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Impact of different packaging materials on qualitative attributes and shelf life during storage of mango (*Mangifera indica* L.) CV. Malihabadi

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Abstract
This study was carried out to examined the effects of different packaging materials on qualitative attributes and shelf life of mango (*Mangifera indica* L.) cv. Malihabadi during storage with administered to 9 packaging treatments such as (T_1- Control 'without packaging', T_2- Fruits packed in LDPE '25 micron', T_3- Fruits packed in LDPE '25 micron' with 0.50% perforation, T_4- Fruits packed in LDPE '25 micron' with 0.75% perforation, T_5- Fruits packed in LDPE '25 micron' with 1.0% perforation, T_6- Fruits packed in polypropylene bag, T_7- Fruits packed in polypropylene bag with 0.50% perforation, T_8- Fruits packed in polypropylene bag with 0.75% perforation and T_9- Fruits packed in polypropylene bag with 1.0% perforation).The results obtained revealed that fruits packed in polypropylene bag with 0.75% perforation is a very good performs at 15 days storage period among all the treatments. The shelf life up to 15 days at ambient condition whereas the shelf life of control treatment was 15 days in respect to TSS (°Brix), Titratable acidity (%), Total Soluble Solid (TSS): Titratable acidity ratio, Ascorbic acid (mg/100 ml), pH and Organoleptic parameter (color, taste, mouth-feel and overall acceptability).

Keywords: Packaging, polypropylene, perforation, storage, shelf life

Introduction
Mango (*Mangifera indica* L.) is considered as king of fruits due to its attractive color, flavor and taste. A worldwide increase in the demand of fresh mango fruit is being observed, increasing the prospect for the producing countries (Amin *et al*., 2007) [1]. However, like all other fresh commodities, its market potential is also linked with the fruit quality and market access (Anwar and Malik, 2007) [2], but it is highly perishable in nature. Every year a huge amount of fruits is lost due to lack of proper handling, transportation, packaging and storage facilities. Several environment condition higher moisture content, soft textures of fruits and susceptibility to various pathogenic infections are the limiting factors to its shelf life (Singh *et al*., 2010) [15]. Storage is essential for extending the consumption period of mango fruits, regulating their supply to the market. For successful storage, temperature and relative humidity are necessary to efficiently control throughout the storage period (Tasneem, 2004) [17]. Besides, proper postharvest treatments and packaging is required for maintaining better quality, extended shelf life having access to international markets (Anwar & Malik, 2007) [2]. Therefore, suitable packages can play a vital role for extending shelf life and maintaining quality of the produce.
The main objective of this research is to determine the shelf life of mango fruit quality such as total soluble solid, titratable acidity, total soluble solid: Titratable acidity ratio, pH and ascorbic acid of mango fruit during storage.

Materials and Methods
The investigation was conducted in department of Post Harvest Technology and biochemistry laboratory, CoH, BUAT, Banda, Uttar Pradesh during year 2022-2023. Healthy mango fruit were collected from mandi of district Banda, for experiment purpose the fruits with uniform size, healthy, colour was selected. Before packing the fruit, they were properly washing chlorinated water (100 ppm) and dried under shade to remove the surface water.
Thereafter, the packed fruits were stored under ambient conditions (20-25 °C and 80-90 RH) in PG laboratory of department of Post Harvest Technology, CoH, BUAT, Banda (U.P.). The lab was properly ventilated and thoroughly cleaned.

The fruits were packed in different packaging materials. The experiment consisted of 9 packaging treatments such as (T_1- Control 'without packaging', T_2- Fruits packed in LDPE '25 micron', T_3- Fruits packed in LDPE '25 micron' with 0.50% perforation, T_4- Fruits packed in LDPE '25 micron' with 0.75% perforation, T_5- Fruits packed in LDPE '25 micron' with 1.0% perforation, T_6- Fruits packed in polypropylene bag, T_7- Fruits packed in polypropylene bag with 0.50% perforation, T_8- Fruits packed in polypropylene bag with 0.75% perforation and T_9- Fruits packed in polypropylene bag with 1.0% perforation). The stored mango fruits then were kept in a room at ambient Temperature. For the study the bio-chemical parameters viz. total soluble solid (TSS), titratable acidity, total soluble solid : Titratable acidity ratio, pH and ascorbic acid, sensory evaluation such as color, taste, mouth-feel and overall acceptability of the fruit for each treatment were recorded every 5 days of storage interval for statistical analysis.

