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Full Length Article

Packaging Material and Ripening Methods Affect Mango Fruit Quality

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ABSTRACT

These studies were conducted on two major postharvest issues of local mango industry. Firstly, more than 90% mangoes are packed in wooden crates, which are being eliminated in export markets. Secondly, calcium carbide (CaC_2) is mostly used for ripening of mango fruit; while, its use is being discouraged worldwide, due to associated health hazards. To find out some better alternatives, two experiments were conducted on commercial mango cv. Samar Bahisht Chaunsa. In both experiments, fruits were packed in traditional wood packaging with newspaper liner (WP) and corrugated cardboard packaging (CBP) for comparison. In first experiment, CaC_2 (2g kg^{-1} of fruit) was used for ripening of mangoes in comparison with ethylene (C_2H_4) application (100 ppm, 20°C, 48 h), followed by ripening at ambient conditions (33±1°C & 60-65% RH). CBP fruit showed significantly lower fresh fruit weight loss (FWL) and better shelf life compared with WP fruit treated with or without CaC_2. WP fruit treated with CaC_2 had faster ripening rate and better peel colour development compared with C_2H_4 treated CBP. In second experiment, WP or CBP fruit were stored (13±1°C & 85-90% RH) for 15 days, followed by natural ripening at two different temperatures (28, 33±1°C). Performance of C_2H_4 (100 ppm, 48 h) at 25°C and 30°C was also evaluated in CBP fruit. Regardless of ripening temperatures and methods, CBP significantly reduced FWL compared with WP. C_2H_4 treatment at higher temperature (30°C) significantly improved quality (total soluble solids & sugars) compared with application at low temperature (25°C), however, the fruit colour was not developed to the desired level. In conclusion, CBP can be substituted for WP due to its demonstrated benefits; however, further studies are needed to develop precise ripening protocol using ethylene at different concentrations and temperature regimes, for improving colour and fruit quality under ambient or post-storage conditions.

Key Words: CaC_2; Ethylene; Ripener-I®; Wood packaging; Corrugated cardboard packaging

INTRODUCTION

Mango (*Mangifera indica* L.) is the second largest fruit being produced in Pakistan and has become an integral part of history and culture of the country (Asif *et al.,* 2002). With over 1.3 million tons annual production, Pakistan is world's fifth largest producer of mango after India, China, Thailand and Mexico (FAO, 2006). A worldwide increase in the demand of fresh mango fruit is being observed, increasing the prospect for the producing countries (Amin *et al.,* 2007). However, like all other fresh commodities, its market potential is also linked with the fruit quality and market access (Anwar & Malik, 2007). Whereas certain pre-harvest factors, like insect pest and disease management (Mahmood & Gill, 2002; Ishaq *et al.,* 2004; Iqbal *et al.,* 2004), are important from production point of view, proper postharvest treatments and packaging are required for maintaining better quality, extended shelf life and having access to international markets (Anwar & Malik, 2007).

Currently, the local mango industry is constrained with two important postharvest challenges. Firstly, most of our mangoes are packed in wooden crates; which apart from causing physical injuries and bruises to fruit during transit (Anwar *et al.,* 2006), are being restricted in international markets on account of quarantine concerns and special disinfestation treatments necessary for international trade (FAO, 2002). Secondly, calcium carbide (CaC_2) is the commonly used chemical for ripening of mango fruit, due to its low price and availability in local market, however, use of this chemical in fruit industry is being discouraged worldwide due to dangers of explosion and carryover of toxic materials like arsenic and phosphorus to consumers, thus making the healthy fruit poisonous (Mariappan, 2004). Since no technical knowledge is considered necessary for its anomalous use (Subramanian, 2004), higher quantity of calcium carbide needed to ripen immature fruit, makes them tasteless (Medlicott, 1986; Padmini & Prabha, 1997).

