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Influence of Packaged Transportation on Shelf Life and Quality of Banana (*Musa spp*) Fruits

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Abstract

The influence of packaged transportation on shelf life and quality of banana (*Musa spp* cv. Dwarf Cavendish) fruit was evaluated. Bananas were transported from production area to Haramaya University (about 900 km) after packed with wooden crate, plastic crate, wooden crate with low density polyethylene plastic (LDPE), plastic crate with LDPE, fiberboard box with LDPE, fiberboard box with LDPE and chemical treatment, and with banana leaf. Plastic crate was better than wooden crate and banana leaf packages in maintaining fruit quality and extending shelf life; however, packing in boxes with plastic liners was better than those without liners. Packing chemical treated bananas in fiberboard box with plastic liners resulted in longer shelf life (13 days) and higher percentage of marketability with conservation of other physico-chemical parameters. This packaging can thus be used to transport and store bananas for more than 24 days with about 90% marketability while other boxes with plastic liner can be used for relatively shorter period of about 8 days. As far as artificial ripening is practiced, plastic crate is also good alternative to pack and transport bananas for local market. However, further study, including cost benefit analysis with bulk transportation is suggested.

INTRODUCTION

Banana (*Musa spp*) is one of the most important fruits produced and consumed in most parts of the world and in Ethiopia as well (Robinson and Sauco, 2010; Yoseph et al., 2014). However, it is a perishable fruit that requires special treatment to reduce spoilage during harvesting, handling and storage. Improper postharvest handling, packaging and transportation, diseases and inadequate storage facilities are indicated to be the major causes for the postharvest loss of banana fruit (del Aguila et al., 2010). Improved postharvest technologies have been in use for a long time to reduce loss and maintain quality of produce in developed world (Kitinoja et al., 2011). However, the situation of postharvest management in developing countries like Ethiopia is still sub-standard while there is a need for alternative technologies for extension of postharvest shelf life and maintaining produce quality. In addition to production problems in Ethiopia, banana is not properly handled from harvest to consumption. Poor postharvest handling practices at the farm and beyond the farm contribute to poor quality bananas reaching the markets (Gebre-Mariam, 1999; Mebratie et al., 2015). Majority of the harvested fruit goes to the wholesaler markets located in metropolitan areas of the country in a distance of 500 to over 1000 km road transport from the production areas. Banana bunches are loaded on open trucks covered with banana leaf for transportation. Handlers usually stand, sit, or even walk on the fruits during loading. Carless handling reflects lack of awareness and the need to protect fruits against injury. As a general assumption, such handling and transport procedures result in fruits with mechanical injuries and low internal and external quality attributes when ripe.

Small scale postharvest practices such as use of improved containers to protect produce from damage during handling and transport have been found to be simple, easy to try and successful in some developing countries (Kitinoja, 2013). Thus, working with farmers and handlers in the postharvest sector and

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investing in simple, low-cost improvements, such as gentle handling and protective packages, can help farmers and marketers to reduce physical injury losses, maintain food quality and improve market value for a longer period (Kitinoja et al., 2011).

The use of packages for harvest and postharvest handling of fresh produce has repeatedly been shown to reduce damage and postharvest losses (Kitinoja, 2013). For bananas transported over long distances, the use of rigid containers may minimize the serious damage occurring during handling and transportation. However, by how far could packing during transport improve shelf life and maintain quality of banana fruit has not been investigated yet in the study area. Hence, this study was undertaken to examine the use of packages, from fruit quality point of view, for transportation and handling of banana fruit. The specific objective was to evaluate the influence of packaging during transportation on quality and shelf life of banana fruit.

