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Studies on effect of storage conditions on physical parameters of pomegranate (*Punica granatum* L.)

SS Patil, SA Ranpise, BB Dhakare and VP Kad

Abstract
The present research work entitled "Standardization of protocol for supply chain management of pomegranate (*Punica granatum* L.)" was conducted at M/s. Sahyadri Farmers Producer Company Limited (SFPCL) - Way to sustainable Agriculture, at post Mohadi, Tal. Dindori, Dist. Nashik. And at Post Harvest Technology Centre, Department of Horticulture, MPKV., Rahuri-413722, Dist-Ahmednagar, Maharashtra during the year 2018-2020. The objectives of present research were to study the effect of storage conditions on quality of pomegranate during supply chain management. In final trial, uniform size pomegranate samples were packed in different types of packaging materials namely liner bags with CFB box, liner bags with crate, 50 micron LDPE bags with CFB box and 50 micron LDPE bags with crate stored in room temperature (17.4 to 29.8 ^{0}C and 31 to 73.00% RH) and cold storage (5-7 ^{0}C and 90.0 to 95% RH). The loss of physical, chemical as well as sensory parameters of pomegranate were found to be less in cold storage (CS) than room temperature (RT).

Keywords: Studies, conditions, parameters, pomegranate, *Punica granatum* L.

Introduction
Pomegranate (*Puncia granatum* L.) is gaining popularity in Maharashtra as well as in whole India mainly because of its versatile adaptability, drought tolerant nature and also the steady and high yield. India is the world's leading pomegranate growing country with about 261 thousand hectares of area, 2315 thousand MT of production (Anon., 2020) [1]. Pomegranate cultivation today is highly remunerative agriculture business in India. The storage life of pomegranate fruit is not more than 10-15 days at room temperature. Research efforts have helped to increase the production of pomegranate but the purpose of obtaining maximum profit will be served only if the increased production is supplemented with similar efforts to minimize the post harvest losses and enhance the shelf life. Pomegranate, being a non-climacteric fruit has a tremendous potentiality for modified atmosphere packaging (MAP) using various polymeric films which will not only retain fruit quality during storage but also help in alleviation of chilling injury during refrigerated transport and storage. Therefore, an integrated approach on both production and post harvest management using recent technologies on post harvest handling *viz*., individual shrink wrapping, waxing, controlled atmosphere (CA) storage coupled with judicious temperature management practices needs more attention for wide distribution of this delicious fruit in the global market (Roy and Waskar, 1997) [16].

Objectives
Study the effect of storage conditions on physical parameters of pomegranate.

Material and Methods
This chapter deals with the material used and the methodologies followed for the investigation on post harvest handling through effective supply chain of pomegranate. The investigation was carried out in the "Sahyadri Farmer's Producer Company Limited (SFPCL) Way to sustainable agriculture", Gat No. 314, Near Water Tank, At/Post- Mohadi, Tal. Dindori, Dist. Nashik. and Post Harvest Technology, Department of Horticulture, MPKV., Rahuri, Dist- Ahmednagar, Maharashtra during 2018-19 and 2019-20. The details of the material, methodology employed and experimental techniques used for the study are presented below

Factor A: Storage conditions: 2
C_1: Room temperature
C_2: Cold storage (5 -7 ^{0}C)

Factor B: Packaging materials: 4
P_1: LDPE packaging with CFB Box
P_2: LDPE packaging with crate
P_3: Liner packaging with CFB Box
P_4: Liner packaging with crate

Table 1: Details of treatment combination

Sr. No.	Treatments	Details of treatment combinations
1	C_1P_1	Ambient temperature + LDPE bags with CFB box
2	C_1P_2	Ambient temperature + LDPE bags with crate
3	C_1P_3	Ambient temperature + Liner packaging with CFB box
4	C_1P_4	Ambient temperature + Liner packaging with crate
5	C_2P_1	Cold storage (5-7 ^{0}C) + LDPE bags with CFB box
6	C_2P_2	Cold storage (5-7 ^{0}C) + LDPE bags with crate
7	C_2P_3	Cold storage (5-7 ^{0}C) + Liner packaging with CFB box
8	C_2P_4	Cold storage (5-7 ^{0}C) + Liner packaging with crate

