been found to enhance shelf life of many fruit crops *viz.*, apple, pears, peach, grapes, sweet cherries and strawberry (Paliyath and Murr, 2007). Keeping these points in view, study was undertaken on effect of hexanal treatment and storage conditions on post-harvest quality of papaya.

## Materials and Methods

The current investigation, "Effect of hexanal and storage conditions on post-harvest quality of papaya (*Carica papaya* L.) cv. Red Lady" was carried out at Instructional farm, Department of Fruit Science, Dr. YSRHU-College of Horticulture, Venkataramannagudem, West Godavari district of Andhra Pradesh during 2021-22 and 2022-23. The experiment was laid out in Factorial CRD with three replications consisted of two factors *viz.*, Hexanal at four levels [$P_1$: 2% Hexanal pre harvest spray at 120 days after fruit set ; $P_2$: 2% Hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip ; $P_3$: 2% Hexanal post-harvest dip ;$P_4$: No pre harvest spray and no post-harvest dip] and storage conditions at two levels [$S_1$: Ambient storage ; $S_2$: Cold storage (13°C)] with eight treatment combinations.

| | | | | |
|---|---|---|---|---|
| $T_1$ | : | $P_1S_I$ | - | 2% Hexanal pre harvest spray at 120 days after fruit set + Ambient storage |
| $T_2$ | : | $P_1S_2$ | - | 2% Hexanal pre harvest spray at 120 days after fruit set + Cold storage (13°C) |
| $T_3$ | : | $P_2S_1$ | - | 2% Hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip + Ambient storage |
| $T_4$ | : | $P_2S_2$ | - | 2% Hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip + Cold storage (13°C) |
| $T_5$ | : | $P_3S_1$ | - | 2% Hexanal post-harvest dip + Ambient storage |
| $T_6$ | : | $P_3S_2$ | - | 2% Hexanal post-harvest dip + Cold storage (13°C) |
| $T_7$ | : | $P_4S_1$ | - | No pre harvest spray and no post-harvest dip + Ambient storage |
| $T_8$ | : | $P_4S_2$ | - | No pre harvest spray and no post-harvest dip + Cold storage (13°C) |

### Preparation of stock solution

Hexanal stock formulation (EFF- enhanced freshness formulation) consisting of hexanal @1% v/v, ascorbic acid @1% w/v, alpha- tocopherol @1% w/v, geraniol @1% v/v, and surfactant Tween 20 @10% v/v, was prepared by dissolving in ethanol @10% v/v as per procedures given by Paliyath and Murr (2007).

### Preharvest spray treatments:

Pre-harvest sprays with 2% hexanal formulation were carried out in Instructional farm, Department of Fruit Science, College of Horticulture, Venkataramannagudem. Pre harvest spraying was done with the help of hand sprayer at 120 days after fruit set. The sprayer was rinsed thoroughly with water before the application of each treatment.

The harvested papaya fruits were labelled according to different treatments and wrapped with paper to prevent the mechanical injury and kept in plastic crates and lined with cushioning material to avoid transportation shocks and transported to the laboratory for conducting the experiment study.

### Postharvest dip

Selected fruits were subjected to dipping in 2% hexanal formulation for 2-3 min according to the treatments and were wiped with a damp cloth soaked in clean water to remove any adhering dirt or debris and then graded for size uniformity and further divided into two sets to store in ambient and cold conditions.

### Storage conditions

### Ambient storage

The ten fruits per treatment for each replication of graded fruits were kept in ambient storage. A comparative control without the dipping treatment was also maintained during each experiment.

The temperature and relative humidity prevailed in ambient conditions during the period of study were recorded 28.0 ± 2°C and 57 % respectively.

### Cold Storage

The second set of graded fruits were kept in cold storage (Temperature: 13°C, RH: 90 ± 3%) facility maintained at Post Harvest Technology Centre, Dr. YSR Horticultural university. The temperature and the humidity were maintained by thermostat and humidistat controller integrated with cold room facility. A comparative control without the dipping treatment was also maintained.

**Fruit quality parameters**

From the harvested lot, diseased fruits and unmarketable fruits were separated. Ten fruits were randomly selected from the remaining lot of healthy fruits to record the following fruit quality parameters from each treatment.

**Total soluble solids (°Brix)**

Fully ripened fruits were peeled and pulp was crushed for juice extraction. The juice was used for determining the total soluble solids by using "digital refractometer" with 0-32 range. The values were expressed as degree brix.

**Titrable acidity (%)**

The titratable acidity was estimated as per the procedure laid out by (Ranganna, 1986).

**TSS/Acid ratio**

The ratio was calculated by dividing total soluble solids with the titrable acidity.

$$\text{TSS} : \text{acid ratio} = \frac{\text{TSS}}{\text{Titrable Acidity}}$$

**Total sugars (%)**

The total sugars were determined as procedure described by Lane and Eynon method (1965).

**Reducing sugars (%)**

The reducing sugars in papaya fruit pulp were determined as per the procedure explained by Lane and Eynon method (1965).

**Non reducing sugars (%)**

The non-reducing sugars in juice were obtained by subtracting reducing sugars from total sugars and expressed in percentage.

Non-reducing sugars (%) = Total sugars (%) - Reducing sugars (%)

**Ascorbic acid (mg 100 g$^{-1}$ pulp)**

Ascorbic acid content of papaya pulp samples was determined by 2, 6-dichlorophenol indophenol visual titration method described by Ranganna (1986).

**Carotenoid content (mg 100g$^{-1}$)**

Carotene content in fruit pulp was estimated by following petroleum ether-acetone extraction method (Ranganna, 1986).

**Statistical Analysis**

The data on various characters studied during the course of investigation were analysed statistically by applying the procedures of analysis of variance as outlined by Sukhatme and Amble (1985). The critical difference among the treatment means was compared at 5 per cent level of significance.

## Results and Discussion

**Total Soluble Solids (TSS) (°Brix)**

The results regarding total soluble solids in fruit pulp of papaya as influenced by hexanal treatments, storage conditions and their interaction effect was presented in table 1. A gradual increase in total soluble solids was noticed upto 6$^{th}$ day of storage period, later it was decreased under ambient storage conditions in untreated fruits. The total TSS was increased gradually upto 12$^{th}$ day of storage under cold storage conditions in untreated fruits.

The TSS was gradually increased from 3$^{rd}$ (9.47) to 6$^{th}$ (10.59) day of storage later it was decreased gradually from 9$^{th}$ (9.91) to 12$^{th}$ (9.59) day of storage in hexanal untreated fruits ($P_4$). The TSS was gradually increased from 3$^{rd}$ to 12$^{th}$ day storage in $P_2$ (8.56, 9.19, 10.65 and 10.97 at 3$^{rd}$, 6$^{th}$ , 9$^{th}$ and 12$^{th}$ day of storage respectively) and $P_3$ (8.72, 9.48, 10.56 and 11.10 at 3$^{rd}$, 6$^{th}$ , 9$^{th}$ and 12$^{th}$ day of storage respectively) treatments whereas in $P_1$ (8.72, 9.64 and 10.70 at 3$^{rd}$, 6$^{th}$ and 9$^{th}$ day of storage respectively) treatment the TSS was increased upto 9$^{th}$ day storage and it was decreased (9.89) at 12$^{th}$ day of storage.

