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COMPARATIVE EFFECTS OF GAMMA IRRADIATION, UV-C AND HOT WATER TREATMENTS ON SENSORY ATTRIBUTES OF MANGO FRUIT (*Mangifera indica* L.) CV. WHITE AND BLACK CHAUNSA

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The study was carried out to explore the effects of ultraviolet irradiations, gamma irradiations and hot water treatment on the sensory attributes (taste, skin color, flavor, flesh color, aroma and acceptability) of black and white Chaunsa varieties of mango. Gamma irradiations at a dosage of 0.5 KiloGray (KGy) and 1 KGy were very much effective in retaining the color, taste and flavor of the mango fruits. Maximum skin color of 7.42 was maintained by 0.5KGy treated white Chaunsa; while, a maximum skin color of 6.28 was maintained by 1KGy treated black Chaunsa. Furthermore, maximum flesh color of 7.58 was maintained by 1KGy treated white Chaunsa; while, 6.46 was maintained by hot water treated black Chaunsa. Moreover, the hot water treatment was also found to be effective in retaining the taste (7.09) of white Chaunsa variety of mango. Both hot water treatment and gamma irradiations also retained better texture of both the mango varieties. Ultraviolet irradiations were less effective in maintaining the sensory attributes of mango varieties. However, throughout the storage a small amount of loss was noticed in the sensory attributes of mango fruit. Hence, gamma irradiations and hot water treatment can be effectively used commercially to enhance the storage life of black and white Chaunsa varieties of mango.
Keywords: Mango fruit, sensory attributes, gamma irradiations, hot water, ultraviolet, storage period.

INTRODUCTION

Mango (*Mangifera indica* L.) is an important tropical fruits grown in Pakistan and it belongs to family Anacardiaceae. In the Indo Pakistan region, it is also known as the king of all fruits. Asia is the major producer of mango with 76.9% of the total world production; while, the 9 countries including Pakistan account for around 86% of total world production (Galan Sauco, 2004). The great acceptability of mango fruit among masses is due to its succulence, exotic flavor and delicious taste. Mango fruit is a great source of carbohydrates, proteins, vitamin A, vitamin C, fats and minerals like calcium, iron and phosphorus. It also has the antioxidant, immunomodulatory, diuretic and wound healing properties (Chaudhary *et al.*, 2017). Moreover, different biochemical changes take place in the mango fruit throughout its life cycle which entirely modify the concentration of pigments, level of carotenoids, titratable acidity, pH, color, sweetness and aroma (Doreyappy-Gowda and Huddar, 2001). However, the export of mango and its distribution throughout the world is limited because of biochemical changes during the post-harvest storage which ultimately reduce its shelf life. Furthermore, various techniques like hot water treatment, controlled atmosphere storage, cold storage, irradiations and edible coatings are being applied to improve the shelf life of mangoes (Ntsoane *et al.*, 2019). Radiations from Cobalt60 and Cesium137 separately or with other treatments like heat are used to delay the ripening process in fruits hence, enhancing their shelf life (Fan, 2012). Likewise, the use of ultraviolet radiations for enhancing the shelf life of fresh fruits has also increased with the passage of time (Bintsis *et al.*, 2002; Marquenie *et al.*, 2003).
Many studies have discussed the sensory attributes of fruits in combination with the conditions and treatments. Additionally, the literature on the effect of different techniques in comparison on the sensory quality of mango fruit is also limited. Hence, the objectives of this study were to perceive the effects of different treatments (gamma irradiations, ultraviolet and hot water) on the sensory attributes of black and white Chaunsa varieties of mango during postharvest storage.

MATERIALS AND METHODS

***Preparation and processing of mango fruits*:** White and black Chaunsa varieties of mango were acquired from a local farm in Multan (Pakistan). Fruits were fresh and mature at the time of harvest. Furthermore, the fruit was cleaned firstly through distilled water and then drying with muslin cloth. After that fruit was transported to Post-Harvest Research Center, Ayub Agricultural Research Institute (AARI), Faisalabad in reefer containers where they were divided into several groups and stored at 11˚C and 85% relative humidity. The irradiations were applied at the Nuclear Institute of Agriculture and Biology and the treatments plan is shown in Table 1. The following treatments were used in the study:

Table 1. The treatments plan for sensory attributes of mango fruits.

