**Effect of Oxalic Acid on Sensory Evaluation of ‘Gola’ Ber (Ziziphus mauritiana Lamk.) Fruit during Storage**

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**A B S T R A C T**

Highly perishable postharvest life of ber fruit is major hindrance towards long storage. Exogenous treatments are essential for delayed or inhibited physiological degrading process which curbs the fruit quality. Hence, a study was designed to evaluate the oxalic acid (OA) treatments effectivity on ber fruit cv. ‘Gola’ during storage. Prior to storage fruits were subjected to 10 min dipping in aqueous solution of oxalic acid at different concentrations (2 mM, 4 mM, 6 mM, 8 mM and 10 mM). Fruits under control were survived only for 5 days and with 2 mM oxalic acid for 7 days. Whereas, shelf life was extended up to 9 days with other concentrations of oxalic acid. In dipping treatment for 10 min at ambient temperature with 10 mM oxalic acid the color coordinate $L^*$, chroma (CIE $C^*$) of ber fruits increased and hue angle (CIE $h^*$) of ber fruits decreased with the advancement of storage time during the entire period of experiment. Sensory evaluation of ber fruit cv. ‘Gola’ was significantly affected by 10 mM OA. Texture, flavor, taste and overall acceptability were registered with significantly highest scores in fruits treated with 10 mM OA.

**Keywords**

Ber fruit, Oxalic acid, Postharvest storage, Sensory evaluation

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**Introduction**

Ber (*Ziziphus mauritiana* Lamk.) is an important fruit of arid and semi-arid regions. Native place of *Z. mauritiana* is central Asia (Morton, 1987). It belongs to the *Rhamnaceae* family. Ber fruit is very perishable during storage at room temperature due to rapid ripening and high susceptibility. Fresh ber fruits deteriorate fast and cannot be kept for more than 5 days under ambient conditions without serious deterioration (Kadam *et al.*, 1993), even though some improved cultivars in India are known to store for up to 15 days without loss of organoleptic quality (Pareek, 2001).

Ber fruits are very nutritious and usually eaten fresh. It is considered to be the ‘poor man’s apple’ which contains good quantities of vitamins, minerals and sugar (Pareek, 1997). Fruits are also eaten in other forms, such as dried, candied, pickled, as juice, or as ber butter (Maydell, 1986). Ber pulp contains 12–23 per cent TSS, 0.13–1.42 per cent acidity, 3.1–14.5 per cent total sugars, 1.4–9.7 per cent reducing sugars, 5.6 per cent sucrose, 1.5 per cent glucose, 2.1 per cent fructose and 1.0 per...
cent starch (Ghosh and Mathew, 2002). Ber pulp contains several bioactive phytochemicals such as phenolic acids, amino acids, phosphorus, calcium, iron, carbohydrates, ascorbic acid, and vitamins A and C (Memon et al., 2012). Jawanda and Bal (1978) reported that ascorbic acid content in different ber cultivars ranged from 39-166 mg 100g⁻¹ of pulp.

Oxalic acid (OA), as an organic acid, is distributed widely in plants, fungi and animals, and plays different roles in different living organisms (Shimada et al., 1997). It has been found in potatoes, beans, spinach, beets, tomatoes, cauliflower, onions, mushrooms, and celery root, among the vegetables and in currants, raspberries, grapes, pears and prunes, among the fruits (Anonymous, 1984). OA might play important roles in systemic resistance, stress response, programmed cell death and redox homeostasis in plant (Kim et al., 2008).

