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Impact of Different Packaging Types and Low Temperature Shipping Durations on Fruit Quality and Marketability of Pakistani Mangoes

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ABSTRACT

Corrugated cardboard boxes are being used for the export of mango fruit worldwide. However, for sea freight, the performance of cardboard box (open vs closed) needs to be evaluated for shipment under low temperature conditions. Under this perspective, two different types of corrugated cardboard box packagings were compared for their effect on the quality, marketability and consumer acceptability in two commercial mango cultivars (Sindhri & Sufaid Chaunsa) of Pakistan under simulated harvest, handling and shipping conditions with storage (11°C; 80-85% RH) intervals of 3, 4 and 5 weeks. Both Sindhri and Sufaid Chaunsa mangoes packed in open top boxes had higher marketability with better firmness and higher sugar contents (less softness score; significant in case of cv. Sufaid Chaunsa only) at ripening as compared to the fruit of closed top boxes. However, the problem of comparatively less peel color development in case of open top packaging needs to be addressed for improving the competitiveness of fruit at retail. Physiological weight loss and rate of respiration were statistically at par in both types of packaging in both cultivars. The low temperature storage duration had significant impact on various physico-chemical and organoleptic fruit quality attributes of both cultivars. Fruit peel color and textural softness were significantly increased with the increase of storage period (from three to five weeks). Moreover, increased weight loss percentage and reduced marketable fruit percentage were observed as the storage/shipping period was extended from three weeks to five weeks. But overall, cv. Sindhri had higher percentage of marketable fruit at all removals due to lower incidence of disease. The trend of disease development was increased in duration of low temperature storage; however, it was less in case of cv. Sindhri, thus indicating its better shipping potential with lower disease incidence as compared to cv. Sufaid Chaunsa. The respiration rate increased with advancement in post shipment ripening stages (i.e., at removal day, after ethylene treatment & at final day of ripening). Overall, open top packaging was found to be more advantageous as compared to closed top packaging, in both cultivars under low temperature storage (11°C; 80-85% RH). More research work is needed for post harvest disease management, particularly in cv. Sufaid Chaunsa, to have commercial success in sea-freighting this cultivar.

Key Words: *Mangifera indica;* Sea-freight; Shipment; Packaging; Storability; Market value

INTRODUCTION

Mango (*Mangifera indica* L., Family Anacardiaceae) is the second most important fruit crop in Pakistan. Over the last decade, world-wide increase in fresh mango trade has been observed due to the advancements in postharvest handling technology along with improvements in logistics and communication. Pakistan is regarded as the world's fifth largest producer (FAO, 2010) with production of 1728 thousand tons (MINFAL, 2009) and fourth largest exporter of mango with export quantity of 84.9 thousand tons (value=29.3 million US dollars) (Anonymous, 2010). At present, the mango exports from Pakistan are predominantly to, UAE, Saudi Arabia, Kuwait, Iran and UK. Internationally collaborative projects like Australia-Pak mango supply chain management project (ASLP) and FIRMS project (USAID) have helped in capacity building and on farm infrastructure development along with the Global GAP certification of mango orchards. Due to these interventions, now Pakistan has also got access to the supermarkets of European Union and USA.

Currently, the bulk of mango is exported by air, however, limited air cargo -facilities and high air freight cost (4 to 5 times higher than sea freight) have given boost to sea freight technology for the export of fresh produce in this era (Malik, 2011). Mango being a climacteric fruit has a

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limited shelf life while sea shipment of mangoes takes much longer time than air freight. Hence, mango industry of Pakistan is currently facing challenges of overcoming fruit quality and limited shelf life issues for delivering mangoes to international markets. Under this perspective suitable packaging is one of the major considerations (Simmons *et al*., 1997). Good packaging materials help the fruit to retain firmness for a reasonable period of time (Nazri, 2003). Corrugated card board boxes are currently being used all over the world, both in air and sea-freight in order to export horticultural commodities. The size and type of cardboard boxes may vary with the markets (Anonymous, 2009). Usually, the two piece cardboard boxes are used for packaging of produce, however, for marine transport; the interest has been increased in the use of open-top fiber board boxes due to relative advantage of better air circulation and reduced ethylene accumulation, thereby extending the shelf life. The use of cardboard boxes in Pakistani mango industry is new and the information is lacking regarding the performance of our local mango cultivars under cardboard packaging during extended storage/shipping conditions. In this context, present study was conducted in order to investigate the impact of two types of packaging (open top vs closed top) on two commercial mango cultivars (Sindhri & Sufaid Chaunsa) of Pakistan under simulated low temperature sea-freight supply chain conditions for delivering mangoes to international markets.