The TSS was increased (9.36, 10.75 and 11.82 at 3$^{rd}$, 6$^{th}$ and 9$^{th}$ day of storage respectively) upto 9$^{th}$ day of storage later it was decreased (10.96 at 12$^{th}$ day of storage) under ambient conditions. The TSS was gradually increased (8.37, 8.70, 9.09 and 9.81 at 3$^{rd}$, 6$^{th}$, 9$^{th}$ and 12$^{th}$ day of storage respectively) under cold storage conditions.

The interaction between hexanal treatments and storage conditions was found significant for total soluble solids in pulp of papaya fruits at all days of observations recorded except at 3$^{rd}$ of storage. The TSS was maximum (12.20) in pulp of untreated fruits kept under ambient conditions at 6$^{th}$ day of storage and in pulp of fruits treated with 2% hexanal as preharvest spray+ post-harvest dip and kept under ambient conditions at 9$^{th}$ (12.51) and 12$^{th}$ (12.91) day of storage. The TSS was lowest (8.32, 8.79 and 9.02 at 6$^{th}$, 9$^{th}$ and 12$^{th}$ day of storage respectively) in pulp of fruits treated with 2% hexanal as preharvest spray+ post-harvest dip and kept under cold storage conditions.

The TSS which was fairly low at harvest, increased as the storage period advanced and reached its peak (11.82) on $9^{th}$ day of storage and declined thereafter under ambient storage. TSS of fruits increased till $24^{th}$ day of storage (12.43) ($P_2S_2$) under cold storage. The TSS of fruits varied from 9.80 to 12.43 was recorded in fruits treated with 2% hexanal pre harvest spray and post-harvest dip treatment and kept under cold storage condition ($P_2S_2$) from $15^{th}$ day to $24^{th}$ day respectively under cold storage.

The total soluble solids in papaya fruit pulp were mainly sugars, salts and organic acids. It was evident that, the TSS was increased progressively upto $6^{th}$ day of storage later it was decreased in untreated fruits kept under ambient conditions. However, the rate of increase in TSS was rapid in untreated fruits, which might be due to faster ripening and quicker hydrolysis of starch into simple sugars up to $6^{th}$ day of storage and high metabolism of fruit senescence process. Wills *et al*. (1980) reported that, TSS of the fruits was increased during ripening because the starch is hydrolysed to mono and disaccharides. The increase in evapo-transpiration losses from the surface of fruit is another reason for increased TSS (Bhullar and Farmahan, 1980). The gradual decline of TSS thereafter might be due to utilization of simple sugars initially in respiration and organic acids thereafter.

The hexanal treated fruits had showed the gradual increase in TSS at all storage intervals because of slow hydrolysis of starch. Additionally, the slower rate of increase in TSS under cold storage was attributed to lower temperature and high relative humidity had resulted in lower utilization of soluble solids during respiration. The slow hydrolysis of soluble solids in fruit had maintained the higher fruit firmness there by extend the shelf life of the fruits upto 24.67 days in $P_2S_2$ treatment. Similar results were reported by Baltazari *et al*. (2018) in sweet orange, Venkatachalam *et al*. (2017), Hutchinson (2018) in papaya, Koua *et al*. (2023) in papaya, Ashitha (2019) in guava, Muthuvel *et al*. (2019) in banana, Gunasekera *et al*. (2018) and Kaur *et al*. (2020) in mango.

**Titrable acidity (%)**

The data on titrable acidity in pulp of papaya fruits as influenced by application of preharvest spray and post-harvest dip of hexanal treatments, different storage conditions and their interaction was presented in table 2. Significant differences were noticed among the hexanal treatments, storage conditions and their interaction for titrable acitidity at all days of observations recorded except at $3^{rd}$ of storage. The data depicted showed a constant declining trend in titrable acidity in treated fruits with an advancement of the storage period.

The titrable acidity was highest (0.37, 0.35 and 0.31 at $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively) in pulp of papaya fruits treated with 2% hexanal as preharvest spray and post-harvest dip at all days of observations recorded ($P_2$) treatment followed by 2% hexanal post-harvest dip ($P_3$) treatment (0.33, 0.29 and 0.26 at $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively). The minimum (0.31, 0.26 and 0.18 at $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively) titrable acidity was recorded in untreated fruits ($P_4$).

The titrable acidity was maximum (0.36, 0.33 and 0.29 at $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively) in fruits stored under cold storage (13℃) conditions ($S_2$) as compared to the titrable acidity (0.30, 0.26 and 0.21 at $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively) recorded in fruits under ambient conditions.

The interaction between the treatments and storage conditions was found significant for titrable acidity in pulp of papaya fruits. The highest (0.41, 0.39 and 0.37 at $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively) titrable acidity was noticed in fruits treated with 2% hexanal as preharvest spray and post-harvest dip and kept under cold storage condition ($P_2S_2$) followed by 2% hexanal post-harvest dip under cold storage ($P_3S_2$) (0.36, 0.33 and 0.30 at $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively). The least titrable acidity (0.29 and 0.23 at $6^{th}$ and $9^{th}$ day of storage respectively) was found in fruits treated with 2% hexanal preharvest sprays and kept under ambient storage condition ($P_1S_1$) at $6^{th}$ and $9^{th}$ day of storage and further it was least (0.17) at $12^{th}$ day of storage in untreated fruits kept under ambient condition ($P_4S_1$).

The titrable acidity of fruits varied from 0.35 to 0.18 in case of in fruits treated with 2% hexanal pre harvest spray and post-harvest dip treatment and kept under cold storage condition ($P_2S_2$) from $15^{th}$ day to $24^{th}$ day respectively under cold storage.

The titrable acidity of fruits was decreased significantly from $1^{st}$ day to $12^{th}$ day of storage in all the treatments. The acidity in fruits is an important factor in determining maturity. It is a measure of all aggregate acids and sum of all volatile and fixed acids. There was a gradual decline in the titrable acidity content of fruits with the progression of storage period (Pool *et al.*, 1972). The decline in titrable acidity during ripening and storage might be due to the utilization of organic acids as substrates in respiration process. This could also be further attributed to the conversion of acids into sugar and utilization of organic acids during respiration. Similar decrease in acidity content of fruits with increase in storage period and utilization of organic acids during respiration was also reported by Waskar and Nikam (1998).

In general, acid content in the papaya followed a declining trend throughout the storage period. The untreated fruits kept under ambient conditions had showed a rapid loss in titrable acidity could be attributed to the prevailing higher temperature and low humidity might have increased the respiration rate, it allowed the faster degradation of organic acids into sugars and utilization of acids during respiration. The hexanal treated fruits kept under cold storage ($13^0$C) condition had showed a gradual decline and maintains more acidity in fruits. This might be due to the decreased rate of metabolic activity at low temperatures might delayed ripening process (Jay, 1978) *i.e.* slow conversion of acids into sugars and might also due to low gaseous exchange from atmosphere to treated fruits The results obtained in the present study are in conformity with the observations of Anusuya (2016) and Kaur *et al*. (2020) in mango, Venkatachalam *et al*. (2017), Yumbya *et al*. (2018) and Muthuvel *et al*. (2019) in banana.