In view of the above two problems, studies for an alternate packaging and ripening agent for mango fruit was imperative. While, the corrugated cardboard packaging (CBP) is commercially used for fruits and vegetables in international markets, its use in domestic mango industry is

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not common, which necessitates studies on its effects on mango fruit shelf life and quality. Further, the local industry is also looking to replace calcium carbide with any suitable alternate. Calcium carbide absorbs moisture and produces acetylene, which is a weak analogue of ethylene, responsible for triggering ripening process (Cua & Lizada, 1990; Singh & Janes, 2001). Research literature indicates that ethrel/ethephon (2-chloroethylphosphonic acid) and ethanol are the two potential chemicals which can be used to ripen mango fruit (Cua & Lizada, 1990; Medlicott *et al.,* 1990; Padmini & Prabha, 1997; Singh & Janes, 2001). On application, these chemicals penetrate into the fruit and decompose into ethylene. While, there are only few reports about the effectiveness of ethephon as a ripening agent (Nair & Singh, 2003), ethanol with trade name of Ripener-I® (70% ethanol) is being used for ripening mango fruit. In Pakistan, no research work and practical knowledge is available about commercial ripening agents other than CaC_2. So, this study was aimed at testing the effect of different packaging materials and ripening methods on mango fruit quality.

MATERIALS AND METHODS

Research experiments were conducted during 2006. Mango fruit cv. Samar Bahisht Chaunsa were sourced from a commerical orchard located in Multan, Pakistan (71°34' 11.68 E & 13°14' 17.08 N, 122 m Altitude). Fruit were harvested at mature green stage, de-sapped to avoid sapburn injury, graded and packed in corrugated cardboard packaging (CBP) and transported to Postharvest Lab., Institute of Horticultural Sciences, University of Agriculture, Faisalabad by road (280 km distance) in an open top truck. At Lab, fruits were divided into two equal lots for further experimentation.

In first experiment, ripening methods were evaluated using different packaging material. Commercial grade calcium carbide was purchased from local market. Fruit were packed in wooden crates with newspaper liner, with or without CaC_2 treatment followed by ripening at ambient temperature (33±1°C & 60-65% RH). For exogenous application of ethylene, commercial Ripener-I® (American Ripener, LLC, Charlotte, NC, USA) was used. Ethylene was produced at 20°C from Ripener-I® through an Ethylene Generator (ARCO Ltd., UK) placed in a closed chamber. Ethylene level was detected by Draeger Pac III Gas Monitor (Draeger Safety Inc., Canada). When ethylene level was attained at 100 ppm, generator was switched off and fruit were kept in same condition for 48 h. After ethylene treatment fruit were ripened at ambient conditions. Treatments were designated as T_0) WP only as control; T_1) WP with CaC_2 application @ 2g kg^{-1}; T_2) CBP only; and T_3) CBP with ethylene application @ 100ppm at 20°C. All treatments were replicated three times.

In second experiment, mango fruit packed in wooden crates (WC) or corrugated cardboard boxes were initially subjected to storage (13±1°C & 85-90% RH) for 15 days followed by treatment with ethylene in comparison with natural ripening (control) at two different temperatures. Treatments replicated three times were designated as T_0) WP with natural ripening at 33±1°C and 60-65% RH as control; T_1) WP with natural ripening at 28±1°C and 60-65% RH; T_2) CBP with natural ripening at 33±1°C and 60-65% RH; T_3) CBP with natural ripening at 28±1°C and 60-65% RH; T_4) CBP with ethylene application @ 100 ppm at 25°C and then ripening at 33±1°C and 60-65% RH; T_5) CBP with ethylene application @ 100 ppm at 30°C and then ripening at 33±1°C and 60-65% RH.

To record ripening rate, fruit softness was observed using a subjective assesment of whether the mango yielded to thumb pressure (1: very hard to 5: over ripe). Eating soft fruit were given 4 scores. Peel colour development was assesed using rating scale of 1 to 5 (where 1 – fully green & 5 – fully yellow). Fresh fruit weight loss (FWL) was also measured simultaneously. Organoleptic properties (aroma, flvaour, pulp colour, taste & texture) were observed using Hedonic scale method given by Peryam and Pilgrim (1957). Fruit were presented to a 10 member taste panel. The panelists assessed fruit samples and rated for general acceptibility (1: dislike extremely to 9: like extremely). During laboratory tests, total titrable acidity (TTA) was determined by method given by Hortwitz (1960). Ascorbic acid contents were estimated by the method of Ruck (1969). TSS was measured by digital refractometer (Atago Co. Ltd., RX-5000, Japan). To estimate the sugars, the method described by Hortwitz (1960) was used. Total carotenoids were measured using spectrophotometer (6405 UV/VIS, Jenway Ltd., Essex, England), absorbance set at 436 nm (Lalel *et al.,* 2003). Measurements were taken in triplicate.

