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Optimizing post-harvest preservation of karonda fruits through packaging materials and storage conditions

Rupali Dhole, Omkar Warang and Pankaj Sante

Abstract
The experiment entitled “Optimizing Post-Harvest Preservation of Karonda Fruits Through Packaging Materials and Storage Conditions” was carried out in Fruit and Vegetable Processing Unit Laboratory, Department of Horticulture, College of Agriculture, Dapoli during 2013-2014. The experiment was conducted with Factorial Complete Randomized Design. The experiment comprised of two factors i.e., Factor A: Packaging material and Factor B: Storage condition and 16 treatment combinations which are repeated three times. The treatment P_1 (Punnet boxes) and S_2 (cold storage) resulted least physiological loss in weight, shrivelling and spoilage which results in maximum shelf life. The treatment P_3 (Thermocol bowl) showed maximum total soluble solids, reducing sugars, total sugars, iron content and minimum titratable acidity. The cold storage (S_2) condition increased the total soluble solids, reducing sugars, total sugars and iron content, while minimum titratable acidity was recorded with ambient storage (S_1) condition. Overall, the combination of Punnet boxes (P_1) and cold storage (S_2) proved to be the most effective in preserving both the physical and chemical parameters of karonda fruits.

Keywords: Post-harvest preservation, karonda fruits, packaging materials

Introduction
The karonda (*Carissa carandas* L.) belongs to the family Apocynaceae and the genus Carissa, which comprises approximately 36 species. It is an evergreen shrub or small tree native to the tropical and subtropical regions of India. This resilient plant thrives in arid tropics and subtropics and can even grow on marginal and wastelands. Karonda is known for its attractive, brightly coloured edible fruits, making it a valuable addition to agriculture.

One of the remarkable features of karonda is its ability to thrive as a rainfed crop with minimal management. It doesn't require extensive care, making it a low-maintenance option for farmers. Furthermore, karonda is often used as a live fence around orchards, providing both a protective barrier and a source of delicious fruits. When the fruits ripen, they exhibit a delightful flavor profile, ranging from sub-acidic to sweet, accompanied by a distinctive aroma. People commonly enjoy ripe karonda fruits as a dessert. However, the utility of karonda extends beyond fresh consumption. Mature fruits are rich in pectin, making them ideal for preparing various products such as jelly, jam, squash, sauce, and syrup. These products are in high demand in the international market due to their unique flavor and nutritional value. The nutritional content of karonda fruits is noteworthy. They are a good source of protein (1.1-2.25%), vitamin C (1.6-17.9 mg/100 g), and essential minerals like iron (39.1 mg/100 g), calcium (21 mg/100 g), and phosphorus (38 mg/100 g) (Kumar and Singh, 1993) [1]. This nutritional profile adds to the appeal of karonda as both a fresh fruit and a source of processed products.

To further enhance the shelf life of harvested karonda fruits, proper packaging is essential. Packaging serves not only as a means of food preservation and protection but also plays a multifaceted role in value addition, quality assurance, quantity control, convenience in handling and distribution, and marketing (Khader, 2004) [2]. Unfortunately, research in this area has been limited, and there is a need for comprehensive studies on karonda packaging to benefit farmers and consumers alike.

The present investigation, titled "Optimizing Post-Harvest Preservation of Karonda Fruits Through Packaging Materials and Storage Conditions," aims to address this gap. By exploring the impact of various packaging materials and storage conditions, this research seeks to extend the shelf life of karonda fruits, ensure their quality, and enhance their marketability. This work can potentially lead to improved packaging solutions that protect against spoilage, simplify distribution and handling, and create a stronger connection between manufacturers and customers.

