



The effect of improved postharvest practices on the postharvest losses and quality of mango fruit in Sri Lanka's supply chain

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ABSTRACT

Purpose: Mango is a prominent fruit crop in Sri Lanka. Improper postharvest practices along the supply chain lead to high losses and low fruit quality. This study aimed to evaluate the effect of adapting improved postharvest technologies in mango value chain in Sri Lanka on loss reduction and fruit quality improvement. **Research method:** Three mango supply chains; *Maho to Colombo*, *Jafna to Colombo*, and *Malsiripura to Colombo* were used for the study. Conventional mango supply chain (CSC) practices were compared with improved (ISC) practices at each supply chain actor. Total postharvest loss and physico-chemical parameters of mango were analyzed at each stage. **Findings:** Total weight loss of mango was significantly ($p < 0.05$) lower in ISC ($6.2 \pm 0.8\%$) than CSC ($39.6 \pm 1.9\%$). Fruit firmness declined and TSS increased along both supply chains with significantly higher rate in CSC. Colour changed significantly within 48 hrs. The L^* and a^* value had decreased while b^* value increased in both chains in peel and pulp. The CSC mangos were completely yellow while ISC mangos were green, at retailer stage. The postharvest life of fresh mango fruits was four days longer in ISC than CSC. Anthracnose and stem end rot were more prominent in CSC. **Limitations:** No limitations to report. **Originality/Value:** The study reveals that improved practices reduces postharvest loss and increases shelf life of mango. It facilitates retaining pulp firmness, slow colour development, and achieve comparable TSS levels. Therefore, improved postharvest handling practices should be promoted among all supply chain actors.

INTRODUCTION

Mango (*Mangifera indica*) is one of the most popular fruits in the world, and it is known as the "King of Fruits" in Asian countries (Sab et al., 2013). It is also one of the most popular and widely consumed fruits in Sri Lanka. Mango is grown in 29,229 ha of area with production of 529.5 million fruits in Sri Lanka (Department of Census and Statistics, 2020). Mango has a large global market potential. Mango has a high market potential worldwide. The main market in Sri Lanka has been identified as selling for fresh produce. However, the major limiting factor in mango industry is the low quality of fresh produce which leads to high postharvest losses. As a result of high postharvest losses of fruits, the nutritional status of the population and the economy of the developing countries are deeply affected. It is reported that 25-45% loss occurs at different postharvest stages of mango (Alam et al., 2019). In Sri Lanka, mango is cultivated mainly in home gardens, so fruit production is scattered throughout the country. The collectors usually harvest most of the fruits, including immature fruits. Incorrect artificial ripening practices are another emerging problem leading to low quality as well as health hazardous issues. Latex dripping from mango stems at harvesting or during collection and transportation causes peel damage (Brecht, 2009). Furthermore, postharvest life of mango fruit is limited by occurrence of diseases such as anthracnose and stem end rot contributing to wastage and economical losses. As a result, finding solutions to problems in the mango industry opens up numerous opportunities for increasing profits, developing the postharvest industry and agriculture, and improving the nutritional status of the community.

Considering this situation in Sri Lanka, National Institute of Postharvest Management launched a development project 'Improvement of supply and value chain management practices of mango in Sri Lanka' to popularize the appropriate postharvest technologies among stakeholders of mango supply chain. Under this project, ten mango processing zones where most of mango collectors were concentrated were established island wide. Stakeholders were adapted to follow improved postharvest technologies for harvesting artificial ripening, sorting, grading and packaging. In addition, equipment, such as, harvesting tools, plastic crates, corrugated fibre board boxes, and, ripening chambers, were also distributed among these stakeholders. The study was thus carried out to assess the postharvest losses and fruit quality of mango along different supply chains starting from harvesting to retail practice through conventional and improved postharvest handling practices. This was conducted to assess the effect of using improved practices on reduction of postharvest losses and improvement of fruit quality of mango intended for local markets in Sri Lanka.