Completely radomized design (CRD) with two factor (packaging material & ripening method) factorial arrangments in first experiment, while three factor (packaging, temperature & ripening method) factorial arreangements in the second experiment were used. All treatments were replicated three times. The experimental data were subjected to analysis of variance (ANOVA) using Genstat Release 8.2 (Lawes Agricultural trust, Rothmsted Experimental Station, UK). Within the analysis of variance, the effects of different treatments and their interaction was assessed. Least significant differences (Fisher's protected LSD) were calculated following significant F test (p=0.05). All assumptions of analysis were checked to ensure validity.

RESULTS AND DISCUSSION

Experiment 1

Effect of packaging material and ripening methods on mango fruit ripening and quality. Effect of packaging material and ripening methods on fruit quality were assesed and statistically analyzed. Ripening time required by each treatment was recorded until fruit attained eatable ripening stage (Table I).

Wood packed (WP) fruit with liner treated with CaC_2 (T_1) demonstrated faster ripening rate followed by WP fruit naturally ripened (T_0) at ambient temperature (33±1°C & 60-65% RH), while CBP fruit were slow in ripening. Early ripening of CaC_2 (the known ripening agent) treated fruit is due to the release of acetylene, while in case of WP naturally ripened fruit, it might be due to used newspaper liner causing more accumulation of endogenously produced ethyelene. It is well known that once climacteric fruit produces ethylene in sufficient amount to affect adjancent tissue, autocatalytic ethylene production starts and copious amount of ethylene is produced (Yang, 1987) triggering ripening process. In case of fruit packed in perforated CBP, due to ventilation, such stimulant (ethylene) was reduced, which might have delayed the ripening process. In this way, maximum time period for ripening was required by CBP fruit ripened naturally (T_2) followed by CBP fruit ripened by exogenous application of ethylene @ 100 ppm at 20°C (T_3).

During ripening, development in fruit peel colour and softness was observed on daily basis (Fig. 1). Significant results revealed highest peel colour (5.0 score) in WP fruit treated with CaC_2 (T_1) followed by WP fruit with liner ripened naturally (T_0: 4.60 score). Lowest peel colour (3.40 score) was observed in CBP fruit (no liner) ripened with exogenous application of ethylene (T_3). Apart from CaC_2 which is a known ripening agent, effect of liner was also pronounced since WP fruit with liner showed better fruit colour than CBP fruit without liner, although both ripened naturally. Moreover, lower peel colour development in ethylene ripened fruit might be due to application of ethylene at lower temperature i.e., 20°C; since low temperature has been found to delay ethylene production and ripening (Malik & Singh, 2005). Development in fruit softness during ripening period was found to be non-significant among different treatments. At the time of analysis, all the treatments exhibited slightly soft to eating soft stage.

Statistically significant differences were found for fresh fruit weight loss (FWL) percentage (Fig. 2). WP naturally ripened fruit (T_0) showed higher FWL (12.51%) followed by CaC_2 ripened WP fruit (T_1: 8.72%). Overall, CBP fruit showed lower FWL percentage as compared to WP (Fig. 2). Naturally ripened CBP fruit (T_2) showed relatively higher FWL (8.03%) than ethylene ripened fruit (T_3: 4.99%). Lower FWL percentage in CBP fruit depicts its better performance over WP. However, FWL is also linked with delay in ripening period of CBP fruit (Table I), as previously reported by Singh *et al.* (2003) that fruit packaging not only reduces water loss but also delays ripening in mango fruit.