**Total sugars (%)**

The data showed significant differences with pre harvest spray and post-harvest treatments and their interaction on percentage of total sugars in papaya fruit. (Table 3). The data revealed that highest percentage of total sugars was recorded in untreated up to $6^{th}$ day of storage.

At $3^{rd}$ day of storage among hexanal treatments, the maximum (7.28) total sugars content was found in untreated fruit ($P_4$) and minimum (6.53) was found in combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$). Among storage conditions, the ambient stored fruits ($S_1$) obtained highest total sugars of (7.32) and cold stored fruits ($S_2$) recorded lowest total sugars (6.39). There were no significant differences between the interactions of treatment combination at $3^{rd}$ day of storage.

At $6^{th}$ day of storage, the highest total sugars content of 8.95 was found in untreated fruits ($P_4$) and least of 7.28 was found in combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$) which was on par with fruits treated in 2% hexanal post-harvest dip ($P_3$) (7.34). The fruits stored in ambient condition ($S_1$) recorded more total sugars (8.76) while, the cold stored fruits ($S_2$) obtained lowest total sugars (6.86) at $6^{th}$ day of storage. There were no significant differences between the interactions of treatment combination at $6^{th}$ day of storage.

At the $9^{th}$ day of storage, maximum percentage of total sugars (8.52) was recorded in combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$) followed by 2% hexanal post-harvest dip ($P_3$) (8.26), and minimum (7.85) was showed in untreated fruits ($P_4$). Among storage conditions, the ambient stored fruits ($S_1$) found highest (8.74) and fruits stored under cold storage ($S_2$) was recorded lowest total sugar content (7.66). With respect to the interaction between hexanal treatments and storage conditions, fruits treated with combined pre and post-harvest treatment of hexanal @ 2% under ambient storage condition ($P_2S_1$) recorded maximum total sugars (9.89) followed by fruits treated with 2% hexanal post-harvest dip untreated fruits stored under ambient storage condition ($P_3S_1$) (9.43) and minimum of 6.64 was noticed in untreated fruits stored under ambient storage condition ($P_4S_1$) at $9^{th}$ day of storage.

At $12^{th}$ day of storage, the maximum total sugars of 9.26 was observed in combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$) followed by 2% hexanal post-harvest dip ($P_3$) (8.91) whereas, minimum total sugars (6.95) were recorded in untreated fruit ($P_4$). There were no significant differences between the storage conditions at $12^{th}$ day of storage. Among the interactions with respect to all treated fruits the maximum total sugars of 10.55 were recorded in fruits treated with combined pre and post-harvest treatment of hexanal @ 2% under ambient storage condition ($P_2S_1$) followed by 2% hexanal post-harvest dip stored under ambient storage condition ($P_3S_1$) (10.03) while, no pre and post-harvest treatment stored under ambient condition ($P_4S_1$) was recorded minimum total sugars of (5.14) followed by fruits treated with 2% hexanal preharvest spray stored under ambient storage condition ($P_1S_1$) (7.26) at $12^{th}$ day of storage. The total sugars of fruits varied from 8.33 to 9.46 in case of fruits treated with 2% hexanal pre harvest spray and post-harvest dip treatment and kept under cold storage condition ($P_2S_2$) from $15^{th}$ day to $24^{th}$ day respectively under cold storage.

**Reducing sugars (%)**

The influence of 2% hexanal preharvest spray and post-harvest dip treatments, storage conditions and their interaction was found significant for percentage of reducing sugars in pulp of papaya fruit. (Table 4).

The highest (4.55 and 5.51 at $3^{rd}$ and $6^{th}$ day of storage respectively) percentage of reducing sugars were noticed in the pulp of untreated fruits ($P_4$) upto $6^{th}$ day storage, later it was gradually decreased at $9^{th}$ (4.66) and $12^{th}$ (4.23) day storage. The percent reducing sugars were gradually increased from $3^{rd}$ to

$12^{th}$ day of storage in all hexanal treated fruits in $P_2$ (4.18, 4.41, 5.23 and 5.67 at $3^{rd}$, $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively), $P_3$ (4.22, 4.60, 5.14 and 5.49 at $3^{rd}$, $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively) except in $P_1$ treatment at $12^{th}$ day of storage (4.08, 4.73, 5.05 and 4.66 at $3^{rd}$, $6^{th}$, $9^{th}$ and $12^{th}$ day of storage respectively).

The percentage reducing sugars were highest (4.62, 5.50 and 5.49 at $3^{rd}$, $6^{th}$ and $9^{th}$ day of storage respectively) in fruits kept under ambient conditions than fruits kept under cold storage ($13^0$C) condition (3.89, 4.12 and 4.55 at $3^{rd}$, $6^{th}$ and $9^{th}$ day of storage respectively).

The interaction between hexanal treatments and storage conditions was found significant for percent reducing sugars in pulp of papaya fruits. The percent reducing sugars were highest (5.13 and 6.58 at $3^{rd}$ and $6^{th}$ day of storage respectively) in pulp of untreated fruits kept under ambient conditions ($P_4S_1$) upto $6^{th}$ day storage later it was decreased at $9^{th}$ (4.21) and $12^{th}$ (3.12) day of storage.

The percent reducing sugars were lowest (3.73 and 3.89 at $3^{rd}$ and 6th day of storage respectively) in pulp of fruits treated with 2% hexanal as preharvest spray and post-harvest dip and kept under cold storage ($P_2S_2$) and highest (6.23 and 6.71 at $9^{th}$ and $12^{th}$ day of storage respectively) in the pulp of fruits treated with 2% hexanal as preharvest spray and post-harvest dip and kept under ambient ($P_2S_1$) conditions at $9^{th}$ and $12^{th}$ day of storage. The percent reducing sugars were gradually increased from $3^{rd}$ to $12^{th}$ day storage in $P_2S_2$ and $P_3S_2$ treatments.

**Non-reducing sugars (%)**

The data showed significant differences with pre harvest spray and post-harvest treatments and their interaction on percentage of non-reducing sugars in papaya fruit (Table 5). The data revealed that highest percentage of non-reducing sugar was recorded in untreated up to $6^{th}$ day of storage.

At $3^{rd}$ day of storage among hexanal treatments, the maximum non-reducing sugar content of 2.84% was found in $P_1$ and minimum (2.35) was found in combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$) followed by 2% hexanal post-harvest dip ($P_3$) (2.48). The fruits stored in ambient condition ($S_1$) recorded maximum non-reducing sugars (2.70) while, cold stored fruits ($S_2$) obtained lowest non-reducing sugars (2.50) at $3^{rd}$ day of storage. Among interactions, 2% hexanal preharvest spray stored under ambient condition ($P_1S_1$) recorded maximum non-reducing sugars (3.22) followed by untreated fruits under cold storage condition ($P_4S_2$) (2.95) and minimum (2.26) was recorded in pulp of fruits treated with 2% hexanal as preharvest spray and post-harvest dip and kept under cold storage ($P_2S_2$) at $3^{rd}$ day of storage.

