Impact of Harvest Time and Temperature on the Quality and Ripening of Mango (*Mangifera indica* L.) Fruit

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Abstract

The Mango fruit contains vitamins, pectin, antioxidants and minerals making it a very nutritious fruit. However, mango being highly perishable fruit has short storage life and varies with the variety of fruit, storage conditions and processing. In this report, the Langra and Samar Bahisht Chaunsa mango fruit varieties were harvested at 6:30am, 1:30pm and 8:30pm for the three consecutive days from the selected trees and stored for ripening at different temperatures. It was observed that the mango fruit quality was highest for fruit harvested at 8:30pm and stored at 40℃ while lowest for fruit harvested at 6:30am and stored at 20℃. The period for ripening was prolonged for fruit harvested at 6:30am and stored at 20℃ while shortest for fruit harvested at 1:30pm and stored at 40℃, irrespective of the variety. The waste percent was minimum in case of fruit harvested at 6:30am and stored at 30℃ while maximum in case of harvesting at 1:30pm and stored at 20℃, irrespective of the variety.

Keywords: Quality; storage temperature; ripening rate; waste percent.

Introduction

Pakistan stands at fifth position among the top mango producing countries in the world with the production of 2.3 million tons (FAOSTAT, 2021). Mango fruit is considered to be the second major fruit crops in Pakistan and is grown on an area of about 158659 hectares (MNFSR, 2020). The mango is one of the most important fruit and is popular both in the fresh and the processed form. It is a climacteric fruit keeps short storage life and has influenced its market potential (Abera et al., 2019; Wong et al., 2016). In addition, the various pre- and post-harvest factors like temperature, transportation conditions, weather conditions and storage have a great impact over the quality of the fruit (Jitjak and Sanoamuang, 2021; Nunes et al., 2007).

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The other unfortunate for this crop is that the required facilities are not available for the proper application of postharvest technologies in Pakistan and hence a considerable amount of the fruit produced is lost during postharvest processing and marketing etc. It is therefore, need of the day to explore various ways and means for the reduction of pre- and postharvest wastage, improve the quality of the fruit and elongate the storage life of mango fruit.

On the other hand it has been well documented that variation in temperature or sun exposure has significant effect over the quality and shelf life (Baloch et al., 2012; Saengnil et al., 2011; Lechaudel and Joas, 2007). Further glazing of the fruit by using edible oil and/ or can infuse into the fruit as a post-harvest has become very much common (Hmmam et al., 2021; Bibi and Baloch, 2014).

It has inspired us to explore the impact of harvesting time and ripening temperature on the quality and shelf life of Langra and Samar Bahisht Chaunsa mango fruit.

Material and Methods

Sampling

The research experiment was conducted over Langra and Samar Bahisht Chaunsa (S.B. Chaunsa) mango varieties. The fruit was harvested randomly by hand from Government Fruit Nursery Farm, Agriculture Extension Department, Dera Ismail Khan, Pakistan. The harvested fruits were washed and cleaned to eliminate all external materials such as dust, dirt etc. The collected fruits were similar in size, had well appearance and were free from damage or infection.

Treatments

To explore the effect of harvesting time, the hard green stage of fruit maturity was harvested at 6:30am (T1), 1:30pm (T2), and 8:30pm (T3) for the three consecutive days from the selected trees. After harvesting, the fruit was characterized according to harvesting time, irrespective of harvesting days. The fruits were stored at three different (20, 30 and 40°C) temperatures. The relative humidity (RH) was kept at 80%, 64% and 58%, respectively till ripening, using Hot Pack incubator (Philadelphia, PA).

Analysis

Two hundred and fifty fruits of mango were collected for every test and variety. Every analysis was carried out three times and the data presented is the average of the repeated analysis over the period of three years. The fruits of mango were analyzed for various parameters at harvest as well as at the ripened stage. The two factor experiment was laid out in Completely Randomized Design (CRD) with three replications.

