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Assessment and management of post harvest losses of fresh mango under small-scale business in Morogoro, Tanzania

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1 SUMMARY

This study was conducted to assess postharvest losses and the effect of shade during wholesale market and hot water treatments on storage of mango cv. 'Dodo'. To assess postharvest losses, mature fruits were packed on semi-rigid bamboo cartons, loaded on a truck without separators in between cartons and transported from Mkuyuni ward to Morogoro urban, Tanzania. The effect of heat stress during the wholesale market was evaluated by storing mango fruits under the sun, woven polypropylene shade and black net shade at Sokoine University of Agriculture. Mango fruits dipped in hot water at 60° C for 10 minutes were compared with untreated ones as control. Results showed that the fruit total postharvest losses were 43.8 % with the wholesale market, transport and harvest stages accounting for 30.6 %, 10.6 and 2.6 % of the total losses, respectively. The main features of fruit deterioration during the wholesale market stage were softening and microbial decay each accounting for 50.7 and 39.6 % of the total losses within the stage, respectively. Microbial decays of 7.2 % and mechanical injuries of 2.0 % were the major features of mango fruit deterioration during the transport and harvest stages. Storing fruits for three days under the woven polypropylene and black net shades significantly reduced fruit postharvest losses by 52.7 and 38 %, respectively in comparison with fruit storage under the sun. Hot water treatment reduced the incidence of microbial decay by 85 % and improved fruit total soluble solids content by 15 % in comparison to untreated fruits. However, hot water treatment reduced fruit firmness and shelflife by 56.0 and 71.4 %, respectively. In the short term, wholesale traders are advised to store fruits under the polypropylene shade while in the long term, municipal and council authorities are argued to construct cold storage facilities for fresh fruits. Furthermore, farmers are advised to disinfect mangoes with hot water, especially those purported for immediate marketing.

2 INTRODUCTION

Mango (*Mangifera indica* L.) is among the most important fruits in Tanzania ranking number one after citrus and pineapple in the export markets (FAO, 1999). Its production in the country was estimated at 254,550 metric tones in 2004/2005 with an average annual growth rate of 21 % between 1990/1991 and 2004/2005 (Match Marker Associates, 2008). Several improved mango cultivars such as Alphonso, Tommy Atkins, Apple and Kent are available in the country but local cultivars still play a major role in the domestic markets (Niyibigira *et al.,* 2004). Several factors affect mango production with postharvest losses being among the major constraints. Postharvest losses of fresh mango fruits are reported to be 25 – 40 % in India and 69 % in Pakistan and microbial decay accounts for 17.0 – 26.9 % of the total postharvest losses in Asian countries (Prabakar *et al*., 2005). Mechanical injuries account for 20 – 25 % of the total postharvest losses in fresh dessert banana (Bezzera da Costa *et al*., 2010) while microbial decay accounts for 44 % of the total postharvest losses in fresh citrus (Bali *et al*., 2008). Similarly, softening caused by enzymatic degradation of carbohydrates and cell wall components is among the principal contributors of postharvest losses in fresh mango fruits (Lohani *et al*., 2004). Postharvest losses of fresh mango fruits in Tanzania have been estimated at 60 % (Match Marker Associates, 2008). Mango cv. 'Dodo' is the most cultivated and traded local variety in the country but little is known about its postharvest losses at different stages of the supply chain. Several techniques are recommended to reduce storage temperatures such as cold storage (Rongchao *et al*., 2006) but their applicability by small-scale farmers and traders remains poor. Little has been studied on the effect of local storage shade structures on storability of fresh mango cv. 'Dodo' in Tanzania. On the other hand, hot water treatment is particularly used as a non-chemical quarantine treatment to retard postharvest microbial decay though it may have detrimental effects on fruit quality of some mango varieties (Jacobi *et al*., 2001; Mansour *et al*., 2006). The effects of hot water treatment to control microbial decay on storability and quality of fresh mango cv. 'Dodo' are hardly known.

The objectives of this study were:

a) To analyse postharvest losses of fresh mango cv. 'Dodo' at various stages of the supply chain.

b) To determine postharvest losses of fresh mango cv. 'Dodo' stored under different shade structures

c) To evaluate the effect of hot water treatment on the control of microbial decay and quality of mango cv. 'Dodo'.

