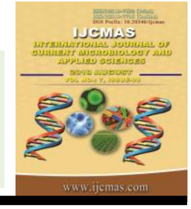
Int.J.Curr.Microbiol.App.Sci (2018) *7*(8): 2584-2591

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 08 (2018)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2018.708.265

Enhancing Firmness and Nutritional Quality of Ber Fruit with Suitable Packaging Materials and Waxing during Storage

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Keywords

Ber, Firmness, Transportation, Storage, Packaging materials, Cushioning Materials

Article Info

Accepted:
15 July 2018
Available Online:
10 August 2018

A B S T R A C T

Ber can provide food security, due to sustained production of the fruit in even degraded lands. It is highly nutritive which untapped source of nutrition. It is an ideal fruit for arid and semiarid regions and tropical and subtropical climate where most of the fruits cannot be grown. Therefore, a study was conducted to evaluate the suitable packaging material for transporting the fruits in distant market by road route. The four packaging materials with and without cushioning materials *viz.* gunny bag, polythene bag, netlon bag and CFB box, two waxing treatments on fruit, *viz.* waxing and not waxing, three storage conditions, viz; room temperature (RT), zero-energy cool chamber (ZECC) and cold storage (CS) were evaluated for better firmness and maintained chemical properties with enhance the shelf life during storage after transportation. The maximum firmness was recorded in RT (6.770 N, 4.550 N), ZECC (6.970 N, 5.957 N) and CS (7.170 N, 6.270 N) stored fruits, which were packed in CFB boxes with providing wax treatment on 6^{th} and 12^{th} day of storage. The minimum PLW (1.38%, 2.77%) was observed in the fruits packed in polythene bag with paper cutting cushioning material and maximum ascorbic acid (92.65 mg/100g, 76.46 mg/100g) was recorded in the CFB boxes packed fruits with cushioning material on 3^{rd} and 6^{th} days after storage (DAS). The maximum reducing sugar (6.26%) was noticed in those fruits packed in netlon bag without cushioning material on 3^{rd} DAS while minimum acidity (0.135%) was recorded in netlon bag without cushioning material packed fruits on 6^{th} DAS. The maximum TSS (15.79%) was observed in the fruits packed in polythene bag with cushioning material on 6^{th} DAS. These results suggested that fruit can be treated with wax for retaining the firmness during storage and cushioning material can be applied during transportation for enhance the quality of the fruits. Polythene bag is the cheapest among all the packaging materials with and without cushioning and waxing.

Introduction

Jujube or Indian plum or ber (*Zizyphus mauritiana* Lam.) is an economically important tropical fruit tree grown all over the drier parts of the Indian sub-continent for its fresh fruits (Awasthi and More, 2009). It is an important drought hardy fruit crop, which can be grown under hostile agro-climatic conditions of the arid region. Since it is hardy and salt tolerant, the tree can be grown even in marginal lands. Ber grows in wild and cultivated forms in India mostly in the marginal soils. The ber cultivation is expending because of its hardy nature to withstand vagaries of nature and commercial yield potential. India annually produces around 750,000 ton in an area of 90,000 ha (More and Awasthi, 2008). Ber is highly nutritive which has untapped sources of nutrition. Ber fruit is richer than apple in protein, phosphorous, calcium, carotene and vitamin C (Bakshi and Singh, 1974). Umran is one of the leading late ripening cultivar of ber i.e. by middle of April. If fruit of this cultivar could be stored for 4-6 weeks i.e. up to end of May, when peach, plum, grapes and mango start arriving then it could help regulate and extend supply of ber during lean period and also ensure remunerative prices to the growers. Ber contain 79-82% moisture, 0.96-1.75% protein and 70-65 mg vitamin C (Pareek *et al.*, 2002). The shelf life of Ber fruit is very short during storage. Orchards are generally situated in remote places and the fruits are to be transported to main market for storage or for further transportation to distance places. The common modes of transportations are by road or rail. Transportation losses are the major issue in fruits and vegetables. The main reason behind it is due to use of improper packaging of the produce. Inadequate selection of packaging materials enhances the physical, physiological and pathological deterioration during transportation and marketing. Suitable packaging is an essential and indispensable component in the transportation of fruits (New *et al.*, 1970 and Singh *et al.*, 1976). Paper cutting is the best cushioning material for reduction of decay loss in storage (Singh and Gupta, 1983). The information on effect of packaging materials on transportation studies and firmness of ber fruits during storage is very limited. Keeping in view the importance of such study, the present investigation was undertaken to evaluate the suitable packaging materials for safely transportation and retain qualities (firmness) of ber fruits during storage.