Materials and Methods

The experiment was carried out in the Fruit and Vegetable Processing Unit Laboratory, Department of Horticulture, College of Agriculture, Dapoli during 2013-2014. The experiment was conducted in Factorial Complete Randomized Design. The experiment comprised of two factors i.e., Factor A: Packaging material and Factor B: Storage condition and 16 treatment combinations which are repeated three times. The factor A consist of 8 levels i.e., P_1- Punnet boxes (transparent), P_2- Aluminium foil boxes, P_3- Thermocol bowl, P_4- CFB boxes, P_5- Plastic bag (200 gauge), P_6- Bamboo basket, P_7- Punnet boxes with polythene bag and P_8- Leaves bowl (control). The factor B consist of 2 levels i.e., S_1 - Ambient Temperature (28±2 °C) and S_2 - Cold Storage (12±1 °C). Ripe and uniform sized fruits of karonda were procured from the Plot No. 4 and 10 from the Experimental Farm of Department of Horticulture, College of Agriculture, Dapoli. About 100 Kg of karonda fruits were brought to the laboratory. Unripe, diseased, damaged and off type fruits were strictly discarded. The selected fruits were thoroughly washed with clean tap water to remove dirt and dust particles adhered to the pericarp of the fruit. Finally, fruits are wiped dry before used for packaging. The different physical parameters such as, physiological loss in weight (PLW) (%), shrivelling (%), spoilage (%) and shelf life, and chemical parameters such as, total soluble solids, reducing sugar, total sugar, titratable acidity and iron content, were recorded 3 days intervals.

Results and Discussion

Physical parameters

The data regarding effect of packaging material and storage condition on physical parameters of karonda is given in Table The effect of different packaging material and different storage condition on physical parameters of karonda was found significant.

Physiological loss in weight (PLW) (%)

Physiological loss in weight (PLW) of karonda fruit observed during the storage period showed an increasing trend from the initial day up to the 9th day. Among the treatments, P_1 displayed the least PLW of 1.23%, 2.01%, and 2.70% on the 3rd, 6th, and 9th days respectively. While punnet boxes primarily serve to protect fruits from physical harm, their design and material properties critically contribute to minimizing PLW. They achieve this by sustaining a conducive environment around the fruits, thus limiting physiological weight loss. This observation resonates with findings from Kumar *et al*. (2021) [3] and Khalid *et al*. (2020) [4] in strawberries, Crouch (1998) [5] in plums, Scheuermann *et al*. (2014) [6] in Murtilla, Adams *et al*. (2017) [7] in banana and Ngcobo *et al*. (2013) [8] in grapes.

Moreover, when the karonda fruit was stored in cold storage (S_2), it exhibited a reduced PLW of 1.88%, 2.83%, and 3.61% during the 3rd, 6th, and 9th days respectively. The low temperature and elevated relative humidity in cold storage are likely responsible for this as they decelerate the respiration and transpiration rates of fruits compared to those at ambient storage. These outcomes align with those reported by Kumar *et al*. (2021) [3] in strawberries, Masalkar *et al*. (2006) [9] in mangoes, Khude (2012) [10] in jackfruits, and Sanas (2014) [11] specifically in karonda.

Shrivelling (%)

Treatment P_1 consistently demonstrated the least amount of shrivelling, recording rates of 4.44% and 13.33% on the 6th and 9th days respectively. This reduction in shrivelling can likely be attributed to the modified atmospheric conditions inside the punnet box. The accumulation of CO_2 combined with a reduction in O_2, with high humidity, contributes to sustained fruit turgidity and firmness throughout storage. This observation is consistent with studies by Antala *et al*. (2008) [12] in mangoes, Crouch (1998) [5] in plums, and Sanas (2014) [11] in karonda.

Treatment S_2 displayed the least shrivelling at 15.82% after 9 days in cold storage. The reduced shrivelling in this treatment can be credited to the low temperatures and high relative humidity in cold storage, which collectively minimize moisture loss from fruits as compared with ambient storage. This reduction in shrivelling was similar with findings from Crouch (1998) [5] in plums and Sanas (2014) [11] in karonda.

Spoilage (%)

Treatment P_1 exhibited the lowest spoilage rates (3.33% and 11.67%) on the 6th and 9th days of storage, respectively. The packaging materials used in this treatment seem to have played a pivotal role in regulating spoilage over time under various storage conditions. This could be attributed to their capability to limit transpiration from the fruit surface and maintain elevated CO_2 levels within the packaging. These outcomes are in line with the findings of Ozkaya *et al*. (2009) [13] and Kumar *et al*. (2021) [3] in strawberries, Crouch (1998) [5] in plums, Phutankar (2013) [14] in jackfruit, and Pattar *et al*. (2021) [15] in jamun.