Materials and Methods

The experiment was carried out at the Department of Horticulture, Rajasthan College of Agriculture, Udaipur. The fruit were selected for uniformity of size and appearance, and blemished and diseased fruit were discarded. Fruits were sorted as per maturity and external colour. Approximate 1.5 kg fruits were taken for per treatment per replication and taken five litter distilled water in five containers and added oxalic acid at a concentration of T₂ (2 mM), T₃ (4 mM), T₄ (6 mM), T₅ (8 mM), T₆ (10 mM) and then dipped the ber fruit in solution at 20°C for 10 minutes and Dipped the ber fruits in distilled water as control (T₁) for 10 minutes at 20°C. The fruits of each treatment were replicated four times. After dip treatments, fruit were dried at room temperature using portable fan. The treated fruits were stored at ambient temperature for 9 days in the room storage and sampled periodically to analyse various physiological and biochemical characteristics. Observations on sensory evaluation were carried out at every 48 hours interval for colour, Texture, flavour, taste and overall acceptability.

**Color measurement (CIE color coordinates, chroma and hue)**

Changes in $L^*$, $a^*$, $b^*$ color co-ordinates on the Hunter scale were measured with Hunter Color Flex (Hunter Lab Color Flex, Hunter Associates Laboratory Inc., Reston, VA, USA) according to Nielsen and Kappel (1996).

The surface color of fruit was measured on Hunter Lab Colorimeter, with reflectance mode (RSIN), CIE Lab scale ($L^*$, $a^*$ and $b^*$), D65 as illuminant and a 10° observer angle as a reference system. Instruments was calibrated with white ceramic tile and black tile and standardized.

Sampling was carried out by loading the quartz cuvettes with fruit sample. The loaded cuvettes were exposed to the aperture and reading were recorded with inbuilt software (Easy Match QC Software) using a xenon light source under double-exposure conditions. The color measurements were expressed in terms of luminosity (lightness) $L^*$ ($L^* = 0$ for black and $L^* = 100$ for white), and the chromacity parameters $a^*$ [green (-) to red (+)] and $b^*$ [blue (-) to yellow (+)]. From these parameters, the cylindrical coordinates $C^*$ (chroma) and $h^\circ$ (hue) were calculated according to equations (1) and (2), respectively (McGuire, 1992). The measurements were made in four replicates and each sample was scanned at four different regions before treatment application and 1, 3, 5, 7, and 9 days of storage.

$$C^* = (a^{*2} + b^{*2})^{1/2}$$ (1)

$$h^\circ = \arctan \left( \frac{b^*}{a^*} \right)$$ (2)
Overall organoleptic rating (out of 9 marks)

The organoleptic evaluation of ber fruits was judged by visual method and on the basis of palatability, scored from 1 to 9 on Hedonic Rating Test Scale. For this purpose, a panel of five judges, who examined the skin colour, pulp color, sweetness and overall acceptance of fruits. The organoleptic evaluation of ber fruits was examined at alternate day of storage (Rangana, 1978).

| Category                        | Marks |
|---------------------------------|-------|
| Extremely acceptable            | 9     |
| Very much acceptable            | 8     |
| Moderately acceptable           | 7     |
| Slightly acceptable             | 6     |
| Neither acceptable nor unacceptable | 5   |
| Slightly unacceptable           | 4     |
| Moderately unacceptable         | 3     |
| Very much unacceptable          | 2     |
| Extremely unacceptable          | 1     |

Number of fruits per each degree of liking

Acceptance (%) = \frac{\text{Total number of fruit in each treatment}}{\text{Number of fruits per each degree of liking}} \times 100

Results and Discussion

The effect of oxalic acid on sensory evaluation

Hunter color values and overall organoleptic score were studied. The effects of OA on fruit during storage are discussed below:

CIE L* color coordinate (luminosity or lightness)

The data on color coordinates for luminosity or lightness (L*) of ber fruits influenced by OA treatments, during storage is presented in Table 1. A perusal of data presented in Table 1 reveal that the color coordinate L* of ber fruits increased with the advancement of storage time during the entire period of experiment. On 5th day of storage the minimum luminosity (L*) was recorded in T1 (50.79) while maximum in T6 (58.48) treatment. While, at the end of experimentation the maximum luminosity (L*) was recorded in T6 (39.89) while minimum in T3 (34.35) and T4 and T5 treatments were found at par with T6 treatment, respectively. However, 5th to 9th day of storage duration luminosity (L*) was fast decrease and all the treatments were significantly different with each other.

