Original Article
Journal of Biosystems Engineering

J. of Biosystems Eng. 40(4):409-416. (2015. 12)
http://dx.doi.org/10.5307/JBE.2015.40.4.409

eISSN : 2234-1862
pISSN : 1738-1266

Feasibility Study on Styrofoam Layer Cushioning for Banana Bulk Transport in a Local Distribution System

W. M. C. B. Wasala[1]*, D. A. N. Dharmasena[2], C. A. K. Dissanayake[1], B. M. K. S. Tilakarathne[1]

[1]*Institute of Post harvestTechnology, Anuradhapura, Sri Lanka*
[2]*Department of Agriculture Engineering, University of Peradeniya, Peradeniya, Sri Lanka*

Received: October 22nd, 2015; Revised: November 6th, 2015; Accepted: November 24th, 2015

Abstract

Purpose: This study evaluates a new banana bulk packaging method under the real transport conditions of Sri Lanka. **Methods:** A field evaluation of optimized 8-mm thick Styrofoam sheets used as the cushioning material was applied. A trial transport was conducted from Thambuttegama to Colombo using a medium-sized open truck, with banana leaves as the control material. Data were recorded at the farmer, transporter, retailer, and consumer stages of the supply chain. Mechanical damage, physiological loss in weight, fruit firmness, total soluble solids, ripeness index, visual quality ratings, and the physical damage index of the bananas were measured at each stage. A cost-benefit analysis was also conducted for both packaging methods. **Results:** The 8-mm styrofoam sheets significantly reduced ($p < 0.05$) the mechanical damage from 26.3% to 12.9% compared to the conventional method for long-distance transport, and the physiological loss in weight showed a decrease of 2.88%. The loss of firmness of the fruits followed a simmilar pattern for both methods until reaching the retailer, but at the consumer was significantly higher ($p < 0.05$) for the control. However, the physical damage index at the retail stage for the control showed symptoms of physical injury, whereas the bananas transported using the cushioning materials exhibited only minor symptoms. Further, the visual quality of the fruits after transport from the farmer to the consumer was preserved, which is one of the main factors affecting consumer preference and retail price. The proposed method increases the profit margin by 51.2% for *Embul* bananas owing to the reduced postharvest losses. **Conclusion:** The 8-mm thick Styrofoam sheets reduced the physical damage to the bananas, with the quality parameters maintained at the prefered level. Moreover, profits may be increased.

Keywords: Banana bunches, Mechanical damages, Postharvest losses, Proper packaging, Styrofoam

Introduction

Bananas (*Musa acuminata* Colla) are widely grown fruit crops in tropical countries, and have a high consumer demand throughout the world. Bananas have become the most important fruit crops in Sri Lanka in terms of hectarage, production, and consumption (Kudagamage et al., 2002). A popularly grown fruit crop for Sri Lankan farmers owing to its high economic gains throughout the year, up to 50,000 ha of farmland is under banana cultivation, with an annual production of about 45,000 tons.

***Corresponding author:** W. M. C. B. Wasala
E-mail: wasala73@yahoo.com

Similar to many other perishable crops, the postharvest losses of bananas are relatively high owing to mechanical damage occurring during postharvest handling and distribution. Although bananas are harvested and transported at the mature green stage, the external appearance of the ripened fruits at the retail outlets is extremely poor as a result of excessive mechanical damage owing to improper postharvest handling throughout the supply chain (Sarananada, 2000). Wasala et al. (2014) reported that the postharvest losses of bananas in Sri Lanka accounts for about 29% from farm gate to the consumer, mainly owing to poor packaging and inappropriate transport. In a conventional distribution, bananas are packed in bulk on trucks without proper cushioning or lining materials and transported throughout the country. Transporters/wholesalers generally attempt to transport the maximum amount of produce per truckload to minimize the transport costs, and frequently pay little attention to mechanical damage.

