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PHYSICAL, MECHANICAL AND CHEMICAL ATTRIBUTES OF MANGO INFLUENCED BY VARIETY AND POST-HARVEST TREATMENTS

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ABSTRACT

Delay of mango ripening would be possible by applying different promising postharvest treatments. Hence, the present study attempts to investigate the effect of different postharvest treatments on the ripening delay of two commercially important mango varieties. The two-factor experiment was laid out in a completely randomized design (CRD) with three replications. A longer period was required to reach ripening stages in the variety Ashwina. The rate of changes in farmness was faster in Fazli than in Ashwina. Weight loss was also minimal (8.90% at 12 DAS) in Ashwina when wrapped in a non-perforated LDPE bag with $KMnO_4$. The highest moisture content (85.80% at 12 DAS) and the lowest dry matter content (14.20% at 12 DAS) were noticed in Fazli wrapped in a non-perforated LDPE bag with $KMnO_4$. Whereas, the lowest moisture content (70.31% at 12 DAS) and the highest dry matter content (29.69% at12 DAS) in Ashwina with control treatment.

Key words : Mango, Postharvest treatment, Quality.

Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical fruits worldwide regarding production, consumption, and nutritional value. It belongs to the Anacardiaceaefamily (Ntsoane *et al*., 2019). Mango fruit contains various bioactive compounds such as vitamin C, â-carotene, and polyphenols, that contribute to antioxidant and nutritional properties (Marcillo-Parra *et al*., 2021). The nutritional content of mangoes is influenced by cultivar, maturity stage, storage conditions and postharvest technologies (Singh and Zaharah, 2015). Mango is a climacteric fruit that is normally harvested at the green mature stage (Rosalie *et al*., 2019) and then ripened to achieve the desired taste and texture (Cortés *et al*., 2016). Due to the highly perishable nature of the mango fruit, a significant amount of quantitative and qualitative postharvest losses occur during marketing. Because of tropical and sub-tropical climatic nature, a great number of mango genotypes exist in Bangladesh especially in the north-western regions (Rahman *et al*., 2022). Ashwina and Fazli are two commercially important mango cultivars characterized bytheir late maturity, high price and availability in the market for longer periods. The post-harvest losses of mango are 17-36%, which may rise to 100%, if proper management strategies are not in place (Alam *et al*., 2017). However, the post-harvest loss of mango in Bangladesh is 27.40% (Hafiz *et al*., 2018). This loss occurs during harvesting,storage, transporting and marketing due to mechanical injuries, adversephysiological changes (loss of weight due to increased respiration and transpiration), softening of the flesh, and lack of resistance capacity against microbial attack. Therefore, harvesting and post-harvest handling must be done with proper care so that no mechanical injury occurs. Besides, the mangoes can be treated with several biological or chemical solutions, or preserved in certain modified atmospheric conditions to enhance shelf life without sacrificing the product quality. In addition, transporting under optimum conditions of temperature, relative humidity, and composition of the atmosphere and the use of ripening retardants can extend mango shelf life (Elzubeir *et al*., 2017). Polyethylene films either sealed or perforated are commonly used wrapping materials to minimize weight loss, reduce abrasion damage, delay fruit ripening and extend shelf-life (Nagaraju and Banik, 2019). Polyethylene box liners have been used for several years in the storage of apples and pears and now are extending to other commodities (Ait-Oubahou *et al*., 2019). It has been shown that fruits packed in polyethylene-lined boxes have a longer shelf-life than controlled fruits (Hailu *et al*., 2014). Potassium permanganate ($KMnO_4$) is quite effective in reducing ethylene levels by oxidizing it to carbon dioxide and water. It is a chemical that has long been used to remove ethylene from the storage atmosphere (Álvarez-Hernández *et al*., 2019). It was demonstrated that $KMnO_4$ retarded the ripening of many fruits (Fatima *et al*., 2023). The use of $KMnO_4$ in conjunction with the modified atmosphere in polyethylene films delayed fruit ripening, maintained quality and extended shelf life in apricots (Moradinezhad and Jahani, 2019), mango (Elzubeir *et al*., 2017) and guava (Murmu and Mishra, 2018).