MATERIALS AND METHODS

In this study, postharvest losses and fruit quality parameters of mango at each post-harvest stage were compared between the conventional and improved supply chains to evaluate the effect of adopting improved postharvest technologies. The study was conducted along three major mango supply chains; Maho to Colombo via Minuwangoda, Jafna to Colombo, and Malsiripura to Colombo. Each chain includes both improved and conventional channels. Further, these three supply chains are used as replicates for data analysis.

Harvesting

In the conventional method, mangoes were harvested using a local mango harvester, but maturity was not taken into account. Then, the fruits were placed on a tent laid on the ground and fruits having any defects such as diseases and damage, were sorted out. Afterwards,

mangoes were packed in wooden boxes with an average holding capacity of 30 kg, consisting of 8-10 layers of mango, and transported to the pack house.

On the other hand, in the improved method, mangoes at the proper maturity were harvested by a specialist harvester. Then harvested mangoes were placed on a delatexing rack with stem end down for about 15 to 20 min to flow out and dry the sap. Afterwards, mangoes were sorted and packed in plastic containers with an average holding capacity of 25 kg, containing 5-6 layers of mango, and transported to the pack house.

Artificial ripening

Mango fruits obtained through the conventional method were laid out in three layers on the cement floor. Then ethephon solution was prepared mixing one lid of ethephon liquid (approximately 10 ml) with 1 L of water and sprayed directly on to mango fruits using a hand sprayer until the fruits get moistened (Fig. 1a). After ethylene treatment, mangoes were kept for three days at ambient condition (30 ± 4 °C of temperature). A ripening chamber with 4.9 m³ capacity was used in improved practice. Plastic containers packed with mango fruits were placed in the chamber keeping $\frac{1}{5}$ of space free. Ethephon solution was diluted (10 ml of ethephon per 1 L of water) and mixed with calcium hydroxide solution (10 g L⁻¹) at 1:1 ratio and 10 ml from the mixed solution was used per 1 ft³ volume of ripening chamber to obtain ethylene gas according to the instructions given by the manufacturer. Then, the mixture was placed in the ripening chamber (Fig. 1b). Mangoes were kept in the chamber for 24 hours and then they were stored outside for another 48 hours at ambient condition (30 ± 4 °C of temperature). After the ripening process, mango fruit samples were collected from both conventional and improved methods for analysis.

Packaging and transportation

After the artificial ripening practice, mango fruits were sorted to remove damaged, diseased and other poor quality fruits. Then, mango fruits subjected to conventional artificial ripening process, were packed in to three ply corrugated fibre board boxes (50 fruits/box, approximately five to six layers of mango) and then covered with newspapers (Fig. 2a). Fruits obtained from improved ripening practice were packed in properly designed and well ventilated five ply corrugated fibre board boxes (50 fruits/box, approximately 3 layers of mango) as shown in Figure 2b. These packed mango fruits were transported from Munuwangoda to Colombo, Jafna to Colombo, and Malsiripura to Colombo in medium size covered trucks with proper ventilation and having leaf spring suspension system, which are commonly used for transporting agricultural produce. Then fruit samples were collected from both methods and from all three delivery channels for analysis. Fruit samples collected at the destinations were analyzed to determine the parameters listed below.

Weight loss and fruit quality

Cumulative weight loss due to mechanical damages and physiological weight loss, pulp firmness, pulp colour and total soluble solids of mango fruits were measured at farm gate, after ripening at pack house, after transporting to whole seller, at retailer and consumer stages.



Fig. 1a. Artificial ripening methods of mango fruits (conventional method).



Fig. 1b. Artificial ripening methods of mango fruits (improved method).