MATERIALS AND METHODS

Treatments and experimental procedure

Seven packaging treatments comprising of wooden crate (WC) alone and with low density polyethylene plastic liner (WC + LDPE) with 65 x 42 x 24 cm internal dimension, plastic crate (PC) alone and with low density polyethylene plastic (WC + LDPE) with 56 x 34 x 28 cm dimension, fiberboard box (50 x 32 x 20 cm) with LDPE plastic (FB + LDPE), fiberboard box with LDPE plastic and chemical treatment (FB + LDPE + Ch), and banana leaf (BL) were used to pack and transport bananas. Banana fruits cv. Dwarf Cavendish were obtained from a commercial farm in Arba Minch area, 500 km south of Addis Ababa, Ethiopia. Fruits were harvested at “three quarters” mature green stage based on loss of angularity and color (Dadzie and Orchard, 1997). Bunches were de-handed and kept under shade to drain the latex. The first and the last two hands on a bunch were discarded and the remaining fruits were selected for uniformity and freedom from defects. Fruits were then assigned randomly to the packaging materials.

Bananas were packed in wooden and plastic crates of about 25 and 20 kg capacity, respectively; and in fiberboard boxes of 12 kg capacity. Bunches wrapped with banana leaf were loaded on a car as a control treatment which is a usual transport system in the area. For packaging with chemical treatment, bananas were dipped in propiconazol (250 mg/l) solution (Sponholz et al., 2004) and drained before packed in fiberboard box with plastic liners. Packed fruits were loaded on a four-wheel pickup car and covered with canvas which then transported to Haramaya University (about 900 km) on the same day during the night and morning time of the next day. Up on arrival, fruits were kept in a storage room at ambient temperature in a randomized complete block design with three replications. The air temperature and relative humidity of the storage rooms were recorded throughout the storage period using digital psychrometer (Jenway-digital psychrometer 5105, UK). The changes in the physico-chemical properties of fruits were assessed at alternate day using nine randomly taken fruits per treatment.

Parameters studied

Physiological weight loss

The physiological weight loss (PWL) of banana fruits was determined according to the methods described by Mohammed et al. (1999). The cumulative weight loss percentage was calculated from a cluster of six fruits per treatment.

Mechanical damage

Assessment of mechanical damage was carried out based on transportation approach following modified procedure of Dadzie and Orchard (1997). Percentages of bruised fruits were assessed based on the method of packaging during and after transportation. Percentage of bruised fruits was calculated before transportation by visual assessment of mechanical damage or bruises on banana fruits (six fruits per replication). A final visual assessment of mechanical damage or bruises on fruits was done after transportation. The percentage bruised fruit was calculated after representative fruits were unpacked and stored for 24 hrs at ambient temperature.

Percentage decay

The number of decayed fruits due to micro-organisms infection was recorded and calculated as a percentage of the total number of fruits using the following equation. Fruit was considered rotten when more than 5% of surface area was decayed, blackened or rotten (Jiang et al., 1999).

$$\text{Percentage decay} = \frac{\text{Number of decayed banana fruit}}{\text{Total number of banana fruit}} \times 100$$

Days to ripening and shelf life

Days to full ripening were determined by observing changes in color, firmness and total soluble solids value of bananas on alternate day basis (Dadzie and Orchard, 1997). Shelf life was assessed by visual inspection of fruits at alternate days; it was calculated as the period in days between commencement of ripening and end of marketable life (Dadzie and Orchard, 1997).

Percentage marketability

Marketability of banana fruits was subjectively assessed according to the procedure described by Mohammed et al. (1999). The descriptive quality attributes were determined by observing the level of decay, color, surface defects, and shriveling. The percentage of marketable fruits was calculated using the following formula.

$$\text{Percentage marketability} = \frac{\text{Number of marketable banana fruit}}{\text{Total number of banana fruit}} \times 100$$

Total soluble solids, titratable acidity and pH

The total soluble solids (TSS), titratable acidity (TA) and pH value of bananas was determined from filtrates of pulp juice. The TSS value was determined using a digital hand held refractometer (Palm Abbetm) at 20 °C as described by Waskar et al. (1999). Total titratable acidity was determined by titration of the filtrate with sodium hydroxide to the phenolphthalein end point (Dadzie and Orchard, 1997). The pH value of banana was measured with a pH meter (ME 962p) following the procedures of Dadzie and Orchard (1997).