MATERIALS AND METHODS

Fruit selection, preparation and transportation: Uniform sized and physiologically mature fruits of mango cv. Sindhri and Sufaid Chaunsa were sourced from a commercial mango orchard located at Lodhran District of Punjab Province (29° 15′ 25N; 71° 32′ 60E), Pakistan. At anticipated time of physiological maturity, the fruit of cv. Sindhri (June 25, 2010) and cv. Sufaid Chaunsa (September 28, 2010) were harvested along with 4-5 cm long intact stalks in order to avoid the skin injury caused by sap flow. Just after harvesting, the fruit were de-sapped in 0.5% lime solution (2-3 min dip followed by tap water wash) to avoid sap burn injury. After de-sapping, the fruit were subjected to cold water fungicidal application (Sportak @ 0.5 mL/L, Active Ingredient: Prochloraz; 2-3 min dip) followed by hot water treatment (52°C; 5 min) to reduce the incidence of disease development during storage. The fruit of both varieties were air dried, packed in plastic bins (double layer) followed by precooling and transported to Postharvest Research and Training Centre (PRTC), Institute of Horticultural Sciences, University of Agriculture, Faisalabad (Pakistan) in a reefer van (at 16°C; 80-85%RH).

Packaging and storage: At PRTC, the fruit were packed in two different types of corrugated cardboard boxes i.e., open top and closed top (treatments), forced air cooled to core temperature of 11°C (10-12 h) followed by storage at 11°C (80-85% RH) up to 5 weeks. The experiment was laid out under Completely Randomized Design along with two factor arrangements and replicated thrice with seven fruits (approx. 4–4.5 kg/box) in each replicate.

Data collection: The fruit were removed from low temperature storage after three, four and five week intervals in accordance with simulated sea shipment studies. After every removal, the fruit were subjected to ethylene ripening (24°C; 100ppm; 48 h) followed by five days of shelf studies at 20°C. Observations were also made on three post shipment ripening stages (i.e., at removal day, after ethylene treatment & at final day of ripening) to check the effect of treatments (packaging) and removals (shipping durations) on peel color, fruit textural softness and disease incidence (stem end rot & body rots). At ripe stage fruit were subjected to bio-chemical analysis such as TSS, total titratable acidity, vitamin C and sugar contents in order to evaluate the internal fruit quality (Amin *et al*., 2007). The percentage of marketable fruits was also calculated. Organoleptic evaluation of ripe fruit was done regarding taste, texture, flavor, pulp color and aroma (Peryam & Pilgrim, 1957). For the measurement of respiration rate, one fruit from each replication was randomly selected and placed into a sealed plastic jar for one hour. Respiration rate was determined by measuring CO_2 production using a CO_2 analyzer (Vaisala MI 70, Vaisala Inc., Helsinki, Finland) and expressed as mmol CO_2 $kg^{-1}h^{-1}$. Fruit peel color, fruit textural softness and disease incidence were estimated by visual observations (Malik & Singh, 2005). Fruit color was scored from 1 to 5 (1: 100% green – 0% yellow; 2: 75% green- 25% yellow; 3: 50% green- 50% yellow; 4: 25% green-75% yellow; 5: 0% green- 100% yellow). Similarly, fruit textural softness was rated from 1 to 5 score (1: hard; 2: sprung; 3: slightly soft; 4: eating soft; & 5: over ripe). Diseases were recorded from 1 to 5 sacle (1: Nill; 2: <5%; 3: 5-10%; 4: 10-25%; & 5: >25%) (Amin *et al*., 2007). Marketable fruit (MF) percentage (no signs of rot) was calculated out of total fruit basis.

