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Improving the Post-harvest Characteristics of Indian jujube (*Ziziphus mauritiana* Lamk cv. Gola) by Modified Atmosphere Packaging

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ABSTRACT: *Ziziphus mauritiana* is a highly perishable fruit of Asiatic origin, and it is difficult to keep fresh after harvest. Rapid ripening, quality loss and sped up ethylene synthesis are the critical factors of short shelf life. In this study, we studied the effectiveness of modified atmospheric packaging on the qualitative parameters of Indian jujube fruit. Fruits were picked at the colour changing stage and packaged in polyethylene bags with one concentration of O_2 (2%) in combination with three CO_2 concentrations (5, 10, and 15%) and kept at 12°C with 85-90 % RH for 35 days. We measured total soluble solids (TSS), titratable acidity (TA), total sugar, reducing sugar, ascorbic acid, and total phenol during storage. Fruit stored in an atmosphere with a environmental gaseous composition served as a control and quickly lost important qualitative characteristics, as seen by faster colour changes, softening, decreased acidity, and increased sugars and total soluble solids. Because of the delay in postharvest ripening, which could be attributed to the effect of MAP on reducing respiration and ethylene production rates, the efficacy of the fruit was higher in the fruit-filled with MAP (2 per cent O_2 + 15 per cent CO_2) compared to the control. Finally, we concluded that the fruit stored with MAP treatments retained maximum quality attributes for 35 days.

Keywords: Ascorbic acid, Indian Jujube, Ripening, Shelf life, titratable acidity.

INTRODUCTION

Indian jujube (*Ziziphus mauritiana* Lamk) is an important fruit crop of arid and semi-arid regions in tropical and subtropical areas. Indian jujube belongs to the Rhamnaceae family of order Rhamnales and genus *Ziziphus*. It is native to South and Central Asia and Gulf countries (Jat *et al*., 2012). Recently, jujube has been grown commercially in many countries such as China, Turkey and Taiwan (Awasthi and More, 2008). Jujube fruit successfully cultivated under drought, diversified soil and adverse climatic conditions, *i.e.* salinity, uneven distribution of rainfall and water-logging condition (Baloda *et al*., 2012). Ber is a vigorous tree that adapts to high temperatures and is well acclimatized to the dry situation. It is appropriate for cultivating an arid and semi-arid tract of the world *viz*., India, Pakistan, Sri Lanka, Afghanistan, Iran, Syria, Myanmar and Australia (Pareek *et al*., 2010).

Indian jujube is classed as a climacteric fruit (Jat *et al*., 2012). The limited storage life and fast perishability of Indian jujube fruit are issues during postharvest storage (Pareek *et al*., 2010). At room temperature, fruits have a shelf life of 2-4 days. Because of the oversupply of fruits in local markets during peak season, a significant amount goes to waste, resulting in considerable postharvest losses. Indian jujube fruit cultivation is lucrative, but it needs careful pre-harvest, harvesting, postharvest treatments, packing, transportation, storage, postharvest pathology, and processing. If attempts to boost output are combined with efforts to reduce postharvest waste and extend shelf life, profits might be improved. Different MAP interventions with cold chain temperatures were attempted to overcome postharvest losses and increase the shelf life of jujube fruits. The impacts of MAP on the postharvest physiology and quality of Indian jujube fruit are not well documented. There has been a significant study gap on jujube's response to changed atmospheric packaging. In recent years, investigations in China have been limited to publishing in Chinese-language journals. Another reason contributing to the research gap might be the limited marketing of jujube fruit worldwide. As a result, the use of various modified atmospheric packaging techniques to extend the shelf life of Indian jujube fruit is still in its early stages and requires additional research from several perspectives.