Statistical analysis

Analysis of variance for the parameters was done using SAS statistical software and comparison of the treatment means with significant difference was made by LSD test at 5% probability level.

RESULTS AND DISCUSSION

Weight loss

Weight loss of banana fruits showed a gradual increase in all treatments with the advancement of the storage period (Figure 1). However, packing bananas in all boxes with LDPE plastic liners significantly ($P < 0.001$) reduced weight loss compared to packing in boxes without plastic and the control. Bananas packed in wooden crate lost 4.9% while those packed in the same box lined with LDPE plastic lost only 0.18% after four days storage. After 14 days, the weight loss increased to a value of 20 - 23% for control package and for bananas packed in boxes without plastic liners while it was less than 6% for bananas packed in boxes with LDPE plastic liners.

The reduced weight loss of bananas packed in boxes with LDPE plastic might be attributed to the higher humidity inside the plastic that result in reduced transpiration. Similar pattern of changes in weight loss of bananas packed with plastic films were reported by Julianti et al. (2012), Hailu et al. (2014) and Zeweter et al. (2012). Ahmad et al. (2001) reported that low humidity (60 - 65 %) increased water loss by 6.95%, which then reduced the quality of ripe banana fruit. Under this study too, the humidity of the ambient was less than 50% which could be the main reason for relatively higher percentage weight loss for bananas packed with no plastic linings.

On the other hand, higher weight loss was recorded from bananas packed in banana leaf and in wooden crate than in plastic crate which might be due to higher chance of physical injury that favor water loss from fruits. Highest percentage in weight loss was also reported for bananas (Prata Ana) facing cutting and abrasion damages (Maia et al., 2011). Physical injuries, especially cutting and scratching, are considered as the most harmful postharvest mechanical injuries for bananas as they lead to increased loss of fresh mass and changes in color (darkening) (del Aguila et al., 2010).

Mechanical damage

Variation on the incidence of mechanical damage was observed to bananas packed and transported in different packages. The highest incidence of external mechanical injury (55.56%) was observed from bananas in the control package (banana leaf) followed by those packed in wooden crate (50%) and in wooden crate with LDPE plastic (44.44%), whereas bananas packed in fiberboard boxes without LDPE plastic lining showed the least injury of 11.11% (Figure 2). The incidence of injury to bananas packed in plastic crate only and with LDPE plastic was 38.89% and 33.33%, respectively.

The higher incidence of injury to bananas packed with banana leaf might be attributed to the non rigidity of the packing material which exposes the fruit to injury. On the other hand, the roughness of the plain wood and the rough edges of wooden crate might be the reason to high mechanical injury to packed bananas. In agreement with this, Maia et al. (2008) reported a high mechanical injury to bananas packed in wooden crate due to compression and surface bruising damages. The relatively reduced incidence of mechanical injury observed for bananas in plastic crate compared to those packed in wooden crate with and without LDPE plastic might also be due to the smoothness to the inner surface of the plastic crate. Its nestability and strength might have also helped to stabilize well during transportation thereby minimizing the damage (Rapusas and Rosa, 2009; Manalili et al., 2011). Likewise, Jayathunge et al. (2011) reported that nestable plastic crates used to pack and transport brinjal and tomatoes had the lowest mechanical damage than wooden crate and fiberboard box package.

On the other hand, the lower incidence of injury to bananas in fiber board boxes with LDPE plastics might be attributed to the reduced vibration damage as the top cover of the box keeps the fruits tight and due to the presence of LDPE plastic that have a cushioning effect as well. In addition, this may also be due to a limited number of box stacks used in this study, which might have minimized the compression damage from overloading. Generally, the incidence of mechanical damage observed to bananas packed in boxes with plastic liners was observed to be lower than those packed in respective boxes without plastic liners, indicating the presence of plastic might have helped to reduce the mechanical damage to some extent. Plastic liners are reported to reduce abrasion damage to a produce (Wills et al., 1989).