Statistical analysis: The data were subjected to analysis of variance (ANOVA) using Statistix 8.1 software and treatment means were compared using Least Significance Difference (LSD) Test at 5% level of significance ($P \leq 0.05$) (Steel *et al*., 1997).

RESULTS

Effects of packaging types on Sindhri and Sufaid Chaunsa mangoes: In cv. Sindhri, packaging significantly affected the fruit color development (Table I). The fruit placed in open top boxes developed significantly less peel color (3.15) as compared to the fruit of closed top boxes (3.29). As regards the biochemical quality attributes, significant effect was observed on titratable acidity and TSS: TA ratio whereas TSS, sugars and vitamin-C contents showed non-significant response to the packaging type (Table I). Percentage of acidity was significantly more (0.33) in the fruit stored in open top corrugated cardboard

Table I: Physico-chemical fruit quality of 'Sindhri' mangoes with respect to different types of packaging and shipping durations

Characters	Color (score)	Softness (score)	Disease Severity (score)	TSS (°Brix)	Acidity (%)	TSS:TA Ratio	Sugar contents (%)			Vit. C (mg/100g)
							Reducing	Non Reducing	Total	
Impact of packaging type										
Open top	3.15b	3.06	0.07	15.78	0.33a	50.36b	2.37	3.85	6.42	101.07
Closed top	3.29a	3.07	0.39	14.96	0.24b	62.17a	2.47	3.92	6.59	102.50
$P \leq 0.05$	*	NS	NS	NS	*	*	NS	NS	NS	NS
Impact of shipping duration										
3 weeks	2.52c	1.60c	0.00	15.75	0.28ab	55.22b	2.44b	3.84b	6.47b	95.69
4 weeks	3.21b	2.61b	0.31	15.08	0.34a	45.54b	2.79a	4.54a	7.56a	112.89
5 weeks	3.94a	3.78a	0.33	15.3	0.23b	68.03a	2.04c	3.27c	5.48c	96.77
	*	*	發NS	NS	*	*	*	*	*	NS

Means not sharing any letter are significantly different from each other
* = Significant; NS= Non-significant

boxes as compared to acidity percentage (0.24) of fruit stored in closed top boxes. Moreover, TSS:TA ratio was higher in fruit stored in closed top boxes as compared to fruit stored in open top boxes (Table I). Packaging had non-significant effect on textural softness and disease development (Table I).

Packaging also had significant effect on respiration (Fig. 1) and weight loss (Fig. 2) in Sindhri mangoes. Moreover, market value of the fruit was also affected significantly. The fruit placed in open top boxes had higher percentage (80.95) of marketable fruit as compared to fruit stored in closed top boxes (65.07) (Fig. 3). Organoleptic attributes remained statistically at par in both packagings (Table II).

In cv. Sufaid Chaunsa, packaging significantly affected the fruit color development, textural softness and sugar contents (reducing sugars, non-reducing sugars & total sugars). The fruit kept in open top boxes had significantly lesser score for textural softness (more firm) and color as compared to fruit stored in closed top boxes (Table IV). Moreover, the percentage of sugar contents i.e. reducing, non-reducing and total sugars was more in fruit stored in open top boxes as compared to fruit stored in closed top boxes (Table IV). Non-significant results were observed regarding the effect of packaging on disease development, acidity, TSS, TSS: TA ratio and vitamin C contents(TableIV).Asregards theorganoleptic characteristics, the fruit stored in closed top corrugated cardboard boxes had significantly higher aroma than that of fruit stored in open top cardboard boxes (Table V). Other organoleptic attributes (including flavor, pulp color, taste & texture) had non-significant response (Table V). Moreover, packaging type had a non-significant effect on respiration rate (Figs. 1 & 4) and physiological weight loss in both cultivars (Figs. 2 & 5). The effect of packaging on market value of fruit of both cvs., was found at par (Figs. 3 & 6).