No.	Treatment	Time of application
T_1	Control	
T_2	0.5 KGy	45 Minutes
T_3	1 KGy	1 hour and 30 minutes
T_4	1.5 KGy	2 hour and 15 minutes
T_5	UV-C	30 minutes
T_6	UV-C	60 minutes
T_7	Hot water (55 ˚C)	5 minutes

Gamma-rays 0.5 kGy, 1 kGy, or 1.5 kGy were generated by using a Gamma-cell Elan 3000 (Elite model D, Nordion International, Inc., Ottawa, Canada) and Cs^{137} which were then applied to the mango fruits. The fruits belong to ultraviolet group were exposed to radiations (UV-C< 280nm) for 30 and 60 minutes period. These radiations (ultraviolet< 250-280 nanometers) were applied for thirty or sixty minutes. Cotton bags were used to place the mango fruits and to further expose them to the hot water at 55ºC for 5 minutes followed by instantaneous cooling in cold water at 20ºC and air drying. After the application of different treatments fruits were stored in a refrigerator at 4-8°C followed by the evaluation of sensory attributes of mango fruit on the 28th and 42nd day of postharvest storage.

***Sensory evaluation test*:** To evaluate the effect of different treatments on the taste, color, acceptability, texture and flavor of black and white Chaunsa, a nine point hedonic scale was used (Javanmard *et al.,* 2012). A panel of 60 members from Ayub Agriculture Research Institute (AARI) and National Institute of Food Science and Technology, Faisalabad evaluated the sensory attributes of mango fruit. Discrete rooms were provided to the panelists so that they do not impact others through conversation and expressions. All the samples were coded so that no one knows the treatments used while each member was requested to evaluate the attributes on a scale of 9 with 1 depicting extreme poor and 9 showing excellent.

RESULTS AND DISCUSSION

***Peel color*:** Color of the peel is an important parameter of the fruit quality as it greatly attracts the consumers. All the treated mangoes at 28th and 42nd storage day possessed attractive peel color varying significantly (P<0.05). In case of white Chaunsa (WC) the panelists selected T_2 with 0.5 KiloGray $^{\gamma}$-irradiated as the best as compared to all the other treatments as well as the untreated samples. At the 28th storage day T_2 scored highest i.e. 8.08 followed by T_3 (7.24) and T_4 (6.33) while the lowest score of 4.31 was scored by T_6 (ultraviolet for 60 minutes) as shown in Table 2a. In comparison, the gamma irradiated white Chaunsa scored far better followed by hot water and ultraviolet treatments. Moreover, among ultraviolet treatments T_5 (UV-C for 30 minutes) scored better hence retaining more color than the T_6. This greater degradation in T_6 was because of the greater pigment degradation by the ultraviolet irradiations applied for 60 minutes. Furthermore, in black Chaunsa (BC) variety at 28th storage day the greater score was attained by T_3 (7.28) followed by T_4 (6.33) and T_7 (6.29); while, the lowest score was shown by T_1 (control). Additionally, T_6 with ultraviolet application for 60 minutes attained less score as compared to T_5 during twenty eight days of storage. Moreover, the similarity between T_4, T_7, T_2 and T_6 might be because of the enzymatic inactivation of same level (El-Samahy *et al*., 2000).

Table 2. Mean sensory scores for skin color at different storage intervals.

(a) At 28 days

Treatments	Variety	
	WC	BC
T_1	4.57±0.030 c	2.61±0.055 e
T_2	8.08±0.057 a	4.34±0.034 d
T_3	7.24±0.031 b	7.28±0.053 a
T_4	6.33±0.030 c	6.33±0.060 b
T_5	5.18±0.036 d	5.26±0.070 c
T_6	4.31±0.038 f	4.29±0.057 d
T_7	6.27±0.037 c	6.29±0.072 b

(b) At 42 days

Treatments	Variety	
	WC	BC
T_1	4.09±0.077 d	2.20±0.052 e
T_2	7.42±0.081 a	3.52±0.066 d
T_3	6.61±0.031 b	6.28±0.029 a
T_4	5.56±0.045 c	5.45±0.017 b
T_5	4.33±0.033 d	4.68±0.070 c
T_6	3.45±0.065 e	3.41±0.031 d
T_7	5.61±0.127 c	5.45±0.040 b