Fig. 2a. Conventional packaging method



Fig. 2b. Improved packaging method

Assessment of mechanical damage

Fruits mechanically damaged due to compression; abrasion and vibration and the combined effect were detected visually and then assessed and weighed. Mechanical damages of fruits at the selected five stages were converted to percentage of losses as reported by Dadzie and Orchard (1997) on visual assessment of mechanical damages of fruits. Percentage of mechanical damages was calculated for different samples using equation (1).

$$MD = \frac{W_2}{W_1} \times 100 \quad (1)$$

Where MD is the percentage of mechanical damage, W_2 is the damaged fruit weight (kg) and W_1 is the initial sample weight (kg).

Physiological loss in weight (PLW)

The physiological weight loss of mango fruits was determined from the difference in weight of fruits at regular intervals after harvesting. Same mango samples were used to take the weight difference from harvesting to the end of the experiment (Ram et al., 2008).

Total Soluble Solids (TSS)

The total soluble solids content in fruit juice was recorded using a hand held refractometer (Model HR-5, ATAGO, Japan) and reading was reported as °Brix. To extract the juice for this test, a piece of 10 g was cut from the whole mango fruit and blended in 50 ml of distilled water in a blender for one minute as explained by Sultani et al. (2010).

Fruit firmness

The pulp firmness was measured using a digital fruit firmness tester (Model 53205, TR Turoni Srl, Italy) with a 4 mm cylindrical shape (flat end) probe.

Data analysis

The experimental design was complete randomized design. Data gathered were analyzed using Analysis of Variance (ANOVA) by Statistical Analysis System (SAS). Percentage data were transformed to arc sin values prior to analysis. Differences between treatment means were obtained by Duncan's Multiple Range Test at 5% significance level ($p < 0.05$).

RESULTS AND DISCUSSION

Weight loss

Table 1 summarizes the quantitative weight loss of mango in different post-harvest stages caused by mechanical damage and physiological weight loss. Weight loss can be used as a quality indicator in the postharvest life of mango. Generally, fruit weight loss progressively increased during the post-harvest period. According to the findings, the total weight loss of mango in the conventional and improved supply chains was 39.6 ± 1.9 percent and 6.2 ± 0.8 percent, respectively revealing that the total weight loss of the improved supply chain was significantly lower ($p < 0.05$) than the conventional supply chain. Findings further exhibited that weight loss quantities at every postharvest stages of the improved supply chain were significantly lower than to the conventional methods. In addition, the weight loss at farmer stage was $4.7 \pm 0.7\%$ where conventional harvesting methods were practiced while improved harvesting practices did not show any losses. Mango weight loss is significantly lower when proper post-harvest technologies are being used from harvesting to marketing (Khaliq et al., 2016; Msogoya & Kimaro., 2011). Improved postharvest methods of mango save significant weight losses over the conventional postharvest period (Alam et al., 2019).

The comparatively lower weight losses which were observed in the improved supply chain might be due to practice of recommended postharvest techniques such as use of proper maturity indices, proper harvesting practices, delatexing, use of plastic crates for packaging and transportation from farm to collecting center, recommended artificial ripening method, proper sorting and grading practices, and recommended corrugated boxes for packaging and transportation from collecting center to the markets. Islam et al. (2013) also reported that use of correct postharvest practices during the postharvest period minimize the weight loss of fruits.

Table 1. Weight loss at different postharvest stages of mango

Supply chain	Weight loss (%)				
	Farmer	Collector	Whole seller	Retailer	Total
Conventional	4.7 ± 0.7^a	15.1 ± 1.2^a	5.1 ± 0.4^a	14.7 ± 0.9^a	39.6 ± 1.9^a
Improved	0.0	1.3 ± 0.2^b	0.8 ± 0.06^b	4.1 ± 0.9^b	6.2 ± 0.8^b

Values with same letters in columns are not significantly different ($p \leq 0.05$)