Materials and Methods

Experimental Site and Plant Material

The study was carried out at Division of Horticultural Crop Processing, Central Institute of Postharvest Engineering and Technology, Abohar (Punjab) for two consecutive years. Uniform and healthy fruits of Umran cultivar at colour turning stage (golden yellow color stage) of maturity were harvested from twenty year old trees. Damaged, diseased and other undesirable fruits were sorted out and healthy fruits were selected.

Treatment Methodology

Three kg of fruits was packed in each of the packaging material i.e. polythene bag (100 gauge), corrugated fiberboard box (4 ply), gunny bag and netlon bag. In the polythene bag 2% of total area was perforated and in corrugated fibre board (CFB) boxes 2 cm^2 perforation was given on both sides for ventilation. Two types of treatment were given, waxing and non-waxing in all the four packaging materials. Edible wax (stafresh) was used for waxing the fruits. All the treatments were replicated three times for finding the decay loss and PLW for sampling during experiment for chemical analysis. Before transporting the fruits, the initial firmness study was conducted of fresh fruits. Fruits were stored in room temperature, zero energy cool chamber and cold storage and firmness study was conducted on 6^{th} and 12^{th} day of storage after transportation. The firmness of ber fruits were studied using Texture Analyzer using a 2 mm dia SS probe with the following testing modes; Pretest speed-2 mm/s, Test speed-2 mm/s, Posttest speed- 10 mm/s and Distance- 5.0 mm. The transported studies were conducted with three kg of fruits packed in each package (gunny bag, polythene bag, CFB boxes and netlon bag). Two types of treatment were given, with and without cushioning material. Paper cutting (2%, 20 gm/kg fruit) was used as cushioning material. The treatments were replicated thrice. The fruits were transported to Amritsar next day after harvesting covering 560 km by road. After transportation, the fruits were stored in ambient condition.

Observations recorded

The effects of transportation on quantitative and qualitative losses were recorded in terms of PLW, Decay loss, TSS, acidity and ascorbic acid of fruits. The physiological loss in weight, decay/ spoilage loss and total soluble solids were determined by standard methods. Economic shelf life (in days) of fruits was determined by counting the number of days, on the date after which cumulative spoilage percentage of fruits in particular treatment exceeded 12%, from the date of harvest of the fruits (Singh *et al.,* 2003).

Acidity, ascorbic acid and reducing sugar content were determined by the methods of advocated by AOAC (1990). The respiration rate was measured as suggested by Loomis and Shull (1973). The linear dimensions, length (L) and diameter (D) were measured using Vernier calipers. The size was calculated using the linear dimensions and were expressed in term of geometrical mean diameter (D_g) was calculated using the following formula (Mohsenin, 1970):

$$D_g = (LD^2)^{2/3} \quad (1)$$

Spheroid expresses the shape character of the solid relative to that of a sphere of the same volume. It is an index of roundness. According to Jain and Bal (1997), the degree of sphericity (Ø) can be expressed as follows:

$$Ø = D_g/L \quad (2)$$

The principal dimensions were used to calculate the volume (V) and surface area (S) of the fruit by using the following equations (Mohsenin, 1970):

$$V = \frac{\pi D^2 L}{4} \quad (3)$$

$$S = \pi D_g^2 \quad (4)$$

Results and Discussion

The results obtained during course of this investigation are interpreted in the light of work done in this direction and presented here under;