Table 2: Temperature (^{0}C) and Relative Humidity (%) conditions in the storage environment of pomegranate fruits

SN.	Storage condition	Temperature range (^{0}C)	R.H. Range (%)
1.	Room temperature (RT)	17.40 - 30.80	31.00 -70.00
2.	Cold storage (CS)	5-7	85 - 95

Details of Observations

1. Physiological loss in weight (PLW) (%)

The weight of the fruits were recorded on every third day and subtracted from the initial weight. The loss of weight in grams in relation to initial weight was calculated and expressed as percentage (Pawaskar, 2020) [14].

$$\text{PLW (\%)} = \frac{\text{Initial weight of fruit} - \text{Subsequent day weight of fruit}}{\text{Initial weight of fruit}} \times 100$$

2. Fruit firmness (N)

The firmness of the fruits were tested by a pocket penetrometer (Fruit Tester FT 327). The probe of the penetrometer was pierced through the fruit pulp and the pressure required was recorded on every alternate day. Each time punctures were made at two locations on fruit surface and their average was computed. The firmness was expressed as N (Newton).

Results and Discussion

1. Physiological loss in weight (PLW %)

The data on changes in physiological loss in weight of pomegranate fruits are presented in Table 3 In all the treatments, studied in the present investigation, the physiological loss in weight (PLW) increased with increase in the storage period. This may be due to loss of water from the fruits.

The enhanced period of exposure of fruits to atmosphere and increased respiration may have resulted in loss of weight in the form of water.

a) Effect of individual factor

Effect of storage conditions

The samples stored in room temperature (RT) on 18th day and in cold storage (CS) on 98th day recorded the PLW as 12.28 and 12.81 per cent, respectively.

The minimum reduction of physiological loss in weight of pomegranate fruits were found in C_2 (Cold Storage) as 12.81 per cent on 98th days of storage. While, the maximum reduction in physiological loss in weight was observed in C_1 (Room Temperature) as 12.28 per cent on 18th day of storage, respectively.

Effect of packaging materials

The individual effect of all packaging materials on physiological loss in weight of pomegranate fruits were found to be significant during storage period. The treatment P_3 (Liner packaging with CFB box) showed the lowest PLW value as 10.79 per cent on 98th day followed by P_4 (Liner packaging with crate) as 11.88 per cent on 77th day and P_1 (LDPE bags with CFB box) as 13.15 per cent on 63th day. Whereas the highest PLW was observed in P_2 as 13.35 per cent 42th day.

b) Interactions

The interaction effect of storage conditions and different packaging materials on physiological loss in weight of pomegranate fruits were significantly increased during storage period in all treatment combinations.

At the end of 18th day of pomegranate fruits stored in room temperature (RT), C_1P_3 (Ambient temperature + Liner packaging with CFB box) recorded the lowest PLW as 9.86 per cent followed by C_1P_4 (Ambient temperature + Liner packaging with crate) as 11.25 per cent at the end of 15th day storage and highest in C_1P_2 (Ambient temperature + LDPE bags with crate) as 13.81 per cent on 6th day of storage. In CS on 98th day of storage, the lowest PLW was observed in C_2P_3 (Cold storage (5-7 ^{0}C) + Liner packaging with CFB box) as 11.71 per cent followed by C_2P_4 (Cold Storage (5-7 ^{0}C) + Liner packaging with crate) as 12.50 per cent at the end of 77th day storage and highest in C_2P_2 (Cold storage (5-7^{0}C) + LDPE bags with crate) as 13.90 per cent on 42th day of storage.

The fruits continue to live even after harvest. The process of transpiration or moisture loss continues, but there is no way to replenish it. The physiological loss in weight indicates the total moisture lost during storage and respiration, which results in desiccation and a shriveled appearance of the fruit (Davies and Hobson, 1981) [6]. The physiological loss is essentially due to transpiration and respiration process (Krishnamurthy and Subramanyam, 1973) [11].

The mechanism of moisture loss from fruit is essentially the same as the evaporation of water. The driving force is the vapor pressure of the moisture in fruit when this vapor pressure in the fruit is higher than that of the surrounding air, moisture will be lost from the fruit to the atmosphere.