Effect of OA on lightness (L*) in fruit skin was measured with significant differences among the treatments (Table 1). Fruits of ber cv. ‘Gola’ treated with 10.0 mM L-1 OA, were observed maximum L* compared with rest of treatments. Least L* values were measured in control up to day 5 during the storage period. Lower OA concentrations (T4 and T5) were at par with T6 treatment. L* in ber fruit skin increased during first day then it decreased constantly until end of the experiment. The lightness was found significantly higher in the skin of ber fruits treated with OA @ 10 mM L-1. Quality ber fruits with excellent skin color appeal consumers at market. Apart from other quality parameters, color is a major factor to create attraction for buyer (Studman, 1994). Lightness (L*) values have great importance and these can be attributed to the total pigment in the fruit skin (Silva et al., 2005). Moreover, as higher as L* values would be, the freshness of the product would be higher as well.

The T6 treatment was showed increased lightness (L* values) during storage period. Untreated fruits (control) were recorded with darker (decreased L* values) skin compared with OA treated fruits however, 10.0 mM OA had lighter (increased L* values) skin. It has been reported that decrease in L* values is an indicative of fruit browning (Sapers and Miller 1993; Son et al., 2000; Son and Lee, 2001). In similar manner decreased L* values of control
fruits could be correlated to its corresponding higher PPO activity levels in control fruits.

**Hue angle (CIE \( h^\circ \))**

The data on color coordinates for CIE \( h^\circ \) (hue angle) of ber fruits influenced by OA treatments, during storage is presented in Table 2.

A perusal of data presented in Table 2 reveal that the hue angle (CIE \( h^\circ \)) of ber fruits decreased with the advancement of storage duration in all treatments. The rate of decrease was non-significantly affected by application of OA treatments during storage except 7th and 9th day of storage in which it was found to be significant. On 5th day of storage the minimum hue angle (CIE \( h^\circ \)) was recorded in T1 (51.85) while maximum in T6 (57.55) treatment.

While at the end of experimentation the minimum hue angle (CIE \( h^\circ \)) was found in T3 (49.84) and maximum in T6 (54.69) treatment. Hue angle (\( h^\circ \)) of skin of ber fruit was non-significantly affected by different OA treatments up to day 5, whereas significant difference observed on 7th and 9th day of storage (Table 2). The maximum \( h^\circ \) values were observed in the skin of 10 mM L\(^{-1}\) OA treated fruits, while, control fruit had least \( h^\circ \) values up to 5th day of storage. No significant changes were found among OA treatments and control up to 5th day of storage. The \( a^* \) and \( b^* \) values are used to calculate hue angle (McGuire, 1992). Treatment means showed significant effects of OA on hue (\( h^\circ \)) during storage period of 7th and 9th day.

Treated fruits had increased \( L^* \) and \( h^\circ \) values in peach fruit skin as compared with control during storage period (Abbasi et al., 2010). The interaction between treatments and storage days was noted significant on 7th and 9th day and showed a decline for \( h^\circ \) in all treatments. It has been reported that treatments and ripening period had significant interactions for \( h^\circ \) in plums (Khan and Singh, 2010).