Effect of shipping/storage durations on Sindhri and Sufaid Chaunsa mangoes: In cv. Sindhri shipping durations significantly affected the fruit color development and textural softness (Table I). A general increasing trend was observed in fruit peel color development and textural softness with increase in shipping period. Non-significant

Table II: Organoleptic fruit quality of 'Sindhri' mangoes with respect to different types of packaging and shipping durations

Characters	Aroma (Score)	Taste (Score)	Flavor (Score)	Pulp Color (Score)	Texture (Score)
Impact of packaging type					
Open top	4.94	4.84	4.42	6.23	6.24
Closed top	4.69	5.10	4.50	6.24	5.99
$P \leq 0.05$	NS	NS	NS	NS	NS
Impact of shipping duration					
3 weeks	5.92a	4.50	3.00c	6.58	6.21ab
4 weeks	3.82c	4.88	4.78b	5.99	5.70b
5 weeks	4.72b	5.53	5.60a	6.13	6.43a
	*	NS	*	NS	*

Means not sharing any letter are significantly different from each other
* = Significant; NS= Non-significant

Table III: Physical quality of 'Sindhri' mangoes at different post shipment stages

Storage time	Color (Score)	Softness (Score)	Disease Severity (Score)
After storage	2.54c	2.27c	0.00b
After 48 h ethylene exposure	3.01b	2.63b	0.22ab
At ripening	4.12a	3.10a	0.47a
$P \leq 0.05$	*	*	*

Means not sharing any letter are significantly different from each other
* = Significant; NS= Non-significant

difference was recorded among the different storage durations regarding disease development (Table I). Among the biochemical attributes; sugars contents, acidity and TSS: TA ratio was significantly affected by the storage duration (Table I). The sugar contents and acidity percentage were higher in fruit removed after fourth week of storage followed by the fruit removed after third week. Lowest sugar contents and acidity percentage were estimated in fruit stored after fifth week of storage. TSS: TA ratio was maximum in fruit removed after fifth week of storage followed the fruit removed after four and three weeks, respectively which were statistically at par (Table I). The shipping durations had a non-significant effect on vitamin C and TSS (Table I). Organoleptic parameters including aroma, flavor and texture were significantly influenced by shipping durations, whereas taste and pulp color remained statistically at par (Table II).

Table IV: Physico-chemical fruit quality of 'Sufaid Chaunsa' mangoes with respect to different types of packaging and shipping durations

Characters	Color (score)	Softness (Score)	Disease severity (score)	TSS (°Brix)	Acidity (%)	TSS:TA Ratio	Sugar contents (%)			Vit. C (mg/100g)
							Reducing	Non Reducing	Total	
Impact of packaging type										
Open top	3.36b	2.91b	1.85	21.74	0.26	45.69	1.93a	3.05a	5.13a	21.50
Closed top	3.49a	3.08a	2.08	21.92	0.23	51.86	1.73b	2.80b	4.66b	20.07
$P \leq 0.05$	*	*	NS	NS	NS	NS	*	*	*	NS
Impact of shipping duration										
3 weeks	2.91c	2.44c	1.34b	22.95	0.37a	63.10a	1.63b	2.64b	4.42b	24.73
4 weeks	3.57b	3.09b	2.17a	20.53	0.23b	50.12b	2.08a	3.32a	5.58a	15.05
5 weeks	3.80a	3.45a	2.38a	22.02	0.14c	33.09c	1.76b	2.81b	4.69b	22.58
	*	*	*	NS	*	*	*	*	*	NS

Means not sharing any letter are significantly different from each other
* = Significant; NS= Non-significant

Table V: Organoleptic fruit quality of 'Sufaid Chaunsa' mangoes with respect to different types of packaging and shipping durations

Characters	Aroma (Score)	Taste (Score)	Flavor (Score)	Pulp color (Score)	Texture (Score)
Impact of packaging type					
Open top	6.39b	7.02	6.82	7.21	6.08
Closed top	6.79a	6.66	6.64	6.90	6.29
$P \leq 0.05$	*	NS	NS	NS	NS
Impact of shipping duration					
3 weeks	8.58a	8.92a	8.75a	8.42a	8.33a
4 weeks	6.12b	5.61b	5.52b	6.42b	5.98b
5 weeks	5.08c	6.00b	5.92b	6.33b	4.25c
	*	*	*	*	*