The low temperature and high humidity prevalent in cold storage may be responsible for reduction in PLW by reducing the rate of respiration and transpiration processes. Findings of this study are supported by Bakshi *et al*. (2013) [2]. The high relative humidity in packing (Khan and Singh, 2008) [10], reduced rate of senescence, respiration by antioxidants

(Bhardwaj *et al.*, 2005 and Reddy *et al.*, 2014) [4, 15] might have resulted in reduced PLW of fruit.

Fruit response to cold storage conditions were strongly influenced by cultivar. Cold storage had a positive effect on most of the fruit attributes. After storage, during shelf period, fruit quality deteriorated quickly. Water loss represents a major portion of fruit weight loss (75-90%; Kader *et al.*, 1984) [8]. Increase in vapor pressure deficit (VPD) during shelf period due to higher temperature and lower relative humidity must have increased rate of fruit water loss. Skin of pomegranate is very porous and allows rapid loss of moisture (Kader *et al.*, 1984) [8].

Table 3: Effect of different packaging material on PLW (%) of pomegranate cv. Bhagwa under different storage conditions

Treatments	Days after storage																		
	Initial day	3 Day	6 Day	9 Day	12 Day	15 Day	18 Day	21 Day	28 Day	35 Day	42 Day	49 Day	56 Day	63 Day	70 Day	77 Day	84 Day	91 Day	98 Day
Storage condition																			
C_1	0	4.17	5.26	8.14	9.97	11.10	12.28		-	-	-	-	-	-	-	-	-	-	-
C_2	0	2.83	4.35	5.13	6.11	7.44	8.35	9.21	10.05	10.38	11.09	11.42	11.67	11.93	12.14	12.45	12.56	12.63	12.81
S.Em. (±)		0.03	0.01	0.04	0.01	0.06	0.01	0.01	-	-	-	-	-	-	-	-	-	-	-
CD at 1%		0.12	0.04	0.15	0.04	0.24	0.04	0.04	-	-	-	-	-	-	-	-	-	-	-
Packaging materials																			
P_1	0	4.48	6.26	7.96	9.82	10.51	10.81	11.3	11.78	11.96	12.3	12.65	12.94	13.15	-	-	-	-	-
P_2	0	6.77	10.8	11.11	11.51	12.21	12.65	13.15	13.21	13.26	13.35	-	-	-	-	-	-	-	-
P_3	0	1.96	3.59	4.72	6.05	7.17	8.05	8.64	8.89	9.18	9.29	9.38	9.48	9.58	9.81	10.08	10.29	10.45	10.79
P_4	0	2.8	4.58	6.75	9.06	8.93	9.53	9.88	10.37	10.47	10.79	11.01	11.13	11.34	11.53	11.88	-	-	-
S.Em. (±)		0.01	0.04	0.01	0.02	0.03	0.01	0.04	0.01	0.06	0.01	0.01	0.16	0.35	0.03	0.01	-	-	-
CD at 1%		0.04	0.16	0.04	0.06	0.12	0.04	0.15	0.04	0.24	0.04	0.04	0.64	1.39	0.12	0.04	-	-	-
Interaction																			
C_1P_1	0	5.25	8.45	10.61	13.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C_1P_2	0	9.22	13.81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C_1P_3	0	2.82	4.78	6.24	8.21	8.91	9.86		-	-	-	-	-	-	-	-	-	-	-
C_1P_4	0	3.42	6.86	8.89	10.81	11.25	-	-	-	-	-	-	-	-	-	-	-	-	-
C_2P_1	0	3.71	4.91	5.31	6.42	7.81	8.42	9.42	10.35	10.72	11.4	12.1	12.68	13.1	-	-	-	-	-
C_2P_2	0	4.32	6.83	7.44	7.91	9.62	10.49	11.49	12.45	13.25	13.9	-	-	-	-	-	-	-	-
C_2P_3	0	1.18	2.44	3.23	4.49	5.72	6.69	7.43	7.93	8.51	8.72	8.92	9.13	9.33	9.76	10.32	10.72	11.03	11.71
C_2P_4	0	2.25	3.32	4.61	5.36	6.64	7.81	8.51	9.48	9.69	10.32	10.76	11.01	11.42	11.82	12.5	-	-	-
S.Em. (±)		0.03	0.01	0.04	0.16	0.35	0.03	0.27	0.26	0.06	0.01	0.01	0.24	0.25	0.23	0.24	-	-	-
CD at 1%		0.12	0.04	0.16	0.64	1.39	0.12	1.07	1.03	0.24	0.04	0.04	0.95	0.99	0.91	0.95	-	-	-

Moisture loss leading to shriveling and loss of turgidity. The lower PLW values in cold storage can be attributed to the low moisture loss due to prevailing low temperature.