Means sharing similar letter in each column are statistically non-significant (P<0.05); BC= Black Chaunsa; WC= White Chaunsa

Panelists marked the peel color changes after 42 days of storage as slightly lower than the peel color after 28 days of storage. T_2 treatment (0.5 KGy) in white Chaunsa still scored better (7.42) as compared to other treatments followed by T_3 and T_7. Moreover, T_6 (3.45) and T_1 scored less (4.09) as compared to others and showed less appealing peel color (Table 2b). During the course of fruit ripening the synthesis and degradation of the pigments take place which lower the color scores with the passage of time (Valero and Serrano, 2010). Moreover, this greenish color disappearance is because of the loss of the chlorophyll with the ripening followed by the carotenogenesis which brings the bright yellowish color during ripening (Serrano *et al.*, 2011). After 42 days of storage T_4 of black Chaunsa (BC) scored 5.45 as it retained the color slightly better followed by T_3 and T_2; while, the lowest color score (3.41) was attained by T_6 (ultraviolet for 60 minutes). Furthermore, the irradiations clearly slowed down the ripening process which ultimately delayed the degradation of chlorophyll and the carotenoids synthesis (Kittur *et al.*, 2001).

***Flesh color*:** All the treated mangoes at 28th and 42nd storage day possessed attractive flesh color varying significantly ($P<0.05$). In case of white Chaunsa (WC) the panelists selected T_3 with 1.0 kiloGray γ-irradiated as the best as compared to all the other treatments as well as the untreated samples. At the 28th storage day T3 scored highest i.e. 8.13 followed by T_4 (7.41) and T_2 (7.30); while, the lowest score of 4.26 was scored by T_5 (ultraviolet for 30 minutes). In comparison, the gamma irradiated white Chaunsa scored far better followed by hot water and ultraviolet treatments. Moreover, among ultraviolet treatments T_6 (UV-C for 60 minutes) scored 5.21 hence retaining more color than 4.26 scored by T_5 (Table 3a). This greater degradation in T_5 was because of the greater pigment degradation by the ultraviolet irradiations applied for 30 minutes. Furthermore, in black Chaunsa (BC) variety at 28th storage day the greater score of 7.15 was attained by T_7 (hot water treatment) followed by T_3 (1.0 KGy) and T_2 (0.5 KGy); while, the lowest score of 2.60 was shown by T_5 (UV-C for 30 minutes). Moreover, the similarity between T_1 and T_4 might be because of the enzymatic inactivation of same level (El-Samahy *et al.*, 2000).

Panelists marked the flesh color changes after 42 days of storage as slightly lower than the flesh color after 28 days of storage. T_3 treatment (1 KGy) in white Chaunsa still scored better as compared to other treatments followed by T_4 and T_2. Moreover, T6 and T1 scored 4.62 and 4.78 which is less as compared to others and showed less appealing flesh color (Table 3b). During the course of fruit ripening the synthesis and degradation of the pigments take place which lower the color scores with the passage of time (Valero and Serrano, 2010). Moreover, the disappearance of the greenish color of flesh is because of the loss of the chlorophyll with the ripening followed by the carotenoids synthesis which bring the bright yellowish color on ripening (Serrano *et al.*, 2011). After 42 days of storage T_7 of black Chaunsa (BC) scored better i.e. 6.46 as it retained the flesh color slightly better followed by T_3 and T_2; while, the lowest color scores were attained by T_5 (ultraviolet for 30 minutes). Furthermore, the irradiations clearly slowed down the ripening process which ultimately delayed the degradation of chlorophyll and the carotenoids synthesis (Kittur *et al.*, 2001).

Table 3. Mean sensory scores for flesh color at different storage intervals.