Means not sharing any letter are significantly different from each other
* = Significant; NS= Non-significant

Table VI: Physical quality of 'Sufaid Chaunsa' mangoes at different post shipment stages

Storage time	Color (Score)	Softness (Score)	Side rot (Score)	SER (Score)
After storage	2.61c	2.09c	1.42b	0.80b
After 48hrs ethylene exposure	3.24b	2.91b	2.05a	1.22b
At ripening	4.43a	3.98a	2.42a	2.31a
$P \leq 0.05$	*	*	*	*

Means not sharing any letter are significantly different from each other
* = Significant; NS= Non-significant

The percentage of marketable fruit was significantly affected by shipping durations showing an inverse relation (Fig. 3). As shipping period was increased, marketable fruit (MF) percentage was decreased. Higher percentage (80.95) of marketable fruit was observed in fruit removed after third week of storage and lowest percentage (57.14) in fruit removed after fifith week of storage. Non-significant impact of shipping duration was recorded on the rate of respiration (Fig. 1) and weight loss (Fig. 2).

In case of cv. Sufaid Chaunsa; significant increase in fruit color development, textural softness along with disease incidence was noted with the increase of shipping/storage duration with maximum respective score in the fruit removed after five weeks of storage (Table IV).

Sugar contents (reducing, non-reducing & total sugars) were significantly affected by shipping durations. Maximum sugar contents were observed in fruit removed in fourth week followed by fruit removed in fifth and third week (Table IV). During the storage period, sugar contents showed a general trend of an initial increase followed by a deceasing pattern. Titratable acidity was found maximum in fruit removed after three weeks of storage and minimum in fruit removed after five weeks. Overall, the titratable acidity decreased significantly as shipping period was increased (Table IV). TSS: TA ratio was recorded maximum in fruit removed after three weeks of storage and decreased as the shipping period was increased up to five weeks with overall decreasing trend (Table IV). Non-significant results were found regarding the effect of shipping durations on TSS and vitamin C (Table IV).

Organoleptic parameters were significantly affected by shipping durations (Table V). Maximum score for aroma, taste, flavor, pulp color and texture was observed in fruit removed after three weeks of storage. The shipping durations significantly affected the percentage of marketable fruit (Fig. 6). Higher marketable fruit percentage (71.43) was observed after third week of storage, which decreased as the storage/shipping period was extended upto five weeks (30.95).

Physiological weight loss was significantly affected by shipping durations with maximum weight loss after five weeks (9.83) and minimum after three weeks (6.39) of storage (Fig. 5). Respiration rate showed non-significant response in this regard (Fig. 4).

The performance of Sindhri and Sufaid Chaunsa mangoes at different post shipment stages: Significant advancement in fruit skin color, textural softness and disease development was recorded in both Sindhri and Sufaid Chaunsa mangoes at the three different post shipment ripening stages (at removal from storage, after 48 h exposure of ethylene and at ripe stage) Table III and VI. Moreover, significant differences were also noted in the rate of respiration and physiological weight loss at three stages (Figs. 1 & 4).

In sindhri mangoes, CO_2 production (mmol/kg/hour) and physiological weight loss (%) was found minimum at removal from storage whereas maximum at fully ripe stage (Figs. 1 & 2). Similar trend was found in Sufaid Chaunsa mangoes regarding rate of respiration and physiological weight loss (Figs. 4 & 5).

