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EFFECTS OF FUNGICIDES AND STORAGE TEMPERATURE ON SHELF LIFE AND FRUIT QUALITY OF STORED MANGO (*MANGIFERA INDICA* L.)

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Abstract

Postharvest fungal spoilage, particularly anthracnose is a serious problem of mango and it is considered as the main hurdle faced by Pakistan in exporting its mango fruit. In this study, the effects of three different fungicides (topsin-M, carbendazim, and aliette) on shelf life and quality of mango fruit was evaluated at two different storage temperatures i.e., room temperature (23 ± 3ºC) and at refrigerated temperature (5ºC). Storage temperatures also affected weight loss, total soluble solids, fruit firmness, total titratable acidity and decay of mango fruit. Optimum holding storage temperature observed for stored mango fruit with least chilling injury symptom and decay was 5ºC. Fungicide treated fruits stored refrigerated showed least changes in physiochemical properties with no visual infection of anthracnose on fruit. Among fungicides, carbendazim treatment was found more effective at both storage temperatures. Carbendazim treated mango fruit showed least and steady increase in total soluble solids, gradual increase in pH and steady decrease in total titratable acidity.

Key words: Mango, Postharvest, Fungicides, Temperature, Decay percent, Physio-chemical, Properties, Anthracnose.

Introduction

Mango (*Mangifera indica* L.) grown tropically and non-tropically including Pakistan (Anon., 2012). During storage and transport fungal spoilage is considered as the major reason for postharvest spoilage of fresh fruit and vegetables which causes substantial losses at market stage (Moss, 2002; Fatima *et al.,* 2009). The quality of mango fruit is majorly affected by postharvest diseases that reduced shelf life (Zheng *et al.*, 2012). Anthracnose or blackening of the mango fruit during transit or marketing seriously reduces consumers acceptance, hence its price (Arauz, 2000; Ploetz *et al.,* 1996; Syed *et al.,* 2017). This disease is found latent when fruits are harvest but as soon as they start ripening, blackening of fruits also progress resulting in spoilage of fruit and it appears as single most important quality threats to mango fruit (Dodd *et al*., 1997; Jeffries *et al.*, 1990; Gupta *et al.*, 2015; Syed *et al.*, 2017). Fungicides are the main approaches used as pre and postharvest treatments in order to reduce losses due to anthracnose. The use of fungicide gets limited day by day due to public concerns over toxic deposits. However, in many developing countries fungicides are considered to be high-priced for mango growers (Dodd *et al*., 1989). Several alternate techniques are used in order to minimize deterioration, encompass the shelf life and enhance mango fruit quality, such as hypobaric storage, low temperature, controlled or modified atmosphere storage, irradiation and coatings, chemicals, biological (Ravindra & Goswami, 2008, Habiba *et al*., 2017; 2019). Reduce physio-chemical changes and control or delay in ripening process of mango fruits is gained through controlled atmosphere (Sudhakar & Gopalakrishna, 2008). Refrigeration for storage of most perishable fresh produce is highly recommended (Gross *et al*., 2004). Low temperature helps in retarding spoilage, inhibition of microbial growth and subdues objectionable metabolic variations, thus, maintains fruit quality and prolongs storage period. Nevertheless, some products are prone to chilling injury and deteriorate hastily if they are kept at chilling temperatures below their threshold (Wang & Wang, 2009). Low temperature storage may cause undesirable flavor, physiological disorders and poor coloration (Thompson, 2010). Uninterrupted use of fungicide can lessen postharvest decay and may increase the shelf life of mango fruit. Development of eco-friendly bio preservative is required due to consumer concerns about the fungicides present on surface of the fruit, resistance shown by pathogens, and their negative impact on human health and environment (Mari *et al.,* 2014) Widely used systemic fungicide for the control of postharvest diseases like stem end rot and anthracnose of mango as pre harvest spray or postharvest spray and to some extent as hot dips is carbendazim (methyl-2-benzimidazole carbamate) (Bhattacherjee *et al.*, 2009). Postharvest life of vegetables and fruits and their metabolic processes are affected by providing low temperature storage conditions (Sivakumar *et al*., 2011). The purpose of this study was to determine the efficacy of some commercial fungicides in reducing decay and minimizing other physiochemical changes to maintain the quality of mango fruit stored at refrigerated temperature (5°C) and room temperature (23 ± 3°C).