Percent decay

The packaging materials used during transportation and storage influenced the prevalence of decay to bananas during storage. Bananas packed in wooden crate and in plastic crate with LDPE plastic showed 9.92% and 12.01% decay after eight days storage, increasing to 76.14% and 78.11%, respectively, after 14 days (Figure 3), whereas, the percent decay for bananas packed in wooden crate and in plastic crate (with no plastic liners) was 12.14% and 14.69%, respectively after 14 day storage. An increase in percent decay from 7.10% on day eight to 51.38% on day 14 was observed for bananas packed in fiberboard box with plastic liners while no decay was observed to chemical treated bananas packed in the same box till the 26th day of storage. Decay to fruits packed in banana leaf was observed on day 16.

The higher percent decay of bananas transported and stored in boxes with plastic liners might be attributed to the higher relative humidity created inside the packages favoring the growth of microorganisms under ambient transport and storage conditions. Similar results of higher spoilage for bananas packed in poly bags were reported by Narayana et al. (2002) and Hassan et al. (2005). Hailu et al. (2012) also reported decay loss as the main reason for unmarketability of bananas packed in polyethylene bags. On the other hand, the lower percentage of decayed fruits in packages without LDPE plastic could be due to the lower relative humidity of the packaging environment which disfavors the multiplication of microorganisms. The reduced humidity and reduced chance of entrance for microorganisms, as intact bunch was maintained in storage, might be the reasons behind delay in decay development to banana bunches packed in banana leaf.

Days to full ripe stage

Bananas transported and stored in different packages showed a variation in the number of days to attain full ripe stage (ripening stage 6). Bananas packed in boxes with plastic liners took relatively shorter time, 12 to 13 days, to reach full ripe stage indicating faster ripening rate than fruits in other packages while chemical treated bananas in fiber board box with plastic took 21 days to attain full ripe stage (Table 1). Bananas packed in wooden crate, in plastic crate and with banana leaf took 16 days to ripe. Bananas in these packages even failed to develop to full ripe stage showing dull color and shriveling symptoms, indicating an alteration to the normal ripening process.

The relatively shorter days to ripe for bananas in boxes with plastic liners might be due to the increased chance of earlier decay development induced by higher temperature and relative humidity developed in the plastic during transportation and storage. It has been indicated that ripening may be enhanced by ethylene released from mycelia of fungi such as Colletotrichum musae (Daundasekera et al., 2003). On the other hand, the increased water loss from fruits might lead to shriveling and alter the ripening process of bananas packed with banana leaf, in wooden crate and plastic crate. Finger et al. (1995) noted that water loss from banana fruit caused a decrease in the maximal rates of respiration and ethylene production which might consequently reduced the decline in chlorophyll content and color change in fruit skin. Another study also indicated that untreated bananas for ripening treatment (ethrel) showed a sign of shriveling and failed to ripe even after 8 days of storage (Kulkarni et al. 2011). The delay in ripening to the chemical treated fruits in fiber board box with plastic might be due to the MAP created inside the plastic as well as the reduced chance of decay incidence that could have extended climacteric rise and the ripening process.

Shelf life

Packing in boxes (wooden, plastic, fiberboard) with plastic liners increased the shelf life of bananas to 7-8 days as compared to 6 days in plastic crate and 4.67 days in wooden crate and banana leaf packages (Table 1). On the other hand, packing chemical treated bananas in fiberboard box with plastic liner resulted in the longest shelf life (13 days) of all other packages. The MAP created in the plastic might be the reason for the relatively longer shelf life of bananas in boxes with plastic liners than bananas packed in boxes with no liners and those packed with banana leaf. Similar findings by Narayana et al. (2002) reported a shelf life of 6.67 days for bananas kept in polybags under ambient condition. Other studies also showed that bananas packed in polyethylene lined boxes had longer shelf life than non-packed fruits (Kader, 2002). Furthermore, the reduced decay development might have helped to attain longer shelf life of chemical treated bananas.