Fig. 1: Respiration rate in open and closed top packaged Sindhri mangoes with respect to different shipping durations and post shipment handling stages (*P*≤0.05)

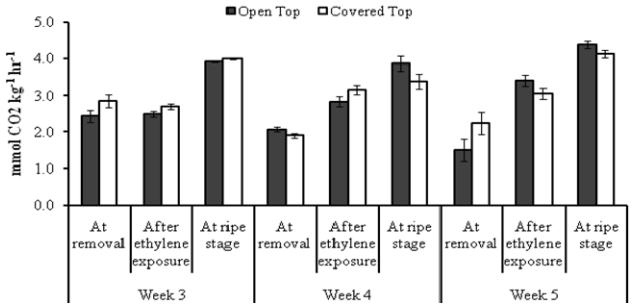


Fig. 2: Physiological weight loss in open and closed top packaged Sindhri mangoes with respect to different shipping durations and post shipment handling stages (*P*≤0.05)

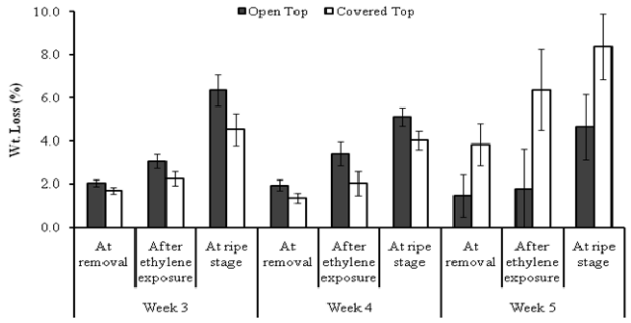
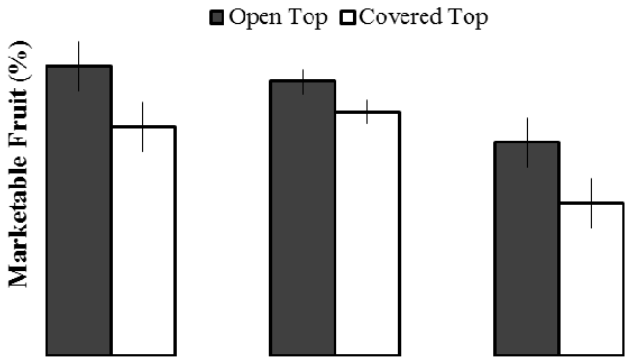


Fig. 3: Marketable fruit percentage in open and closed top packaged Sindhri mangoes at ripe stage with respect to different shipping durations (*P*≤0.05)



DISCUSSION

Mango is a climacteric fruit and produce reasonable amount of ethylene (0.1 to 2 microliters per kilogram per hour) during ripening process (Lalel *et al*., 2003a & b; Kader, 2008). In both cultivars, significantly more peel color development was observed in fruit stored in closed top boxes (Table I & IV). This seems to be the impact of ethylene accumulation that could hasten the ripening process as earlier reported by Malik (2003).

Fig. 4: Respiration rate in open and closed top packaged Sufaid Chaunsa mangoes with respect to different shipping durations and post shipment handling stages (*P*≤0.05)

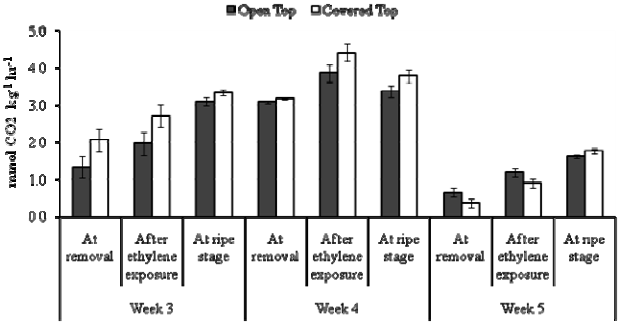


Fig. 5: Physiological weight loss in open and closed top packaged Sufaid Chaunsa mangoes with respect to different shipping durations and post shipment handling stages (*P*≤0.05)