Treatment S_2, when stored under cold conditions, noted the least spoilage (11.24%) after 9 days. The cold storage conditions are known to curtail the metabolic activities in fruits, leading to a reduced respiration rate, subsequently delaying their senescence. Additionally, many microorganisms, encompassing various bacteria and fungi, exhibit stunted growth rates under colder conditions, which directly correlates with the reduced spoilage observed in fruits stored in such environments. These findings are supported by research conducted by Garande (1992) [16] in jamun, Mali (1999) [17] in papaya, Mann and Dhillon (1998) [18] in grapes, and Khude (2012) [10] in jackfruit.

Shelf life (Days)

During the storage evaluation, treatment P_1 showed maximum shelf life of 9.50 days. The use of Punnet boxes in this treatment provided a modified atmosphere within the package. This modified environment reduced the rates of both transpiration and respiration in the stored fruits. As a result, the metabolism of the fruit slowed down, while its turgidity was retained, leading to an enhanced shelf life. Such observations align with the findings from Alique *et al*. (2003) [19] in sweet cherries, Scheuermann *et al*. (2014) [6] in Murtilla, and Adams *et al*. (2017) [7] in bananas.

Concurrently, fruits stored under cold storage conditions, specifically treatment S_2, also showed maximum shelf life of 9.50 days during the storage period. The cold conditions inherently reduce the rate of metabolic activities in fruits, particularly respiration. Furthermore, these lowered temperatures not only decrease transpiration rates but also inhibit the proliferation of spoilage-causing microorganisms, such as fungi and bacteria. This confluence of factors collectively contributes to extending the shelf life of fruits. These findings are consistent with studies by Garande (1992) [16] in jamun, Mali (1999) [17] in papaya, Mann and Dhillon (1998) [18] in grapes, and Sanas (2014) [11] in karonda.

Chemical parameters

Total soluble solids (ºB)

The data regarding effect of packaging material and storage condition on total soluble solids is presented in the Table 2. During 3, 6 and 9 days storage, treatment P_3 showed maximum TSS. content (12.40, 12.70 and 11.20 0Brix), respectively. The TSS of fruits increased at 3 and 6 days of storage and further it decreased at 9 days of storage. The increase in TSS during storage might be attributed to the increasing concentration of soluble solids in fruit as a result of water loss of fruit and accumulation of soluble sugars with the progression of the storage period. The results of the present study are in close conformity with the findings reported by Sood *et al.* (2012) [20] in strawberry and Adams *et al*. (2017) [7] in bananas.

The TSS content of karonda fruit increased from initial (10.60° Brix) to 6th day of storage (11.59° Brix) and then decreased at 9th day of storage (8.37° Brix), at ambient temperature (S_1). While in cold storage condition (S_2), T.S.S content of karonda fruit increased continuously from initial (10.60° Brix) to 6th day of storage (12.07° Brix) and then decreased at 9th day of storage (11.82° Brix). At 9 days storage, karonda fruit stored at cold storage (S_2) recorded maximum TSS content (11.82° Brix) and it was significantly superior over ambient storage. The TSS increased during early days of storage, which was probably due to hydrolysis of polysaccharides. Due to the hydrolysis, the non-soluble fraction converted into soluble fraction. The decrease in TSS after a particular peak period in storage may be due to increase in senescence process, which resulted in increased respiration rate. Similar findings were also reported by Meena *et al*. (2009) [21] in ber and Chandra and Kumar (2012) [22] in guava.

Reducing sugars (%)

Table 2 presents the data concerning the impact of packaging material and storage conditions on reducing sugars in karonda fruits. Over a storage period of 3, 6, and 9 days, it was observed that treatment P_3 exhibited the highest reducing sugar content, measuring 5.83%, 5.97%, and 5.26%, respectively. Notably, the reducing sugar content in the fruits increased at 3 and 6 days of storage but decreased at the 9 days of storage. This initial increase can be attributed to the hydrolysis of non-reducing sugars into reducing sugars. These findings are similar with observations made by Sood *et al*. (2012) [20] in strawberries, Adams *et al*. (2017) [7] in bananas, and Sanas (2014) [11] in the case of karonda.