The post-harvest life of any fruit consists of ripening and senescence. The ripening and subsequent senescence are the totals of severalpost-harvest changes. Hence, it is necessary to understand the post-harvest physiology of mango to develop and apply adequate post-harvest technologies, such as hot water treatment, storage in a polythene bag, use of fungicide and $KMnO_4$ in polythene bags, storage in low temperatures, etc. to fulfill the requirements of national and international trade through prevention of post-harvest losses. Many workers studied the effects of many postharvest treatments with a large number of mango cultivars and observed the extended shelf life (Gomasta *et al*., 2017; Hoque *et al*., 2018; Islam *et al*., 2016; Mounika *et al*., 2017; Perumal *et al*., 2021). However, little information on Fazli and Ashwina is available in the scientific literature. Therefore,the present study was undertaken to study the effects of different post-harvest treatments on the physical, mechanical and biochemical changes of mango during storage.

Materials and Methods

The experiment was carried out at the laboratories of the Horticulture and Biochemistry Department, Bangladesh Agricultural University, Mymensingh. Mature fruits of similar shape, uniform size, and free from visible disease symptomsof two mango varieties namely, Fazli and Ashwina were collected from the mango orchards at Chapainawabganj, Bangladesh. The maturity of mangoes was indicated when the shoulders were in line with the stem end and the color was olive green. Maturity was also judged by the grower's recommendation. The experiment consisted of seven post-harvest treatments *viz*., T_0: Control (ambient temperature without wrapping), T_1: Fruit wrapping with thin plastic film, T_2: Paper wrapping and storing at 15ºC, T_3: Fruit wrapping in non-perforated LDPE bag containing $KMnO_4$ (5 g fruit^{-1}), T_4: Fruit wrapping in non-perforated LDPE bag without $KMnO_4$, T_5: Fruit treated with hot water at 50ºC for 5 minutes and T_6 : Fruit store at 12ºC without any treatment or wrapping. The two-factor experiment was laid out in a completely randomized design with three replications. The skin adherences, dots and latex were cleaned by gently wiping the fruits with a moist and clean towel. The cleaned fruits were kept on brown papers those were previously placed in the laboratory at ambient conditions and air dried.

Data on fruit physical parameters (color, firmness, weight loss, moisture content and dry matter content) were recorded at an interval of 3 days during storage. The changes in the color of mango during storage and ripening were determined objectively using a numerical rating scale of 1-7 followed by Hafiz *et al*. (2018). Weight loss was measured by using the method described by Vázquez-Celestino *et al*. (2016), while the moisture content of the fruit was determined by the method described by Bai *et al*. (2021). The percent dry matter content of the pulp was calculated from the data obtained during moisture estimation using the formula followed by Anderson *et al*. (2017).

Statistical analysis

The collected data were tabulated and analyzed using the statistical package program 'R' (version 4.2.2). A two-way analysis of variance was performed where treatment means were compared based on Fisher's protected least significant difference (LSD) test, with significance tested at $p< 0.01$.

Results and Discussion

The main effect of variety, post-harvest treatments, and their interactions were significant ($p<0.01$) on the studied parameters under this experiment (Table 1).

Color is one of the most important criteria for the quality assessment of most fruits (Goldenberg *et al*., 2018). The changes in the color of mango peel from green to breaker are the most obvious phenomenon that occurs

Table 1 : ANOVA of different parameters under study.

Parameters	Variety (V)	Treatment (T)	Interaction (V×T)
Color	**	**	**
Firmness	**	**	**
Weight loss	**	**	**
Moisture content (%)	**	**	**
Dry matter content (%)	**	**	**
Total Soluble Solids (% Brix)	**	**	**

during the storage of fruits. Change of peel color during ripening and senescence of fruits involves chlorophyll degradation or qualitative and quantitative alternation of the green pigment into other pigments (Aziz *et al.*, 2021). During color change, the pulp becomes softer and sweeter as the ratio of the sugar to starch increases and the characteristic aroma is produced. A longer period is required for Ashwina than Fazli to reach different stages of ripening. The higher color score of 5.89 was observed in Fazli, while the lower color score of 5.12 was recorded in Ashwina on the 12th day of storage (Table 2) might be due to varietal character (Penyimpanan, 2013).