3 MATERIALS AND METHODS

3.1 Experiment 1: Postharvest losses were determined using mango cv. 'Dodo' grown in small-scale farmers' orchards at Mkuyuni ward in Morogoro region. Fruit maturity index was determined based on a few fruits dropping off a tree. Fruits were picked using a bag and knife attached to a pole and kept into a semi-solid bamboo carton, which was carefully descended to the ground using a rope. The fruits were sorted and packed in semi-solid bamboo cartons the following day. Prior to packing, cartons were cushioned by dry banana leaves and 130 fruits were packed per carton. The top of cartons was also covered with dry banana leaves. An open body truck was fully loaded with 50 cartons of fruits without separators in between them, and the fruits were transported for two hours from Mkuyuni ward to Morogoro urban market (40 km) during the morning hours (8.00 am to 10.00 am). After the arrival at the urban market, the fruit cartons were kept on the ground under the sun for three and five days to simulate wholesale marketing during high and low demand seasons. The assessment of mango fruit deterioration was carried out during the harvest, transport and wholesale market stages.

3.2 Experiment 2: This experiment was carried out at Sokoine University of Agriculture (SUA) using mango fruits harvested, packed and transported as in the experiment 1. Two shade structures were constructed each with a dimension of 300 cm width, 300 cm length and 300 cm height. The first shade structure was roofed using woven polypropylene sheet (Twiga Cement Ltd.) from locally available used cement bags. The second shade structure was roofed with black net which has a shading capacity of 40 % (Balton Tanzania Company). The experiment layout was completely randomized design with three treatments. The treatments were woven polypropylene shade, black net shade and full sunlight as a control. A treatment consisted of 5 cartons of fruits replicated three times. Temperatures and relatively humidity in the chambers were measured daily using a digital thermometer (Electronic Temperature Instruments Ltd.) and hygrometer (Dickson TH 550). The average daily temperature and relative humidity were 28.8 °C and 47.0 % under the woven polypropylene shade structure, 29.7 °C and 46.0 % under the black net shade structure and 31.7 °C and 44.2 % under the sun.

3.3 Experiment 3: This experiment was carried out at SUA using mango fruits harvested, packed and transported as in the experiment 1. The experiment layout was completely randomized design with two treatments. Mango fruits were dipped in hot water for 10 minutes at 60 °C, dried using clean cloth and stored for assessment on benches in the Postharvest Laboratory. Hot water untreated mango fruits were used as control. A treatment was replicated three times and each replicate consisted of 120 fruits. Temperatures and relative humidity were measured as in experiment 2 above. The average temperature and relative humidity in the laboratory were 29.5 °C and 65 %, respectively.

3.4 Data collection and analysis*:* At the harvest stage data were collected during grading and packaging using 5000 fruits whereas at the transport stage, data were taken immediately after the fruit arrival at the wholesale market using 2000 fruits. Data at the wholesale market stage were collected from randomly selected 1000 fruits each in the third and fifth day from the date of fruit arrival from the orchard. On the other hand, data in experiment 2 were collected using 390 fruits per replicate in the third day from the date of fruit arrival from the orchard whereas data for experiment 3 were taken from 60 fruits per treatment. Data for experiment 1 and experiment 2 were scored based on the number of damaged (postharvest losses). Data for experiment 3 included the incidence of microbial decay, fruit total soluble solids, pH, firmness and shelflife.

Damaged fruits were scored based on incidences of microbial decay, mechanical injuries and softening. Incidence of mechanical injury was scored as the number of fruits with broken peel and or pulp whereas the incidence of microbial decay was scored as the number of fruits with decay symptoms. The causal agents of the fruit microbial decay were identified using a compendium of mango diseases and disorders (Prakash, 2003). Decay due to fruit fly infestation was scored based on presence of larvae in the fruit pulp. Fruit softening was measured by punching the pulp with a penetrometer (David Bishop Instruments) and fruits with penetration pressure of less than 1.0 kg/cm^2 were considered to be soft. Total soluble solids were measured using digital refractometer (A. Krüss Optronic DR 5000) and pH using pH meter (Hanna Instruments). Fruit shelflife was scored as a number of days when 50 % of the fruits was considered unfit for human consumption.

Percentage data were arcin transformed before performing analysis of variance using COSTAT6.4 (Cohort Software, Minneapolis, USA) computer statistical software. Mean separation was performed based on Tukey Honest Significant (Tukey-HSD) test at a probability level of 5 % (Zar, 1997).