In the case of karonda fruit stored at ambient temperature (S_1), the reducing sugar content increased from the initial value of 4.98% to 5.46% at 6 days of storage, after which it decreased to 3.93% at the 9 days storage. However, when stored under cold storage conditions (S_2), the reducing sugar content continued to rise from the initial 4.98% to 5.67% at 6 days of storage, and it only slightly decreased to 5.55% at the 9 days storage. At the end of the 9 days storage period, karonda fruit stored in cold storage (S_2) exhibited the highest reducing sugar content, which was significantly superior to that stored under ambient conditions (S_1). The observed increase in reducing sugars during the early stages of storage is likely due to the breakdown of more complex carbohydrates, such as starches, into simpler sugars, including reducing sugars like glucose and fructose. Once this peak is reached, the concentrations of reducing sugars in the fruit can start to decline. This decrease may result from ongoing metabolic processes, such as glycolysis, in which sugars are further broken down to produce energy. These findings align with those reported by Singh *et al*. (2010) [23] in the case of ber fruits and Sanas (2014) [11] regarding karonda.

Total sugars (%)

The data regarding the influence of packaging material and storage conditions on total sugars in karonda fruits is summarized in Table 2. Among the various treatments, treatment P_3 (8.42%, 8.76%, and 7.73%) exhibited the highest total sugar content during 3, 6, and 9 days of storage, respectively. It is worth noting that the total sugar content in the fruits increased at 3 and 6 days of storage and then decreased by the 9 days storage. This observed increase in sugar content during storage can likely be attributed to the conversion of starch and polysaccharides into soluble sugars and the dehydration of the fruits. These findings are consistent with results reported by Phutankar (2013) [14] in jackfruit and Sanas (2014) [11] in karonda.

When karonda fruits were stored at ambient temperature (S_1), the total sugar content increased from the initial (7.31%) to 6 days (7.96%) of storage and subsequently decreased to 9 days (5.77%) storage. In contrast, when the fruits were stored in cold storage conditions (S_2), the total sugar content continuously increased from the initial (7.31%) to 6 days (8.32%) of storage and then slightly decreased to 9 days (8.15%) storage. At the end of the 9 days storage period, karonda fruits stored in cold storage (S_2) displayed the highest total sugar content, which was significantly superior to that of fruits stored under ambient conditions (S_1). The increase in total sugar during storage can be attributed to the rise in both reducing and non-reducing sugars, which result from the conversion of starch into simpler sugars. The subsequent reduction in sugar content is likely due to the utilization of sugar in the process of respiration. Similar findings regarding total sugars have been reported by Parihar and Kumar (2007) [24], Singh *et al*. (2010) [23] in ber, and Chandra and Kumar (2012) [22] in guava.

Titratable acidity (%)

The data regarding effect of packaging material and storage condition on titratable acidity is presented in the Table 3. During 3, 6 and 9 days of storage, treatment P_3 (0.68%, 0.63% and 0.51%) recorded minimum titratable acidity, respectively. Similar results were found by Kumar *et al*. (2021) [3] in strawberry, Alique *et al*. (2003) [19] in sweet cherry and Sanas (2014) [11] in karonda.

The acidity content of karonda fruit decreased from initial (0.82%) to 9 days (0.52%) storage, at ambient temperature (S_1). While in cold storage condition (S_2), acidity content of karonda fruit decreased continuously from initial (0.82%) to 9 days (0.62%) storage. At 9 days of storage, Karonda fruits at ambient temperature (S_1) (0.52%) showed minimum titratable acidity and it was significantly superior over cold storage. This might be due to the fact that high temperature and low humidity at ambient storage resulted in faster degradation of organic acids during respiration. Similar findings of acidity were observed by Jadhav *et al.* (2006) [25] and Sanas (2014) [11] in karonda.