Organoleptic evaluation

For all the samples, the skin color, aroma, flavor and taste were determined using Hedonic scale (Larmond, 1977). A panel of twenty-one experts whose age was 20-45 years was prepared. Twenty-one fruits of mango for every sample were randomly selected and were cut into six parts. The obtained material was divided equally amongst the experts. Panelists were sent to various compartments which were constructed for the determination and had adequate light to judge the real color of the sample. The panelists scored the various samples by assigning the numbers from 0-10 (0-2 means extremely disliked, 2.1-4.0 fair, 4.1-6.0 good 6.1-8.0 very good and greater than 8 means excellent aroma, taste and flavor). The skin color of mango samples was categorized as 0-2 means green, 2.1-4.0 light green, 4.1-6.0 light yellow, 6.1-8.0 yellow and 8.1-10 full yellow.

The firmness of fruit was determined with a Bosch penetrometer (model FT 327). The firmness was measured by the force (g- mm^{-2}) necessary for a 2 mm probe to puncture the fruit peel at four different points and taking average of the values. The values obtained were rescaled according to Hedonic scale for comparison purpose (Larmond, 1977); 2-4.0 means were very soft, 4.1-6.0 soft, 6.1-8.0 slightly soft and 8. 1-10 firm.

Content of Moisture and pH Measurement

The contents of moisture were measured by taking 10 g pulp of mango fruit, drying at 76°C in an oven up to constant weight and calculating the loss in weight (AOAC, 2000). The pH was determined using a Microprocessor pH meter supplied by Denver, USA.

Measurement of Acidity

The total titratable acidity was measured by titrating 100 mL of juice against sodium hydroxide having concentration as 0.1 N (AOAC, 2000). The finale point in this condition was estimated when the mixture

containing juice, phenolphthalein (an indicator) and sodium hydroxide turned pink.

Measurements of Total Solids, Total Soluble Solids and Ascorbic Acid

The pulp of five mango fruit was took and thoroughly mixed and it was used for the evaluation of total solid, ascorbic acid and total soluble solids. For the total solids (TS) assessment, thirty grams of flesh sample was dried out at 76°C in an oven and TS was measured (AOAC, 2000). Ten grams of pulp was used for the measurement of total soluble solids (TSS) using digital refractometer (Atago-Palette PR 101, Atago Co. Ltd., Itabashi-Ku, Tokyo, Japan). The ascorbic acid contents were measured by titrating ten gram of mixed pulp sample against the standard 2, 6 dichlorophenol dyes, following the method outlined in (AOAC, 2000).

Measurements of Total Carotenoids and Total Sugar

The total carotenoid content of flesh was measured subsequent the procedure of Anwar et al., (2008) and were stated as μg/g of β-carotene equivalent from a standard curve of β-carotene. Total sugar was estimated by evaluating the refractive index using digital refractometer.

Measurement of Ripened Stage

The fruit ripened stage was noticed through the difference in color, sugar contents and firmness with the passage of time (Shorter and Joyce, 1998).

Marking of Fruit as Waste

Fruit waste was measured as when its value of firmness was lesser than 4 in Hedonic scale and/or it was either infected by a disease.

Statistical Analysis

Each value was expressed as the mean of three independent experiments. Data were assessed by analysis of variance (ANOVA) through Duncan's multiple range tests using SPSS software (SAS Institute Inc., Cary, NC).

Results and Discussion

The quality score of organoleptic and chemical constituents of mango fruit in relative to time of harvest significantly different with various treatments. The data showed that almost all the attributes for

harvesting at 1:30 and 8:30pm were statistically at par but dissimilar from harvesting at 6:30am, showing that delaying the time of harvest from 6:30am increase the process of ripening (Tables 1 & 2).