Bio-chemical Characteristics

Total Soluble Solid (^{0}Brix)

The total soluble solids were determined with the help of hand refractometer of range 0-45 ^{0}Brix (QA Supplies, LLC). One or two drops of juice were placed on the refractometer prism and the percent TSS on the scale were recorded. The reading was calibrated against a standard temperature of 20 °C (AOAC, 1989) [3].

Titratable acidity (%)

Titratable acidity was determined by titrating 2 ml of juice against 0.1 N NaOH using phenolphthalein as the indicator. Titratable acidity was calculated by the method (Ranganna, 1986) [12].

Total Soluble Solid (TSS): Titratable acidity ratio

Total Soluble Solid (TSS): Titratable acidity ratio was calculated by dividing the total soluble solid content by titratable acidity of each treatment and average was recorded.

Ascorbic acid (mg /100 ml): Ascorbic acid content of the juice was estimated using the detective dye 2, 6 dichlorophenol indophenols (DCPIP) visual titration method (Rangana, 1995) [11].

pH: ELTOP-3030 pH meter pH was used to measure pH of fruit juice (AOAC, 1989) [3].

Organoleptic evaluation

The color, taste and mouth-feel of the samples were assessed by the Hedonic scale (Shah *et al*., 2020) [14] with a 9- point scale as the best.

Statistical analysis

All data of triplicate were submitted to a two-way analysis of variance (ANOVA), which considered packing materials and storage periods as sources of variation.