Fruit firmness

It is evident from the data presented in Table 1 that the change in firmness of fruits during storage, affected by packaging materials and storage environments. The firmness was studied on 6th and 12th day of storage of the fruits. The fruits were intact (higher firmness) in the refrigerated storage condition, while the change in firmness was higher in the fruits, which were stored in room temperature condition. It was found that the waxed fruits were firmer than the unwaxed fruits. Also, it was noticed that the fruits packed in netlon bags, lost their intactness early than the fruits packed in other packaging materials, whereas the fruits packed in CFB boxes were more firm than the other packaging materials. The firmness showed a linear decline with the increase in storage intervals. This may be due to higher respiration rate resulting quick decaying of fruits packed in netlon bags. Jagtap and Katrodia (1998) reported that packing fruits in polythene bag reduced the physiological weight in loss considerably. The fruits packed in CFB carton had better shelf life and marketability with higher organoleptic value. In the room temperature, on 6th day of storage the maximum firmness (6.770 N) was observed in fruits packed CFB box with wax treatment whereas the minimum (4.810 N) was found in netlon bag without wax treated fruits. The similar trend was also observed on 12th day of storage. The fruits which were packed in CFB box with wax treatment showed maximum (4.550 N) firmness whereas the minimum (3.090 N) firmness was found in netlon packed unwaxed fruits. Similar trend was noticed in these fruits, which were stored in zero energy cool chamber. On the 6th and 12th day of storage the maximum firmness (6.970 N and 5.957 N) were found in CFB boxes with wax treated fruits. While minimum firmness (5.417 N and 4.363 N) were observed in netlon bag packed without wax treated fruits. As in room temperature and in zero energy cool chamber, the fruits stored in cold storage also showed the same trend of firmness of the fruits. On 6th and 12th day of storage, the maximum (7.170 N, 6.270 N) firmness was noticed in CFB boxes with wax treated fruits while minimum (5.700 N, 4.930 N) firmness was observed in netlon bag packed fruits. This may be due to higher respiration rate in netlon bag compared to other packaging materials. The present results are inconformity with the finding of Jagtap and Katrodia (1998), Kaur *et al.*, (2013) and Hailu *et al.*, (2014) in Sapota, pear and banana, respectively.

Table.1 Effect of packaging material and wax treatment on firmness of ber fruits during different storage conditions (Mean values of two years)

Treatments	Firmness (N)					
	Room Temperature		Zero Energy Cool Chamber		Cold Storage	
	6th Day	12th Day	6th Day	12th Day	6th Day	12th Day
T_1 (GB+NW)	5.153	3.100	5.480	4.990	5.830	5.260
T_2 (GB+W)	6.223	3.880	6.230	5.240	6.480	5.650
T_3 (PB+NW)	5.820	3.570	5.930	5.070	6.100	5.610
T_4 (PB+W)	6.116	3.910	6.163	5.530	6.380	5.840
T_5 (CFB+NW)	5.870	3.980	5.937	5.080	6.590	5.960
T_6 (CFB+W)	6.770	4.550	6.970	5.957	7.170	6.270
T_7 (NB+NW)	4.810	3.090	5.417	4.363	5.700	4.930
T_8 (NB+W)	5.570	3.560	5.983	5.160	6.220	5.360
CD (5%)	0.331	0.090	0.383	0.241	0.378	0.080

Initial Firmness: 7.351 N

GB- Gunny bag PB- Polyethylene bag CFB- Corrugated fiber board box W- Wax NW-Nonwax

Table.2 Effect of packaging and cushioning material on transportation studies of ber fruits during storage (Mean values of two years)