Biochemical anlysis of fruit subjected to different packaging materials and ripening methods without storage is given in Table II. Total soluble solids (TSS) were maximum (32.6°Brix) in naturally ripened WP fruit (T_0) that was statistically similar to those treated with CaC_2 (T_1) and naturally ripened in CBP (T_2) fruit i.e., 31.34 and 31.13°Brix, respectivelly. Significantly lower TSS (25.76°Brix) was recorded in ethylene ripened fruit (T_3) compared with control (T_0). Higher amount of TSS in WP lined with newspaper might be due to accelerated rate of metabolism in fruit, as minimum days were required by the

Table I. Time period (days) required by each treatment to reach eatable ripening quality

Treatment	Ripening period (days)		
	Treatment period	*Ambient ripening	Total
T_0	03	03	06 c
T_1	03	02	05 d
T_2	Nil	08	08 a
T_3	02	05	07 b
LSD (P<0.05)			0.4707

** Ambient ripening conditions (33±1°C and 60-65% RH). Means sharing common letters do not differ significantly*

T_0) Wood packaging with newspaper liner; T_1) Wood packaging with newspaper liner + CaC_2 @ 2g kg^{-1}; T_2) Corrugated cardboard packaging; T_3) Corrugated cardboard packaging + ethylene @ 100ppm at 20°C

Fig. 1. Development of fruit softness and peel colour in in different packaging and ripening methods (Experiment 1). Vertical bars represent standard deviation of replications (*P* <0.05)

T_0) Wood packaging with newspaper liner; T_1) Wood packaging with newspaper liner + CaC_2 @ 2g kg^{-1}; T_2) Corrugated cardboard packaging; T_3) Corrugated cardboard packaging + ethylene @ 100ppm at 20°C

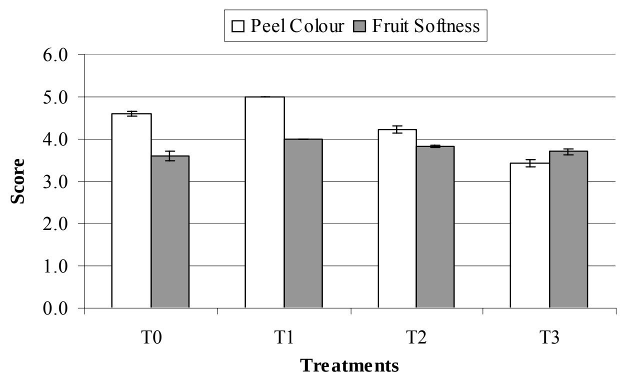


Fig. 2. Fresh fruit weight loss (%) in fruit ripened in various packaging materials (Experiment 1). Vertical bars represent standard deviation of replications (*P*<0.05)

T_0) Wood packaging with newspaper liner; T_1) Wood packaging with newspaper liner + CaC_2 @ 2g kg^{-1}; T_2) Corrugated cardboard packaging; T_3) Corrugated cardboard packaging + ethylene @ 100ppm at 20°C

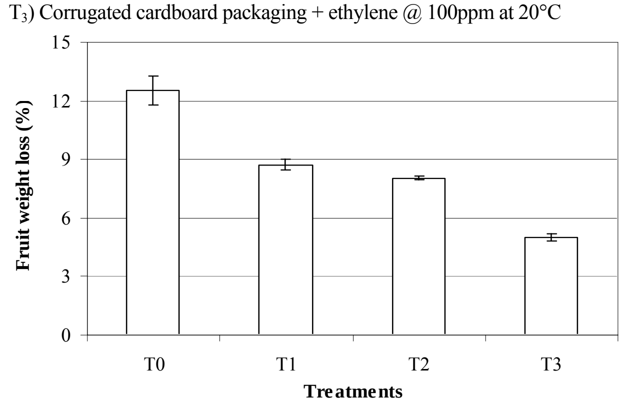


Table II. Effect of different ripening methods and packaging materials on biochemical characteristics of fruit without storage

Treat.	TSS (Brix)	Ascorbic acid (mg $100g^{-1}$)	TTA (%)	TSS/TTA ratio	Sugars (%)			Total Carotenoids (μg g^{-1})
					Total	Reducing	NRS	
T_0	32.61a	37.78a	0.16a	198.5	24.39a	5.98a	17.49a	121.8ab
T_1	31.34a	27.78b	0.09b	349.8	23.13b	5.78ab	16.47b	133.5a
T_2	31.13a	37.78a	0.11b	280.7	22.81b	5.34b	16.59b	104.4c
T_3	25.76b	36.67a	0.10b	256.8	18.79c	4.66c	13.42c	109.2bc
LSD (P <0.05)	*1.61*	*4.44*	*0.04*	*NS*	*1.08*	*0.60*	*0.633*	*13.60*

Means sharing common letters do not differ significantly

T_0) Wood packaging with newspaper liner; T_1) Wood packaging with newspaper liner + CaC_2 @ 2g kg^{-1}; T_2) Corrugated cardboard packaging; T_3) Corrugated cardboard packaging + ethylene @ 100ppm at 20°C

same treatments to reach optimum eatable ripening stage (Table I). The reason for lowest amount of TSS in ethylene ripened fruit might be due to slow rate of fruit ripening at relatively lower temperature i.e., 20°C, as mentioned earlier.