Table 1

Average Values of Organoleptic Parameters Measured at Harvest Time for Langra and Samar Bahisht Chaunsa Mango Fruit

Variety	Treatment	Color	Firmness	Aroma	Taste	Flavor
Langra	T_1	$0.83^{b\dagger}$	9.51^{a}	0.92^{b}	0.96^{b}	0.95^{b}
	T_2	0.92^{a}	9.24^{b}	1.08^{a}	1.11^{a}	1.10^{a}
	T_3	0.99^{a}	9.35^{b}	1.14^{a}	1.17^{a}	1.15^{a}
S. B. Chaunsa	T_1	0.92^{b}	9.70^{a}	0.97^{b}	1.16^{a}	1.13^{a}
	T_2	1.13^{a}	9.48^{b}	1.14^{a}	1.25^{a}	1.22^{a}
	T_3	1.16^{a}	9.50^{b}	1.18^{a}	1.29^{a}	1.26^{a}

T_1, T_2 and T_3 stand for the fruit harvested at 6:30am, 1:30pm and 8:30pm, respectively. †Values having different superscript in the columns are significantly different under the limit of $P < 0.05$. The comparison has been made within the variety.

Table 2

Average Values of Chemical Constituents of Langra and Samar Bahisht Chaunsa Mango Fruit Measured at Harvest Time

Variety	T*	Total sugar (%)	TC (µg/g)	A (%)	AA (mg/ 100g)	pH	MC (%)	TSS (%)	Total solids (%)
Langra	T_1	$3.95^{b\dagger}$	26.22^{b}	3.52^{a}	289.64^{a}	3.16^{b}	80.97^{a}	7.78^{a}	19.03^{a}
	T_2	4.24^{a}	26.89^{a}	3.39^{b}	288.95^{b}	3.24^{a}	79.65^{b}	7.29^{b}	20.15^{b}
	T_3	4.38^{a}	27.29^{a}	3.34^{b}	288.04^{b}	3.35^{a}	80.45^{a}	7.95^{a}	19.55^{a}
S.B. Chaunsa	T_1	5.11^{b}	58.09^{b}	2.45^{a}	183.61^{a}	3.39^{b}	77.89^{a}	6.65^{a}	22.11^{a}
	T_2	5.29^{a}	58.72^{a}	2.32^{b}	182.89^{b}	3.48^{a}	76.36^{b}	6.17^{b}	23.64^{b}
	T_3	5.45^{a}	59.21^{a}	2.21^{b}	182.08^{b}	3.54^{a}	77.34^{a}	6.94^{a}	22.54^{a}

*T, TC, A, AA, MC and TSS stand for treatments, total carotenoids, acidity, ascorbic acid, moisture contents and total soluble solids, respectively. T_1, T_2 and T_3 stand for the fruit harvested at 6:30 am, 1:30 pm and 8:30 pm, respectively. †Values having different superscript in the columns are significantly different under the limit of $P < 0.05$. The comparison has been made within the variety.

However, the data showed that attributes of organoleptic such as aroma, color, flavor and taste were maximum for fruits harvested at 8:30 pm and minimum at 6:30am harvested fruits (Tables 3a & b). The reason behind it can be that at 8:30 pm harvested mango fruit had more exposure to sunlight and/or high temperature and hence had fast rate of ripening (Saengnil et al., 2011; Amin et al., 2008). The impact of ripening temperature on the characteristics of organoleptic was also significant. The maximum values of organoleptic characteristics were noted for fruits ripened at 40°C and the minimum for 20°C, irrespective of the variety (Table 3a & b).

Table 3a

Average Values of Organoleptic Parameters Measured at Ripened Stage for Langra Mango Fruit Stored at Different Temperatures

T*	ST (°C)	Color	Firmness	Aroma	Taste	Flavor
T_1	20	$6.01^{f†}$	6.82^{c}	5.91^{e}	6.11^{e}	6.02^{f}
	30	7.41^{d}	7.64^{a}	7.35^{b}	7.56^{c}	7.46^{d}
	40	7.89^{c}	7.79^{a}	7.86^{b}	8.02^{b}	7.95^{c}
T_2	20	6.31^{f}	6.01^{d}	6.15^{d}	6.51^{d}	6.47^{e}
	30	7.77^{c}	7.17^{b}	7.72^{b}	7.92^{c}	7.85^{c}
	40	8.12^{b}	7.35^{b}	8.01^{a}	8.39^{b}	8.31^{b}
T_3	20	6.67^{e}	6.56^{c}	6.45^{c}	6.95^{d}	6.91^{e}
	30	8.02^{b}	7.55^{a}	7.91^{b}	8.13^{b}	8.11^{b}
	40	8.45^{a}	7.69^{a}	8.37^{a}	8.59^{a}	8.52^{a}

*T and ST stand for treatments and storage temperature. T_1, T_2 and T_3 stand for the fruit harvested at 6:30am, 1:30pm and 8:30pm, respectively. Values having different superscript in the columns are significantly different under the limit of $P < 0.05$.