Treatments	PLW (%)		Decay loss (%)		TSS (%)		Ascorbic acid(mg/100g)		Reducing sugar (%)		Acidity (%)	
	3 DAS	6 DAS	3 DAS	6 DAS	3 DAS	6 DAS	3 DAS	6 DAS	3 DAS	6 DAS	3 DAS	6 DAS
T_1 (GB)	6.15	15.27	6.24	16.65	16.31	14.97	81.56	67.34	6.12	5.27	0.169	0.142
T_2 (GB+CM)	5.78	12.07	5.64	14.63	16.11	15.08	86.24	71.52	6.07	5.31	0.174	0.148
T_3 (PB)	2.62	3.14	5.13	14.57	15.82	15.67	84.17	72.19	5.76	5.62	0.182	0.167
T_4 (PB+CM)	1.38	2.77	4.92	11.24	15.54	15.79	89.62	75.34	5.73	5.68	0.185	0.171
T_5 (CFB)	4.16	7.43	3.12	11.81	16.28	15.13	86.24	72.53	5.89	5.37	0.189	0.170
T_6 (CFB+CM)	3.92	7.12	2.87	9.72	16.04	15.46	92.65	76.46	5.85	5.41	0.192	0.174
T_7 (NB)	6.89	16.05	7.68	19.24	16.49	14.88	78.49	63.14	6.26	5.11	0.160	0.135
T_8 (NB+CM)	6.11	15.72	5.74	15.97	16.21	14.96	82.75	66.82	6.18	5.20	0.163	0.138
CD (5%)	1.07	0.06	0.11	1.79	0.07	0.07	0.54	0.07	0.06	0.08	0.009	0.01

GB- Gunny bag PB- Polyethylene bag CFB- Corrugated fiber board box NB- Netlon bag CM- Cushioning material, DAS= Days after storage

Table.3 Changes in physico-chemical properties of ber fruits before and just after transportation (Mean values of both years)

Fruit properties	Before transportation (Initial value)	After transportation (48 hrs after harvesting)
Physical properties		
Fruit weight (g)	54.66	51.28
Length (cm)	5.67	5.64
Diameter	4.50	4.48
Geometrical dia (cm)	4.85	4.82
Sphericity	0.86	0.83
Volume (cm^3)	89.90	86.74
Surface area (cm^2)	74.04	71.38
Chemical properties		
TSS (%)	13.2	13.8
Acidity (%)	0.212	0.207
Ascorbic acid (mg/100g)	112	108
Reducing sugar (%)	4.12	4.43

Table.4 Comparative cost of different packaging materials with and without waxing and cushioning material

Packaging materials	Unwaxed fruits without cushioning material	Unwaxed fruits with cushioning material	Waxed fruits without cushioning material	Waxed fruits with cushioning material
Gunny bag	Rs. 0.63/kg	Rs. 0.75/kg	Rs. 1.13/kg	Rs. 1.25/kg
Polyethylene bag	Rs. 0.40/kg	Rs. 0.52/kg	Rs. 0.90/kg	Rs. 1.02/kg
CFB boxes	Rs. 3.30/kg	Rs. 3.42/kg	Rs. 3.80/kg	Rs. 3.92/kg
Netlon bag	Rs. 0.80/kg	Rs. 0.92/kg	Rs. 1.30/kg	Rs. 1.42/kg