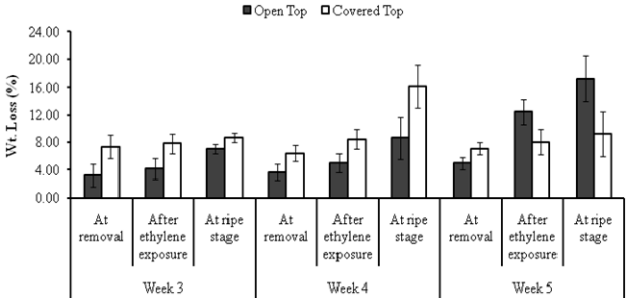
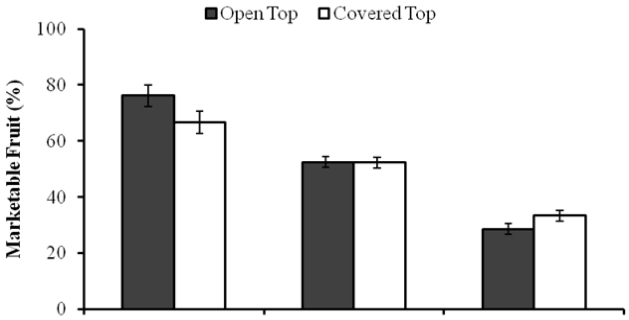


Fig. 6: Marketable fruit percentage in open and closed top packaged Sufaid Chaunsa Mangoes at ripe stage with respect to different shipping durations (*P*≤0.05)



In cv. Sufaid Chaunsa significantly higher sugar contents were found in fruit placed in open top boxes as compared to the fruit stored in closed top boxes indicating the impact of packaging on bio-chemical attributes (Table IV). Fruit sugar contents (reducing, non-reducing & total sugars) have been reported to increase during the ripening process in storage (Fuchs *et al*., 1980). However, non-significant response of cv. Sindhri towards packaging indicates that difference in response of two cultivars in this context. Less TSS:TA acid ratio in Sindhri mangoes placed

in open top boxes could be related to more acid contents in open top boxes (Table I).

Overall, the non-significant response of organoleptic attributes of both cultivars (except aroma in Sufaid Chaunsa) indicates that packaging has no significant effect on organoleptic attributes (Table II & V). There could be a possibility of losing aroma in surrounding atmospheres in the fruit of cv. Sufaid Chaunsa stored in open top cardboard boxes. Hence, fruit stored in open top boxes have less aroma as compared to fruit stored in closed top boxes. The retention of aromatic compounds in boxes with top closed could be due to closed environment. Aroma compounds are often only released upon cell disruption when previously compartmentalized enzymes and substrates interact (Buttery, 1993; Singh *et al*., 2004).

Significant change in peel color and fruit textural softness with reference to low temperature storage/shipping durations in both cultivars indicates the significant impact of storage on physiological processes related with fruit peel color development and textural softness (Table I & IV). Moreover, increased color development and advancement in fruit softening in relation to post shipment ripening stages could be due to the exogenous ethylene application (after storage). The fruit usually became softer and green color is lost gradually as the ripening process proceeds during extended storage. The physiochemical changes involving in the degradation of chlorophyll and increased level of carotenoid pigments could be related to this softening and loss of green color (Wills *et al*., 1982). The inhibition of enzymatic and metabolic activities responsible for earlier ripening by low temperature storage have been reported in various studies (Campbell & Malo, 1969; Barmore, 1974; Weichmann, 1987; Doreyappa-Gowda & Huddar, 2001; Montalvo *et al*., 2007; Kader & Mitcham, 2008).

In both mango cvs. the sugar contents increased during storage but in prolonged storage (beyond four weeks) a significant decrease was observed as earlier reported by Hulume (1971). The increase in sugars could be due to the breakdown of polysaccharides into water soluble sugar (Table I & IV). Decrease of sugar contents in long term storage is due to further utilization of sugars in metabolic processes in the fruit (Rathore *et al*., 2007). Other findings also indicated that as ripening progresses the starch is completely hydrolyzed into sugars such as glucose, fructose and sucrose (Mattoo *et al*., 1975; Wiley, 1994; Kittur *et al*., 2001; Srinivasa *et al*., 2002). The decreasing trend of acidity with extended storage might be due to the oxidation of organic acid and further utilization in metabolic process in the fruit (Table I & IV). These results coincided with those of Doreyappa-Gowda and Huddar (2001) who reported a similar decreasing pattern in acidity in different varieties of stored mango fruit for a long time (Srinivasa *et al*., 2002).