MATERIALS AND METHODS

A. Plant materials and modified atmosphere packaging treatments

Fruits of the Indian jujube (*Z. mauritiana* Lamk. cv. Gola) were collected at an instructional farm in Rajasthan, India. I picked fruits at the tinting stage and brought them to the laboratory in an air-conditioned vehicle. Fruit of equal size, shape, and absence of physical defects was chosen and distributed randomly into three lots, then washed and dried under the ceiling fan in the shade. Fruit of each lot was placed inside the low-density polythene bags with two concentrations of O_2 (2 %) with three CO_2 levels (5%, 10%, and 15%, with the balance of N_2) using a gas mixture (Model MAP Mix 9001, PBI Dansensor, Ringsted, Denmark). As a control, fruits packed with an ambient gaseous composition (21 per cent O_2 + 0.03 % CO_2) were used. We sealed the packets with a MAP machine (Model VAC STAR S 220 MP, Sweden) and maintained them at 12°C temperature. We made observations at the beginning of the experiment and 7-day intervals during storage. The total phenol contents, TSS, sugars, acidity, and ascorbic acid, were measured.

Quality traits analysis. The total soluble content (0-30) was determined using a "Zeiss" Hand Refractometer, and the result was adjusted at 20°C and given as °Brix (AOAC, 2007). The fruit's acidity was calculated by titrating the juice against a standard 0.1 N NaOH, using phenolphthalein indicator, and was expressed as a percentage. We assessed the total sugar using the anthrone reagents technique (Dubois *et al.*, 1951), and reducing sugar was measured using dinitrosalicylic acid as described by Miller (1959). Absorbance was determined using a spectrophotometer (Double beam SL 210 UV Visible Spectrophotometer, Ellico, Hyderabad, India) at 630 and 510 nm for total sugars and reducing sugars, respectively. The sugars content of the sample was compared to a standard curve made from glucose. The percentage was used to express the result value. The amount of ascorbic acid of fruits was evaluated by titrating the juice against a 2, 6-dichlorophenol indophenols dye solution until it turned a bright pink colour that lasted 15 seconds. The results were represented in mg ascorbic acid /100g^{-1}. Fruit phenolic compound content was determined spectrophotometrically with Folin-Ciocalteu reagents, and designated as a percentage.

Sensory evaluation. A panel of five trained people (aged 25-55) analyzed visual appearance. Evaluation were scored based on a 10 point Hedonic Rating Test Scale (1 = extremely unacceptable, 3 = moderately unacceptable, 5 = neither acceptable nor unacceptable, 7 = moderately acceptable, 10 = extremely acceptable) based on (Rangana, 1978). The overall sensory score was measured on the same scale and referred to as the overall organoleptic score.

Statistical analysis. A completely randomized design was used to perform this experiment. Used SPSS 13.0 to analyze all of the variables (SPSS Inc., Chicago, IL, USA). A one-way analysis of variance was statistically analyzed. Duncan's multiple range tests were used to compare means. Results with a significance level of P0.05 are considered significant.

RESULTS AND DISCUSSION

Total soluble solids and titratable acidity. Changes in TSS content due to various MAPs during storage of ber fruits. The TSS content (°B) in ber fruit continuously increased until the peak and then declined slightly, irrespective of storage temperature. Conversely, the increase in TSS was lower with MAP treatments due to a lower reduction in the hydrolysis of polysaccharides and acids than control fruit. The highest fluctuated TSS content has been exhibited in fruit stored at environmental composition during storage. At the end of storage, *i.e*. 35th day, the maximum TSS content (15.00°B) were recorded in 2% O_2 + 5% CO_2 and 2% O_2 + 10% CO_2 treatments, whereas, minimum (14.00 °Brix) in control fruit. The TSS content coincides with ripening and is attributed to the conversion of starch into simple sugar at beginning of the experiment.

Furthermore, the lower temperature reduces the consumption of sugars in respiration during senescence (Yang *et al*., 2010). There were non-significant differences in acidity among the treatments (Table 1). A slight decrease in acidity was seen for all MAP treatments during storage, but MAP (2% O_2 + 15% CO_2) was the most effective treatment for Indian jujube fruit. The acidity decreased to 0.42%, which represent a 20 per cent loss. The positive impact of MAPS in retaining higher acidity content in fruit compared to control as observed in the present study. The low oxygen and high CO_2 concentration significantly reduced the respiratory activities of fruit, which causes lower consumption or conversion of organic acids into sugars during respiratory metabolism Yang *et al*., (2010).