Materials and Methods

Mango fruit: Fresh healthy mangoes were collected from the supermarkets in Karachi, Pakistan and moved to the laboratory on the same day. Fruits were cleaned and classified on the basis of size and color. Mango fruits with uniform shape, maturity, size and those free from blemishes were used.

Application of fungicide on mango fruit: The efficacy of fungicides (topsin-M, carbendazim, aliette) for the control of postharvest quality losses and increasing shelf life in stored mango were evaluated. The mangoes were surface sterilized with bleach and air dried, dipped separately in aqueous suspension of above three fungicides (20 mg/L). Control fruits were dipped in sterilized water. Mango fruits were air dried and kept in a perforated basket, while tops were covered with polyethylene sheet. One set was kept at room temperature (25±5ºC), while the other set was kept at refrigerated temperature (5ºC). The experiment was conducted with four replicates and observations were recorded every third day with three mango per treatment.

Loss in weight. pH, total soluble solids and titratable acidity of fruit: Method of Anon., (1994) and Habiba *et al.,* (2019) was used to calculate/ determine the reduction in fruit weight, pH, and change in titratable acidity with time.

Firmness of fruit: Firmness of fruit was determined by a penetrometer (PCE-PTR 200) and expressed in Newton (Habiba *et al.,* 2019)

Decay/rotting percent: Decay percentage of mango was determined by visual observation (Habiba *et al.,* 2019).

Statistical analysis

Data was analyzed using software (CoStat) and least significant difference (LSD) was determined at ($p<0.05$).

Results

Effect of fungicides on percent weight loss of stored mango fruit: Three different fungicides (topsin M, carbendazim and aliette) in the concentration of 20mg/L were used for this study showed different effects on the percent weight loss of stored mango fruit as compared to untreated set (control). Among treatments the minimum weight loss on the ninth day of storage was exhibited by carbendazim (12.95%) as compared to control and other treatments at room temperature. All three treated fungicides have exhibited minimum weight loss in storage mango fruit as compared to control set during storage at room temperature (Table 1).

Refrigerated temperature (5ºC) proved the best control paradigm by showing maximum weight retention in treatments and control set. During storage of nine days slight and non-significant weight loss was examined in all three fungicides treated mango fruit (3.42, 3.97, and 3.59%). This percent weight loss is equal to one third of treated fruit kept at room temperature. However, maximum percent weight loss was examined on the ninth day of storage in a control set (5.73%) kept at refrigerated temperature (Table 1).

Effect of fungicides on the firmness (N) of stored mango fruit: At room temperature, all three fungicide treatments have shown maximum retention of fruit firmness as compared to the control set. Among treatments carbendazim showed maximum fruit firmness on the third, sixth and ninth day of storage (1.32, 1.3, 1.28) (Table 2).

At refrigerated temperature, fruit firmness was retained in all treated fruit as compared to the treated fruit kept at room temperature. The maximum fruit firmness on the ninth day of study among treatments was exhibited by carbendazim (1.76N) followed by topsin-M (1.58N) and aliette (1.28N) as shown in Table 2.

Effect of fungicides on total soluble solids (%) of stored mango fruit: In this study total soluble solid in stored mango fruit increased in both treated and untreated fruit. However this increasing pattern was least in fruit that is treated with carbendazim from the first day of experimentation till the ninth day of storage, i.e., 19.4%, 21.85%, 22.75% and 24%. However, control set at room temperature showed maximum total soluble solid contents in mango fruit on the ninth day of storage (25.25%). Effect of fungicides on total soluble solids of mango fruit stored at room temperature is shown in Table 3.