4 RESULTS AND DISCUSSION

4.1 Postharvest losses of mango fruits during along supply chain: The wholesale market was the most critical stage with the highest postharvest losses of 30.6 % followed by the transport and harvest stages with losses of 10.6 and 2.6 %, respectively (Table 1). The total postharvest losses of fresh mango cv. 'Dodo' fruits from harvesting to the fifth day of the wholesale market stage were 43.8 % with a shelflife of seven days. The postharvest losses of 43.8 % reported in cv. 'Dodo' are lower than 60 % as reported earlier in Tanzania (Tiisekwa *et al.*, 2005). The low postharvest loss observed in this study was possibly due to the short transport distance from the production area to the urban market.

Table 1: Proportion of undamaged and damaged mango cv. 'Dodo' fruits at various stages of the supply chain from Mkuyuni ward to Morogoro urban

Supply chain stage	Undamaged fruits (%)	Fruit postharvest losses (%)
Harvest	97.4^{a}	2.6^{c}
Transport	89.4^{b}	10.6^{b}
Wholesale marketing (3rd day)	84.9^{b}	15.1^{b}
Wholesale marketing (5th day)	69.4^{c}	30.6^{a}

Means bearing the same superscript letter within the column are not significant (P < 0.05) different according to Tukey-HSD test.

The high postharvest losses of 30.6 % encountered in mango cv. 'Dodo' at the wholesale market contradict with Prabakar *et al.* (2005) who reported low postharvest losses of 3.0 % during the similar stage. This discrepancy is possibly due to the fact that mango fruits in this study stayed longer in the wholesale market to simulate low demand during the peak mango production season. The increase in postharvest losses by 102.6 % between the third and fifth day of the wholesale storage provides evidence that the critical factors that contribute to high losses in mangoes are mainly at this stage.
The postharvest loss of 10.6 % observed in cv. 'Dodo' during the transport stage despite the short transport distance was probably due to improper transport practices. These practices include loading of cartons on a truck without separators between cartons, overloading of cartons and poor arrangement of such cartons on a truck (Pathac, 2006). On the other hand, the low postharvest losses of 2.6 % encountered in mango cv. 'Dodo' during the harvest stage are comparable to those reported in mango cv. 'Peter' in Nigeria (Prabakar *et al.*, 2005) and implies that farmers in the study area are using good harvesting practices.

4.2 Features of postharvest deterioration of fresh mango fruits: Softening and microbial decay were the main features of mango fruit losses accounting for 15.5 and 15.0 % of the total postharvest losses at the wholesale market stage (Table 2). Microbial decay of 7.2 % and mechanical injury 2.0 % were the main deterioration features of cv. 'Dodo' during transport and harvesting stages, respectively.

Table 2: Features of postharvest damage of fresh mango cv. 'Dodo' fruits during harvesting, transportation and wholesale marketing stages.

Fruit damage feature (%)	Harvest stage	Transport stage	Wholesale market stage
Mechanical injury	2.0^{a}	1.8^{b}	0.1^{c}
Softening	0.0^{b}	1.6^{b}	15.5^{a}
Microbial decay	0.6^{b}	7.2^{a}	15.0^{b}

Means bearing the same superscript letter within the row are not significant ($P < 0.05$) different according to Tukey-HSD test.

The increased fruit softening in cv. 'Dodo' during the wholesale market stage was possibly due to the breakdown of carbohydrates during fruit ripening. Several reports have also associated fruit softening with enzymatic degradation of carbohydrates and cell wall components due to high temperatures (Brummell and Harpster, 2001; Lohani *et al.*, 2004). The high incidences of microbial decay at the transport and wholesale market stages of cv. 'Dodo' were possibly due to development of wound and non-wound decay pathogens, respectively. Fruit infections with wound pathogens increase with mechanical injuries while non-wound infections increase with fruit ripening and softening (Prabakar *et al.*, 2005; Weor, 2007).

4.3 Influence of shade on postharvest losses of fresh mango fruits: Storing mango fruits under the sun significantly ($P < 0.05$) increased the quantity of damaged fruits due to softening. Fruit damage accounted for 15.5 % under the sun compared with 9.3 and 7.1 %a under the black net and polypropylene shades, respectively (Table 3).

Table 3: Deterioration of fresh mango cv. 'Dodo' fruits in the third day of wholesale marketing stage under different types of shades

Storage environment	Undamaged fruits (%)	Damaged fruits (%)
Full sunlight	84.9^{b}	15.1^{a}
Black net shade	90.7^{a}	9.3^{b}
Polypropylene shade	92.9^{a}	7.1^{b}

Mean bearing the same superscript letter within the column are not significant ($p < 0.05$) different according to Tukey-HSD test.