At $6^{th}$ day of storage, the highest non-reducing sugar content of 3.45 was found in untreated fruits ($P_4$) and lowest of 2.74 was found in fruits treated in 2% hexanal post-harvest dip ($P_3$) followed by combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$) (2.87). The fruits stored in ambient condition ($S_1$) recorded maximum non-reducing sugars (3.26) while, cold stored fruits ($S_2$) obtained lowest non-reducing sugars (2.74) at $6^{th}$ day of storage. Whereas the interaction between the treatment showed that untreated fruits under ambient condition ($P_4S_1$) observed maximum non-reducing sugar (3.54) content followed by untreated fruits under cold condition ($P_4S_2$) (3.35) and minimum non-reducing sugars of 2.46 was recorded in fruits treated with 2% hexanal post-harvest dip under cold storage ($P_3S_2$) at $6^{th}$ day of storage.

At $9^{th}$ day of storage, maximum percentage of non-reducing sugars (3.29) was recorded in combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$) followed by untreated fruits ($P_4$) (3.19), and minimum (3.12) was showed in 2% hexanal post-harvest dip ($P_3$). Among storage conditions, the ambient stored fruits ($S_1$) found highest (3.25) and fruits stored under cold storage ($S_2$) was recorded lowest non-reducing sugar content (3.11). With respect to the interaction between hexanal treatments and storage conditions, untreated fruits stored under cold storage condition ($P_4S_2$) registered maximum non-reducing sugars (3.94) followed by fruits treated with combined pre and post-harvest treatment of hexanal @ 2% under ambient storage condition ($P_2S_1$) (3.66) and minimum of 2.43 was noticed in untreated under ambient storage ($P_4S_1$).

At $12^{th}$ day of storage, the maximum non-reducing sugars of 3.59 was observed in combined treatment of pre and post-harvest treatment @ 2% hexanal ($P_2$) followed by 2% hexanal post-harvest dip ($P_3$) (3.42) whereas, minimum non-reducing sugars (2.72) were recorded in untreated fruit ($P_4$). The cold stored fruits ($S_2$) showed highest non-reducing sugar of 3.24 while ambient stored fruits ($S_1$) had showed least non-reducing sugar of 3.14 at $12^{th}$ day of storage. Among the interactions with respect to all treated fruits the maximum non-reducing sugars of 3.84 was recorded in fruits treated with combined pre and post-harvest treatment of hexanal @ 2% under ambient storage condition ($P_2S_1$) followed by untreated fruits stored under cold storage condition ($P_4S_2$) (3.42) and no pre and post-harvest treatment stored under ambient condition ($P_4S_1$) was recorded minimum non-reducing sugar of (2.02) followed by fruits treated with 2% hexanal preharvest spray stored under ambient storage condition ($P_1S_1$) (3.01) at 12$^{th}$ day of storage.

The untreated fruits under ambient condition had exhibited rapid increase in total sugars, reducing sugars and non-reducing sugars (10.12, 6.58 and 3.54 respectively) upto 6$^{th}$ day of storage thereafter showed a decreasing trend (5.14, 3.12 and 2.02 respectively at 12$^{th}$ day of storage). It was evident from data recorded on TSS (9.47 °Brix at 3$^{rd}$ day of storage) content of fruits might be due to rapid hydrolysis of starch into sugars which accelerated the fruit ripening/senescence up to 6$^{th}$ day of storage as earlier reported by Devarakonda *et al.* (2020) in papaya. Arundathi *et al.* (2019) reported that the reduction in sugar content at the later stages of storage might be attributed to the complete utilisation of sugars in ripening process.

The per cent total, reducing and non-reducing sugars showed an increasing trend in pulp of fruits stored at cold temperatures upto 12$^{th}$ day storage, whereas in fruits stored at ambient temperatures exhibited an increasing trend upto 6$^{th}$ day of storage and decreasing trend at 9$^{th}$ and 12$^{th}$ day of storage. This might be due to slow down of respiration and other metabolic activities at low temperatures thereby reduced the utilization of the sugars in the process as indicated by the slowdown of change in peel colour.

It was evident that, the total, reducing and non-reducing sugars were increased gradually up to 12$^{th}$ day of storage in pulp of fruits treated with 2% hexanal as preharvest spray and post-harvest dip and kept under cold storage condition ($P_2S_2$). The slow increase in total sugars in fruit pulp was noticed due to slow rise in TSS (9.02°Brix) content of fruits and also might be due to slowdown of the activities of hydrolytic enzymes by suppression of ethylene production (Muthuvel *et al*., 2019; Paliyath and Subramanian, 2008; Yumbya *et al*., 2019). Similar findings were recorded by Shabina *et al*. (2019), Bharathi *et al.* (2021) in guava and Preethi *et al*. (2021) in mango.

## Ascorbic acid (mg 100g$^{-1}$)

The data on ascorbic acid content in papaya fruit pulp as influenced by the different hexanal treatments and storage conditions and their interaction effect was presented in the table 6. The ascorbic acid content in fruit pulp had showed a declining trend with an advancement of storage period.

The ascorbic acid content was maximum (86.36, 83.50, 79.39 and 73.70 at 3$^{rd}$, 6$^{th}$ , 9$^{th}$ and 12$^{th}$ day of storage respectively) in pulp of papaya fruits treated with 2% hexanal as preharvest spray and post-harvest dip treatment ($P_2$) at all the days of observations recorded. It was on par with 2% hexanal post-harvest dip ($P_3$) treatment at all the days of observations recorded (84.84, 80.21, 76.65 and 72.02 at 3$^{rd}$, 6$^{th}$, 9$^{th}$ and 12$^{th}$ day of storage respectively). The lowest (81.82, 76.48, 72.43 and 63.91 at 3$^{rd}$, 6$^{th}$, 9$^{th}$ and 12$^{th}$ day of storage respectively) ascorbic acid content was noticed in pulp of untreated papaya fruits at all the days of observations recorded.

The ascorbic acid content was significantly maximum (82.97, 81.60 and 76.44 at 6$^{th}$, 9$^{th}$ and 12$^{th}$ days of storage respectively) in pulp of papaya fruits kept under cold storage than papaya fruits kept under ambient (77.19, 70.56 and 63.69 at 6$^{th}$, 9$^{th}$ and 12$^{th}$ days of storage respectively) conditions at all storage intervals except at 3$^{rd}$ day of storage.

The interaction between hexanal treatments and storage conditions was found significant for ascorbic acid content in pulp of papaya fruits at 9$^{th}$ and 12$^{th}$ day of storage. The ascorbic acid content was highest (84.81 and 81.12 at 9$^{th}$ and 12$^{th}$ days of storage respectively) in pulp of papaya fruits treated with 2% hexanal as preharvest spray and post-harvest dip and kept under cold storage ($P_2S_2$). The ascorbic acid content was lowest (68.53 and 60.12 at 9$^{th}$ and 12$^{th}$ days of storage respectively) in pulp of untreated papaya fruits kept under ambient conditions ($P_4S_1$).