(a) At 28 days

Treatments	Variety	
	WC	BC
T_1	5.50±0.037 d	3.60±0.058 e
T_2	7.30±0.037 b	5.33±0.047 c
T_3	8.13±0.037 a	6.36±0.050 b
T_4	7.41±0.023 b	3.57±0.070 e
T_5	4.26±0.037 e	2.60±0.070 f
T_6	5.21±0.059 d	4.35±0.052 d
T_7	6.18±0.047 c	7.15±0.056 a

(b) At 42 days

Treatments	Variety	
	WC	BC
T_1	4.78±0.070 d	2.87±0.042 e
T_2	6.60±0.030 b	4.85±0.072 c
T_3	7.58±0.029 a	5.56±0.045 b
T_4	6.74±0.043 b	2.91±0.064 e
T_5	3.44±0.034 e	2.20±0.056 f
T_6	4.62±0.047 d	3.59±0.043 d
T_7	5.48±0.036 c	6.46±0.027 a

Means sharing similar letter in each column are statistically non-significant ($P<0.05$).

***Flavor*:** Flavor is another important parameter of fruit quality which is greatly associated with the consumer acceptability. The results indicated that the effect of all the treatments on the flavor were highly significant ($P<0.05$). Moreover, the significant difference among the flavor of different treatments might be because of their nature. In case of white Chaunsa, all the treatments attained an average score over 5 apart from the ultraviolet irradiated samples (Table 4a). Likewise, the treatments applying gamma irradiations at high dosage of 1KGy and 1.5KGy retained better flavor than all other treatments. This flavor retention was greater is highly irradiated white Chaunsa samples which might be because of the slowed down the ripening and biochemical processes during postharvest storage. Furthermore, T_4 with dosage of 1.5 KiloGray gamma irradiations on black Chaunsa retained better flavor i.e. 7.32 after 28 days of postharvest storage. Moreover, during the storage of 28 days the white Chaunsa variety of mango retained better flavor than the black Chaunsa; while, the maximum score of 7.27 was attained by T_3 treated white Chaunsa.

In addition, the flavor at 28th storage day was better than the flavor at 42nd storage day. High doses of gamma irradiations (1kGy and 1.5kGy) scored 6.61 and 5.59 in case of white Chaunsa; while, the scores of 5.76 and 6.70 were attained by black Chaunsa after 42 days of storage. However, all other treatments were below average hence possessing a declined flavor (Table 4b). During the course of fruit ripening different changes in the fruit composition occur such as the accumulation of volatile compounds (Valero and Serrano, 2010). Different components of mango fruit provide flavor to it among which fatty acids and organic compounds are the major important components. Palmitic acid is converted into Palmitoleic acid with the passage of time which ultimately changes the sensory attributes (flavor and aroma). Moreover, different type of esters, alcohols and ethers are formed from different organic compounds throughout the postharvest storage (McWilliam, 1989).

Table 4. Mean sensory scores for flavor at different storage intervals.

(a) At 28 days

Treatments	Variety	
	WC	BC
T_1	6.34±0.031 b	4.47±0.042 d
T_2	5.50±0.052 c	5.26±0.052 c
T_3	7.27±0.021 a	6.37±0.063 b
T_4	6.41±0.031 b	7.32±0.055 a
T_5	3.26±0.075 d	4.26±0.056 d
T_6	3.34±0.045 d	3.31±0.077 e
T_7	5.21±0.059 c	5.16±0.062 c

(b) At 42 days

Treatments	Variety	
	WC	BC
T_1	3.57±0.037 d	3.65±0.040 d
T_2	4.85±0.070 c	4.56±0.045 c
T_3	6.61±0.028 a	5.76±0.045 b
T_4	5.59±0.028 b	6.70±0.047 a
T_5	2.54±0.073 e	3.76±0.064 d
T_6	2.70±0.045 e	2.72±0.029 e
T_7	3.55±0.056 d	4.52±0.066 c

Means sharing similar letter in each column are statistically non-significant (P<0.05)

***Taste*:** Taste of the fruit is another important parameter of its eating quality as it greatly affects the acceptance of the fruit by the consumers. The results indicated that the effect of all the treatments on the taste were highly significant ($P<0.05$). At 28th day of storage the white Chaunsa possessed an average taste score of greater than 5 in case of control, hot water and gamma irradiated samples; whereas, the best score of 8.06 was scored by the hot water treated white Chaunsa followed by gamma irradiated samples (Table 5a). Moreover, the results shown by the ultraviolet irradiated mango samples were not that much inspiring. Likewise, in the black Chaunsa variety greater color scores were attained by the gamma irradiated (1kGy and 1.5kGy) followed by the hot water samples. Furthermore, all the treatments showed a drop in taste score with the passage of time. Moreover, the high dosage of ultraviolet radiations poses some sensory deficiencies in the products (El-Samahy *et al*., 2000).