Result and Discussion

Bio-chemical Characteristics

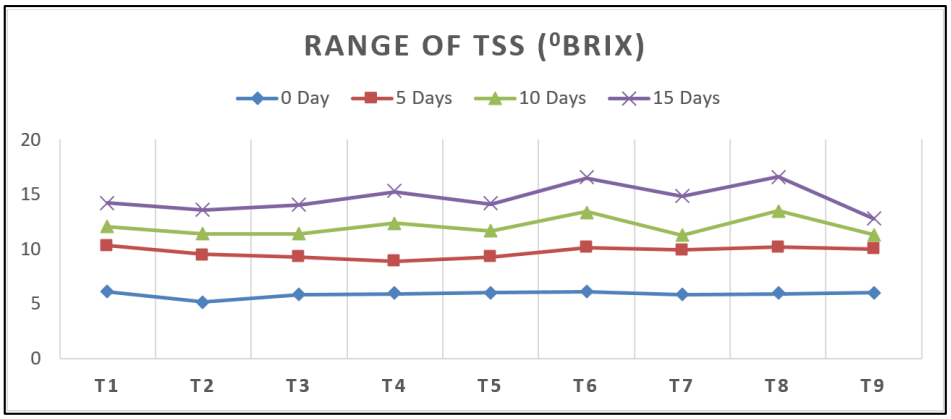

Fig 1: Effect of packing material on TSS (^{0}Brix) of mango fruit

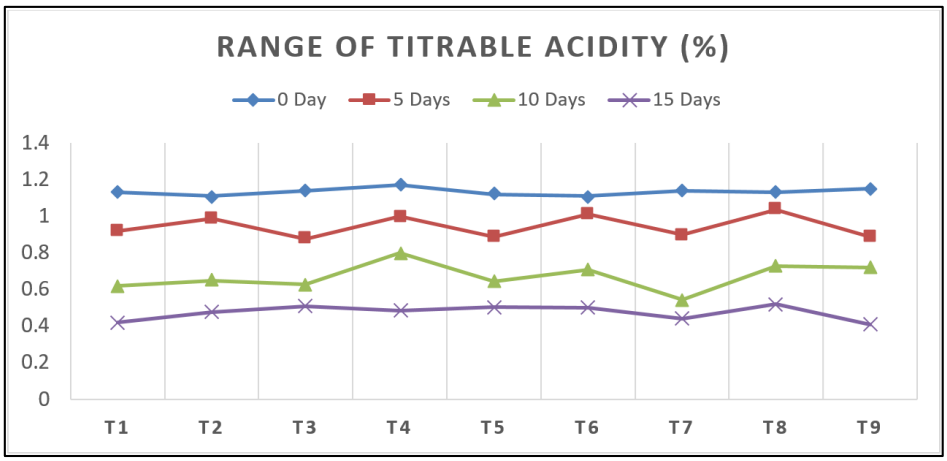

Fig 2: Effect of packing material Titratable acidity (%) of mango fruit

The lowest TSS (Total soluble solid) was notice at 0 days of storage period, but it increased with increasing storage period (Fig 1). The TSS was the maximum (14.660) at 15 days and minimum value (5.867) day stored for 0 days. The TSS remained almost significant with 15 days of storage. TSS was significantly affected by packaging materials. Indicate that during the TSS of mango fruit significantly increase. The interaction of packaging materials and storage period was also had significant effect on TSS in mango fruits. The highest value T_8 (16.600) at 15 days while minimum value T_2 (5.200) at 0 days of storage period. It may be due to the reason that the increase of total soluble solids in mango fruits during the ripening process is attributing to the biochemical conversions of starch into sugar. Insoluble protopectin into pectin and loss of organic acid through oxidation are responsible for the increase of total soluble solids, it's observed by (Ebrahimi and Rastegar, 2020) [5].

Perusal of data in (Fig 2) revealed that the titratable acidity was significantly affected by packaging materials. Titratable acidity was also affected from Storage period are significant. The highest titratable acidity (1.133) at zero day while lowest titratable acidity was observed (0.474) at 15 days of storage perio was notice. The interaction of both factors was found significant on titratable acidity. Acidity content was decrease with packaging materials and time during the storage period in all the treatment. The reason was might be due to decrease rapidly up to rapid ripening processes in the pulp. The titratable acidity was more decrease probably due to rapid utilization of acid of the fruit pulp in respiration process. The results are in conformity with (Chowdhury *et al*., 2018) [4] in packaging techniques on quality & shelf life of mango.

Table 1: Effect of packing material on TSS: Titratable acidity ratio and Ascorbic acid of mango fruit

TSS : Titratable acidity ratio						Ascorbic acid (mg/100 ml)				
Treatment	**Storage period**				**Mean**	**Storage period**				**Mean**
	0	**5**	**10**	**15**		**0**	**5**	**10**	**15**	
T_1	5.390	11.220	19.430	33.800	17.460	43.800	34.630	26.350	17.230	30.503
T_2	4.680	9.630	17.490	28.630	15.108	43.600	33.320	23.220	19.230	29.843
T_3	5.080	10.590	18.070	27.470	15.303	43.900	36.390	28.890	23.560	33.185
T_4	5.040	8.917	13.790	31.573	14.830	47.700	39.460	33.230	25.163	36.388
T_5	5.350	10.470	18.100	27.960	15.470	44.600	35.860	29.420	24.300	33.545
T_6	5.495	10.000	19.253	32.860	16.902	44.800	39.580	31.220	26.300	35.475
T_7	5.080	11.010	20.560	33.770	17.605	43.900	36.830	30.600	25.300	34.158
T_8	5.220	9.830	18.460	31.920	16.358	45.030	39.860	31.620	26.500	35.753
T_9	5.210	11.240	15.710	31.210	15.843	44.900	36.500	29.360	24.300	33.765
Mean	5.172	10.323	17.874	31.021		44.692	36.937	29.323	23.543	
	(A)	(B)	(AxB)			(A)	(B)	(AxB)		
C.D.	0.685	0.457	1.370			0.260	0.173	0.520		
SE(d)	0.343	0.229	0.686			0.130	0.087	0.260		
SE(m)	0.242	0.162	0.485			0.092	0.061	0.184		

Where, (A) = Treatment, (B) = Storage period, (AxB) = Interaction

It apparently from the data presented in data (table 1) shows that the TSS: Titratable acidity ratio was affected by packaging materials are significant. Among the different packaging material and storage period treatments, the fruit under the T_7 (Fruits packed in polypropylene bag with 0.50% perforation) highest positive value for TSS: Titratable acidity ratio at 15 days of storage period. The interaction of packing materials and storage period was also found significant on TSS: Titratable acidity ratio. These results are supported by (Kumar *et al*., 2022) [9] in kinnow fruit.