Sugars. Fruit's total sugar content raised during the first 28 days of storage, then diminished (Table 1). Fruit kept with MAP (2 % O_2 + 10 % CO_2) had the highest sugar content (12.94%) at the end of storage, whereas fruits served as control had the lowest sugar (Table 1). The conversion of cell wall materials including pectin and hemicelluloses into reducing molecules and decreased respiration rates and delayed senescence in MAP-treated fruits. Jawanda *et al.,* (2009) also recorded a similar result in Indian ber during postharvest. During the early phases of ripening, the lowering sugar concentration increased somewhat before declining. After 28 days of storage in MAP (2 per cent O_2 + 15 per cent CO_2), the reducing sugar content of fruits reached a maximum of 6.25 per cent, while the lowest reducing sugars (6.00 per cent) were found in fruit served as control. Hydrolysis of sucrose, which produces glucose and fructose, could contribute to the initial increase in glucose and fructose concentration (Ding *et al.,* 2000). In Chinese bayberry, low-temperature storage kept all sugars at greater levels (Yang *et al.,* 2010). Litchi fruit's total sugars were reduced throughout 9 days of storage, but there was no difference in packing treatment (Somboonkaew and Terry, 2010). In litchi, sucrose concentration has been linked to TSS (Paull and Chen, 1987). The TSS content in this study was likewise connected with total sugar concentrations, which was validated by Paull and Chen (1987).

Table 1: Total soluble solids, titratable acidity and sugar content of Indian ber fruit cv. 'Gola' under modified atmosphere packaging.

MAPS	Storage period (d)				
	7	14	21	28	35
Total soluble solids (°Brix)					
Control	9.67 ± 0.26 ^{b}	11.00 ± 0.29 ^{b}	12.00 ± 0.32 ^{b}	14.00 ± 0.37 ^{b}	14.00 ± 0.37 ^{a}
2% O_2 + 5% CO_2	9.00 ± 0.24 ^{ab}	11.00 ± 0.29 ^{b}	12.00 ± 0.32 ^{b}	13.00 ± 0.34 ^{a}	15.00 ± 0.40 ^{b}
2% O_2 + 10% CO_2	8.67 ± 0.23 ^{a}	10.00 ± 0.26 ^{a}	11.00 ± 0.29 ^{a}	13.00 ± 0.35 ^{a}	15.00 ± 0.40 ^{b}
2% O_2 + 15% CO_2	9.67 ± 0.26 ^{b}	10.70 ± 0.28 ^{ab}	13.00 ± 0.34 ^{c}	13.00 ± 0.33 ^{a}	14.00 ± 0.37 ^{a}
Titratable acidity (%)					
Control	0.510 ± 0.019 ^{a}	0.503 ± 0.003 ^{a}	0.381 ± 0.003 ^{a}	0.413 ± 0.002 ^{a}	0.338 ± 0.001 ^{a}
2% O_2 + 5% CO_2	0.512 ± 0.004 ^{a}	0.505 ± 0.004 ^{a}	0.468 ± 0.003 ^{b}	0.421 ± 0.001 ^{b}	0.347 ± 0.004 ^{b}
2% O_2 + 10% CO_2	0.514 ± 0.013 ^{b}	0.507 ± 0.004 ^{a}	0.472 ± 0.004 ^{c}	0.430 ± 0.001 ^{c}	0.360 ± 0.001 ^{c}
2% O_2 + 15% CO_2	0.515 ± 0.012 ^{b}	0.510 ± 0.003 ^{a}	0.477 ± 0.004 ^{d}	0.437 ± 0.002 ^{d}	0.369 ± 0.002 ^{d}
Total Sugar (%)					
Control	10.60 ± 0.28 ^{a}	12.00 ± 0.32 ^{a}	13.73 ± 0.36 ^{c}	15.40 ± 0.39	12.32 ± 0.33
2% O_2 + 5% CO_2	9.80 ± 0.26 ^{b}	12.10 ± 0.32 ^{a}	13.55 ± 0.34 ^{a}	15.50 ± 0.41	12.94 ± 0.34
2% O_2 + 10% CO_2	10.00 ± 0.26 ^{c}	11.80 ± 0.31 ^{b}	13.60 ± 0.29 ^{b}	15.40 ± 0.33	12.90 ± 0.19
2% O_2 + 15% CO_2	10.60 ± 0.28 ^{d}	12.00 ± 0.32 ^{a}	13.65 ± 0.27 ^{bc}	15.40 ± 0.29	12.60 ± 0.16
Reducing sugar					
Control	3.30 ± 0.03 ^{c}	4.00 ± 0.04 ^{b}	5.10 ± 0.11 ^{b}	6.10 ± 0.16 ^{b}	5.40 ± 0.14 ^{a}
2% O_2 + 5% CO_2	3.10 ± 0.03 ^{b}	4.00 ± 0.04 ^{b}	4.92 ± 0.09 ^{b}	6.13 ± 0.17 ^{c}	5.62 ± 0.15 ^{b}
2% O_2 + 10% CO_2	3.00 ± 0.02 ^{a}	3.92 ± 0.03 ^{a}	4.82 ± 0.07 ^{a}	6.00 ± 0.17 ^{a}	5.40 ± 0.09 ^{a}
2% O_2 + 15% CO_2	3.40 ± 0.03 ^{d}	3.94 ± 0.03 ^{a}	4.92 ± 0.06 ^{a}	6.25 ± 0.16 ^{d}	5.72 ± 0.17 ^{c}