Table 3b.
Average Values of Organoleptic Parameters Measured at Ripened Stage for Samar Bahisht Chaunsa Mango Fruit Stored at Different temperatures.

T*	ST (°C)	Color	Firmness	Aroma	Taste	Flavor
T_1	20	$6.31^{e\dagger}$	7.12^{b}	6.41^{e}	6.45^{e}	6.45^{e}
	30	7.79^{c}	7.75^{a}	7.65^{c}	7.81^{c}	7.64^{c}
	40	8.12^{b}	7.87^{a}	8.11^{b}	8.36^{b}	8.21^{b}
T_2	20	6.51^{e}	6.39^{d}	6.51^{f}	6.99^{e}	6.91^{e}
	30	8.01^{b}	7.39^{b}	7.99^{c}	8.13^{b}	8.02^{b}
	40	8.45^{a}	7.61^{a}	8.41^{b}	8.62^{a}	8.55^{a}
T_3	20	6.92^{d}	6.71^{c}	6.99^{d}	7.11^{d}	7.01^{d}
	30	8.31^{b}	7.53^{a}	8.32^{b}	8.39^{b}	8.31^{b}
	40	8.72^{a}	7.72^{a}	8.75^{a}	8.84^{a}	8.77^{a}

*T and ST stand for treatments and storage temperature. T_1, T_2 and T_3 stand for the fruit harvested at 6:30 am, 1:30 pm and 8:30 pm, respectively. Values having different superscript in the columns are significantly different under the limit of $P < 0.05$.

The fruit of mango were studied for chemical characteristics at the stage of ripened and results for various storage temperatures are recorded in Tables 4a & b. The pH, carotenoids, soluble solids and sugar contents were maximum level for fruit harvested at 8:30pm (T_3) and the minimum for fruit of mango harvested at 6:30am (T_1), irrespective of the storage temperature as well as variety. The cause for such determined tendency could be that mango fruit harvested at 8:30pm results in more treated to light of sun during the day time, that increase the quality of fruit due to prevailing high temperature (Bibi and Baloch, 2014; Cecchi et al., 2005; Narain et al., 1998). However, the total solids and ascorbic acid contents were maximum level at 6:30am harvested fruits of mango and both were the minimum at 8:30pm harvested mango fruit, irrespective of storage temperature and variety. The content of moisture was also the maximum for fruit of mango harvested at 6:30am and the minimum for fruit of mango harvested at 1:30pm. The statistical analysis made in this respect concluded that most of the measured attributes are significantly different under the limit $P < 0.05$ for storage temperature as well as treatments (Table 4a & 4b).

Table 4a.
Average Values of Chemical Constituents Measured at Ripened Stage for Langra Mango Fruit Stored at Different Temperatures.

T*	ST (°C)	Total sugar (%)	TC (µg/g)	A (%)	AA (mg/ 100g)	pH	MC (%)	TSS (%)	Total solids (%)
T_1	20	$18.78^{f\dagger}$	54.64^{g}	0.63^{a}	89.81^{a}	4.79^{c}	70.19^{c}	19.49^{e}	29.81^{c}
	30	21.41^{c}	61.42^{d}	0.53^{a}	80.19^{d}	5.06^{b}	71.28^{b}	22.36^{c}	28.81^{d}
	40	22.49^{b}	63.45^{b}	0.45^{b}	77.31^{f}	5.17^{a}	72.39^{a}	23.45^{b}	27.71^{e}
T_2	20	19.45^{d}	55.29^{f}	0.60^{a}	88.35^{b}	4.84^{c}	68.66^{e}	20.42^{d}	31.34^{a}
	30	21.99^{c}	62.71^{c}	0.48^{b}	79.46^{e}	5.14^{a}	69.61^{c}	22.62^{c}	30.39^{b}
	40	22.97^{b}	64.72^{a}	0.43^{c}	76.31^{g}	5.24^{a}	70.66^{c}	23.71^{b}	29.34^{c}
T_3	20	19.87^{d}	55.91^{e}	0.59^{a}	87.72^{c}	4.89^{c}	69.31^{d}	20.75^{d}	30.69^{b}
	30	22.47^{b}	62.96^{c}	0.47^{b}	78.15^{e}	5.21^{a}	70.41^{c}	23.41^{b}	29.59^{c}
	40	23.61^{a}	64.99^{a}	0.41^{c}	75.34^{h}	5.34^{a}	71.31^{b}	24.49^{a}	28.69^{d}