Furthermore, the highest weight loss had been observed at the level of retailer in both supply chains. This might be due to various factors. One main factor was displaying these mangoes in the open troughs along the roadsides, because most of the fruit retail outlets are road side retail outlets with few protective measures in place to preserve the quality of the fruits. Thus, these get directly exposed to sun. Further, the mangoes were fully ripe when reach the retailers. Therefore, metabolic reactions are at maximum level, with the physiological state of the fruit and the surrounding ambient storage conditions (Kaur, 2017). Additionally, this might had been aggravated by the improper postharvest practices conducted during the supply chain activities. And the damages caused to the fruits at each stage during the supply chain might have acted as a cumulative cause for increased weight loss. The common problems leading to weight losses observed along the supply chain were, presence of immature fruits, over ripening, crushing, bruising, insect infestation and diseases.

Change in pulp firmness

Firmness is one of the major quality attributes that decide the acceptability of fruit to the customer. The study findings on fruit firmness revealed a drastic and continuous decline in fruit firmness along the supply chain (Fig. 3). This decline was significantly higher ($p < 0.05$) in conventional supply chain than the improved supply chain. Decrease in fruit firmness might be due to artificial ripening which was conducted at the point of collector.

Ethylene plays a direct role in the ripening and softening of mango fruit. As a result, when exposed to a high ethylene dosage, the fruit ripening and softening processes accelerate during the postharvest period, reducing postharvest life (Barman et al., 2014; Kaur, 2017). According to Khaliq et al. (2016), fruit softening is associated with a reduction in firmness, which is directly liable for the decrease of cell turgor of fresh fruits. Mango fruit ripening is known to be a leading textural softening process during the postharvest period. Alam et al. (2019) and Khaliq et al. (2016) also had confirmed that the pulp firmness of the mango rapidly reduces with enhancing time of the postharvest period. The research further revealed that firmness had drastically decreased in conventional direct spraying of ripening agent on the mangoes than in mangoes which are artificially ripened by the recommended inducing of ripening process by exposure to ethylene gas. In non-recommended ripening of mango, it leads to acute physicochemical changes within a short period of time such as softening of fruits, color change (formation of pigments), odor and flavor changes, and reduction of organic acid content. The firmness had decreased in direct ethephon treated mango than the mango, which were not directly treated with ethephon (Kaur, 2017).