Percentage marketability

Transporting bananas with varying packages resulted in a significant ($P < 0.001$) difference to the percentage marketability of stored bananas. Packing with banana leaf resulted in the lowest fruit marketability while the highest marketability was observed from chemical treated bananas packed in fiber board box with plastic liners (Table 2). Packing in plastic crate, followed by wooden crate, was better in retaining more percentage of marketable bananas than packing in banana leaf. Likewise, plastic lining of fiberboard box, plastic crate and wooden crate were better in maintaining fruits marketability than packages without plastic linings and those in banana leaf package (control) during most of the storage periods. Except for chemical treated bananas, fruits marketability started to decline from day 6 onwards and reduced on day 10 to about 70% for banana leaf while more than 85% marketability was observed in packages with LDPE linings. Chemical treated bananas lined with LDPE plastic were 100% marketable up to day 22 by which time fruits in all other packages were totally discarded.

The reduced marketability of bananas packed with banana leaf followed by those packed in wooden crate compared to packing in plastic crate might be attributed to the prevalence of physical injury and more weight loss that resulted in browning and shriveling of fruits as observed in this study. The rigidity of plastic crates and their smooth internal surfaces is known to allow better protection of fresh produce (Rapusas and Rosa, 2009). On the other hand, packaging in boxes with plastic liners might help bananas to maintain their marketability long through atmospheric modification and weight loss reduction. It is known that packing produce in polyethylene plastic produces higher relative humidity inside the package and hence reduces weight loss of the produce (Elkashif et al., 2005). However, decay development was the main reason to end up marketable life of fruits packed in boxes with plastic liners and no chemical treatment. Similar results were reported by Hailu et al. (2014) and Zeweter et al. (2012) for reduced marketability of bananas packed in polyethylene plastic mainly due to decay development. Packing chemical treated fruits in boxes with plastic liners helped fruits to maintain their marketability for longer period which might be due to suppression of disease development.

Total soluble solid

A progressive increase in total soluble solid (TSS) content with a slight decrease with the advancement of storage period was observed from bananas in most of the packages (Figure 4). Green bananas on day 2 had TSS values of 2.0 - 2.3 °Brix with the value increasing to 10.2 - 17.85 °Brix in the different packages during the storage period. However, significant difference on TSS value was observed from day 6 onwards, a faster increasing rate and higher value observed for bananas packed in wooden, plastic and fiberboard boxes with plastic liners. A slower change and lower TSS value was observed from in boxes with no plastic liner and those packed with banana leaf. In bananas treated with propiconazol (250 mg/l) and packed in fiberboard box with LDPE, TSS value showed a steep increase from 3.85 °Brix on day 12 to the highest (17.9 °Brix) on day 24.

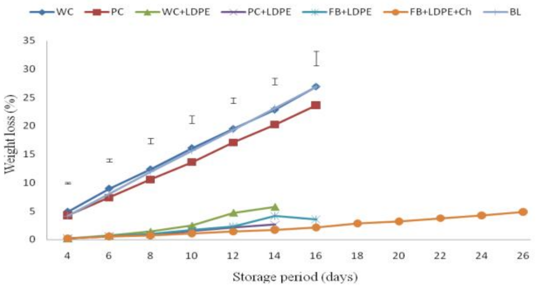

Figure 1. Percent weight loss of cv. Dwarf Cavendish bananas stored at ambient temperature after packaged transportation. WC: wooden crate; PC: plastic crate; FB: fiberboard box; BL: banana leaf (control); LDPE: low density polyethylene plastic; Ch: chemical. The vertical bars represent the LSD value at P = 0.05.