The influence of storage durations was significant on ascorbic acid in (table 1). The ascorbic acid was highest at storage time (0 day) and was followed by fruits stored for 5 days and decreased with increasing storage durations. The maximum ascorbic acid value (44.692) at 0 days however, minimum value (23.543) was observed in mango fruit. Ascorbic acid was affected from packaging materials are significant. The highest value T_4 (36.388) while lowest value T_2 (29.843) was observed. The interaction of packaging materials and storage period factors was significant on ascorbic acid. The slow degradation rate due to decrease metabolic rate at lower temperature. The might be due to a reduced rate of fruit metabolic activities, mainly respiration. The similar result was found (Heidari *et al*., 2011) [7] in effect of storage time on quality of mango fruit.

Data in (table 2) pertaining to the pH of mango juice was significantly affected by packaging materials. The highest value of juice pH T_9 (3.945) but lowest value T_4 (3.828) was noted in mango fruit juice. Noted data on storage period showed that storage period had significantly affected the pH of mango fruit juice. The maximum pH of juice (4.608) was noted at 15 days of storage duration, followed by storage at zero days for which pH of fruit juice was recorded (3.173), Data related to interaction showed that on the initial day of the storage, the pH of fruit juice of all fruits was statistically the same. However, a significant difference among the mango fruits was observed in the increasing pH of the juice. The fruit juice observed the maximum pH of fruit juice T_8 (4.690) at 15 days while minimum value T_1 (3.150) and T_8 (3.150) of storage period. These results are in parallel by (Raese and Drake, 1993) [10]. Result may be due to increased phenomenon of pH in storage is because of the development of free acid and pectin hydrolysis. Similar result was found (Anwar and Malik, 2007) [2] in ripening quality and storage life of mango.

Table 2: Effect of packing material on pH and color of mango fruit

Treatment	pH					Color				
	Storage period				Mean	Storage period				Mean
	0	5	10	15		0	5	10	15	
T_1	3.150	3.560	4.190	4.600	3.875	8.000	7.300	5.000	3.500	5.950
T_2	3.180	3.540	4.250	4.570	3.885	8.000	7.200	5.400	4.200	6.200
T_3	3.200	3.470	4.270	4.650	3.898	8.000	7.000	5.100	4.000	6.025
T_4	3.160	3.350	4.300	4.500	3.828	8.000	7.000	5.600	4.400	6.250
T_5	3.190	3.650	4.230	4.630	3.925	8.000	7.100	5.300	4.100	6.125
T_6	3.170	3.580	4.260	4.670	3.920	8.000	7.300	6.100	4.767	6.542
T_7	3.200	3.750	4.210	4.610	3.943	8.000	7.000	5.400	4.300	6.175
T_8	3.150	3.430	4.280	4.690	3.888	8.000	7.500	6.300	5.000	6.700
T_9	3.160	3.780	4.290	4.550	3.945	8.000	7.500	6.300	5.000	6.690
Mean	3.173	3.568	4.253	4.608		8.000	7.211	5.611	4.363	
	(A)	(B)	(AxB)			(A)	(B)	(AxB)		
C.D.	0.032	0.021	0.064			N/A	0.858	N/A		
SE(d)	0.016	0.011	0.032			0.644	0.429	1.288		
SE(m)	0.011	0.008	0.023			0.455	0.304	0.911		

Where, (A) = Treatment, (B) = Storage period, (AxB) = Interaction

Table 3: Effect of packing material on taste and mouth -feel of mango fruit

Treatment	Taste					Mouth-feel				
	Storage period				Mean	Storage period				Mean
	0	5	10	15		0	5	10	15	
T_1	7.000	6.100	4.500	3.400	5.250	8.000	6.200	4.800	3.500	5.625
T_2	7.000	6.000	5.000	4.000	5.500	8.000	6.300	5.100	4.000	5.850
T_3	7.000	6.200	5.367	4.400	5.742	8.000	6.800	5.800	5.100	6.425
T_4	7.000	6.300	5.600	4.600	5.875	8.000	7.000	6.300	5.600	6.725
T_5	7.000	6.200	5.300	4.200	5.675	8.000	6.500	5.300	4.200	6.000
T_6	7.000	6.600	5.800	4.800	6.050	8.000	7.100	6.400	5.800	6.825
T_7	7.000	6.100	5.200	4.533	5.708	8.000	6.567	6.000	5.200	6.442
T_8	7.000	6.800	6.000	5.000	6.200	8.000	7.200	6.500	6.000	6.925
T_9	7.000	6.200	5.200	4.000	5.600	8.000	7.000	6.100	5.300	6.600
Mean	7.000	6.278	5.330	4.326		8.000	6.741	5.811	4.967	
	(A)	(B)	(AxB)			(A)	(B)	(AxB)		
C.D.	N/A	0.567	N/A			N/A	0.798	N/A		
SE(d)	0.425	0.284	0.851			0.599	0.399	1.197		
SE(m)	0.301	0.200	0.601			0.423	0.282	0.846		