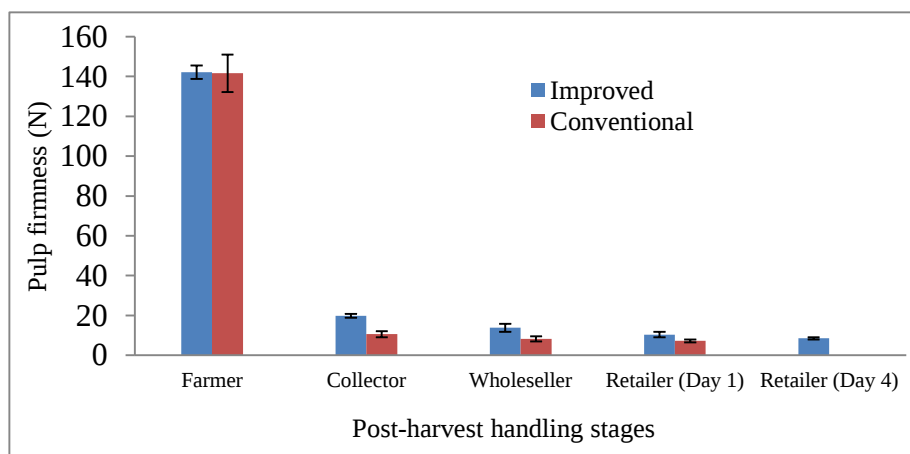


Fig. 3. Changes in pulp firmness of mango during postharvest period

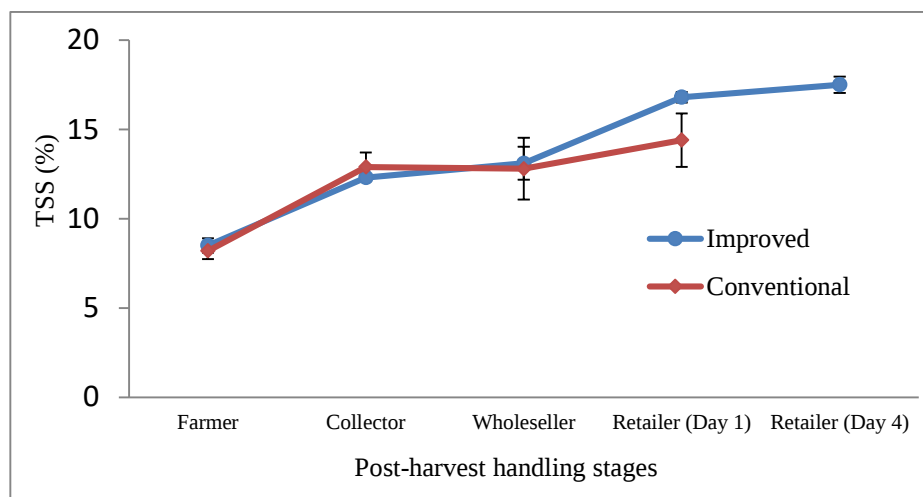


Fig. 4. Variation of total soluble solids (TSS) of Mango during the supply chain

Effect on total soluble solids (TSS)

TSS of mango fruits which were handled in both conventional and improved methods gradually increased along the supply chain. The rise of TSS during ripening may be due to increase in organic solute concentration and various anabolic and catabolic processes of mango (Gowda & Huddar, 2001). Further, Kaur (2017) stated that artificial fruit ripening through ethylene treatment induces the ripening process and increase TSS in mango fruits. This is due to converting the complex carbohydrates and polysaccharides in to simple sugar substances which makes the fruit much sweeter. TSS values of improved and conventional practices were 17.7 and 14.4° brix respectively at retail point which was significantly different. However, significant differences of TSS between two mango supply chains were not reported at farmer, collector and wholesaler points. Recommended artificial ripening treatments with ethylene in gaseous form improve the sensory qualities of fruits due to the role of ethylene in promoting changes such as production of more sugars, and release of volatile compounds during the ripening period, which are important for the flavour (Hewajulige & Premaseela., 2020).

Changing of pulp colour during ripening

The flesh color of ripening mango changes from light yellow to dark yellow due to the accumulation of carotenoid which is an important factor of nutritional quality and market acceptance (Ma et al., 2018). The 'L' value indicates the lightness which extends from 0 (black) to 100 (white). As shows in Fig. 1, the L* of mango pulp gradually reduced in both methods during the postharvest period while mango fruits at wholesale and retail points of improved supply chain indicated significantly lower L* values. Artificial ripening is a mechanism that accelerates the degradation of chlorophyll and causes yellowness in many fruits having green tissues (Kaur, 2017). The 'a' value indicates the turning of fruits from green (-) to red (+). Initially, a* value from farmer to wholesaler exhibited slight decline in both value chains, thereafter, a* value progressively increased. But no significant different was observed between two methods. The 'b' values indicate the turning fruits from yellowness to blueness. Positive (+) values are towards yellowness while negative (-) values are towards blueness. A rapid rise in b* value of mango pulp showed from farmer to collector point (Fig. 7). The ripening of mango fruits is practiced at collector point. Hence, colour change of pulp could be clearly identified at collector point. Kulkarni et al. (2004) have mentioned that applying of ethylene to mango fruits improve their colour.