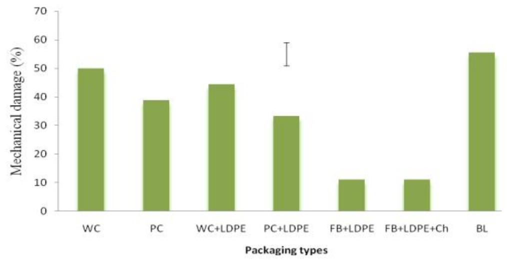

Figure 2. Percent of mechanical injury to cv. Dwarf Cavendish bananas after packaged transportation. WC: wooden crate; PC: plastic crate; FB: fiberboard box; BL: banana leaf (control); LDPE: low density polyethylene plastic; Ch: chemical. The vertical bar represents the LSD value at P = 0.05.

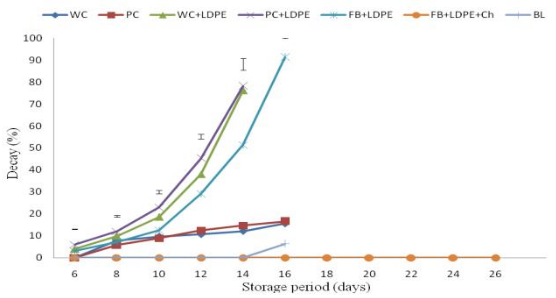

Figure 3. Percent decay of cv. Dwarf Cavendish bananas stored at ambient temperature after packaged transportation. WC: wooden crate; PC: plastic crate; FB: fiberboard box; BL: banana leaf (control); LDPE: low density polyethylene plastic; Ch: chemical. The vertical bars represent the LSD value at P = 0.05.

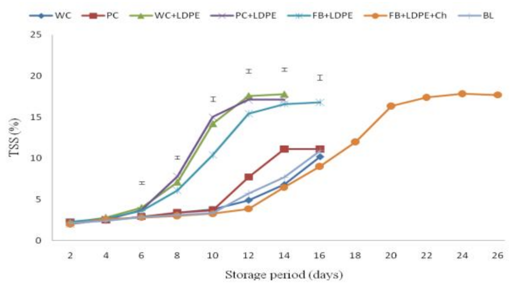

Figure 4. Total soluble solid content of cv. Dwarf Cavendish bananas stored at ambient temperature after packaged transportation. WC: wooden crate; PC: plastic crate; FB: fiberboard box; BL: banana leaf (control); LDPE: low density polyethylene plastic; Ch: chemical. The vertical bars represent the LSD value at P = 0.05.

The increased TSS value of bananas in packages with LDPE plastic could be explained by the faster ripening process of fruits, which might have been enhanced by the decay development. A similar result of higher TSS value was reported by Hailu et al. (2012) for bananas packed in polyethylene plastics than packages without plastic linings. Higher TSS content was also reported by (El-Kashif et al., 2010) for bananas packed in cartons lined with polyethylene film. On the other hand, the incomplete ripening process due to moisture loss might have resulted in lower TSS value of bananas packed in plastic and wooden crates and in banana leaf. A relatively lower chance of mechanical damage to bananas in plastic crate than those in wooden crate and banana leaf might contribute to reduced water loss which in turn has an implication in the ripening process. Water loss is reported to cause decrease in the rates of respiration and ethylene production of banana during ripening, resulting in an abnormal ripening with a decreased pulp softening and excessive browning of skin (Finger et al., 1995). Modified atmosphere (reduced O_2 and increased CO_2) created inside the plastic coupled with reduced decay development may delay the ripening process of chemical treated fruits that might have contributed to slower starch to sugar conversion process (Truter and Combrink, 1990).

Table 1: Ripening period and shelf life of cv. Dwarf Cavendish bananas stored after packaged transportation.