*T, ST, TC, A, AA, MC and TSS stand for treatments, storage temperature, total carotenoids, acidity, ascorbic acid, moisture contents and total soluble solids, respectively. T_1, T_2 and T_3 stand for the fruit harvested at 6:30am, 1:30pm and 8:30pm, respectively. Values having different superscript in the columns are significantly different under the limit of $P < 0.05$.

Table 4b.
Average Values of Chemical Constituents Measured at Ripened Stage for Samar Bahisht Chaunsa Mango Fruit Stored at Different Temperatures.

T*	ST (°C)	Total sugar (%)	TC (µg/g)	A (%)	AA (mg/ 100g)	pH	MC (%)	TSS (%)	Total solids (%)
T_1	20	$20.69^{e\dagger}$	80.34^{h}	0.52^{a}	73.41^{a}	4.92^{c}	69.63^{c}	20.59^{e}	30.37^{c}
	30	23.58^{c}	86.19^{e}	0.42^{b}	67.47^{c}	5.15^{b}	70.51^{b}	24.46^{c}	29.49^{d}
	40	24.56^{b}	89.36^{b}	0.38^{b}	65.51^{d}	5.25^{b}	71.53^{a}	25.45^{b}	28.47^{e}
T_2	20	21.45^{d}	81.72^{g}	0.50^{a}	71.85^{b}	5.11^{b}	67.48^{e}	22.35^{d}	32.52^{a}
	30	24.51^{b}	87.69^{d}	0.41^{b}	65.99^{d}	5.32^{a}	68.10^{d}	25.46^{b}	31.90^{b}

	40	25.52[a]	90.16[a]	0.35[c]	63.81[e]	5.42[a]	69.39[c]	26.57[a]	30.61[c]
	20	21.83[d]	82.78[f]	0.48[a]	71.35[b]	5.16[b]	68.55[d]	22.74[d]	31.45[b]
T_3	30	24.79[b]	88.61[c]	0.39[b]	65.38[d]	5.43[a]	69.65[c]	25.62[b]	30.35[c]
	40	25.85[a]	90.82[a]	0.33[c]	63.32[f]	5.49[a]	70.64[b]	26.69[a]	29.36[d]

*T, ST, TC, A, AA, MC and TSS stand for treatments, storage temperature, total carotenoids, acidity, ascorbic acid, moisture contents and total soluble solids, respectively. T_1, T_2 and T_3 stand for the fruit harvested at 6:30am, 1:30pm and 8:30pm, respectively. †Values having different superscript in the columns are significantly different under the limit of $P < 0.05$.

The required time for fruit ripening was longer for the mango fruit harvested at 6:30am (T_1) and the shorter for fruit of mango harvested at 1:30pm (T_2) for both Langra and Samar Bahisht Chaunsa varieties (Figure 1). The variance might be due to the statement that at 6:30am harvested fruit had less treated to field heat as compared to other treatments hence the rate of ripening was slow down (Baloch *et al*., 2011; Cecchi *et al*., 2005). On the other hand, the fruit of mango took shorter time to ripening at 40°C and the longer when exposed to 20°C during ripening, irrespective of variety or treatment (Bibi and Baloch, 2014; Gofure *et al.*, 1997). It was also observed that the rate of ripening was higher for Langra fruit and slower for the variety of Samar Bahisht Chaunsa.