Ascorbic acid is the most abundant water-soluble antioxidant present in plants and protecting from oxidative damage. Ascorbic acid is essential for human health, and in order to survive human beings healthy must obtain this, through their diet primarily from fresh fruits and vegetables. In this experiment, there was a gradual decline in the ascorbic acid content in the pulp of papaya fruits during storage period irrespective of the treatments. An initial increase in ascorbic acid could be due to availability of fruit sugar, a precursor of ascorbic acid synthesis but during later stages, the oxidative destruction of ascorbic acid into dehydroascorbic acid by oxidase enzyme might have contributed to decrease in ascorbic acid (Mapson, 1970). The ascorbic acid content was gradually declined in fruits treated with 2% hexanal as preharvest spray + post-harvest dip and kept under cold storage conditions could be due to decreased oxidation during storage (Hutchinson *et al.*, 2018, Koua *et al.*, 2023 in papaya) and also might be due to control of fruit ripening by decreasing the production of ethyelene as well as reactive oxygen species. The results are in conformity with the observations of Yumbya (2018) and Muthuvel *et al*. (2019) in banana and Kaur *et al*. (2020) in mango.

**Carotenoid content (mg 100g$^{-1}$)**

The data on carotenoid content in pulp of papaya fruits as influenced by 2% hexanal as pre harvest sprays and post-harvest dip, storage conditions and their interaction was presented in the table 7.

The carotenoid content in pulp of papaya fruit was gradually increased from 3$^{rd}$ to 12$^{th}$ day of storage in all the treatments except in untreated fruits at 12$^{th}$ day of storage. There were no significant differences were found between the hexanal treatments, storage conditions and their interactions at 3$^{rd}$ day of storage. The carotenoid content was significantly maximum (1.64, 1.73 at 6$^{th}$ and 9$^{th}$ day of storage respectively) in pulp of untreated fruits ($P_4$) and 2% hexanal as combined pre and post-harvest treatment ($P_2$) at 12$^{th}$ day storage (1.77). The carotenoid content in fruits was lowest (1.54) ($P_3$) at 6$^{th}$ day 2 and 1.65 ($P_1$) 9$^{th}$ day of storage and ($P_4$) at 12$^{th}$ day of storage (1.71).The carotenoid content was more (1.70 and 1.76 at 9$^{th}$ and 12$^{th}$ day of storage respectively) in fruits kept under ambient conditions ($S_1$) than fruits kept under cold storage ($S_2$) (1.66 and 1.72 at 9$^{th}$ and 12$^{th}$ day of storage respectively) condition.

The interaction between hexanal treatments and storage conditions was found significant for carotenoid content in pulp of papaya fruits at all days of observations recorded except at 3$^{rd}$ day of storage. The carotenoid content in pulp of papaya fruits was highest in untreated fruits kept under cold storage conditions ($P_4S_2$) at 6$^{th}$ (1.65) and 9$^{th}$ (1.78) and in pulp of fruits treated with 2% hexanal as preharvest spray and post-harvest dip and kept under ambient conditions ($P_2S_1$) at 12$^{th}$ (1.85) day of storage. The carotenoid content was lowest in pulp of papaya fruits treated with 2% hexanal as post-harvest dip and kept under ambient condition ($P_3S_1$) and $P_1S_2$ treatments at 6$^{th}$ day (1.52), $P_3S_2$ at 9$^{th}$ day (1.61) and $P_4S_1$ treatment at 12$^{th}$ day (1.62) of storage.

Carotenoids are natural organic pigments and lipophilic compounds found in the chromoplasts of flowering plant kingdom and are important parameters in imparting attractive colours such as yellow, orange and red (Da silva *et al.*, 2014). In the present investigation, rapid and maximum increase in β-carotene content was observed in untreated fruits up to 9$^{th}$ day of storage. This might be due to production of more ethylene which led to activate chlorophyllase enzyme which results in rapid degradation of chlorophyll thereby change the peel and pulp colour by formation and accumulation of carotenoid pigments during fruit ripening.

The preharvest spray and post-harvest dip of fruits in 2% hexanal and kept under cold storage had delayed the fruit ripening which resulted in lower increment of carotenoid content in fruit pulp during storage, but at the end of 12$^{th}$ day of storage, hexanal treated fruits were able to maintain higher β-carotene content than untreated fruits. The untreated fruits were unable to retain the β-carotene content in the present study might be due to isomerization and oxidative degradation. The more availability of oxygen and light might stimulate the enzymes, metals and co-oxidation by lipid hydroperoxide (Mercadante and Rodriguez, 1998). The rapid decrease in carotenoid content in untreated fruits might be due to lack of protection from oxidative degradation which was provided by hexanal in treated fruits. The present study was in concordance with Hutchinson *et al*. (2022) in papaya and Preethi *et al*. (2021) in mango.

The concentration of carotenoids improves as the temperature decreases and declines as light intensity increases. Factors that influence the accumulations of water and fruit dry matter have been reported to impact on the biochemical attributes, especially ascorbic acid accumulation in fruits. The changes observed in the mango fruits were positively correlated with the total carotenoids, and respectively increased with ripening (Mercadante and Rodriguez, 1998). The papaya fruits subjected to hexanal formulation spray attained significant colour development due to the presence of hexanal. Though hexanal is known for its characteristic retention of green colour in many fruits, data evidenced a positive acceleration of carotenoid synthesis in the sprayed fruits, while this was unseen in the untreated control fruits. Thus, the experiment confirmed the impact of the hexanal formulation on papaya fruits in terms of enhancing their storage life and fruit quality. The present study is in concordance with Hutchinson *et al*. (2022) in papaya and Preethi *et al*. (2021) in mango.

**Table 1 :** Effect of hexanal and storage conditions on total soluble solids (°Brix) of papaya cv. Red Lady.

| Hexanal (P) | Storage conditions (S) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd day | | | 6th day | | | 9th day | | | 12th day | | |
| | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) |
| $P_1$ | 9.23 | 8.20 | **8.72** | 10.60 | 8.67 | **9.64** | 12.25 | 9.15 | **10.70** | 10.02 | 9.76 | **9.89** |
| $P_2$ | 9.00 | 8.12 | **8.56** | 10.06 | 8.32 | **9.19** | 12.51 | 8.79 | **10.65** | 12.91 | 9.02 | **10.97** |
| $P_3$ | 9.08 | 8.36 | **8.72** | 10.14 | 8.81 | **9.48** | 12.06 | 9.06 | **10.56** | 12.54 | 9.65 | **11.10** |
| $P_4$ | 10.13 | 8.80 | **9.47** | 12.20 | 8.98 | **10.59** | 10.45 | 9.36 | **9.91** | 8.37 | 10.80 | **9.59** |
| **Mean of (S)** | **9.36** | **8.37** | | **10.75** | **8.70** | | **11.82** | **9.09** | | **10.96** | **9.81** | |
| **Factors** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** |
| **Hexanal (P)** | 0.08 | | 0.25 | 0.12 | | 0.35 | 0.11 | | 0.32 | 0.10 | | 0.31 |
| **Storage (S)** | 0.06 | | 0.18 | 0.08 | | 0.25 | 0.08 | | 0.23 | 0.07 | | 0.22 |
| **P x S** | 0.12 | | NS | 0.17 | | 0.50 | 0.15 | | 0.45 | 0.15 | | 0.44 |

| Hexanal (P) | 15th day | | 18th day | | 21st day | | 24th day+ 2 days | |
|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ |
| $P_1$ | * | 10.05 | * | 11.14 | * | * | * | * |
| $P_2$ | * | 9.80 | * | 11.05 | * | 11.68 | * | 12.43 |
| $P_3$ | * | 10.12 | * | 10.56 | * | * | * | * |
| $P_4$ | * | * | * | * | * | * | * | * |