At refrigerated temperature, total soluble solid content in stored mango fruit showed a slight and gradual increasing pattern from the first day of storage till the final day of storage as compared to the treated and non-treated fruit kept at room temperature. Least accumulation of total soluble content in mango fruit is examined in carbendazim treated fruit on the ninth day of storage (20.5%) followed by aliette and topsin-M (23.25%) as shown in Table 3.

Effect of fungicides on pH of stored mango fruit: pH of mango fruit showed an increasing trend in storage at both temperatures as shown in Table 4. This rise is steady in both treated and non-treated fruit. However a slight increasing pattern was observed in treatments as compared to control set kept at both temperatures. The pH range during storage at room temperature was 4.75 to 5.83 while at refrigerated temperature the range of increasing pH of stored mango fruit was 4.75 to 5.48 as shown in Table 4.

Effect of fungicides on total titratable acidity (%citric acid) of stored mango fruit: Total titratable acidity in mango fruit increased on the third day at both storage temperatures. However after the third day of storage it starts decreasing till the final day of storage both at room and refrigerated temperature. The maximum rise on third of storage at room temperature was exhibited by the control set. The increased total titratable acidity among treatments was shown least by fruit treated with carbendazim at room and refrigerated temperature respectively as shown in Table 5. The steady increase and decrease of total titratable acidity was exhibited by fruit treated with carbendazim on the ninth day of storage at both room and refrigerated temperature.

Effect of fungicides on percent decay of stored mango fruit: During storage anthracnose was the common disease observed in both treated and untreated fruit. At room temperature (23 ± 3ºC) fungicide treated fruit showed the least percent decay (50%-75%) as compared to the control set (87.5%) on the ninth day of storage as shown in Table 6.

Temperature was found a vital factor for the control of decay of fruit during storage. At refrigerated temperature (5ºC) no major signs of decay were observed till the final day of storage in both treated and non-treated fruit (Table 6). Pictorial view of stored mango fruits (treated & non-treated) at both storage temperatures is shown in Figure 1 (A-F).

Table 1. Effect of fungicides on weight loss of mango fruit stored at 23 ±3ºC & 5ºC.

Treatments	Room temperature (23 ±3ºC)				Refrigerated temperature (5ºC)			
	0D	3D	6D	9D	0D	3D	6D	9D
Control	0 ± 0	3.64 ± 0.27	9.25 ± 1.05	14.33 ± 1.42	0 ± 0	1.42 ± 0.06	3.33 ± 1.22	5.73 ± 2.81
Topsin M	0 ± 0	2.05 ± 0.22	7.69 ± 0.25	13.23 ± 1.57	0 ± 0	1.26 ± 0.27	2.27 ± 0.29	3.42 ± 0.94
Carbendazim	0 ± 0	3.4 ± 0.35	8.81 ± 0.90	12.95 ± 1.10	0 ± 0	1.33 ± 0.17	2.05 ± 0.25	3.97 ± 0.27
Aliette	0 ± 0	3.38 ± 0.39	9.04 ± 1.11	13.16 ± 2.24	0 ± 0	1.19 ± 0.08	2.0 ± 1.18	3.59 ± 0.75

$LSD_{0.05}$= Treatments[1] = 0.45; Days[2] = 0.45; Temperatures[3] = 0.32

Table 2. Effect of fungicides on firmness of fruit (N) of mango fruit stored at 23 ±3ºC & 5ºC