The post-harvest treatments had a significant effect on the changes in the peel color of the mango. The highest color scores (1.79, 4.51, 5.64 and 5.81 at 3, 6, 9 and 12 DAS, respectively) were observed in T_0 (control), while the lowest color score (1.04, 2.91, 3.99 and 4.71 at 3, 6, 9 and 12, respectively) was recorded in T_3 (non-perforated LDPE bag with $KMnO_4$), followed by T_4 (LDPE plastic bag without $KMnO_4$) (1.04, 3.36, 4.30 and 4.89 at 3, 6, 9 and 12 DAS, respectively). The combined effects of variety and post-harvest treatments combination were also significant in color changes on different days of storage. The highest color score (5.81) was observed in Fazli when kept at the control condition as against the lowest (4.22) in Ashwina stored in a non-perforated LDPE bag with $KMnO_4$ (Table 3) meaning that the change of color was slower in LDPE bag with $KMnO_4$ treatment than that of the other post-harvest treatments. This is in line with the findings of Elzubeir *et al.* (2017), who reported that polyethylene film lining and $KMnO_4$ delayed peel color development in mangoes. Polyethylene wrapping resulted in a modified atmosphere with lower O_2 concentration, which suppresses ethylene biosynthesis, and higher CO_2, which inhibits ethylene action (Ahammed and Li, 2022). $KMnO_4$ in conjunction with film further

Table 2 : The main effect of varieties and treatments on color, firmness and weight loss (%) of mango at different days after storage.

Factors	Color change at different DAS				Firmness at different DAS				Weight loss (%) at different DAS			
	3	6	9	12	3	6	9	12	3	6	9	12
Variety (V)												
Fazli	1.49	4.07	5.22	5.89	2.08	3.07	4.10	5.15	4.91	7.65	9.62	10.94
Ashwina	1.04	3.36	4.44	5.12	2.05	2.98	3.95	4.62	5.50	7.91	9.97	11.17
$LSD_{0.01}$	0.027	0.076	0.066	0.105	0.038	0.090	0.047	0.066	0.157	0.108	0.214	0.223
Treatment (T)												
T_0	1.79	4.51	5.64	5.81	2.55	3.46	4.51	5.40	6.58	9.08	11.01	12.56
T_1	1.33	3.86	5.01	5.60	2.10	3.18	4.13	4.95	6.39	8.89	10.89	12.09
T_2	1.45	3.90	5.15	5.73	1.75	2.77	3.84	4.71	4.49	6.99	9.05	10.22
T_3	1.04	2.91	3.99	4.71	1.56	2.41	3.38	4.41	2.69	5.69	7.77	8.87
T_4	1.04	3.36	4.30	4.89	2.31	3.33	4.30	5.06	4.30	6.80	8.89	10.15
T_5	1.16	3.75	4.90	5.54	2.47	3.36	4.41	5.25	5.79	8.29	10.29	11.49
T_6	1.08	3.71	4.85	5.54	1.73	2.67	3.63	4.46	6.31	8.71	10.71	12.02
$LSD_{0.01}$	0.051	0.143	0.124	0.196	0.071	0.168	0.088	0.124	0.295	0.202	0.401	0.417

Color scores (1: green, 2: breaker, 3: up to 25% yellow, 4: 25-50% yellow, 5: 50-75% yellow 6: 75-100% yellow, and 7: blackened/ rotten), **Firmness scores (**1: hard green, 2: sprung, 3: between sprung and eating ripe, 4: eating ripe, 5: overripe, and 6: totally unfit for consumption) and **Treatment** (T_0: Control, T_1: Wrapping with thin plastic film, T_2: Paper wrapping and store at 15ºC, T_3: Fruit wrapped in non-perforated LDPE bag with KMnO4, T_4: Fruit wrapped in non-perforated LDPE bag without KMnO4, T_5: Fruit treated with hot water at 50ºC, T_6: Fruit store at 12ºC).