Increasing the amount of investment into the postharvest handling of bananas can have a major impact on minimizing waste and increasing food supply while protecting the environment through a reduction in the use of production inputs. According to Dharmasena and Sarananda (2012), 97% of the fruits and vegetables in Sri Lanka are handled through conventional distribution channels in which the agricultural produce is channeled through economic centers with the involvement of a middleman, with improper handling frequently practiced. Although proper handling and packaging protocols are available, the design and development of an appropriate bulk packaging and transportation system for transporting whole banana bunches in a conventional distribution chain is an essential task for the Sri Lankan postharvest system owing to the present demand for whole bunches among the stakeholders. With proper handling and transportation, consumers will be able to meet their required quantity, quality, and maximum shelf life after purchasing. Based on a transport simulation, Wasala et al. (2015) reported that the bulk packaging of banana bunches using 8-mm thick Styrofoam cushioning sheets between bunch layers is successful in minimizing the mechanical damage to the fruits during transport. Therefore, to validate the results of laboratory experiments, the objective of the present research was to investigate the effects of bunch layer cushioning using 8-mm thick Styrofoam sheets for bananas transported by truck under actual field conditions.

Materials and Methods

Field-testing of selected packaging techniques

The banana supply chain from Thambuttegama to Colombo (120 km), which has been categorized as an A-grade national road, was selected for the present transport study. The average roughness of the road is 2.15 m/km. Styrofoam sheets of 8-mm in thickness were placed between the bottom to the top-most banana bunch layers on a truck (Figure 1) and transported 120 km for 5 h during the day time. Styrofoam, a commonly used cushioning material for fruits, has a high mechanical strength in terms of compression, tension, bending, and shear, and has a smooth surface with high water and vapor resistant properties. It is also resistant to most acids and salts, and can be used repeatedly for an extended period of time. The density of the material is 0.9 g/cm^3 on average. The average daytime temperature and RH recorded were 29±4°C and 68±5%, respectively. The truck was a medium-sized open truck with a leaf spring suspension, which is commonly used for transporting construction materials.

For the control, a truck of the same type and size was selected, and the bananas packed using a conventional method were transported to Colombo. For the conventional packing method, fresh banana leaves were placed between bunches, which is a usual practice (Figure 2). After transport to the final destination, 27 bunches were selected as the testing samples representing the front, center, and rear locations of the truck, as well as the top, middle, and bottom layers (Figures 3 and 4). The stacking width of the bananas in the truck was seven bunch columns for both packs.

Figure 1. Use of Styrofoam layers (new method)

Figure 2. Use of banana leaves (control)

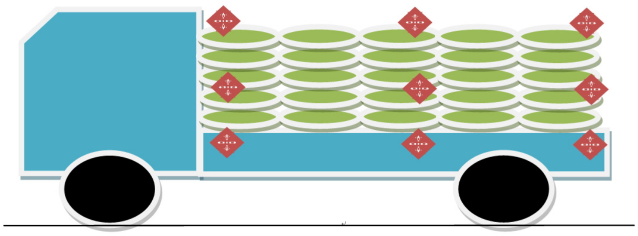

Figure 3. Sampling points (side view)

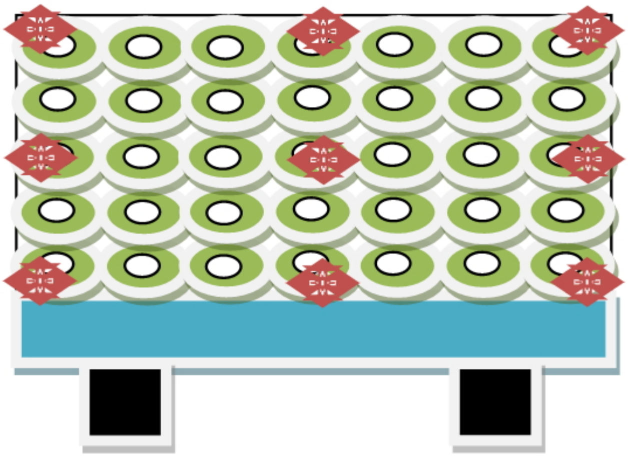

Figure 4. Sampling points (end view)

Environmental data collection

The temperature and relative humidity, both in-pack and in-fruit, were measured at the starting point of the journey, during transport, at the end of the journey, and at the retailer and consumer levels. While traveling, environmental data were collected at 2-h intervals. At the retailer and consumer stages, the daily average data were collected.