Packaging	Days to full ripe stage	Shelf life†
Wooden crate	16.00^{b}	4.67^{d}
Plastic crate	16.00^{b}	6.00^{c}
Wooden crate + LDPE	13.33^{c}	7.33^{b}
Plastic crate + LDPE	12.00^{c}	8.00^{b}
Fiberboard box + LDPE	12.67^{c}	7.33^{b}
Fiberboard box + LDPE + Ch	21.33^{a}	13.00^{a}
Banana leaf (control)	16.00^{b}	4.67^{d}
CV (%)	8.22	9.55
SE	0.69	0.60
Significance	***	***

†Calculated as the period (in days) between commencement of ripening and end of salable life. LDPE: low density polyethylene plastic; Ch: chemical; *** indicate significant differences at $P \leq 0.001$. Means followed by the same letter in a column are not significantly different at $P < 0.05$ (LSD test).

Titratable acidity

Generally, an increasing trend as ripening progresses and then a decreasing pattern with the advancement of ripening was observed for titratable acidity (TA) values of bananas stored in different packages (Figure 5). The increase in TA value was faster for bananas packed in wooden crate, plastic crate and fiberboard box with plastic liners attaining maximum values of 0.49%, 0.47% and 0.49%, respectively.

On the other hand, bananas packed in wooden crate, in plastic crate and with banana leaf also showed a gradual increase in TA with peak value of 0.29%, 0.31% and 0.27% respectively. Similarly, the TA for chemical treated bananas packed in fiberboard box with plastic showed a gradual increase reaching peak value (0.45%) on day 20.

Table 2: Percentage marketability of cv. Dwarf Cavendish bananas stored after packaged transportation.

Treatments	Storage period (days)								
	6	8	10	12	14	16	22	24	26
Wooden crate	94.14^{bc}	83.92^{d}	75.86^{e}	65.36^{e}	52.85^{e}	27.33^{c}			
Plastic crate	96.47^{ab}	85.65^{d}	80.47^{d}	69.52^{d}	56.59^{cd}	33.65^{b}			
Wooden crate + LDPE	97.52^{ab}	90.48^{c}	85.85^{c}	74.01^{c}	54.70^{de}	-			
Plastic crate + LDPE	99.44^{a}	91.99^{bc}	87.52^{c}	78.32^{b}	58.59^{c}	-			
Fiber board box + LDPE	99.37^{a}	95.13^{b}	91.65^{b}	79.70^{b}	69.20^{b}	37.00^{b}			
Fiber board box + LDPE + Ch	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00	92.50	55.00
Banana leaf (control)	90.45^{c}	79.42^{e}	70.02^{f}	53.43^{f}	42.30^{f}	26.27^{c}			
CV (%)	2.54	2.39	2.67	1.84	3.17	4.38			
SE	0.83	1.50	2.12	2.80	3.85	6.79			
Significance	**	***	***	***	***	***			

LDPE: low density polyethylene plastic; Ch: chemical; **, *** indicate significant differences at $P \leq 0.01$ and $P \leq 0.001$, respectively. Means followed by the same letter in a column are not significantly different at $P < 0.05$ (LSD test).

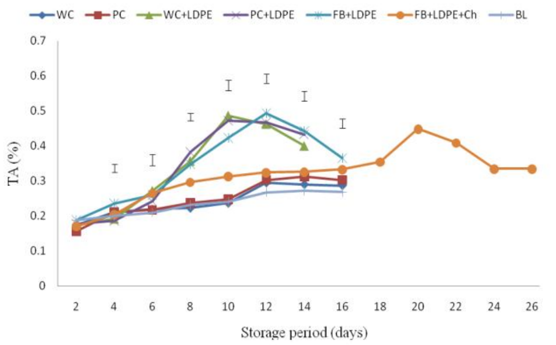

Figure 5. Titratable acidity of cv. Dwarf Cavendish bananas stored at ambient temperature after packaged transportation. WC: wooden crate; PC: plastic crate; FB: fiberboard box; BL: banana leaf (control); LDPE: low density polyethylene plastic; Ch: chemical. The vertical bars represent the LSD value at P = 0.05.