**Fruit total soluble solids at harvest: $P_1$ (7.63), $P_2$ (7.73), $P_3$ (7.52) and $P_4$ (7.48)**

***Indicates termination of storage**

$P_1$: 2% hexanal pre harvest spray at 120 days after fruit set

$P_2$: 2% hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip

$P_3$: 2% hexanal post-harvest dip

$P_4$: No pre harvest spray and no post-harvest dip

$S_1$: Ambient storage

$S_2$: Cold storage (13°C)

**Table 2 :** Effect of hexanal and storage conditions on titrable acidity (%) of papaya cv. Red Lady.

| Hexanal (P) | Storage conditions (S) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd day | | | 6th day | | | 9th day | | | 12th day | | |
| | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) |
| $P_1$ | 0.33 (1.15) | 0.38 (1.18) | **0.36 (1.16)** | 0.29 (1.14) | 0.35 (1.16) | **0.32 (1.15)** | 0.23 (1.11) | 0.32 (1.15) | **0.28 (1.13)** | 0.20 (1.10) | 0.29 (1.14) | **0.25 (1.12)** |
| $P_2$ | 0.35 (1.16) | 0.43 (1.20) | **0.39 (1.18)** | 0.33 (1.15) | 0.41 (1.19) | **0.37 (1.17)** | 0.30 (1.14) | 0.39 (1.18) | **0.35 (1.16)** | 0.25 (1.12) | 0.37 (1.17) | **0.31 (1.14)** |
| $P_3$ | 0.36 (1.17) | 0.38 (1.17) | **0.37 (1.17)** | 0.29 (1.14) | 0.36 (1.17) | **0.33 (1.15)** | 0.25 (1.12) | 0.33 (1.15) | **0.29 (1.14)** | 0.21 (1.10) | 0.30 (1.14) | **0.26 (1.12)** |
| $P_4$ | 0.36 (1.17) | 0.37 (1.17) | **0.37 (1.17)** | 0.30 (1.14) | 0.32 (1.15) | **0.31 (1.14)** | 0.26 (1.12) | 0.25 (1.12) | **0.26 (1.12)** | 0.17 (1.08) | 0.18 (1.09) | **0.18 (1.08)** |
| **Mean of (S)** | **0.35 (1.16)** | **0.39 (1.18)** | | **0.30 (1.14)** | **0.36 (1.17)** | | **0.26 (1.12)** | **0.33 (1.15)** | | **0.21 (1.10)** | **0.29 (1.13)** | |
| **Factors** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** |
| **Hexanal (P)** | 0.008 | | NS | 0.002 | | 0.005 | 0.002 | | 0.005 | 0.001 | | 0.002 |
| **Storage (S)** | 0.006 | | NS | 0.001 | | 0.004 | 0.001 | | 0.004 | 0.001 | | 0.002 |
| **P x S** | 0.012 | | NS | 0.002 | | 0.007 | 0.002 | | 0.007 | 0.001 | | 0.003 |

| Hexanal (P) | 15th day | | 18th day | | 21st day | | 24th day+ 2 days | |
|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ |
| $P_1$ | * | 0.26 | * | 0.19 | * | * | * | * |
| $P_2$ | * | 0.35 | * | 0.27 | * | 0.21 | * | 0.18 |
| $P_3$ | * | 0.27 | * | 0.20 | * | * | * | * |
| $P_4$ | * | * | * | * | * | * | * | * |

**Fruit titrable acidity at harvest: $P_1$ (0.47), $P_2$ (0.46), $P_3$ (0.41) and $P_4$ (0.40)**

*** Indicates termination of storage,**

**Figures in parenthesis are square root transformation values**

$P_1$: 2% hexanal pre harvest spray at 120 days after fruit set

$P_2$: 2% hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip

$P_3$: 2% hexanal post-harvest dip

$P_4$: No pre harvest spray and no post-harvest dip

$S_1$: Ambient storage

$S_2$: Cold storage (13°C)

**Table 3 :** Effect of hexanal and storage conditions on total sugars (%) of papaya cv. Red Lady.

| Hexanal (P) | Storage conditions (S) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd day | | | 6th day | | | 9th day | | | 12th day | | |
| | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) |
| $P_1$ | 7.41 (2.90) | 6.42 (2.72) | **6.92 (2.81)** | 8.59 (3.10) | 6.74 (2.78) | **7.67 (2.94)** | 9.01 (3.16) | 7.34 (2.89) | **8.18 (3.03)** | 7.26 (2.87) | 8.11 (3.02) | **7.69 (2.95)** |
| $P_2$ | 7.06 (2.84) | 5.99 (2.64) | **6.53 (2.74)** | 8.13 (3.02) | 6.42 (2.72) | **7.28 (2.87)** | 9.89 (3.30) | 7.15 (2.86) | **8.52 (3.08)** | 10.55 (3.40) | 7.96 (2.99) | **9.26 (3.20)** |
| $P_3$ | 7.16 (2.86) | 6.22 (2.69) | **6.69 (2.77)** | 8.19 (3.03) | 6.49 (2.74) | **7.34 (2.88)** | 9.43 (3.23) | 7.08 (2.84) | **8.26 (3.04)** | 10.03 (3.32) | 7.78 (2.96) | **8.91 (3.14)** |
| $P_4$ | 7.64 (2.94) | 6.92 (2.81) | **7.28 (2.88)** | 10.12 (3.33) | 7.78 (2.96) | **8.95 (3.15)** | 6.64 (2.76) | 9.05 (3.17) | **7.85 (2.97)** | 5.14 (2.48) | 8.75 (3.12) | **6.95 (2.80)** |
| **Mean of (S)** | **7.32 (2.88)** | **6.39 (2.72)** | | **8.76 (3.12)** | **6.86 (2.80)** | | **8.74 (3.11)** | **7.66 (2.94)** | | **8.25 (3.02)** | **8.15 (3.02)** | |
| **Factors** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** |
| **Hexanal (P)** | 0.022 | | 0.068 | 0.019 | | 0.059 | 0.014 | | 0.044 | 0.017 | | 0.051 |
| **Storage (S)** | 0.016 | | 0.048 | 0.014 | | 0.041 | 0.010 | | 0.031 | 0.012 | | NS |
| **P x S** | 0.032 | | NS | 0.027 | | NS | 0.020 | | 0.062 | 0.024 | | 0.072 |

| Hexanal (P) | 15th day | | 18th day | | 21st day | | 24th day+ 2 days | |
|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ |
| $P_1$ | * | 8.32 | * | 9.09 | * | * | * | * |
| $P_2$ | * | 8.33 | * | 8.85 | * | 9.17 | * | 9.46 |
| $P_3$ | * | 8.54 | * | 8.38 | * | * | * | * |
| $P_4$ | * | * | * | * | * | * | * | * |