The rate of increase in physiological loss in weight was found to be faster at RT storage as compared to CS storage might be due to temperature or rate of respiration. Results are in accordance with the findings reported by Jain (1999) for acid lime; Dhemre (2001) [7] for mango; Waskar (2011) [19]; Barman *et al.* (2011) [3] and Kumar *et al.* (2013) [12] for pomegranate fruit.

2. Firmness (N)

The firmness of pomegranate fruits were significantly influenced by different packaging materials and storage conditions. The firmness of pomegranate fruits were significantly decreased in all treatment combinations by increasing storage period.

a) Effect of individual factor

Effect of storage conditions

At the beginning of the storage, the firmness (N) of fresh pomegranate fruits was 27.60 N. The firmness of pomegranate fruits stored in room temperature (RT) on 18th day and at cold storage (CS) on 98th day was recorded as 19.65 N and 20.96 N, respectively. The firmness observed in pomegranate fruits was higher in cold storage (CS) than room temperature (RT).

Effect of packaging materials

The individual effect of packaging materials on firmness of pomegranate fruits showed significant result throughout the storage period. Treatment P_3 (liner packaging with CFB box) showed the highest firmness as 21.54 N on 98th day followed by P_4 (Liner packaging with crate) with 20.77 N on 77th day while the lowest firmness was observed in P_2 (LDPE bags with crate) as 18.57 on 42nd day of storage followed by P_1 (LDPE bags with CFB box) with 20.36 N on 63th day.

b) Interactions

The interaction effect of different packaging materials and storage conditions on firmness of pomegranate was significantly decreased during storage period in all treatment combinations. At the end of 18th day storage in room temperature (RT), treatment C_1P_3 (Ambient temperature + Liner packaging with CFB box) recorded highest firmness as 20.83 N followed by C_1P_4 (Ambient temperature + Liner packaging with crate) as 20.03 N at the end of 15th day and lowest in C_1P_2 (Ambient temperature+ LDPE bags with crate) as 18.13 N at the end of 6th day storage. At the end of 98th day storage in CS, treatment C_2P_3 (Cold storage (5-7 ^{0}C) + Liner packaging with CFB box) recorded highest firmness as 21.54 N followed by C_2P_4 as 20.77 N at the end of 77th day of storage and lowest in C_2P_2 (Cold storage (5-7 ^{0}C) + LDPE bags with crate) as 19.05 N.

The fruit firmness is one of the most crucial factors in determining the post harvest quality of fruits (Shear, 1975). This could be attributed to slow degradative changes during initial period. Thereafter with advancement of storage, loss of moisture from the fruit through the peel of pomegranate fruit might have resulted in decreased firmness. Although the peel

appears to be thick, it has numerous minute openings that permit free movement of water vapor, making the fruit highly susceptible to water loss (Kader *et al.*, 1984) [8]. The decrease in firmness during respiration may be due to break down of insoluble proto pectine into soluble pectine or by cellular disintegration leading to membrane permeability (Brinston *et al.*, 1988) [5].

The decline in firmness during storage is mainly due to the dissolution of the middle lamella, the reduction of cell-to-cell adhesion and the weakening of parenchyma cell walls as a result of the action of cell wall modifying enzymes leading to shriveling and softening (Paniagua *et al*., 2014) [13].

At low temperature, reduced metabolic activities and reduced evapotranspiration loss of water could be the reason of slower decrease in firmness. These findings are in accordance with work of Kaur *et al*. (2017) [9].

The post-harvest storage of pomegranate fruit is accompanied by loss of cell-wall integrity due to break down of pectic substances leading to an increase in soluble pectin and decrease in fruit firmness. Singh *et al*. (2014) [18] reported continuous decline in fruit firmness in all packaging material by the passage of storage period and also reported that fruit stored in refrigerated MAP has more firmness than other storage conditions.