Singinifantly higher amount of total titrable acidity (TTA) was found in WP (T_0: 0.16%) compared with all other traetements, which were at par with each other. TSS/TTA ratio was found to be non significantly different among treatments. Statistically significant differences were found among treatments regarding ascrobic acid (Vitamin C) contents (Table II). Treatments, in which fruit were naturally ripened (T_0 & T_2), produced higher amount of ascorbic acid (37.78 mg 100 g^{-1}). Lowest amount of ascrobic acid (27.78 mg 100 g^{-1}) was estimated in WP fruit treated with CaC_2 (T_1), while CBP fruit treated with ethylene @ 100 ppm at 20°C (T_3) depicted slightly lower amount of ascorbic acid (36.67 mg 100 g^{-1}) contents than estimated in CBP fruit only (T_2). Overall, higher TTA and ascorbic acid contents in naturally ripened fruit might be due to slow rate of metabolic activites than chemically ripened ones. Lower TTA contents in T_1 revealed the triggering affect of CaC_2-induced acetylene on metabolic activities of fruit (Medlicott *et al.,* 1990). Maximum amount of total sugars (24.39%) was found in naturally ripened WP fruit (T_0), while CBP fruit treated with ethylene (T_3) showed lowest total sugars level (18.79%). Reducing and non-reducing sugars behaved in the same fashion as it was observed in total sugars. Naturally ripened CBP fruit (T_2) showed lower total carotenoids (104.38 μg g^{-1}) as compared to CaC_2 treated WP fruit (T_1; 133.48 μg g^{-1}). Over all, WP fruit showed higher development of total carotenoids than CBP fruit. The reason might be the use of newspaper liner, which accumulated ethylene along with rise in fruit's internal temperature and ultimately accelerated the ripening metabolism resulting in more total carotenoid contents. Whereas, in CBP, ventilated environment might have hindered the ethylene accumulation around fruit and thus inhibited acceleration of metabolism, which resulted in lesser production of total carotenoids.

During evaluation of organoleptic characteristics, non-significant differences were recorded except for fruit pulp colour (Table III). Lowest pulp colour rating (4.83 score) was given to ethylene ripened fruit (T_3), while all other treatments were statistically at par with each other. Lower pulp colour development in ethylene ripened fruit has been

Table III. Effect of different ripening methods and packaging materials on organoleptic characteristics of fruit without storage

Treat.	Pulp Colour	Taste	Flavour	Text	Aroma
T_0	6.86a	7.10	6.97	6.56	6.74
T_1	6.90a	6.36	6.33	6.21	6.79
T_2	6.86a	6.12	6.42	6.19	6.60
T_3	4.83b	6.25	5.97	5.36	5.94
LSD (P<0.05)	0.700	NS	NS	NS	NS

Means sharing common letters do not differ significantly

T_0) Wood packaging with newspaper liner; T_1) Wood packaging with newspaper liner + CaC_2 @ 2g kg^{-1}; T_2) Corrugated cardboard packaging; T_3) Corrugated cardboard packaging + ethylene @ 100ppm at 20°C

already reflected as lower total carotenoid contents in the same fruit (Table II). It can be linked to the low efficacy of exogenously applied ethylene at low temperature (20°C), which could not help fruit trigger their ripening changes effectively (Malik & Singh, 2005). Further research work on ethylene treatment needs to be carried out at different temperature regimes to resolve the issue of peel colour development.