**Fruit total sugars at harvest: $P_1$ (6.05), $P_2$ (5.94), $P_3$ (5.85) and $P_4$ (5.82)**

*** Indicates termination of storage,** **Figures in parenthesis are square root transformation values**

$P_1$: 2% hexanal pre harvest spray at 120 days after fruit set $S_1$: Ambient storage

$P_2$: 2% hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip $S_2$: Cold storage (13°C)

$P_3$: 2% hexanal post-harvest dip

$P_{4:}$ No pre harvest spray and no post-harvest dip.

**Table 4 :** Effect of hexanal and storage conditions on reducing sugars (%) of papaya cv. Red Lady.

| Hexanal (P) | Storage conditions (S) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd day | | | 6th day | | | 9th day | | | 12th day | | |
| | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) |
| $P_1$ | 4.19 (2.28) | 3.96 (2.23) | **4.08 (2.25)** | 5.34 (2.52) | 4.12 (2.26) | **4.73 (2.39)** | 5.62 (2.57) | 4.47 (2.34) | **5.05 (2.46)** | 4.25 (2.29) | 5.06 (2.46) | **4.66 (2.38)** |
| $P_2$ | 4.63 (2.37) | 3.73 (2.18) | **4.18 (2.27)** | 4.92 (2.43) | 3.89 (2.21) | **4.41 (2.32)** | 6.23 (2.69) | 4.23 (2.29) | **5.23 (2.49)** | 6.71 (2.78) | 4.63 (2.37) | **5.67 (2.58)** |
| $P_3$ | 4.54 (2.35) | 3.89 (2.21) | **4.22 (2.28)** | 5.17 (2.48) | 4.03 (2.24) | **4.60 (2.36)** | 5.91 (2.63) | 4.37 (2.32) | **5.14 (2.47)** | 6.36 (2.71) | 4.62 (2.37) | **5.49 (2.54)** |
| $P_4$ | 5.13 (2.48) | 3.97 (2.23) | **4.55 (2.35)** | 6.58 (2.75) | 4.43 (2.33) | **5.51 (2.54)** | 4.21 (2.28) | 5.11 (2.47) | **4.66 (2.38)** | 3.12 (2.03) | 5.33 (2.52) | **4.23 (2.27)** |
| **Mean of (S)** | **4.62 (2.37)** | **3.89 (2.21)** | | **5.50 (2.55)** | **4.12 (2.26)** | | **5.49 (2.54)** | **4.55 (2.35)** | | **5.11 (2.45)** | **4.91 (2.43)** | |
| **Factors** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** |
| **Hexanal (P)** | 0.009 | | 0.028 | 0.013 | | 0.038 | 0.009 | | 0.028 | 0.013 | | 0.039 |
| **Storage (S)** | 0.007 | | 0.020 | 0.009 | | 0.027 | 0.007 | | 0.020 | 0.009 | | NS |
| **P x S** | 0.013 | | 0.040 | 0.018 | | 0.054 | 0.013 | | 0.040 | 0.018 | | 0.055 |

| Hexanal (P) | 15th day | | 18th day | | 21st day | | 24th day+ 2 days | |
|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ |
| $P_1$ | * | 5.11 | * | 5.56 | * | * | * | * |
| $P_2$ | * | 4.81 | * | 5.19 | * | 5.43 | * | 5.56 |
| $P_3$ | * | 5.19 | * | 5.32 | * | * | * | * |
| $P_4$ | * | * | * | * | * | * | * | * |

**Fruit reducing sugars at harvest: $P_1$ (3.78), $P_2$ (3.62), $P_3$ (3.55) and $P_4$ (3.57)**

*** Indicates termination of storage,** **Figures in parenthesis are square root transformation values**

$P_1$: 2% hexanal pre harvest spray at 120 days after fruit set $S_1$: Ambient storage

$P_2$: 2% hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip $S_2$: Cold storage (13°C)

$P_3$: 2% hexanal post-harvest dip

$P_{4:}$ No pre harvest spray and no post-harvest dip.

**Table 5 :** Effect of hexanal and storage conditions on non-reducing sugars (%) of papaya cv. Red Lady.

| Hexanal (P) | Storage conditions (S) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd day | | | 6th day | | | 9th day | | | 12th day | | |
| | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) |
| **$P_1$** | 3.22 (2.05) | 2.46 (1.86) | **2.84 (1.96)** | 3.25 (2.06) | 2.62 (1.90) | **2.94 (1.98)** | 3.39 (2.10) | 2.87 (1.97) | **3.13 (2.03)** | 3.01 (2.00) | 3.05 (2.01) | **3.03 (2.01)** |
| **$P_2$** | 2.43 (1.95) | 2.26 (1.81) | **2.35 (1.83)** | 3.21 (2.05) | 2.53 (1.88) | **2.87 (1.97)** | 3.66 (2.16) | 2.92 (1.98) | **3.29 (2.07)** | 3.84 (2.20) | 3.33 (2.08) | **3.59 (2.14)** |
| **$P_3$** | 2.62 (1.90) | 2.33 (1.83) | **2.48 (1.86)** | 3.02 (2.01) | 2.46 (1.86) | **2.74 (1.93)** | 3.52 (2.13) | 2.71 (1.93) | **3.12 (2.03)** | 3.67 (2.16) | 3.16 (2.04) | **3.42 (2.10)** |
| **$P_4$** | 2.51 (1.87) | 2.95 (1.99) | **2.73 (1.93)** | 3.54 (2.13) | 3.35 (2.09) | **3.45 (2.11)** | 2.43 (1.85) | 3.94 (2.22) | **3.19 (2.04)** | 2.02 (1.74) | 3.42 (2.10) | **2.72 (1.92)** |
| **Mean of (S)** | **2.70 (1.92)** | **2.50 (1.87)** | | **3.26 (2.06)** | **2.74 (1.93)** | | **3.25 (2.06)** | **3.11 (2.02)** | | **3.14 (2.03)** | **3.24 (2.06)** | |
| **Factors** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** |
| **Hexanal (P)** | 0.012 | | 0.025 | 0.007 | | 0.023 | 0.004 | | 0.013 | 0.007 | | 0.022 |
| **Storage (S)** | 0.006 | | 0.017 | 0.005 | | 0.016 | 0.003 | | 0.009 | 0.005 | | 0.015 |
| **P x S** | 0.012 | | 0.035 | 0.011 | | 0.032 | 0.006 | | 0.018 | 0.010 | | 0.031 |

| Hexanal (P) | 15th day | | 18th day | | 21st day | | 24th day+ 2 days | |
|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ |
| **$P_1$** | * | 3.21 | * | 3.53 | * | * | * | * |
| **$P_2$** | * | 3.52 | * | 3.66 | * | 3.74 | * | 3.90 |
| **$P_3$** | * | 3.35 | * | 3.06 | * | * | * | * |
| **$P_4$** | * | * | * | * | * | * | * | * |