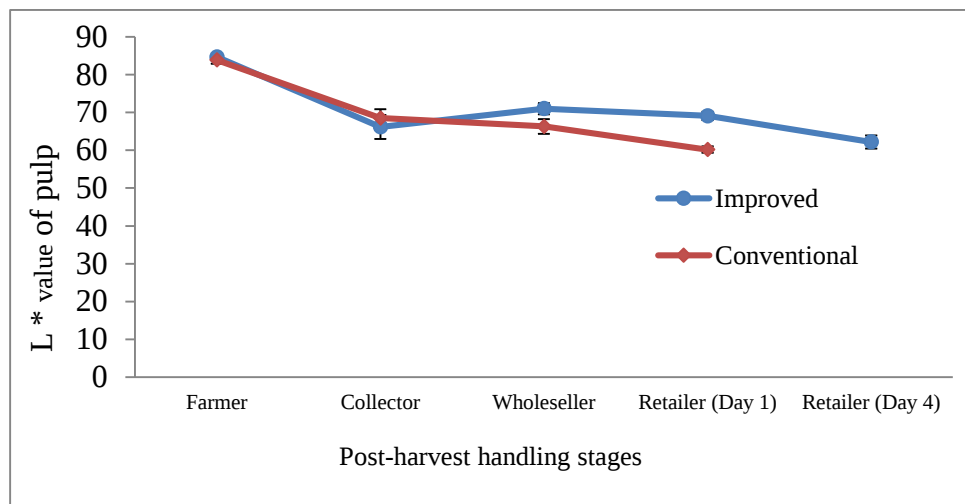


Fig. 5. Changes in L^* value during postharvest period

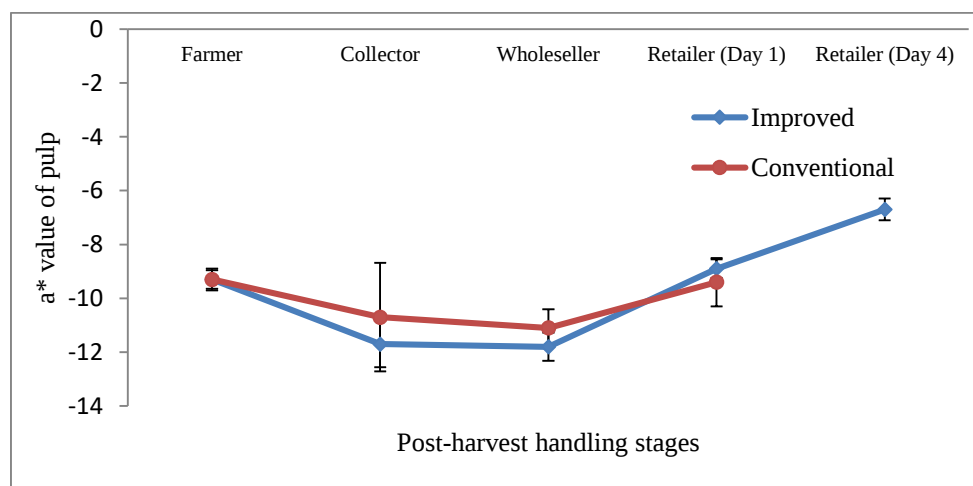


Fig. 6. Changes in a^* value during postharvest period

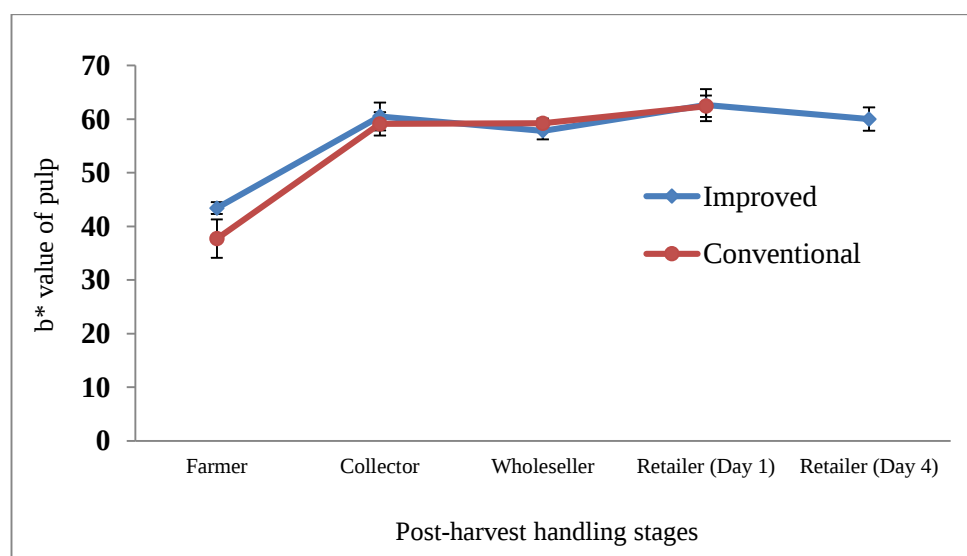


Fig. 7. Changes in b^* value during postharvest period

Changes in visual qualities

The visual qualities of mango fruits handled in both conventional and improved value chains did not show any difference from harvesting to ripening practices. But once artificial ripening was completed, blotchy appearance was observed on mango fruits which were subjected to conventional ripening method (Fig. 8a). The peel colour became completely yellow at the retail stage. But mango fruits ripened in the improved supply chain, using the chamber remained in green colour at the collector stage (Fig. 8b) and only stem part of the fruits became yellow colour at the retailer stage. But the yellow colour gradually increased with time after reaching the retail level during the postharvest life.

Effect on postharvest life of mango fruits

The conventional supply chain's postharvest life of fresh mango fruits was found to be shorter than that of the improved supply chain. The study revealed that the shelf life of ripe mango fresh fruits of conventional supply chain was only one day at retail point in marketable quality. The fruits became over ripe and not suitable for consumption earlier than the fruits of the improved chain. However, it was observed that mango fruits of subjected to improved practices could be kept in same quality for four days at the retail stage. Diseases such as anthracnose and stem end rot were observed at the retailer level more prominently in the conventional supply chain. One of the main reasons could be higher fruit peel with latex during conventional harvesting. But this incidence was minimized by conducting proper delatexing techniques in improved harvesting. According to the Yunita et al. (2018), Post-harvest disease in mangoes is caused due to contamination of fruit skin with sap coming out of the fruit stalk during harvesting.