Table 3 : Interaction effect of varieties and treatments on color, firmness and weight loss (%) of mango on different days after storage.

Variety	Post-harvest treatments	Color change at different DAS				Firmness at different DAS				Weight loss (%) at different DAS			
		3	6	9	12	3	6	9	12	3	6	9	12
Fazli	T_0	1.79	4.51	5.64	5.81	2.77	3.74	4.72	5.50	6.27	8.90	10.75	12.45
	T_1	1.33	3.86	5.01	5.60	2.11	3.25	4.25	5.02	6.20	8.58	10.58	11.78
	T_2	1.45	3.90	5.15	5.73	1.58	2.60	3.71	4.81	3.79	7.19	9.19	10.49
	T_3	1.04	2.91	3.99	4.71	1.42	2.39	3.40	4.64	2.69	5.70	7.70	8.90
	T_4	1.04	3.36	4.30	4.89	2.47	3.51	4.48	5.15	3.56	7.04	9.04	10.44
	T_5	1.16	3.75	4.90	5.54	2.67	3.55	4.65	5.27	5.92	7.66	9.66	10.86
	T_6	1.08	3.71	4.85	5.54	1.58	2.45	3.52	4.72	5.94	8.48	10.48	11.70
Ashwina	T_0	1.25	4.17	5.53	6.12	2.33	3.19	4.30	5.00	6.90	9.29	11.27	12.67
	T_1	1.00	3.50	4.70	5.33	2.10	3.11	4.02	4.75	6.58	9.20	11.20	12.40
	T_2	1.08	3.55	4.82	5.36	1.88	2.95	3.97	4.40	5.19	6.79	8.92	9.96
	T_3	1.00	2.65	3.25	4.22	1.71	2.43	3.36	4.18	2.70	5.69	7.85	8.85
	T_4	1.00	2.81	3.85	4.52	2.16	3.15	4.12	4.85	5.04	6.56	8.74	9.86
	T_5	1.00	3.42	4.52	5.16	2.27	3.17	4.18	5.00	5.66	8.92	10.92	12.12
	T_6	1.00	3.42	4.45	5.16	1.88	2.89	3.75	4.21	6.48	8.94	10.94	12.34
$LSD_{0.01}$		0.071	0.202	0.175	0.276	0.101	0.237	0.124	0.175	0.416	0.285	0.566	0.588

Color scores (1: green, 2: breaker, 3: up to 25% yellow, 4: 25-50% yellow, 5: 50-75% yellow 6: 75-100% yellow, and 7: blackened/rotten), **Firmness scores (**1: hard green, 2: sprung, 3: between sprung and eating ripe, 4: eating ripe, 5: overripe, and 6: totally unfit for consumption), Treatment (T_0: Control, T_1: Wrapping with thin plastic film, T_2: Paper wrapping and store at 15ºC, T_3: Fruit wrapped in non-perforated LDPE bag with KMnO4, T_4: Fruit wrapped in non-perforated LDPE bag without KMnO4, T_5: Fruit treated with hot water at 50ºC, T_6: Fruit store at 12ºC).

reduces ethylene levels by oxidizing it to CO_2 and water (Elzubeir *et al*., 2018). These conditions are conducive to delaying fruit ripening and hence result in a longer green life of the fruits.