Weight losses and fruit quality

Mechanical damage, physiological loss in weight, fruit firmness, visual quality, total soluble solids (TSS), and ripeness index were measured at the farm gate, after transport, at the retailer, and at the consumer stages.

Assessment of mechanical damage

Fruits mechanically damaged from compression, abrasion, vibration, and their combined effects were detected visually and then assessed and weighed. The mechanical damage to the fruits at the four selected stages was converted into a percentage of loss, as reported by Dadzie and Orchard (1997), upon a visual assessment. The percentage of mechanical damage 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)

After conducting the experiment, the physiological weight losses of the banana fruits were determined based on their difference in weight at regular intervals. The same banana samples were used to find the weight difference from harvest to the end of the experiment (Ram et al., 2008).

Total soluble solids

The TSS content in fruit juice was recorded using a hand-held refractometer (Model HR-5, ATAGO, Japan) and the reading was reported as °Brix. To extract the juice for this test, a 10-g piece was cut from the whole banana fruit and blended in 50 ml of distilled water in a blender for 1 min as described by Sultani et al. (2010).

Visual quality rating (VQR) and physical damage index (PDI)

The VQR, ripeness index, and physical damage index were determined through visual observations of the fruits and by using guidelines provided by Kader and Cantwell (2007).

Fruit firmness

The firmness of the banana fruits was measured at the initial stage just before the crop was loaded, immediately after the test, and during the storage period using a digital fruit firmness tester (Model 53205, TR turoni Srl, Italy) with a 4-mm cylindrically shaped (flat ended) probe. Three readings were taken from each fruit.

Data analysis

A completely randomized design method was used for this experiment. The data gathered were analyzed using an Analysis of Variance (ANOVA) by SAS program. The percentage data were transformed into arc sin values prior to the analysis. The differences between treatment means was obtained using Duncan's Multiple Range Test at a 5% significance level ($p < 0.05$). The non-parametric data were fitted to a Friedman test using MINTAB version 11 for Windows, and the sum of the ranks was separated manually at a significance level of $\alpha = 0.05$.

Cost analysis

A cost-benefit analysis for both the newly proposed and conventional packaging methods was conducted based on the field performance test results. The cost of transport was calculated using the fixed and operational costs, and the economic feasibility of the new packaging technique was assessed based on the revenue incurred at the destination. The economic loss from mechanical damage incurred during transport was also applied to the cost calculations.

Results and Discussions

Mechanical damages

Table 1 shows the percentage of mechanical damage and the physiological loss in weight (PLW) of banana fruits at the farmer, transporter, retailer and consumer levels of the distribution chain.

The percentage of mechanical damage of banana bunches transported using the proposed method was significantly lower ($p < 0.05$) than that of the conventional method. Ekanayake and Bandara (2002) reported that postharvest losses of bananas in Sri Lanka account for about 30% mainly owing to a lack of suitable infrastructure for transport from the production point to the consumer. Postharvest losses of 28.5% were recorded in India through a wholesale channel consisting of the farmer, wholesaler, retailer, and consumer (Murthy et al., 2007). Abrasion and impact injury were mainly observed as the sources of mechanical damage to the fruit surfaces. The results show that the use of 8-mm thick Styrofoam sheets between bunch layers reduces the amount of mechanical damage by 51% with respect to conventional transport. Further, it was found that at all stages, except for the farm gate, the percentage of mechanical damage of banana fruits transported using the new method was significantly lower than when transporting them using the conventional method. Vursavus and Ozoguven (2007) also reported that the effects of transport on agricultural products depend on the type of packaging and cushioning materials used. In addition, Ilayas et al. (2007) reported that mechanical damage to bananas is higher during wholesale and retail marketing than during harvesting and consumption within the producer-to-consumer supply chain.