Mean ± SD (n = 3); different letters within a column are significantly different at $p < 0.05$

Ascorbic acid and total phenol. The ascorbic acid content of jujube fruit decreased during storage, with a higher rate of decrease in fruit served as control (Table 2). The higher ascorbic acid content (64 mg/100g^{-1}) was recorded in fruit stored in 2% O_2 + 15% CO_2 atmosphere and minimum (47 mg/100g^{-1}) in control at the end of storage. The MAP treatment (2% O_2 + 15% CO_2) was the most effective in retaining ascorbic acid content throughout storage. This result agrees with the finding of Guil-Guerrero *et al*. (2004) under different packaging films. The total phenol content of jujube fruit was also recorded during storage, as present in Table 2. The results showed that the level of phenol content decreased in MAP and control fruit with the storage period. Still, the MAPs showed non-significant differences during the entire period of storage. We observed the maximum phenol content in fruit stored with 2% O_2 + 15% CO_2 atmosphere and minimum in range. MAP storage has been found to benefit the preservation of bioactive chemicals in fruits and vegetables, although there are currently just a few papers on the subject. After 21 days of storage, broccoli heads lost 50% of their total antioxidants, phenolics, and ascorbic acid, whereas losses were decreased in broccoli wrapped with micro-perforated and non-perforated PP films. Total antioxidants have been linked to total phenolics in broccoli and, to a lesser extent, ascorbic acid in loquat kept at 2°C. In contrast, levels at harvest were maintained in loquat preserved under MAP conditions (Amoros *et al.*, 2008). MAP helped in preserving papaya, fruit's antioxidant properties by keeping appropriate amounts of ascorbic acid and lycopene content during postharvest storage (Singh and Rao, 2005).

Sensorial properties. Weight loss, flavour changes, decay incidence, and shrivelling are important postharvest factors, which decline the postharvest qualities of Indian jujube fruit. A trained panel of five individuals conducted a weekly sensory examination focused on the overall organoleptic excellence of Indian jujube fruit. Sensory panellists regarded the stored fruit of all treatments as freshly picked jujube fruit after 1 week of storage, but the control fruit had a minor drop in sensory quality (Table 2). Following this examination, the sensory quality of the fruit as a whole deteriorated noticeably. Panellists recorded significant differences ($P<0.005$) between control and treated fruit at the end of storage. The fruit stored with MAP (2 % O_2 + 15 % CO_2) had the highest sensory assessment score, but control fruit decreased to the actual threshold of acceptability after 35 days of storage, owing to increased water loss.