Iron content (mg/100 g)

The data regarding effect of packaging material and storage condition on iron content is presented in the Table 3. During 3 and 6 and 9 days storage, treatment P_3 (31.43 mg/100 g, 27.25

mg/100 g and 22.77 mg/100 g) showed maximum iron content, respectively. The iron content of fruits decreased continuously from initial to 9 days of storage.

The iron content of karonda fruit decreased from initial (0 days) (35.82 mg/100 g) to 9 days (16.45 mg/100 g) storage, at ambient temperature (S_1). While in cold storage condition (S_2), iron content of karonda fruit decreased continuously from initial (35.82 mg/100 g) to 9 days (22.12 mg/100 g) storage. At 9 days of storage, Karonda fruits stored at cold storage (S_2) recorded maximum iron content and it was significantly superior over ambient storage. Similar findings of iron were observed by Wani *et al.* (2013) [26] in karonda jam.

Conclusion

In conclusion, the research conducted on the "Effect of packaging materials and storage conditions on physical and chemical parameters of karonda cv. Konkan Bold" has provided valuable insights into enhancing the post-harvest preservation and quality of karonda fruits. The results highlighted the significance of Punnet boxes (P_1) and cold storage (S_2) in minimizing physiological loss in weight, shrivelling and spoilage, ultimately leading to an extended shelf life. The modified atmospheres created by Punnet boxes and the low temperatures in cold storage played vital roles in preserving the fruits, reducing moisture loss, and inhibiting the growth of spoilage-causing microorganisms. Treatment P_3 (thermocol bowl) consistently exhibited higher total soluble solids, reducing sugars, total sugars, iron content and lower titratable acidity, signifying its effectiveness in maintaining the overall quality of karonda fruits during storage. Cold storage (S_2) further enhanced the preservation of total soluble solids reducing sugars, total sugars and iron content offering better quality retention compared to ambient storage (S_1). The findings suggested that cold storage helps to slow down metabolic processes and maintain the quality of the fruits.

Overall, the combination of Punnet boxes (P_1) and cold storage (S_2) proved to be the most effective in preserving both the physical and chemical parameters of karonda fruits. This approach not only extended the shelf life of the fruits but also retained their nutritional quality, making them more appealing to consumers. These results have practical implications for farmers and the fruit processing industry, as they can adopt these packaging and storage strategies to improve the marketability of karonda fruits and reduce post-harvest losses.

Table 1: Effect of packaging material and storage conditions on physical parameters of karonda

Treatments	PLW (%)				Shrivelling (%)				Spoilage (%)				Shelf life (Days)
Factor A: Packaging material													
	0 Days	3 Days	6 Days	9 Days	0 Days	3 Days	6 Days	9 Days	0 Days	3 Days	6 Days	9 Days	
P_1	0.00	1.23	2.01	2.70	0.00	0.00	4.44	13.33	0.00	0.00	3.33	11.67	9.50
P_2	0.00	1.33	2.46	4.01	0.00	0.00	6.67	15.55	0.00	0.00	6.67	15.00	8.50
P_3	0.00	2.52	4.78	6.03	0.00	0.00	5.55	15.55	0.00	0.00	5.00	13.33	9.00
P_4	0.00	1.93	4.13	6.20	0.00	0.00	11.11	23.33	0.00	0.00	7.41	21.66	5.50
P_5	0.00	1.54	2.83	4.23	0.00	0.00	7.78	20.00	0.00	0.00	6.67	20.00	7.00
P_6	0.00	1.27	2.38	4.45	0.00	0.00	12.22	26.66	0.00	0.00	10.00	21.69	5.00
P_7	0.00	1.86	2.90	4.56	0.00	0.00	6.67	16.66	0.00	0.00	6.67	19.99	8.00
P_8	0.00	5.19	8.52	12.41	0.00	0.00	14.44	28.89	0.00	0.00	11.67	28.41	5.00
SEm±	0.00	0.01	0.02	0.02	0.00	0.00	1.36	2.52	0.00	0.00	0.96	1.70	0.50
CD at 1%	0.00	0.05	0.06	0.06	0.00	0.00	5.27	9.74	0.00	0.00	3.71	6.60	1.93
Factor B: Storage conditions													
S_1	0.00	2.32	4.65	7.52	0.00	0.00	17.21	24.16	0.00	0.00	14.34	26.69	4.87
S_2	0.00	1.88	2.83	3.61	0.00	0.00	0.00	15.82	0.00	0.00	0.00	11.24	9.50
SEm±	0.00	0.01	0.01	0.01	0.00	0.00	0.68	1.26	0.00	0.00	0.48	0.85	0.25
CD at 1%	0.00	0.03	0.03	0.03	0.00	0.00	2.64	4.87	0.00	0.00	1.86	3.30	0.96