Transportation studies

The data pertaining to PLW, decay loss, TSS, ascorbic acid, reducing sugar and acidity affected by transportation of fruits and the effect of packaging material and cushioning material (Table 2). The fruits were stored in ambient condition after transporting for a distance of 560 km by road. After 3^{rd} and 6^{th} day of transportation during storage minimum PLW (1.38%, 2.77%) was observed in the fruits which were packed in polythene bags with cushioning materials, whereas the maximum (6.89%,16.05%) was found in the fruits packed in netlon bags without cushioning materials. Dalal and Subramanyam (1970) reported that the transpiration and respiration rate is lesser in polythene bags compared to CFB boxes, gunny bags and netlon bags thus helps in checking the loss in fruit weight during storage. The minimum decay loss (2.87%, 9.72%) on 3^{rd} and 6^{th} day after transportation was found in the fruits, which were packed in CFB box with cushioning material. On the 3^{rd} day after transportation, the maximum TSS (16.49%) was noted in netlon bag packed fruits without cushioning material and the minimum in polythene bag with cushioning material. But the TSS started decreasing after 3^{rd} day of storage. In initial stage increase in TSS during storage might be associated with the transformation of peptic substances, starch, hemi cellulose or other polysaccharides in soluble sugars and also with the dehydration of fruits (Singh *et al.*, 2003; Singh *et al.*, 2004 and Singh *et al.*, 2005). Slow increase in TSS during storage in wax treated fruits was due to slow weight loss that caused less dehydration of the fruits (Kumar *et al.*, 2005). The ascorbic acid content decreased with increase in storage period. On 3rd and 6th day after storage, maximum (92.65 mg/100g, 76.46 mg/100g) content of ascorbic acid was observed in the fruits, which were packed in CFB box with cushioning material. During storage, oxidizing enzymes like ascorbic acid oxidase, peroxidase, catalase and polyphenol oxidase might have caused decrease in ascorbic acid of the fruits (Singh *et al.*, 2003 and Singh *et al.*, 2005). Activities of oxidizing enzymes might be reduced in the treated fruits that resulted in higher level of ascorbic acid content up to last day of storage. This finding is in agreement with those of Mahajan *et al.*, (2005) in kinnow fruits. The maximum reducing sugar (6.26%) was noticed in netlon bag packed fruits without cushioning material and minimum (5.73%) was found in polythene bags with cushioning material on the 3^{rd} day of storage. The reducing sugar increased with increase in the storage period but after a particular point of time, it started decreasing. An increase in sugars during storage was due to conversion of starch and polysaccharides in to soluble sugars and dehydration of fruits. The acidity content also continuously decreased with increase in storage period after transportation. The minimum acidity (0.135%, 0.160%) was observed in the fruits packed in netlon bags without cushioning materials and the maximum was found in the fruits packed in CFB boxes with cushioning materials. The reduction in acidity during storage might be associated with the conversion of organic acids in to sugars and their derivatives or their utilization in respiration (Singh *et al.*, 2003 and Singh *et al.*, 2005). The treated fruits could maintain higher level of acidity up to last day of storage. It might be due to reduced respiration rate in the later stage of storage as affected by wax treatments. These results are in accordance with Singh *et al.*, (2005) in aonla and mango. Krishnamurthy (1990) reported that an adequate packaging protects the produce from physical, physiological and pathological deterioration during transport and market. Dasgupta and Mandal (1989), reported that higher losses due to post harvest diseases were observed in the perishables with long route and hours of transit period during transportation. Raman *et al.*, (1988) observed that during transporting fruits and vegetables from the production centers to the urban markets even if 2 per cent wastage is reduced, there would be a saving of Rs. 100-200 crores per year in India. The initial physico-chemical properties of fruits are shown in Table 3. The data given in Table 4 indicate the cost comparison of treatment fruits packed in different packaging materials. Polyethylene bag is the cheapest (Rs. 1.02/kg, Rs. 0.90/kg, Rs. 0.52/kg and Rs. 0.40/kg) among all the packaging materials with and without cushioning materials and waxing, respectively.

Fruit can be treated with wax for retaining the firmness during storage and cushioning material can be applied during transportation for enhance the quality of the fruits. Polythene bag is the cheapest among all the packaging materials with and without cushioning and waxing.

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How to cite this article:

Meena, H.R., S. Kala, R.K. Meena, G.L. Meena and Singh, R.K. 2018. Enhancing Firmness and Nutritional Quality of Ber Fruit with Suitable Packaging Materials and Waxing during Storage. *Int.J.Curr.Microbiol.App.Sci.* 7(08): 2584-2591.
doi: https://doi.org/10.20546/ijcmas.2018.708.265