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The low fruit softening encountered in mango cv. 'Dodo' stored under either polypropylene shade or and black net shade was possibly due to reduction in temperatures. Similar results have been reported in mango cv. 'Peter' stored under a jute-thatched hut in Nigeria (Weor, 2007). The reduction in postharvest losses by 53.9 % when cv. 'Dodo' fruits are stored under the polypropylene shade provides evidence that temperature is a critical factor affecting shelflife of fresh mango fruits during the wholesale market. These results are in agreements with Panhwar (2005) who reported on an exponential increase of ripening and softening rates of mango fruits as temperatures approached to 32 °C.

4.4 Effect of hot water treatment on control microbial decay and fruit quality: The incidence of microbial decay decreased from 15.5 % in untreated fruits to 2.3 % in hot water treated fruits (Table 4). Moreover, hot water treatment significantly improved ($P < 0.05$) fruit quality by increasing pulp total soluble solids content from 14.0 % in untreated fruits to 16.2 % in hot water treated fruits. On the contrary, fruit firmness decreased from 5.0 kg/cm^2 in untreated fruits to 2.2 kg/cm^2 in hot water treated fruits. Likewise, fruit shelflife decreased from 12 days in untreated fruits to 7 days in hot water treated fruits.

Table 4: Effect of hot water treatment on microbial decay and fruit quality of mango cv. 'Dodo'

Storage environment	Hot water treated fruits	Hot water untreated fruits
Incidence of microbial decay (%)	2.3^{a}	15.5^{a}
Fruit pulp Brix (%)	16.2^{a}	14.0^{b}
Fruit firmness day 7 (kg/cm^2)	2.2^{b}	5.0^{a}
Fruit pulp pH	3.8^{a}	3.6^{a}
Fruit shelflife (Number of days)	7.0^{a}	12.0^{a}

Mean bearing the same superscript letter within the column are not significant ($p < 0.05$) different according to Tukey-HSD test.

Hot water treatment in mango cv. 'Dodo' decreased microbial decay with a disinfection efficiency of 85 %. This result is comparable with previous reports in which dipping mango fruits in hot water at 55 °C for 10 minutes reduced microbial decay with disinfection efficiencies of 80 and 83 % for fruit fly eggs and anthracnose disease, respectively (Benitez *et al.*, 2006; Mansour *et al.*, 2006). Moreover, hot water treatment in mango cv. 'Dodo' increased total soluble solids content and this observation agrees with Mansour *et al.* (2006). The decrease in fruit firmness of cv. 'Dodo' reported in this study has also been reported in mango cv. 'Kensington' and is due to increased enzymatic carbohydrate breakdown caused by high water temperatures (Mansour *et al.*, 2006; Jacobi *et al.*, 2001). The short fruit shelflife of mango cv. 'Dodo' as a result of hot water treatment was probably caused by carbohydrate degradation and loss of fruit firmness. Ferris (1993) also reported on a strong positive correlation between either fruit firmness or carbohydrate content and fruit shelflife in banana. The reduction in fruit shelflife of mango cv. 'Dodo' disagrees with the report by Mansour *et al.* (2006). This discrepancy is possibly due to difference in mango varieties and therefore underscores the need to optimize hot water temperatures based varieties.

5 CONCLUSION

Mango cv. 'Dodo' suffers total postharvest loss of 43.8 % with the major causes being softening and microbial decay. The wholesale market is the most critical stage accounting for 30.6 % of the total losses while transport and harvest stages account for 10.6 and 2.6 % only. The postharvest losses at the wholesale market stage are associated with heat stress and microbial decay. A reduction of temperatures by storing fresh mango fruits under the polypropylene shade minimises the losses by 53.9 % whereas hot water treatment reduces microbial decay by 85 %. Hot water treatment increases fruit total soluble solids content by 15.7 % but also reduces fruit firmness and shelflife by 56 and 41.7 %, respectively. In the short term, wholesale traders are advised to store mango fruits under the woven polypropylene shades. Farmers are advised to reduce microbial decay by treating with hot water all mango fruits purported for immediate marketing. In the long term, municipal and council authorities are argued to construct cold storage facilities in urban markets for improving quality and shelflife of fresh fruits.

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