Table 4: Effect of different packaging material on Firmness (N) of pomegranate cv. Bhagwa under different storage conditions

Treatments	Days after storage																		
	Initial day	3 Day	6 Day	9 Day	12 Day	15 Day	18 Day	21 Day	28 Day	35 Day	42 Day	49 Day	56 Day	63 Day	70 Day	77 Day	84 Day	91 Day	98 Day
Storage condition																			
C_1	27.60	24.62	23.41	22.61	21.22	20.15	19.65		-	-	-	-	-	-	-	-	-	-	-
C_2	27.60	26.72	26.06	25.62	25.02	24.52	23.63	23.24	23.03	22.76	22.55	22.32	22.05	21.73	21.49	21.32	21.16	21.14	20.96
S.Em. (±)		0.03	0.02	0.03	0.01	0.03	0.03	0.03	-	-	-	-	-	-	-	-	-	-	-
CD at 1%		0.12	0.08	0.12	0.04	0.12	0.12	0.12	-	-	-	-	-	-	-	-	-	-	-
Packaging materials																			
P_1	27.60	25.84	23.26	21.93	22.36	22.17	21.73	21.42	21.01	20.85	21.38	21.21	20.82	20.36	-	-	-	-	-
P_2	27.60	23.86	21.42	20.98	20.22	19.89	19.40	19.02	18.69	18.23	18.57		-	-	-	-	-	-	-
P_3	27.60	26.84	26.35	25.87	25.23	24.53	23.63	23.06	22.81	22.7	23.08	22.92	22.83	22.52	22.38	22.22	21.93	21.89	21.54
P_4	27.60	26.11	25.34	24.86	23.62	22.71	22.38	22.23	21.91	21.64	22.33	22.13	21.74	21.27	20.99	20.77	-	-	-
S.Em. (±)		0.79	0.02	0.03	0.01	0.03	0.03	0.02	0.03	0.01	0.03	0.03	0.01	0.03	0.03	0.02	-	-	-
CD at 1%		NS	0.08	0.12	0.04	0.12	0.12	0.08	0.12	0.04	0.12	0.12	0.04	0.12	0.12	0.08	-	-	-
Interaction																			
C_1P_1	27.6	24.33	20.61	19.61	18.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C_1P_2	27.6	22.22	18.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C_1P_3	27.6	26.25	25.49	24.72	23.61	22.70	20.83		-	-	-	-	-	-	-	-	-	-	-
C_1P_4	27.6	25.61	24.25	23.61	21.44	20.03	-	-	-	-	-	-	-	-	-	-	-	-	-
C_2P_1	27.6	27.35	25.9	25.45	25.11	24.73	23.84	23.19	22.41	22.08	21.83	21.15	20.82	20.36	-	-	-	-	-
C_2P_2	27.6	25.49	24.71	23.82	22.32	21.64	20.12	19.91	19.52	19.32	19.05		-	-	-	-	-	-	-
C_2P_3	27.6	27.42	27.23	27.01	26.84	26.22	25.84	25.28	24.78	24.56	23.33	23.01	22.83	22.52	22.38	22.22	21.93	21.89	21.54
C_2P_4	27.6	26.61	26.42	26.11	25.83	25.39	24.73	24.42	23.79	23.24	22.62	22.05	21.74	21.27	20.99	20.77	-	-	-
S.Em. (±)		1.4	0.02	0.03	0.01	0.03	0.03	0.02	0.03	0.01	0.03	0.03	0.01	0.03	0.03	0.02	-	-	-
CD at 1%		NS	0.08	0.12	0.04	0.12	0.12	0.08	0.12	0.04	0.12	0.12	0.04	0.12	0.12	0.08	-	-	-

Summary

Studies on effect of storage conditions on quality of pomegranate fruit

The storage conditions had significant effect on physical parameters of pomegranates fruit. The fruit in all the treatments showed increasing trends of physiological loss in weight while, in firmness (N) showed decreasing trend during the advancement of storage period in RT and CS. The loss of physical parameters of pomegranates fruits were found to be less in CS followed by in RT.

Conclusion

The fruits stored in cold storage have longer shelf life than the fruits stored in room temperature.

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