Other than the fruit peel, pulp of the mango fruits also started to change colour along the supply chain. The pulp colour of mango fruits ripened by spraying ethephon became yellow (Fig. 9a). But it was initially yellowish orange around the seed and more yellowish towards the peel of mango fruits ripened in chamber (Fig. 9b). Ethylene gas treatment usually accelerates the chlorophyll degradation and induces yellowness in green tissues of fruits (Mahajan et al., 2008). Exogenous ethylene treatment can induce ripening of fruits by increasing the level of endogenous ethylene (Maduwanthi & Marapana, 2019) which resulted in the natural ripening process giving the observed colour change.



Fig. 8a. Fruits with blotchy appearance.



Fig. 8b. Properly ripen fruits.



Fig. 9a. Pulp colour development of ripened mango fruits with conventional method.



Fig. 9b. Pulp colour development of ripened mango fruits with improved method.

CONCLUSION

The research revealed that both qualitative and quantitative postharvest loss reduces with improved practices at each stage in the mango supply chain in Sri Lanka. These improved handling practices had significantly reduced the postharvest weight loss from $39.6 \pm 1.9\%$ to $6.2 \pm 0.8\%$. Furthermore, use of improved practices increases the shelf life of mango. It further support in retaining the pulp firmness, slow colour development, and with compatible TSS levels. Therefore, it is suggested that improved postharvest handling practices should be promoted among all stakeholders of the mango supply chain to reduce postharvest loss of mango in Sri Lanka.

Conflict of interest

The authors have no conflict of interest to report.

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