In cv. Sindhri, low temperature significantly affected aroma and flavor. The fruit removed after three weeks of storage have higher score for aroma and flavor. The higher score for all organoleptic characteristics in cv. Sufaid Chaunsa in the beginning and then a significant decreasing trend during storage might be due to changes in sugar and acid contents (Table II & V). Overall, fruit of Sufaid Chaunsa got more score for taste and other organoleptic characteristics, which could be due to more TSS value of Sufaid Chaunsa fruit than Sindhri variety.

Marketable fruit percentage in both cvs. decreased as the shipping period was prolonged (Fig. 3 & 6). This decreasing trend could be related with the spoilage of fruit caused by various fungal diseases like stem end rot, side rots etc. during extended storage. These fungal diseases have been reported to cause fruit spoilage during storage (Jeffries *et al*., 1990; Crane & Campbell, 1991; Eckert *et al*., 1996). High relative humidity is maintained in cold stores to avoid shrivelling of fruit which on the other hand provides a favorable environmnet for disease development (Gadgile *et al*., 2009a, & b; Slaughter, 2009; Anonymous, 2011). The disease development proceeds due to advancement in autocatalytic changes as the storage period is increased, which in turn decreases the market and consumer acceptibility of fruit (Chavez, 2007).

In both mango varieties it was observed that disease development enhanced as the storage period was increased (Table I & IV) keeping in consideration also the post shipment ripening stages, where disease incidence increased as the fruit became more soft and yellow (Table III & VI). But, significantly less disease development was observed particularly in cv. Sindhri. This lower disease incidence could be due to HWT and fruit dipping in Prochloraz (0.5 mL/L) before storage. The beneficial effects of Procholoraz application for suppression of post harvest pathogens have been reported by Muller and Burt (1989). Couey *et al*. (1984) and Lonsdale (1993) also reported significant control of decay development by hot water treatments (52–55°C). The reduction in disease and decay development by Prochloraz dips following HWT in various mango cultivars has been reported (Prusky *et al*., 1999). Further, Dang *et al*. (2008) reported that hot water dipping along with fungicide treatments can reduce the postharvest disease incidence and severity. Howover, in this studies overall disease percentage was very high and that is not commercially acceptable especially after three weeks of storage. More studies on disease control using combined application of different fungicides should be investigated to limit the disease outbreak in earlier storage/shipping periods.

Fruits are living entities and continue to respire even after their removal from parent plant (Bora & Narain, 1997). As mango is a climacteric fruit but respiration patterns and ripening behaviors vary among cultivars, with different climatic conditions and growing locations (Krishnamurthy & Subramanyam, 1970). In both cultivars shipping durations had affected the respiration rate non-significantly. A significant effect of post shipment ripening stages on respiration rate was observed. Overall, an increasing trend of CO_2 production was observed in both cvs. Reduced CO_2 production at earlier post shipment ripening stage could be

due to the reason that fruit were cool when removed from cold storage. After ethylene treatment (second stage) an increased CO_2 production was observed, which continued till the third stage (final ripening day). Brecht and Yahia (2009) also reported an increased production of CO_2 as the ripening process proceeds along with external ethylene application (Tucker, 1993; Salveit, 1999).

Weight loss was significantly affected by shipping durations and post shipment ripening stages. Fruit weight loss was significantly increased as the storage/shipping period was increased. The major factors responsible for fruit weight loss are higher respiration and transpiration rates, which fruit experience during ripening at room temperature (Bora & Narain, 1997). Increased weight loss in various cultivars of mango with prolonged storage periods and during ripening has been reported (Mathur *et al*., 1953; Abbasi *et al*., 2009).

In conclusion, open top corrugated cardboard boxes can be preferred over closed top boxes for the sea shipping of mango cv. Sufaid Chaunsa and Sindhri keeping in view that some variability in varietal response exists with regards to packaging. In both cultivars, marketable fruit percentage, which actually represents consumer and commercial criterion, was more in open top corrugated cardboard boxes as compared to closed ones. Moreover, cv. Sindhri showed better shipping potential with higher percentage of marketable fruit than cv. Sufaid Chaunsa, which is more prone to post harvest storage diseases during long term storage, which requires further research. More research work is needed for effective postharvest disease control during sea shipping of mangoes.

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