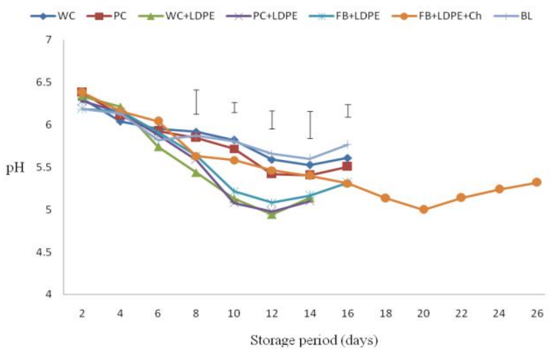

Figure 6. Fruit pulp pH value of cv. Dwarf Cavendish bananas stored at ambient temperature after packaged transportation. WC: wooden crate; PC: plastic crate; FB: fiberboard box; BL: banana leaf (control); LDPE: low density polyethylene plastic; Ch: chemical. The vertical bars represent the LSD value at P = 0.05

Similar patterns of TA value were reported for bananas packed in unvented polybags where acidity increased up to the end of green life and then decreased while it remained the same in control fruits till the end of shelf life (Narayana et al., 2002). Generally, the rate of increase in TA was faster for bananas in packages with LDPE plastics (except chemical treated ones) and reached peak value earlier than others. This might be due to the enhanced ripening process as a result of decay development. The rate of change and maximum value of TA was lower for fruits packed in banana leaf and for those packed without LDPE plastic. This may be because of the altered ripening process of bananas in humidity stressed environment which makes ripening incomplete and thus lower changes and peak values of TA (Finger et al., 1995). The relatively faster decline in acidity of bananas packed with LDPE plastic towards the end of the storage life might be due the utilization of the acids in the respiration process (Patil and Hulmani, 1998).

pH of the fruits

The pH value of bananas from different packages showed a general decreasing trend towards the ripening stage and then a slight increase towards the end of shelf life (Figure 6). The pH values ranged from 4.94 to 6.38 with significant ($P < 0.01$) variation between the treatments observed from day 8 onwards. The pH was higher for bananas packed with banana leaf, wooden crate and plastic crate than fruits in respective packages with LDPE. This might be due to the slower ripening process of fruits in these packages. Reduced ripening rate might have resulted from the humidity stressed environment in packages with no plastic liners and, from the MAP and reduced decay in case of chemical treated bananas. On the other hand, pH value of bananas in packages with LDPE plastic was lower, which may be attributed to increase in total acids of bananas towards the ripening stage. It is noted that free acidity increases and pH decreases during ripening in banana pulp (Dadzie and Orchard, 1997). Decay development in the plalstic packages might have enhanced the ripening process and related changes to bananas in these packages.

CONCLUSION

Use of packaging during transportation has helped to maintain quality and extend shelf life of bananas after harvest. Quality and shelf life of bananas was good when packed and transported in plastic crate followed by in wooden crate as compared to those packed with banana leaf. Packing in plastic crate and wooden crate with LDPE plastic was better than packing in these boxes without plastic liners, while fiberboard box with plastic liner and chemical treatment was by far better than all other packages in maintaining quality and shelf life of stored bananas after transportation. As far as quality and marketability is concerned, fiberboard box with plastic liner and chemical treatment was found to be better to transport and store bananas for longer period. Packaging in other boxes with plastic liners was also good alternatives to maintain fruit quality for relatively shorter period. Compared to the local used packages, such as banana leaf and wooden crate, plastic crate was better in extending shelf and maintaining bananas quality. Packaging and transporting in banana leaf, wooden and plastic crate failed to ripen properly, indicating a need for an artificial ripening treatment for fruits to attain full ripe stage. Thus, as far as local transport is concerned, plastic crate can be used to pack and transport bananas from production areas to central market (where artificial ripening is carried out) with reduced damage, reducing additional costs from plastic liners and chemical treatment. However, cost benefit analysis should be done to see its comparative advantage over the other methods. It is also recommended to carry out these postharvest treatments with more loads in larger trucks. Further study is also suggested to find an alternative organic treatment to replace chemicals for decay control for long distance transport as well for extension of green life of the fruit.

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