Firmness is an important criterion in terms of fruit quality. The firmness of mango pulp from hard to eating ripe are obvious change that occurs during storage. With the change in firmness, the pulp becomes softer and sweeter as the ratio of sugar to starch increases, and a characteristic aroma is produced. The higher rate of firmness score (5.15) was found in Fazli and the lower firmness score (4.62) was noticed in Ashwina (Table 2). The findings are similar to Tasmim *et al*. (2020), who found a higher firmness score in the Fazli variety. The rate of firmness degradation was reduced in the treatment of fruits wrapping with a polythene bag containing $KMnO_4$, while it was the fastest in the control treatment. $KMnO_4$ acted as a scavenger for ethylene gas, which reduced the concentration of ethylene gas production, hence ripening processes became delayed. For combined effects, the maximum change in firmness (5.50) was observed in Fazli with the control treatment and the minimum change in firmness (4.18) in Ashwina when fruits were wrapped in non-perforated LDPE bag with $KMnO_4$. The minimum change in firmness of banana fruits was also reported by Elamin and Abu-Goukh (2009) when wrapped in non-perforated LDPE bag with $KMnO_4$. During ripening, the pectic substances (protopectin, cellulose, hemicelluloses, etc.) are broken down through an enzymatic reaction (Abu-Goukh and El-Hassan, 2019). As a result, the cell wall and the strength of intercellular bonds become weak resulting in the softening of the fruit. Moreover, the lower firmness of apple fruit at ambient conditions was also reported by Kweon *et al*. (2013). During post-harvest storage, one of the most notable changes in mango is softening, which is related to biochemical alteration at the cell wall, middle lamella, and membrane levels. The treatments used in this study had been proven to be effective in reducing this loss of firmness. Among the treatments, a non-perforated LDPE bag with $KMnO_4$ slowed down the losses in the rate of fruit firmness might be due to a modified atmosphere with lower O_2 and higher CO_2 concentration which inhibits the break-down of pectic

Table 4 : The main effect of varieties and treatments on moisture content (%) and dry matter (%) of mango on different days after storage.

Factors	Moisture content (%) on different days after storage				Dry matter (%) on different days after storage			
	3	6	9	12	3	6	9	12
Variety (V)								
Fazli	85.06	83.44	81.42	79.80	14.93	16.56	18.57	20.20
Ashwina	83.67	81.86	80.13	78.23	16.33	18.19	19.86	21.76
$LSD_{0.01}$	0.519	0.339	0.235	0.489	0.351	0.392	0.250	0.237
Treatment (T)								
T_0	76.52	74.93	74.09	71.70	23.48	25.06	25.91	28.20
T_1	79.28	77.36	76.27	74.96	20.71	22.64	23.72	25.00
T_2	86.95	85.99	83.28	81.10	13.04	14.02	16.71	18.80
T_3	91.25	89.14	86.65	85.38	8.75	10.86	13.34	14.60
T_4	89.06	87.96	85.76	83.74	10.93	12.20	14.22	16.20
T_5	84.99	83.20	81.24	79.57	15.00	16.79	18.75	20.40
T_6	82.49	79.95	78.12	76.64	17.51	20.04	21.88	23.30
$LSD_{0.01}$	0.719	0.471	0.326	0.678	0.657	0.734	0.469	0.443

T_0: Control, T_1: Wrapping with thin plastic film, T_2: Paper wrapping and store at 15ºC, T_3: Fruit wrapped in non-perforated LDPE bag with KMnO4, T_4: Fruit wrapped in non-perforated LDPE bag without KMnO4, T_5: Fruit treated with hot water at 50ºC, T_6: Fruit store at 12ºC).

substances, so that a firmer texture is retained for a longer period. On the other hand, the control treatment (without wrapping and stored at ambient temperature) had lower firmness due to cell wall digestion by pectinesterase, polygalacturonase, and other enzymes at high temperatures (Baloch and Bibi, 2012).

In respect of the weight loss of mango, significant variation was observed between the two varieties at all days of storage. The weight loss trended to increase with the advancement of the storage period in both varieties. However, the weight loss was greater (5.50, 7.91, 9.97, and 11.17% at 3, 6, 9, and 12 days of storage, respectively) in Ashwina compared to Fazli (4.91, 7.65, 9.62, and 10.94% at 3, 6, 9 and 12 days of storage, respectively). This phenomenon is in agreement with the research findings of Tasmim *et al*. (2020). The weight loss of fresh produce during the storage period varies depending on the nature and constituents of the commodity stored (Perumal *et al*., 2021 and Srinivasa *et al*., 2006).