**Table.1 Effect of oxalic acid on CIE \( L^* \) (lightness) during storage**

| Treatments | 1st day | 3rd day | 5th day | 7th day | 9th day |
|------------|---------|---------|---------|---------|---------|
| T1 (Control) | 54.77   | 52.85   | 50.79   | -       | -       |
| T2 (2 mM)  | 55.82   | 53.74   | 52.66   | 36.08   | -       |
| T3 (4 mM)  | 55.80   | 53.10   | 52.80   | 37.60   | 34.35   |
| T4 (6 mM)  | 58.16   | 56.85   | 54.27   | 40.50   | 38.28   |
| T5 (8 mM)  | 58.82   | 58.05   | 57.48   | 41.01   | 39.39   |
| T6 (10 mM) | 64.27   | 60.94   | 58.48   | 41.99   | 39.89   |
| SEm±       | 0.84    | 0.81    | 0.78    | 0.57    | 0.62    |
| CD (P=0.05) | 2.513   | 2.419   | 2.340   | 1.731   | 1.934   |

`-' denotes fruits not survived, NS- Non significant
Table 2: Effect of oxalic acid on hue angle (CIE h°) during storage

| Treatments  | 1st day | 3rd day | 5th day | 7th day | 9th day |
|-------------|---------|---------|---------|---------|---------|
| T1 (Control)| 53.04   | 52.12   | 51.85   | -       | -       |
| T2 (2 mM)  | 55.75   | 53.78   | 52.24   | 51.10   | -       |
| T3 (4 mM)  | 56.20   | 55.25   | 54.38   | 52.50   | 49.84   |
| T4 (6 mM)  | 56.95   | 56.15   | 55.64   | 53.34   | 50.40   |
| T5 (8 mM)  | 57.21   | 57.10   | 56.25   | 55.76   | 52.26   |
| T6 (10 mM) | 59.53   | 58.90   | 57.55   | 56.52   | 54.69   |
| SEm±       | 2.03    | 0.88    | 2.30    | 0.79    | 0.78    |
| CD (P=0.05)| NS      | NS      | NS      | 2.39    | 2.41    |

'-' denotes fruits not survived, NS- Non significant

Table 3: Effect of oxalic acid on Chroma (CIE C*) during storage

| Treatments  | 1st day | 3rd day | 5th day | 7th day | 9th day |
|-------------|---------|---------|---------|---------|---------|
| T1 (Control)| 33.95   | 35.61   | 46.31   | -       | -       |
| T2 (2 mM)  | 33.60   | 35.21   | 43.08   | 45.90   | -       |
| T3 (4 mM)  | 33.15   | 34.20   | 41.22   | 43.50   | 45.20   |
| T4 (6 mM)  | 32.65   | 34.05   | 38.04   | 42.94   | 43.63   |
| T5 (8 mM)  | 31.72   | 32.20   | 34.24   | 40.85   | 41.24   |
| T6 (10 mM) | 30.22   | 31.89   | 32.21   | 38.79   | 39.97   |
| SEm±       | 0.84    | 0.98    | 2.56    | 0.64    | 0.68    |
| CD (P=0.05)| NS      | NS      | NS      | 1.95    | 2.11    |

'-' denotes fruits not survived, NS- Non significant

Table 4: Effect of oxalic acid on overall organoleptic rating (out of 9 marks) during storage

| Treatments  | 1st day | 3rd day | 5th day | 7th day | 9th day |
|-------------|---------|---------|---------|---------|---------|
| T1 (Control)| 5.1     | 6.4     | 5.1     | -       | -       |
| T2 (2 mM)  | 5.3     | 6.3     | 7.2     | 4.6     | -       |
| T3 (4 mM)  | 5.7     | 6.9     | 7.4     | 5.1     | 4.9     |
| T4 (6 mM)  | 5.9     | 7.0     | 7.8     | 5.6     | 5.2     |
| T5 (8 mM)  | 6.1     | 7.2     | 8.1     | 6.2     | 5.6     |
| T6 (10 mM) | 6.5     | 7.8     | 8.3     | 7.0     | 6.2     |
| SEm±       | 0.32    | 0.34    | 0.20    | 0.08    | 0.08    |
| CD (P=0.05)| NS      | NS      | 0.58    | 0.24    | 0.25    |

'-' denotes fruits not survived, NS- Non significant
Chroma (CIE $C^*$)

The data on chroma (CIE $C^*$) of ber fruits influenced by OA treatments, during storage is presented in Table 3.