Treatments	Room temperature (23 ±3ºC)				Refrigerated temperature (5ºC)			
	0D	3D	6D	9D	0D	3D	6D	9D
Control	2.22 ± 0.32	1.53 ± 0.11	1 ± 0.08	0.9 ± 0.42	2.22 ± 0.32	1.45 ± 0.40	1.41 ± 0.47	1.33 ± 0.36
Topsin M	2.22 ± 0.32	1.58 ± 0.40	1.27 ± 0.43	1.22 ± 0.49	2.22 ± 0.32	1.96 ± 0.24	1.63 ± 0.35	1.58 ± 0.39
Carbendazim	2.22 ± 0.32	1.32 ± 0.32	1.3 ± 0.21	1.28 ± 0.13	2.22 ± 0.32	1.82 ± 0.42	1.82 ± 0.22	1.76 ± 0.79
Aliette	2.22 ± 0.32	1.45 ± 0.44	1.31 ± 0.28	1.21 ± 0.28	2.22 ± 0.32	1.82 ± 0.29	1.61 ± 0.19	1.28 ± 0.22

$LSD_{0.05}$= Treatments[1] = 0.17; Days[2] = 0.17; Temperatures[3] = 0.12

Table 3. Effect of fungicides on total soluble solids (%) of mango fruit stored at 23 ±3ºC & 5ºC.

Treatments	Room temperature (23 ±3ºC)				Refrigerated temperature (5ºC)			
	0D	3D	6D	9D	0D	3D	6D	9D
Control	19.4 ± 3.38	20.5 ± 1.29	24 ± 2.16	25.25 ± 2.0	19.4 ± 3.38	21.5 ± 1.29	22.5 ± 1	23.5 ± 1.73
Topsin M	19.4 ± 3.38	23.25 ± 0.9	23.9 ± 1.90	24.5 ± 1.29	19.4 ± 3.38	21.4 ± 0.76	21.5 ± 2.6	23.25 ± 1.2
Carbendazim	19.4 ± 3.38	21.85 ± 1.66	22.75 ± 1.2	24 ± 1.41	19.4 ± 3.38	22.85 ± 3.4	23 ± 2.94	20.5 ± 1.73
Aliette	19.4 ± 3.38	22.85 ± 1.9	24.25 ± 1.89	24.5 ± 1.29	19.4 ± 3.38	22 ± 2.70	23.35 ± 3.8	23.25 ± 0.9

$LSD_{0.05}$= Treatments[1] = 1.19; Days[2] = 1.19; Temperatures[3] = 0.84

Table 4. Effect of fungicides on pH of mango fruit stored at 23 ±3ºC & 5ºC.

Treatments	Room temperature (23 ±3ºC)				Refrigerated temperature (5ºC)			
	0D	3D	6D	9D	0D	3D	6D	9D
Control	4.75 ± 0.16	5.15 ± 0.15	5.83 ± 0.16	5.83 ± 0.15	4.75 ± 0.16	5.05 ± 0.26	5.14± 0.19	5.48±0.45
Topsin M	4.75 ± 0.16	5.35 ± 0.05	5.79 ± 0.33	5.95 ± 0.14	4.75 ± 0.16	4.99 ± 0.32	5.08±0.33	5.08±0.36
Carbendazim	4.75 ± 0.16	5.22 ± 0.26	5.48 ± 0.13	5.84 ± 0.68	4.75 ± 0.16	5.11 ± 0.24	5.11±0.24	5.21±0.21
Aliette	4.75 ± 0.16	5.27 ± 0.32	5.48 ± 0.13	5.72 ± 0.40	4.75 ± 0.16	5.16 ± 0.22	5.16±0.23	5.24±0.26

$LSD_{0.05}$= Treatments[1] = 0.13; Days[2] = 0.13; Temperatures[3] = 0.09

Table 5. Effect of fungicide on total titratable acidity (%citric acid) of mango fruit stored at 23 ±3ºC & 5ºC.