Considering post-harvest treatments, the total weight loss was estimated to be the highest (6.58, 9.08, 11.01, and 12.56% at 3, 6, 9 and 12 days of storage, respectively) in case of T_0 (control), while the lowest (2.69, 5.69, 7.77 and 8.87% at 3, 6, 9, and 12 days of storage, respectively) was observed in T_3 treatment (Non-perforated LDPE bag with $KMnO_4$) (Table 2). The combined effect of variety and treatments on total weight loss was highly significant in all stages of observation. At the 12 days of storage, the highest total weight loss (12.67%) was noted in Ashwina at T_0 (control), while the lowest (8.85%) was recorded in the same variety at T_3 (Non-perforated LDPE bag with $KMnO_4$) (Table 3). The major reason for weight loss includes transpiration water loss and loss of carbon reserves due to respiration (Perumal *et al*., 2021). Among the treatments, the use of $KMnO_4$ in conjunction with HDPE resulted in more reduction in weight loss from the fruits. Similar results were reported in other mango varieties (Kitchener and Abu-Samaka) (Elzubeir *et al*., 2017) and nectarine (Bal, 2018). This could be due to a delay in the fruit ripening in the presence of $KMnO_4$ as described earlier. Since ripening was delayed in the presence of $KMnO_4$, tissue permeability would be decreased and a reduction in weight loss in the fruit would be obvious. Moreover, delay ripening was subjected to HDPE with $KMnO_4$ treatment indicating that the hydrophobicity and compatibility of $KMnO_4$ with the surface of the fruit might have caused the closing of the fruit stomata opening thus preventing water loss. Lugassi (2020), found significantly reduced transpiration of young green citrus fruits, which indicates the stomatal response to sugar as like stomata of leaf. Stomata of fruits are plugged and stop functioning and it's illustrated the identical water loss of mature yellow fruits on the way to maturity.Significant variation with respect to percent moisture content was observed between the two varieties used in the present study on the 3rd, 6th, 9th and 12th day of storage (Table 4).

It was also shown that moisture percent decreased with the increase in storage period in both varieties and the moisture content ranged from 85.06% to 79.80% in Fazli, while 83.67% to 78.23% in Ashwina. Fazli was found to have higher moisture percent during the storage period which corroborated the findings of Hoque *et al*. (2018). The result of the present study supports the findings of Ali *et al*. (2019), who reported that the moisture content of pulp in Ashwina was 78.45%. Moreover, Islam *et al*. (2016)reported 82.95, 87.13, 81.90 and 80.19% moisture in BAU Mango-1, BAU Mango-6, BAU Mango-7 and BAU Mango-8, respectively, at the ripening stages which results are almost same in the study values ranges from 78.23 to 85.06%. The variation among treatments was significant concerning moisture content at the 3rd, 6th, 9th and 12th days of storage. The maximum moisture content (91.25, 89.14, 86.65 and 85.38% at 3, 6, 9 and 12 DAS, respectively) was recorded in T_3 treatment, as compared to the minimum moisture content (76.52, 74.93, 74.09 and 71.70% at 3, 6, 9 and 12 DAS, respectively) in T_0 treatment (Table 4). The combined effect of variety and post-harvest treatments varied significantly with respect to moisture content on different days of the storage period. On the last day of storage, the highest moisture content (85.80%) was recorded in Fazli treated with T_3, while the lowest moisture content (70.31%) was found in Ashwina with T_0 (control) treatment (Table 5). The higher moisture content of mango fruit wrapped in a non-perforated LDPE bag with KMnO4 was probably due to the reduction of mango transpiration by modified atmosphere packaging (Chang *et al*., 2017)and the effect of $KMnO_4$ on physiological metabolism also helped to maintain moisture (Lufu *et al*., 2020).

The dry matter content of mango increased over time (Table 5). The increase in dry matter content of mango during storage might be attributed to the loss of water. This statement was proven by Nordey *et al*. (2016), who observed to increase in pulp dry matter content of mango by 11.5 to 21% during storage. Significant variation was observed in dry matter content between the two varieties during storage. Comparative higher dry matter (16.33, 18.19, 19.86 and 21.76% at 3, 6, 9 and 12 DAS, respectively) was determined in Ashwina than Fazli (14.93, 16.56, 18.57 and 20.20% at 3, 6, 9 and 12 DAS, respectively) which showed parity to the findings of Galib *et al*. (2022). The post-harvest treatments exhibited significant differences in dry matter content during storage.