Experiment 2

Optimizing post-storage ripening conditions for better mango fruit quality. Fruit packed in wooden crates or in cardboard boxes, stored for 15 days (13±1°C & 85-90% RH), were taken out and subjected to natural or chemical ripening at two different temperatures. Naturally ripened fruit took three days to reach optimum eating quality, whereas those subjected to ethylene treatment @ 100 ppm at different temperature regimes (25°C in T_4 & 30°C in T_5) for 48 h, took only one day to reach optimum eating quality. In this way, all the treatments (naturally ripened & ethylene ripened) reached optimum eating quality at same time i.e., 18 days (Table IV).

Peel colour development was significantly improved in fruit stored in WP with newspaper liner and ripened naturally (T_0: 2.73, T_1: 2.47 score), followed by CBP fruit treated with ethylene (T_4: 2.07, T_5: 2.20) as shown in Fig. 3. Least peel colour development was recorded in CBP fruit (T_2:1.73, T_5: 1.80). Fruit, ripened naturally at higher temperature (33±1°C) showed better peel colour development than fruit ripened at lower temperature (28±1°C). As clear from Fig. 3, none of the treatment could develop above 50% yellow fruit peel colour (3.0 score). When removed from cold storage, all the fruit had same

Table IV. Time period (days) required by each treatment to reach eatable ripening quality after storage

Treat.	Storage Period	Ripening Period		Total
		Treatment Period	Ambient Temp.	
T_0	15	----	03	18
T_1	15	----	03	18
T_2	15	----	03	18
T_3	15	----	03	18
T_4	15	02	01	18
T_5	15	02	01	18
LSD (P <0.05)				NS

Means sharing common letters do not differ significantly
T_0) Wood packaging with newspaper liner + ripening at 33±1°C & 60-65% RH; T_1) Wood packaging with newspaper liner + ripening at 28±1°C & 60-65% RH; T_2) Corrugated cardboard box + ripening at 33±1°C & 60-65% RH; T_3) Corrugated cardboard box + ripening at 28±1°C & 60-65% RH; T_4) Corrugated cardboard box + ripening with ethylene @ 100ppm at 25°C and then at 33±1°C & 60-65% RH; T_5) Corrugated cardboard box + ethylene @ 100ppm at 30°C and then at 33±1°C & 60-65% RH

peel colour (100% green) and softness level (sprung). But, upon ripening at different temperatures, the treatments showed different behaviour in fruit softness development. T_0 and T_1 in WP and ethylene treated CBP fruit (T_5) were eating soft, while other treatments remained between 'sprung' (2 score) and 'slightly soft' (score 3) stage. (Fig. 3). Lower fruit peel colour and softness in mango cv. Samar Bahisht Chaunsa seem to be the effect of storage conditions, which disturbed the normal ripening process of fruit. This could also be a cultivar specific behaviour, since Samar Bahisht Chaunsa is prone to abnormal ripening more than cv Sindhri under storage conditions (Malik, 2006) Moreover, prolonged mango storage (e.g., at 13°C) or ripening at 30°C desynchronizes the ripening process, so that fruit generally soften but retain some of the green skin colour (Saks *et al.,* 1999).

During storage, significant difference in FWL was observed among treatments (Fig. 4). Highest FWL percentage was recorded in WP fruit (T_0:10.91%, T_1: 10.06%,), whereas CBP fruit exhibited more or less same results in the range of 4.05-4.46%. During post-storage stage, higher FWL was again more in WP fruit (T_0:3.38%, T_1: 3.44%). CBP fruit showed non-significant difference in FWL (2.50-3.01%) regardless of ripening method. Overall, total FWL was significantly higher in WP fruit (T_0 & T_1), whereas CBP with ethyelene ripened fruit (T_4 & T_5) showed least FWL. This difference is attributed to faster ripening in WP fruit, which cause higher fruit weight loss. Ripening at higher temperature (T_5), enhanced ripening with increased FWL percentage, while ripening method (natural or chemical) did not significantly affect FWL during and after storage (Fig. 4).