Treatments	Room temperature (23 ±3ºC)				Refrigerated temperature (5ºC)			
	0D	3D	6D	9D	0D	3D	6D	9D
Control	0.12 ± 0.02	0.34 ± 0.09	0.27 ± 0.03	0.23 ± 0.03	0.12 ± 0.02	0.39 ± 0.03	0.35 ± 0.05	0.23 ± 0.05
Topsin M	0.12 ± 0.02	0.31 ± 0.08	0.25 ± 0.02	0.24 ± 0.03	0.12 ± 0.02	0.38 ± 0.08	0.30 ± 0.05	0.28 ± 0.04
Carbendazim	0.12 ± 0.02	0.27 ± 0.06	0.25 ± 0.05	0.27 ± 0.04	0.12 ± 0.02	0.31 ± 0.02	0.30 ± 0.07	0.31 ± 0.07
Aliette	0.12 ± 0.02	0.32 ± 0.06	0.25 ± 0.02	0.23 ± 0.05	0.12 ± 0.02	0.41 ± 0.15	0.27 ± 0.05	0.23 ± 0.05

$LSD_{0.05}$= Treatments[1] = 0.02; Days[2] = 0.02; Temperatures[3] = 0.02

Table 6. Effect of fungicides on percent decay of mango fruit stored at 23 ±3ºC & 5ºC.

Treatments	Room temperature (23 ±3ºC)				Refrigerated temperature (5ºC)			
	0D	3D	6D	9D	0D	3D	6D	9D
Control	0	8.33	62.5	87.5	0	0	0	0
Topsin M	0	8.33	37.5	62.5	0	0	0	0
Carbendazim	0	0	37.5	50	0	0	0	0
Aliette	0	33.33	62.5	75	0	0	0	0

$LSD_{0.05}$= Treatments[1] = 8.07; Days[2] = 8.07; Temperatures[3] = 5.70

[1]Mean values for treatment in column showing differences greater than LSD values are significantly different at $p<0.05$
[2]Mean values for time in rows showing differences greater than LSD values are significantly different at $p<0.05$
[3]Mean values for temperature in rows showing differences greater than LSD values are significantly different at $p<0.05$

3rd Day
Refrigerated temperature

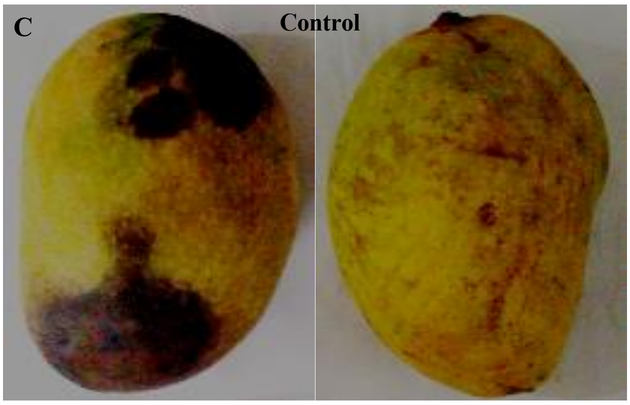
Control Topsin-M Aliette Carbendazim

Fig. 1A. Mango fruit on the 3rd day of experimentation stored at room temperature (23 ±3ºC).

3rd Day
Refrigerated temperature

Control Topsin-M Aliette Carbendazim

Fig. 1B. Mango fruit on the 3rd day of experiment stored at refrigerator temperature (5ºC).



Room temperature Refrigerated temperature

Fig. 1C. Mango fruit from the control set on the 9th day of experimentation.

Room temperature Refrigerated temperature

Fig. 1D. Topsin-M treated mango fruit on the 9th day of experimentation.

Room temperature Refrigerated temperature

Fig. 1E. Aliette treated mango fruit on the 9th day of experimentation.

Room temperature Refrigerated temperature

Fig. 1F. Carbendazim treated mango fruit on the 9th day of experimentation.