T7 (hot water treatment) in white Chaunsa scored best (7.09) on 42nd storage day (Table 5b) but the taste after 42 days was not good as compared to the taste on 28th storage day. Moreover, in black Chaunsa the highest score of 6.59 was attained by T_3. Minimum scores of 2.97 and 4.77 were attained by T_6 treated white Chaunsa and T_1 treated black Chaunsa respectively. Furthermore, the taste, acidity, total soluble solids and total sugars go hand in hand during the fruit ripening. Moreover, during the fruit ripening the organic acids decrease while the TSS and total sugars increase in the fruit which ultimately effect the taste (Rao *et al.,* 2016).

Table 5. Mean sensory scores for taste at different storage intervals.

(a) At 28 days

Treatments	Variety	
	WC	BC
T_1	6.23±0.037 c	5.49±0.035 d
T_2	6.42±0.049 c	6.39±0.064 c
T_3	7.34±0.034 b	7.38±0.057 b
T_4	5.30±0.052 d	8.35±0.040 a
T_5	4.29±0.038 e	5.31±0.057 d
T_6	3.41±0.050 f	6.17±0.068 c
T_7	8.06±0.048 a	7.12±0.051 b

(b) At 42 days

Treatments	Variety	
	WC	BC
T_1	6.61±0.031 b	4.77±0.052 d
T_2	5.63±0.047 c	5.59±0.077 c
T_3	6.65±0.027 b	6.59±0.041 b
T_4	4.60±0.045 d	7.26±0.048 a
T_5	3.63±0.056 e	4.85±0.082 d
T_6	2.97±0.040 f	5.52±0.036 c
T_7	7.09±0.035 a	6.47±0.037 b

Means sharing similar letter in each column are statistically non-significant (P<0.05)

***Texture*:** Fruit texture determines the freshness or softness of fruit which is a valuable parameter of sensory quality. The results indicated that the effect of all the treatments on the texture were highly significant ($P<0.05$). At 28th day of storage a maximum texture score of 7.36 was attained by T_2 (0.5 kGy) treated white Chaunsa followed by T7 (hot water) and T_1 (control); while, the minimum was shown by T_5 (UV for 30 minutes). Moreover, in black Chaunsa on the 28th storage day the maximum texture score of 7.15 was obtained by T_6 (UV for 60 minutes); while, minimum of 4.69 was secured by T_4 (Table 6a). Hence, ultraviolet treated black Chaunsa retained better texture after 28 days of storage.

Similarly, in white Chaunsa on the 42nd storage day the maximum texture score of 6.49 was secured by T_7 (hot water treatment) while the minimum texture score of 3.59 was attained by T_5 (UV for 30 minutes). Moreover, in black Chaunsa on the 42nd storage day the maximum texture score of 6.58 was obtained by T_6 (UV for 60 minutes) and T_5 (UV for 30 minutes) (Table 6b). On the 42nd day of storage a greater loss of texture score was observed as compared to 28th storage day.

Table 6. Mean sensory scores for texture at different storage intervals.

(a) At 28 days

Treatments	Variety	
	WC	**BC**
T_1	6.37±0.030 b	5.51±0.046 c
T_2	7.36±0.034 a	6.41±0.043 b
T_3	6.35±0.040 b	5.57±0.037 c
T_4	5.47±0.033 c	4.69±0.059 d
T_5	4.30±0.037 d	6.34±0.052 b
T_6	6.22±0.059 b	7.15±0.060 a
T_7	7.22±0.047 a	6.19±0.075 b