Fruits' sensory characteristics are preserved in MAP conditions with the right atmospheric composition. After 18 days of storage at 1°C, for example, ratings for crunchiness and juiciness were higher in non-perforated than in perforated, and no changes were found after 53 days about the scores at day 18 in Table grapes (Martinez-Romero *et al.*, (2003). However, low O_2 has unfavourable secondary effects on oxidative processes, such as respiration, which is essential for substrate formation; however, fragrance production is restored when the fruits are exposed to normal air (Artes *et al.*, 2006).

Table 2: Ascorbic acid, total phenol and over all acceptability of Indian jujube fruit cv. 'Gola' under modified atmosphere packaging.

MAPS	Storage period (d)				
	7	14	21	28	35
Ascorbic acid (mg $100g^{-1}$)					
Control	94.00 ± 2.19 a	88.00 ± 2.33 a	76.00 ± 2.01 d	61.00 ± 1.61 a	47.00 ± 1.24 a
2% O_2 + 5% CO_2	103.00 ± 2.73 b	97.00 ± 2.57 b	84.00 ± 2.22 a	70.00 ± 1.85 b	55.00 ± 1.46 b
2% O_2 + 10% CO_2	104.00 ± 2.75 c	99.00 ± 2.62 c	86.00 ± 2.28 b	71.00 ± 1.8 c	62.00 ± 1.64 c
2% O_2 + 15% CO_2	104.00 ± 2.75 c	101.00 ± 2.67 d	89.00 ± 2.35 c	75.00 ± 1.98 d	64.00 ± 1.69 d
Total phenol (%)					
Control	0.094 ± 0.019 a	0.089 ± 0.003 a	0.082 ± 0.003 a	0.074 ± 0.002 a	0.064 ± 0.001 a
2% O_2 + 5% CO_2	0.100 ± 0.004 c	0.096 ± 0.003 b	0.090 ±0.003 c	0.084 ±0.001 c	0.077 ±0.001 d
2% O_2 + 10% CO_2	0.098 ± 0.013 bc	0.094 ± 0.004 b	0.087 ±0.004 b	0.081 ±0.001 b	0.074 ±0.001 c
2% O_2 + 15% CO_2	0.097 ± 0.012 a	0.092 ± 0.004 a	0.086 ±0.004 b	0.079 ±0.002 b	0.071 ±0.002 b
Overall acceptability score					
Control	5.00 ± 0.13 a	6.00 ± 0.16 a	6.75 ± 0.18 a	6.00 ± 0.16 a	5.00 ± 0.13 a
2% O_2 + 5% CO_2	5.75 ± 0.15 c	6.50 ± 0.17 b	7.25 ± 0.19 b	6.50 ± 0.17 b	5.75 ± 0.15 c
2% O_2 + 10% CO_2	5.00 ± 0.13 a	6.00 ± 0.16 a	6.75 ± 0.16 a	6.10 ± 0.19 a	5.50 ± 0.09 b
2% O_2 + 15% CO_2	5.25 ± 0.14 b	6.00 ± 0.16 a	6.75 ± 0.11 a	6.00 ± 0.14 a	5.00 ± 0.13 a

Mean ± SD (n = 3); different letters within a column are significantly different at $p < 0.05$

CONCLUSION

Finally, we concluded that the MAP technique effectively delayed the senescence process of Indian jujube fruits by suppressing ripening, colour, and other quality attributes. In most cases, the effect was more significant in fruits packaged with MAP (2 % O_2 + 15% CO_2) than in others, most likely because of the reduced oxygen inhibiting ethylene synthesis more effectively. However, additional study into the influence of these packages on active phytochemicals at lower temperatures under MAP conditions is needed.

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Conflict of Interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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