Table 5 : Interaction effect of varieties and treatments on moisture content (%) and dry matter (%) of mango on different days after storage.

Variety	Post-harvest treatments	Moisture content (%) on different days after storage				Dry matter (%) on different days after storage			
		3	6	9	12	3	6	9	12
Fazli	T_0	76.48	75.69	75.08	73.10	23.44	24.31	24.92	26.90
	T_1	81.79	79.24	77.84	76.04	18.21	20.76	22.16	23.96
	T_2	87.73	86.04	83.17	81.03	12.27	13.96	16.83	18.97
	T_3	91.59	90.17	86.68	85.80	8.41	9.83	13.22	14.20
	T_4	89.44	88.26	86.17	84.21	10.34	11.74	13.83	15.79
	T_5	85.76	83.88	82.12	80.20	14.24	16.12	17.88	19.80
	T_6	82.42	80.80	78.91	78.22	17.58	19.20	21.09	21.78
Ashwina	T_0	75.56	74.18	73.10	70.31	23.52	25.82	26.90	29.69
	T_1	76.78	75.48	74.71	73.89	23.22	24.52	25.29	26.11
	T_2	86.18	85.94	83.40	81.18	13.82	14.08	16.60	18.82
	T_3	90.91	88.11	86.63	84.97	9.09	11.89	13.37	15.03
	T_4	88.47	87.67	85.39	83.28	11.53	12.66	14.61	16.72
	T_5	84.23	82.53	80.37	78.95	15.77	17.47	19.63	21.05
	T_6	82.56	79.11	77.33	75.07	17.44	20.89	22.67	24.93
$LSD_{0.01}$		1.371	0.897	0.622	1.292	0.928	1.037	0.662	0.626

T_0: Control, T_1: Wrapping with thin plastic film, T_2: Paper wrapping and store at 15ºC, T_3: Fruit wrapped in non-perforated LDPE bag with KMnO4, T_4: Fruit wrapped in non-perforated LDPE bag without $KMnO_4$, T_5: Fruit treated with hot water at 50ºC, T_6: Fruit store at 12ºC).

Table 6 : The main effect of varieties and treatments on the TSS content of mango on different days after storage.

Factors	TSS (% Brix) at different DAS			
	3	6	9	12
Variety (V)				
Fazli	15.27	20.96	25.54	22.44
Ashwina	14.15	19.70	23.20	21.95
$LSD_{0.01}$	0.090	0.076	0.164	0.157
Treatment (T)				
T_0	15.94	22.00	25.37	20.23
T_1	14.60	20.56	24.55	22.72
T_2	15.05	20.75	24.75	23.75
T_3	15.36	21.30	25.07	23.50
T_4	14.17	19.62	24.25	20.45
T_5	14.10	19.50	23.80	20.90
T_6	13.76	18.63	22.83	23.85
$LSD_{0.01}$	0.168	0.143	0.307	0.295

T_0: Control, T_1: Wrapping with thin plastic film, T_2: Paper wrapping and store at 15^{0}C, T_3: Fruit wrapped in non-perforated LDPE bag with $KMnO_4$, T_4: Fruit wrapped in non-perforated LDPE bag without $KMnO_4$, T_5: Fruit treated with hot water at 50^{0}C, T_6: Fruit store at 12^{0}C).

The highest dry matter content (23.48, 25.06, 25.91 and 28.20% at 3, 6, 9 and 12 DAS, respectively) was observed in T_0 (control) treatment, as against the lowest (8.75, 10.86, 13.34 and 14.60% 3, 6, 9 and 12 DAS, respectively) in T_3 treatment (Table 4). Considering the combined effect, the highest dry matter content (29.69%) was manifested from Ashwina with the T_0 treatment in comparison to the lowest (14.20%) in Fazli when combined with the T_3 treatment (Table 5). The increase in dry matter content with an increasing storage period was probably due to osmotic withdrawals of water from the pulp to peel through transpiration and evaporation.