Discussion

Export and domestic marketing of mango fruit is limited by postharvest disease thus decreasing its quality attributes and shelf life with economic losses (Bally *et al.*, 2009; Barkai-Golan, 2001; Narayanasam, 2006). Mango is found susceptible to postharvest fruit decay owed to rapid development of disease and ripening like other fruits (Prabakar *et al.*, 2005). Anthracnose (*Colletotrichum gloeosporioides*) is one of the common postharvest diseases of mango fruit (Bally *et al.*, 2009). Various pre and postharvest disease controlling studies stated in includes hot water dips, vapor heat treatments, emulsion coatings and fungicidal treatments (Diaz-Sobac *et al.*, 2000; Sanders *et al.*, 2000; Sopee & Sangchote, 2005). In this study, three fungicides (topsin-M, carbendazim, aliette) were taken in account to study their effect on postharvest fungal decay (anthracnose infection) control on mango fruit during storage at two different temperatures in comparison with the non-treated fruit (control set). Fungicide treatments have successfully controlled the anthracnose infection as compared to control sets at both temperatures. Widely used systemic fungicide for the control of postharvest diseases like stem end rot and anthracnose of mango as pre harvest spray or postharvest spray and to some extent as hot dips is carbendazim (methyl-2-benzimidazole carbamate) (Sharma *et al.*, 1994; Bhattacherjee *et al.*, 2009).

Fresh fruit quality is one of the chief aspects having substantial association with the customer's acceptance and its marketing capacity and has continually been a key problem of investors from manufacture level to selling rate (Shewfelt, 1999). Mango stored at refrigerated temperature showed better results in maintaining the postharvest quality of mango fruit by causing least negative changes in its physiochemical properties. Maximum quality retention with minimum physiochemical changes were observed in treatments at refrigerated temperature. Low temperature extends the postharvest life and changes the rate of metabolic processes of vegetables and fruit (Sivakumar *et al*., 2011). The weight of mango fruit decreased during storage, irrespective of the fungicide treatment, and the rate of the weight loss observed was more in fruit stored at room temperature.

Texture is an acute quality characteristic that helps both the consumer and industry govern the suitability of food (Ma *et al*., 2017). The decrease in firmness was observed with the increase in storage duration and more firmness indicated at refrigerated temperature and is due to the slow and steady metabolic processes. Loss of firmness is primarily related with enzymatic breakdown of pectin is regulated by polygalacturonase and pectin methylesterase (Barbagallo *et al*., 2012). Structural carbohydrates like starch and pectic substances are more accountable for sustaining firmness of fruit (Manganaris *et al*., 2008). pH of stored mango fruits showed an increasing pattern during this study. This pH increment could be due to an increase in the vitamin C content. Similar findings were reported by Machado *et al.* (2007), while studying the storage of jabuticaba fruits covered with the plastic packages stored at low temperatures. They correlated the increase in pH with the increase in the vitamin C content. A steady decrease in citric acid content of the fruit was observed during storage in treated and untreated fruit. The degree of decrease in total titratable acidity was significantly higher in untreated (control) fruit as compared to treated fruit. This may be due to greater availability of oxygen by oxidation process which causes its rapid loss. Decay tends to increase during storage periods. More decay was observed in mangoes stored at room temperature as compared to mangoes (treated and non-treated) kept at refrigerated temperature. Ketsa *et al*., (2000) also reported a rapid increase in decay at different storage temperatures. However, carbendazim treatment showed a significant result comparatively to other treatments and control.

Conclusions

The combined preservation approach (chemical & physical) can offer interesting opportunities for extending shelf-life and quality of perishable fruits and vegetables. Fungicide as a source of postharvest disease management is appreciated and accepted to some extent but not completely appreciated. Although cold storage is considered the best and safest tool for the control of postharvest losses, long preservation on cold storage may alternatively alter the sweetness of fruit. On the other hand fungicide may prevent the fruit from complete damage and extend shelf life but it also has a negative impact not only on fruit but also reported with health and environmental hazards as well, so effort must be taken in order to bring change in such a way that it prevent fruit and should not be risky for human and environment.

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