Where, (A) = Treatment, (B) = Storage period, (AxB) = Interaction

Evaluation of organoleptic attributes

Color, taste and mouth-feel

Peel color, taste, and mouth-feel are regarded as very important aspects which determine the quality and marketability of horticultural commodities. Further, the acceptance of a consumer is usually determined by the peel color of mango fruits. The least color, taste and mouth-feel the highest firmness of fruit was observed at storage time (0 day). The data recorded on the organoleptic attributes of mango fruits are presented in (table 2 & 3). Show that the color, taste and mouth-feel was significantly affected by packaging materials. The minimum values for fruits (color =T_1 (5.950), taste = T_1 (5.250) and mouth-feel = T_1 (5.625) while maximum value (color =T_8 (6.700), taste = T_8 (6.200) and mouth-feel = T_8 (6.925) was recorded. The interaction of both factors was significant on Peel color, taste, and mouth-feel. Peel color, taste, and mouth-feel value was decreasing with packaging materials and time during the storage period in all the treatment. The maximum values was observed for mango fruits (color =T_1 to T_9 (8.000), taste = T_1 to T_9 (7.000) and mouth-feel = T_1 to T_9 = (8.000) at zero day while minimum value (color =T_3 (4.000), taste = T_1 (3.400) and mouth-feel = T_1 (3.500) at 15 days of storage period. The highest color score was noted in fruits packed in polypropylene bag with 0.75% perforation, When storage duration is increased, the fruit color is decreased or lost due to the banishment of colorful pigment from the fruit surface (Ribeiro *et al*., 2007) [13]. The minimum score of tastes in uncoated fruits is due to anaerobic respiration, which leads to more ethanol production and odd flavors (Guire, 1997) [6]. The mouth-feel it could be due to decreased respiration rate and other biochemical reactions responsible for ripening of fruit during storage (Herianus *et al*., 2003) [8].

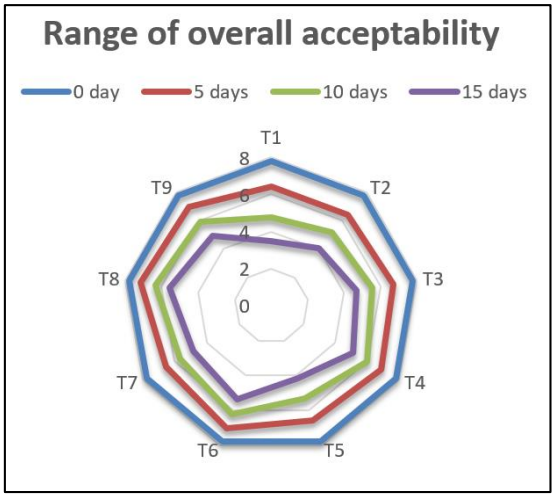

Fig 3: Effect of packing material on organoleptic attributes of mango fruit

Overall acceptability of mango fruit decrease progressively during storage in all packaging materials. The figure 3 showed that mango fruits packed in Fruits packed in polypropylene bag with 0.75% perforation followed by fruits packed in polypropylene bag minimum decrease in overall acceptability during 15 days s in storage of mango bar in LDPE.

Conclusion

Different packaging materials and various storage durations significantly affected different bio chemical and organoleptic parameters of mango fruit. Among all the packaging materials used for mango storage at room temperature, color polyethylene bags were found more effective in maintaining fruit total soluble solid (TSS), titratable acidity, color, taste, mouth-feel and overall acceptability. The current study leads to the conclusion that packed in polypropylene bag with 0.75% perforation are exceedingly recommended for packaging material of mango at room temperature in addition mango can be best consumed at late days (15 days) after harvest for more sweetness due to high TSS.

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