The difference in terms of total soluble solids content (TSS) between the two varieties of mango was found to be statistically significant during storage (Table 6). The percentage of total soluble solids content increased up to 9 days of storage and decreased at 12 days of storage. The increase in TSS might be due to the alteration in cell wall structure and breakdown of complex carbohydrates into simple sugars during storage. This increase and decrease in TSS are directly correlated with hydrolytic changes in starh and conversion of starch to sugar being an important index of ripening process in mango and other climacteric fruit and further hydrolysis decreased TSS during storage. Similar pattern of TSS was observed in mango (Rathore *et al.*, 2007). The variety Fazli showed higher TSS content (15.27, 20.96, 25.54 and 22.44% Brix at 3, 6, 9 and 12 DAS, respectively) than Ashwina (14.15, 19.70, 23.20 and 21.95% Brix at 3, 6, 9 and 12 DAS, respectively).

The various postharvest treatments used in the present investigation showed statistically significant variation with respect to TSS content at all days of storage. On the 3rd day of storage, the percent of TSS content of fruits ranged between 15.94% (control) and 13.76% (stored at 12ºC). At 9 days of storage, the highest TSS content (25.37%) was found in control fruits, while the lowest (22.83%) was also in low-temperature storage at 12ºC (T_6), however, the TSS content of all treatments decreased at 12 days after storage with the highest (23.85%) in T_6 and the lowest (20.23%) from T_0 (control). The combined effect of variety and postharvest treatments of mango in respect of TSS content was significant during storage (Table 7).

At 9 days of storage, the highest (26.60%) TSS content was observed in Fazli at the control treatment as against the lowest (21.50%) in Ashwina at T_6 (low-temperature storage at 12ºC). However, the TSS content at 12 days after storage was recorded as the highest (24.34) in Fazli treated at low temperature (12ºC) treatment, as compared to the lowest (20.05%) observed

Table 7 : Interaction effect of varieties and treatments on TSS content of mango on different days after storage.

Variety	Post-harvest treatments	TSS (% Brix)			
		3	6	9	12
Fazli	T_0	16.33	22.50	26.60	20.32
	T_1	15.36	21.12	25.60	22.97
	T_2	15.50	21.50	26.00	23.95
	T_3	16.08	22.50	26.00	23.63
	T_4	14.70	20.15	25.50	20.85
	T_5	14.65	20.00	24.95	21.05
	T_6	14.27	19.00	24.17	24.34
Ashwina	T_0	15.55	21.50	24.15	20.14
	T_1	13.85	20.00	23.50	22.47
	T_2	14.60	20.00	23.50	23.55
	T_3	14.64	20.10	24.15	23.37
	T_4	13.65	19.10	23.00	20.05
	T_5	13.56	19.00	22.65	20.75
	T_6	13.25	18.26	21.50	23.36
$LSD_{0.01}$	0.237	0.202	0.434	0.416	

T_0: Control, T_1: Wrapping with thin plastic film, T_2: Paper wrapping and store at 15ºC, T_3: Fruit wrapped in non-perforated LDPE bag with KMnO4, T_4: Fruit wrapped in non-perforated LDPE bag without KMnO4, T_5: Fruit treated with hot water at 50ºC, T_6: Fruit store at 12ºC).

in Ashwina when conbined with the T_4 treatment.

Conclusion

Considering the findings, it may be concluded that post-harvest loss of mango could be minimized by delaying the decay or spoilage at storage by a non-perforated LDPE bag with $KMnO_4$. The delayed ripening of mangoes with the above-mentioned treatments might be related to the slower changes in physical, mechanical, and chemical components. However, for further study, investigation related to physiochemical changes like respiration rate, ethylene production, etc. should be considered for a better understanding of the delayed ripening of mango as influenced by variety and postharvest treatments.

Author's contribution

Conceptualization and designing of the research work (AA and MKH); Execution of field/lab experiments and data collection (AA, MAH, JG and MHR); Analysis of data and interpretation (AA, MAH and MI); Preparation of manuscript (AA, MAH, MI and AHA).

Declaration

The authors do not have any conflict of interest.

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