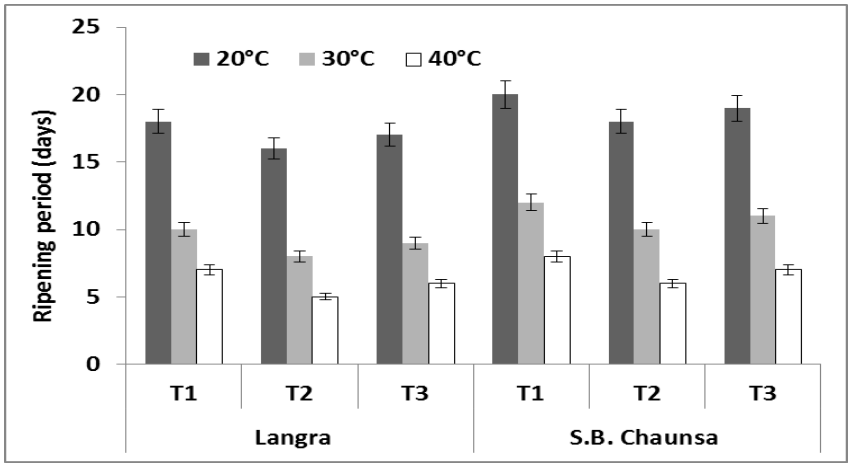

Figure 1: Time required by the Langra and Samar Bahisht Chaunsa fruit to reach at the ripened stage as affected by storage temperature and treatments. T_1, T_2 and T_3 stand for the fruit harvested at 6.30 am, 1.30 pm and 8.30 pm, respectively.

The percent of waste was maximum for fruit harvested at 1:30pm (T_2) and minimum at 6:30am (T_1) harvested fruit, irrespective of the storage temperature as well as variety. The waste percent was lowest at 30°C as compared to other temperature. It was also lowest for Samar Bahisht Chaunsa as compared to Langra mango fruit variety (Figure 2).

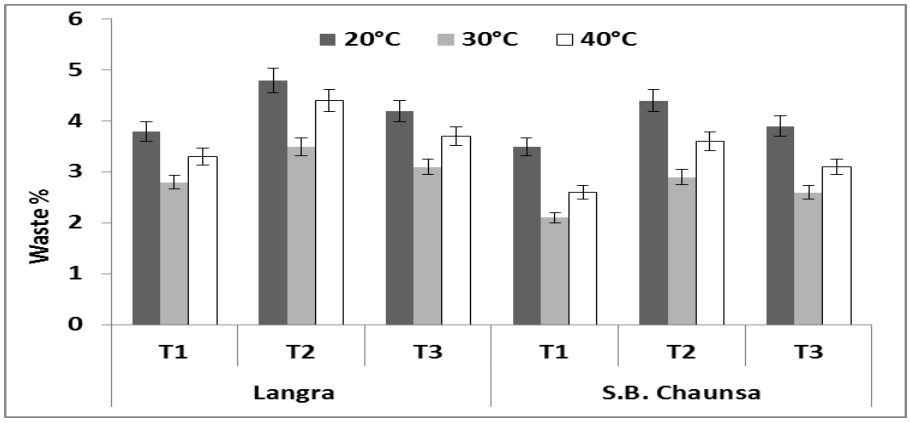

Figure 2: Waste percent of the Langra and Samar Bahisht Chaunsa fruit during the ripening process. T_1, T_2 and T_3 stand for the fruit harvested at 6.30 am, 1.30 pm and 8.30 pm, respectively.

Conclusion

It can be concluded that quality was minimum for mango fruit harvested at 6.30am time and maximum for fruit harvested at 8;30pm time and; it was minimum for 20°C and maximum for 40°C, irrespective of the variety. The rate of ripening was fastest for mango fruit harvest at 1:30pm time and stored at 40 °C and; it was slowest for fruit harvested at 6:30am time and stored at 20°C, irrespective of the variety. It was also observed that the rate of ripening was fastest in Langra as compared to Samar Bahisht Chaunsa variety. The waste percent was minimum for fruit harvested at 6:30am time and stored at 30°C and maximum for fruit harvested at 1:30pm time and stored at 20°C, irrespective of the variety.

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