Biochemical analysis of fruit subjected to different packaging materials and ripening methods is presented in Table V. Highest amount of TSS (29.3°Brix) was developed in CBP fruit ripened with ethyelene at 30°C (T_5), which was statistically similar to that of WP fruit with liner and ripened

Fig. 3. Development of fruit softness and peel colour in stored fruit in various packaging materials (Experiment 2). Vertical bars represent standard deviation of replications (*P*<0.05)
T_0) Wood packaging with newspaper liner + ripening at 33±1°C & 60-65% RH; T_1) Wood packaging with newspaper liner + ripening at 28±1°C & 60-65% RH; T_2) Corrugated cardboard box + ripening at 33±1°C & 60-65% RH; T_3) Corrugated cardboard box + ripening at 28±1°C & 60-65% RH; T_4) Corrugated cardboard box + ripening with ethylene @ 100ppm at 25°C and then at 33±1°C & 60-65% RH; T_5) Corrugated cardboard box + ethylene @ 100ppm at 30°C and then at 33±1°C & 60-65% RH

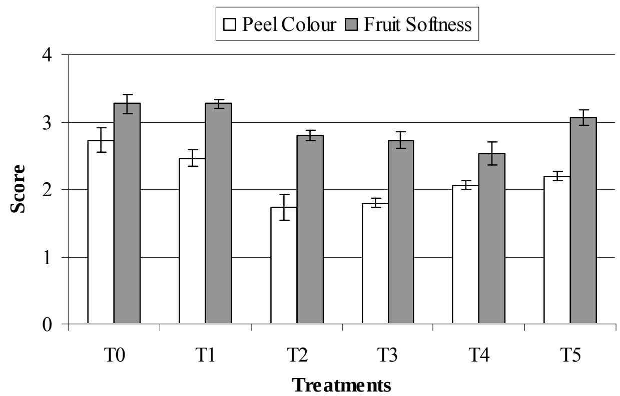
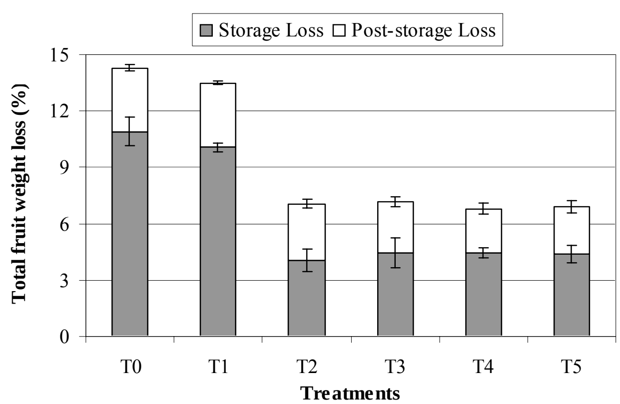


Fig. 4. Fresh fruit weight loss (%) in stored fruit in various packaging materials (Experiment 2). Vertical bars represent standard deviation of replications (*P*<0.05)
T_0) Wood packaging with newspaper liner + ripening at 33±1°C & 60-65% RH; T_1) Wood packaging with newspaper liner + ripening at 28±1°C & 60-65% RH; T_2) Corrugated cardboard box + ripening at 33±1°C & 60-65% RH; T_3) Corrugated cardboard box + ripening at 28±1°C & 60-65% RH; T_4) Corrugated cardboard box + ripening with ethylene @ 100ppm at 25°C and then at 33±1°C & 60-65% RH; T_5) Corrugated cardboard box + ethylene @ 100ppm at 30°C and then at 33±1°C & 60-65% RH



naturally at 33±1°C (T_0). Minimum TSS was recorded in naturally ripened CBP fruit (T_2 & T_3), which were statistically at par with each other. Total titrable acidity (TTA) was found to be highest (0.23%) in CBP fruit naturally ripened at 28±1°C (T_3) compared with control (T_0), while CBP fruit ripened naturally at high temperature i.e., 33±1°C (T_2) showed relatively lower contents of TTA (0.20%). Highest TSS/TTA was estimated in CBP fruit treated with ethylene @ 100 ppm at 30°C for 48 h (T_5:

Table V. Effect of different packaging materials and ripening methods on biochemical characteristics of fruit ripened after storage