Table 2: Effect of packaging material and storage conditions on total soluble solids, reducing sugars and total sugars of karonda

Treatments	TSS (°C)				Reducing sugars (%)				Total sugars (%)			
Factor A: Packaging material												
	0 Days	3 Days	6 Days	9 Days	0 Days	3 Days	6 Days	9 Days	0 Days	3 Days	6 Days	9 Days
P_1	10.60	10.70	11.00	10.30	4.98	5.03	5.17	4.84	7.31	7.38	7.59	7.11
P_2	10.60	10.90	11.40	10.40	4.98	5.12	5.36	4.89	7.31	7.52	7.86	7.18
P_3	10.60	12.40	12.70	11.20	4.98	5.83	5.97	5.26	7.31	8.42	8.76	7.73
P_4	10.60	11.00	11.50	9.50	4.98	5.17	5.41	4.47	7.31	7.59	7.94	6.56
P_5	10.60	11.40	12.00	9.20	4.98	5.36	5.64	4.32	7.31	7.87	8.28	6.35
P_6	10.60	12.20	12.10	10.00	4.98	5.73	5.69	4.70	7.31	8.31	8.35	6.90
P_7	10.60	12.00	12.40	10.40	4.98	5.64	5.82	4.89	7.31	8.28	8.55	7.18
P_8	10.60	11.60	11.40	9.80	4.98	5.45	5.36	4.61	7.31	8.00	7.87	6.76
SEm±	0.08	0.17	0.18	0.19	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CD at 1%	NS	0.66	0.70	0.75	NS	0.05	0.05	0.05	NS	0.05	0.05	0.05
Factor B: Storage conditions												
S_1	10.60	11.57	11.59	8.37	4.98	5.43	5.46	3.93	7.31	7.92	7.96	5.77
S_2	10.60	11.47	12.07	11.82	4.98	5.39	5.67	5.55	7.31	7.91	8.32	8.15
SEm±	0.04	0.09	0.09	0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD at 1%	NS	NS	0.35	0.38	NS	0.03	0.03	0.03	NS	0.03	0.03	0.03

Table 3: Effect of packaging material and storage conditions on titratable acidity and iron content of karonda

Treatments	Titratable acidity (%)				Iron content (mg/100 g)			
	0 Days	3 Days	6 Days	9 Days	0 Days	3 Days	6 Days	9 Days
P_1	0.82	0.76	0.71	0.62	35.82	31.23	27.18	21.85
P_2	0.82	0.71	0.64	0.56	35.82	29.23	24.73	20.71
P_3	0.82	0.68	0.63	0.51	35.82	31.43	27.25	22.77
P_4	0.82	0.72	0.69	0.60	35.82	26.57	23.12	19.11
P_5	0.82	0.73	0.67	0.57	35.82	28.32	23.90	18.99
P_6	0.82	0.71	0.64	0.58	35.82	25.54	21.69	16.51
P_7	0.82	0.70	0.62	0.56	35.82	27.26	22.31	18.18
P_8	0.82	0.69	0.64	0.55	35.82	27.04	21.74	16.23
SEm±	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CD at 1%	NS	0.05	0.05	0.05	NS	0.05	0.05	0.05
Factor B: Storage conditions								
S_1	0.82	0.65	0.59	0.52	35.82	26.84	22.25	16.45
S_2	0.82	0.76	0.70	0.62	35.82	29.90	25.72	22.12
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD at 1%	NS	0.03	0.03	0.03	NS	0.03	0.03	0.03

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