(b) At 42 days

Treatments	Variety	
	WC	**BC**
T_1	5.60±0.033 c	4.89±0.041 d
T_2	6.62±0.025 a	5.73±0.063 bc
T_3	5.73±0.045 bc	4.93±0.033 d
T_4	4.79±0.048 d	4.08±0.036 e
T_5	3.59±0.057 e	5.83±0.105 b
T_6	5.60±0.039 c	6.58±0.033 a
T_7	6.49±0.035 a	5.65±0.062 c

Means sharing similar letter in each column are statistically non-significant (P<0.05)

Many enzymes like pectinesterases and polygalacturonases are responsible for the cell wall digestion hence; their increased activity with the ripening also tends to increase the fruit softness. Additionally, the insoluble protopectin is converted into soluble pectin and pectic acid which reduces the cell wall integrity ultimately decreasing the fruit texture score (Kabbashi *et al.*, 2017). Whereas, the irradiations also induce the softening in fruits due to the alteration of pectin and cellulose which ultimately softens the fruit texture (Kudachikar *et al*., 2001).

Overall acceptability**:** Overall acceptability of fruits depends greatly upon the color, texture, taste, aroma and appearance of fruit. At 28th day of storage a maximum acceptability score of 8.30 was attained by T_7 (hot water) treated white Chaunsa followed by T_3 (1.0 kGy) and T_2 (0.5 kGy) while the minimum of 4.92 was shown by T_5 (UV for 30 minutes). Moreover in black Chaunsa on the 28th storage day the maximum texture score of 7.40 was obtained by T_7 (hot water) while minimum of 4.81 was secured by T_1 (Table 7a). Hence, gamma irradiated white and black Chaunsa were more acceptable after 28 days of storage as compared to others.

Similarly, in white Chaunsa on the 42nd storage day the maximum acceptability score of 7.31 was secured by T_7 (hot water treatment) while the minimum texture score of 4.33 was attained by T_5 (UV for 30 minutes). Moreover, in black Chaunsa on the 42nd storage day the maximum texture score of 6.88 was obtained by T_7 (hot water treatment) and minimum of 4.13 was attained by T_1 (Table 7b). On the 42nd day of storage a greater loss of acceptability score was observed as compared to 28th storage day. The overall acceptability and other sensory attributes of fruit greatly depend upon the ripeness of fruit (Mtebe *et al*., 2006). Moreover, the sensory profile of mango fruit also depend upon the factors like enhanced respiration rates, chlorophyll degradation and the conversion of carbohydrates into sugars, phenolic and organic acids (Herianus *et al*., 2003).

Table 7. Mean sensory scores for overall acceptability at different storage intervals.

(a) At 28 days

Treatments	Variety	
	WC	**BC**
T_1	6.42±0.029 d	4.81±0.038 f
T_2	7.66±0.037 c	5.62±0.051 c
T_3	7.93±0.037 b	7.11±0.060 b
T_4	6.66±0.034 d	5.42±0.042 d
T_5	4.92±0.049 f	5.16±0.045 e
T_6	5.59±0.050 e	5.77±0.047 c
T_7	8.30±0.039 a	7.40±0.049 a

(b) At 42 days

Treatments	Variety	
	WC	**BC**
T_1	5.77±0.054 e	4.13±0.042 f
T_2	6.90±0.033 c	5.07±0.070 c
T_3	7.14±0.043 b	6.33±0.076 b
T_4	5.98±0.055 d	4.84±0.105 d
T_5	4.33±0.067 g	4.53±0.040 e
T_6	4.95±0.075 f	5.07±0.083 c
T_7	7.31±0.062 a	6.88±0.076 a

Means sharing similar letter in each column are statistically non-significant (P<0.05)

Conclusion**:** Results of the study indicate that the gamma irradiations are very good for enhancing the shelf life of mango fruit and they also maintain the sensory attributes of the fruit better as compared to other treatments. In addition, the hot water treatment was also found effective in maintaining the sensory characteristics of black and white Chaunsa varieties of mango. Moreover, the effect of gamma irradiations depends greatly upon their dosage and the variability of sensory parameters. The results show that the gamma irradiations at a dosage of 1.0 KiloGray and hot water treatment at 55ºC for 5 minutes are a potential treatments for enhancing the shelf life of mango fruit commercially (4-8ºC and 85% relative humidity).

Conflict of interest: The authors have no conflict of interest.

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