Treat	TSS (°Brix)	TTA (%)	TSS/TTA Ratio	Sugars (%)			Ascorbic acid (mg $100g^{-1}$)	Total Carotenoids ($\mu g\ g^{-1}$)
				Total	Reducing	NRS		
T_0	29.0ab	0.19bc	111.6ab	21.35ab	5.32a	15.23ab	48.2b	109.6a
T_1	28.4b	0.19bc	108.7b	20.75ab	5.18a	14.78bc	52.9ab	104.5a
T_2	26.5c	0.20ab	96.20bc	19.70cd	4.65b	14.29d	64.9a	78.64b
T_3	26.1c	0.23a	83.20c	19.15d	4.53b	13.88cd	67.7a	78.37b
T_4	28.4b	0.18bc	115.9ab	20.56bc	5.05a	14.73bc	60.8a	74.92b
T_5	29.3a	0.17c	131.6a	21.60a	5.27a	15.51a	55.4a	84.63b
LSD (p<0.05)	0.896	0.029	20.50	0.928	0.329	0.68	16.86	12.26

Means sharing common letters do not differ significantly ($p \leq 0.05$)

T_0) Wood packaging with newspaper liner + ripening at 33±1°C & 60-65% RH; T_1) Wood packaging with newspaper liner + ripening at 28±1°C & 60-65% RH; T_2) Corrugated cardboard box + ripening at 33±1°C & 60-65% RH; T_3) Corrugated cardboard box + ripening at 28±1°C & 60-65% RH; T_4) Corrugated cardboard box + ripening with ethylene @ 100ppm at 25°C and then at 33±1°C & 60-65% RH; T_5) Corrugated cardboard box + ethylene @ 100ppm at 30°C and then at 33±1°C & 60-65% RH

131.6) with statistically similar results in T_0 (111.6) and T_4 (115.9). Naturally ripened CBP fruit showed least TSS/TTA ratio. Significant difference in ascorbic acid contents was observed among fruit packed in different packaging material. CBP fruit naturally ripened showed higher ascorbic acid contents (T_2: 64.9 7 mg 100 g^{-1} & T_3: 67.7 mg 100 g^{-1}) compared with WP fruit naturally ripened (T_0: 48.22 & T_1: 52.9 mg 100 g^{-1}). Highest total sugars contents (21.60%) were analyzed in CBP fruit ripened with ethylene at 30°C (T_5) that was statistically similar to post-stored naturally ripened WP fruit (T_0: 21.35% & T_1: 20.75%) (Table V), but significantly higher than other treatments. Naturally ripened CBP fruit (T_2 & T_3) showed significantly lower reducing and non reducing sugars compared to all other treatments. Significant differences of total carotenoid contents were observed among treatments. WP, naturally ripened fruit showed significantly high total carotenoid contents (T_0: 109.5 $\mu g\ g^{-1}$ & T_1: 104.5 $\mu g\ g^{-1}$) compared with CBP fruit with total carotenoid contents in range of 74.92 to 84.63$\mu g\ g^{-1}$.

These results clearly show that any treatment enhancing ripening will result in higher TSS, TSS/Acid ratio, total sugars and carotenoids, while lower acidity and ascorbic acid. Semi-closed environment of newspaper wrapped fruit in WP (conventional practice) seems to accumulate endogenously produced ethylene and thus producing better fruit peel colour compared with corrugated cardboard packed fruit. Likewise CBP fruit treated with ethylene performed better than those without ethylene treatement. Further increasing temperature slightly enhanced the ripening in both WP and CBP fruit, which is very logical, however the difference between the two temperatures was not enough to make significant effect on various fruit quality parameters.

CONCLUSION

Fruit ripening studies on mango cv Samar Bahisht Chaunsa at ambient temperature revealed that corrugated cardboard packed fruit treated with or without ethylene have shown significantly lower FWL percentage and better fruit shelflife at ambient conditions compared with conventional wooden packaging with liner and ripened with or without CaC_2 treatment. However, exogenous application of ethylene at 20°C, followed by ripening at ambient temperature could not trigger the ripening metabolism at a level to produce fruit colour and quality as of CaC_2 treatment. Studies on poststorage ripening showed that corrugated cardboard packaging again performed better in reducing total FWL compared with control (wooden pacakaging). Further, ethylene treatemnt of CBP fruit at higher temperature (30°C) performed better in improving quality (high TSS & sugars), compared to low temperature (25°C), however, fruit colour was still not developed up to the acceptable level. It can be concluded that while CBP is a better alterante for traditional wood packaging, further studies are needed to optimize ripening conditions for mango cv Chanusa, using ethylene at different concentrations and temperatures, for improving colour and fruit quality under ambient or post-storage conditions.

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