**Fruit non reducing sugars at harvest: $P_1$ (2.47), $P_2$ (2.51), $P_3$ (1.29) and $P_4$ (2.24)**

*** Indicates termination of storage,** **Figures in parenthesis are square root transformation values**

$P_1$: 2% hexanal pre harvest spray at 120 days after fruit set; $S_1$: Ambient storage

$P_2$: 2% hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip; $S_2$: Cold storage (13°C)

$P_3$: 2% hexanal post-harvest dip

$P_4$: No pre harvest spray and no post-harvest dip.

**Table 6 :** Effect of hexanal and storage conditions on ascorbic acid content (mg $100g^{-1}$) of papaya cv. Red Lady.

| Hexanal (P) | Storage conditions (S) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd day | | | 6th day | | | 9th day | | | 12th day | | |
| | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) |
| **$P_1$** | 83.29 | 85.58 | **84.44** | 76.03 | 84.26 | **80.15** | 68.75 | 83.16 | **75.94** | 64.00 | 77.27 | **70.64** |
| **$P_2$** | 85.73 | 86.99 | **86.36** | 81.57 | 85.42 | **83.50** | 73.97 | 84.81 | **79.39** | 66.27 | 81.12 | **73.70** |
| **$P_3$** | 84.58 | 85.09 | **84.84** | 76.31 | 84.11 | **80.21** | 71.22 | 82.09 | **76.65** | 64.38 | 79.66 | **72.02** |
| **$P_4$** | 81.46 | 82.17 | **81.82** | 74.86 | 78.09 | **76.48** | 68.53 | 76.32 | **72.43** | 60.12 | 67.69 | **63.91** |
| **Mean of (S)** | **83.77** | **84.96** | | **77.19** | **82.97** | | **70.56** | **81.60** | | **63.69** | **76.44** | |
| **Factors** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** |
| **Hexanal (P)** | 0.80 | | 2.41 | 0.98 | | 2.95 | 0.89 | | 2.68 | 0.87 | | 2.60 |
| **Storage (S)** | 0.57 | | NS | 0.70 | | 2.09 | 0.63 | | 1.90 | 0.61 | | 1.84 |
| **P x S** | 1.14 | | NS | 1.39 | | NS | 1.26 | | 3.79 | 1.22 | | 3.67 |

| Hexanal (P) | 15th day | | 18th day | | 21st day | | 24th day+ 2 days | |
|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ |
| **$P_1$** | * | 70.76 | * | 62.51 | * | * | * | * |
| **$P_2$** | * | 73.52 | * | 66.22 | * | 63.14 | * | 61.35 |
| **$P_3$** | * | 70.78 | * | 62.14 | * | * | * | * |
| **$P_4$** | * | * | * | * | * | * | * | * |

**Fruit ascorbic acid content at harvest: $P_1$ (90.10), $P_2$ (89.45), $P_3$ (92.76) and $P_4$ (93.56)**

*** Indicates termination of storage**

$P_1$: 2% hexanal pre harvest spray at 120 days after fruit set; $S_1$: Ambient storage

$P_2$: 2% hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip; $S_2$: Cold storage (13°C)

$P_3$: 2% hexanal post-harvest dip

$P_4$: No pre harvest spray and no post-harvest dip.

**Table 7 :** Effect of hexanal and storage conditions on carotenoids content (mg $100g^{-1}$) of papaya cv. Red Lady.

| Hexanal (P) | Storage conditions (S) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd day | | | 6th day | | | 9th day | | | 12th day | | |
| | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) | $S_1$ | $S_2$ | Mean of (P) |
| $P_1$ | 1.45 | 1.43 | **1.44** | 1.60 | 1.52 | **1.56** | 1.70 | 1.60 | **1.65** | 1.76 | 1.70 | **1.73** |
| $P_2$ | 1.48 | 1.52 | **1.50** | 1.59 | 1.58 | **1.59** | 1.72 | 1.64 | **1.68** | 1.85 | 1.69 | **1.77** |
| $P_3$ | 1.44 | 1.41 | **1.43** | 1.52 | 1.56 | **1.54** | 1.71 | 1.61 | **1.66** | 1.79 | 1.68 | **1.74** |
| $P_4$ | 1.52 | 1.51 | **1.52** | 1.63 | 1.65 | **1.64** | 1.68 | 1.78 | **1.73** | 1.62 | 1.8 | **1.71** |
| **Mean of (S)** | **1.47** | **1.47** | | **1.59** | **1.58** | | **1.70** | **1.66** | | **1.76** | **1.72** | |
| **Factors** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** | **S Em ±** | | **CD at 5%** |
| **Hexanal (P)** | 0.03 | | NS | 0.02 | | 0.06 | 0.01 | | 0.04 | 0.01 | | 0.04 |
| **Storage (S)** | 0.02 | | NS | 0.01 | | NS | 0.01 | | 0.03 | 0.01 | | 0.03 |
| **P x S** | 0.04 | | NS | 0.03 | | 0.08 | 0.02 | | 0.05 | 0.02 | | 0.06 |

| Hexanal (P) | 15th day | | 18th day | | 21st day | | 24th day+ 2 days | |
|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ |
| $P_1$ | * | 1.82 | * | 1.84 | * | * | * | * |
| $P_2$ | * | 1.73 | * | 1.79 | * | 1.83 | * | 1.85 |
| $P_3$ | * | 1.74 | * | 1.81 | * | * | * | * |
| $P_4$ | * | * | * | * | * | * | * | * |

**Fruit carotenoid content at harvest: $P_1$ (1.38), $P_2$ (1.37), $P_3$ (1.40) and $P_4$ (1.42)**
*** Indicates termination of storage**

$P_1$: 2% hexanal pre harvest spray at 120 days after fruit set
$P_2$: 2% hexanal pre harvest spray at 120 days after fruit set + 2% hexanal post-harvest dip
$P_3$: 2% hexanal post-harvest dip
$P_4$: No pre harvest spray and no post-harvest dip.

$S_1$: Ambient storage
$S_2$: Cold storage (13°C)

## Conclusion

The present study illustrated the relative efficacy of 2% hexanal as preharvest sprays and post-harvest dips at different storage temperatures. Treatments post-harvest dip @2% hexanal and cold storage temperature (13°C) were more effective than preharvest sprays and ambient storage. While their combined pre and postharvest treatment of hexanal @ 2% under cold storage condition further increased their efficiency leading to delayed post-harvest changes which improved biochemical quality parameters.

### Competing Interests

Authors have declared that no competing interests exist.

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