A perusal of data presented in Table 3 reveal that the chroma (CIE $C^*$) of ber fruits increased with the advancement of storage duration in all treatments. The rate of increase was non-significantly affected by application of OA treatments on ber fruits up to day 5, whereas significant difference after day 7 during the storage period. On 5th day of storage the maximum $C^*$ (chroma) was recorded in T$_1$ (46.31) but minimum in T$_6$ (32.21) treatment. Similarly, at the end of experimentation the minimum chroma (CIE $C^*$) was found in T$_6$ (39.97) and maximum in T$_3$ (45.20) treatment and also found that T$_4$ was at par with T$_3$ treatment.

Chromaticity ($C^*$) in the fruit skin of ber was measured with non-significant differences among the treatments up to day 5, further on 7th and 9th days of storage the CIE $C^*$ were found to be significant (Table 3).

Higher intensity (chroma) was observed in the skin of control fruit compared with OA concentrations up to day 5. Least intensely colored ($C^*$) skin was found in fruits treated with 10 mM L$^{-1}$ OA during storage period. Fruit skin color saturation or intensity is strictly ascribed to high values of chroma ($C^*$). Gomez et al., (1998) reported that increased $C^*$ values are sign of saturated red color. Hue values which are resultants of $a^*$ and $b^*$ help in assessment of changes in color.

Overall organoleptic rating (out of 9 marks)

The overall organoleptic rating of ber fruits influenced by OA treatments during storage is presented in Table 4.

It is clear from data contained in Table 4 that overall organoleptic rating in the ber fruit was non-significantly affected by the application of OA treatments up to day 3, thereafter all treatments were found to be significantly different with each other. An increasing trend was observed up to 5th day of storage, thereafter decreasing trend was observed for overall organoleptic rating. On 1st day of storage, maximum overall organoleptic rating was observed in T$_6$ (6.5) whereas minimum in T$_1$ (5.1) treatment. On 5th day of storage the minimum overall organoleptic score was recorded in T$_1$ (5.1) and maximum in T$_6$ (8.3) and also found that T$_4$ and T$_5$ were at par with T$_6$ treatment. At the end of storage, highest overall organoleptic rating (6.2) was found in T$_6$ treatment while it was lowest in T$_3$ treatment (4.9).

The general appearance and organoleptic qualities i.e., shape, size, colour, texture, flavour, aroma and taste of the fruits altogether determine the consumer’s acceptability of the fruits. Organoleptic characters are very much influenced by the postharvest treatments of fruits. The overall organoleptic rating like color, texture, appearance and taste of the fruit of all treatments deteriorated on account of faster ripening, reduced TSS and consequent decline in acidity.

The score initially increased due to the development in color, flavor and taste, while it declined towards the end of storage as ripening and senescence proceeded. The loss in overall acceptability scores of fruit might be due to degradation of different parameters during storage. Color, flavor, taste and texture are degraded due to browning, moisture losses, the breakdown of sugars, acids and volatile compounds (Amerine et al., 1965).

Generally, all quality parameters contribute to overall acceptability of a commodity. In
present study, overall acceptability is the average of organoleptic parameters such like texture, flavor or taste. Overall acceptability of ber fruits is greatly influenced by appearance, color, texture and flavor (Garg et al., 2005). The organoleptic rating of ber varieties (Naik and Rokhade, 1997) revealed that varieties having medium to high vitamin-C content, TSS and total sugars scored higher while lower values for any these character resulted in lower score. Results showed that OA concentrations significantly affected the overall acceptability of ber fruit from day 5 to end of experiment. Fruits treated with 10 mM OA obtained highest overall acceptability scores compared with other treatments during storage period. Lower OA concentrations (T4 and T5) were found statistically at par (p < 0.05) with T6 treatment. Some other researchers have also reported that OA treated peach fruits had enhanced overall acceptability when compared with control (Zheng et al., 2007).

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