The total PLW of bananas transported using cushioning materials between the banana bunch layers was found to be significantly lower ($p < 0.05$) than for conventional transport. When banana bunches are transported without proper packaging methods, physical stress to the banana fruits is higher owing to impact, compression, and vibration effects. As a consequence, the respiration rate increases, resulting in a higher PLW. Mechanical injury also increases the water loss in banana fruits, as reported by many authors (Dadzie and Orchard 1997; Maia et al., 2011). Ferris et al. (1998) observed that abrasion to bananas increases the fresh fruit weight loss. The newly proposed packaging method was found to reduce the PLW of bananas within the supply chain by 31% in comparison to the control. This proves that a proper packaging method for transporting bananas significantly affects the PLW of the fruits, which was also previously reported by Singh et al. (2003). However, the results indicate that the PLW of banana fruits transported under both methods continuously increased from harvest to consumption, which is due to the natural ripening process. Jindal et al. (2005) reported that the increase in weight loss of the fruits is mainly due to their continuous transpiration of moisture and respiration. The total PLW of the control was 9.3%, which is closer to the level requiring the discarding of the produce (10%). Gast and Flores (1991) reported that fruits and vegetables

Table 1. The percentage of mechanical damage and PLW of bananas under field-test conditions

	Packaging method	Handling stage				
		Farmer	Transporter	Retailer	Consumer	Total
Mechanical damage (%)	New method	2.48^a	5.10^b	3.21^b	2.14^b	12.93^b
	Control	3.02^a	9.82^a	9.92^a	4.25^a	26.29^a
PLW (%)	New method	-	1.24^b	3.39^b	1.83^a	6.45^b
	Control	-	2.42^a	4.76^a	2.15^a	9.33^a

Values with the same letter in the columns for the same parameter are not significantly different at $p < 0.05$

with a PLW of more than 10% should be discarded.

Effects of bulk packaging method on quality parameters for banana fruits

TSS(Total Soluble Solids) and fruit firmness

The TSS and fruit firmness of bananas transported using both methods are shown in Table 2.

There was no significant difference in Brix values of banana fruits transported using both methods at the harvesting, retailer, and consumer stages of the supply chain from the farm gate to the final destination. However, a significantly higher Brix value was shown for fruits of the control group after transport. As reported by Ram et al. (2008), this difference in Brix value may be due to the accelerated conversion rate of starch to simple sugars in the fruit owing to transport stress without proper packaging. Further, Thakur et al. (2005) reported that the increased TSS during transport is related to the fruit damage. Maia et al. (2011) also reported that the TSS in the pulp of damaged fruit was higher than that in undamaged fruit. An increment in Brix values occurred along the supply chain for both new and conventional methods. A previous study by Liew and Lau (2012) reported that the Brix value of desert bananas increased from 4.7 to 19.9% from harvest to consumption.

A large decline in fruit firmness (69.0%) occurred from harvest to consumption in fruits transported under the conventional method, whereas a 51% decline was recorded for the newly proposed packaging method. The amount of mechanical damage to the fruits was also higher under the conventional method than for the new method. The loss of fruit firmness was also higher because of mechanical stresses and injury, which lead to alternations of tissue softening (Saford et al., 1991). Degradation of the cell wall polysaccharides in the fruits was accompanied by a loss of firmness, and vibrations during transport induced changes in the hydrolysis activity, which decomposed the cell walls of the supporting material (Zhau et al., 2007). At the consumer stage, the fruit firmness of bananas transported under the conventional control method was significantly lower than that for fruits transported under the proposed method. Therefore, the use of cushioning materials between banana bunch layers for bulk transport can improve the consumer acceptance by reducing the loss of fruit firmness. Armstrong et al. (1997) indicated that consumers have rated fruit firmness as one of the most important quality attributes when selecting fruit, along with color and aroma.

Physical Damage Index

The Physical Damage Indexes (PDIs) of banana fruits at the different handling stages of the supply chain for the two packaging methods are shown in Figure 5.

There were no symptoms of any physical damage at the harvesting stage. After the transport from Tambuttegama to Colombo (120 km), the PDI of banana bunches transported using the new method remained unchanged, whereas for the control the index showed minor symptopms of physical injury, which would not affect the price. Therefore, the

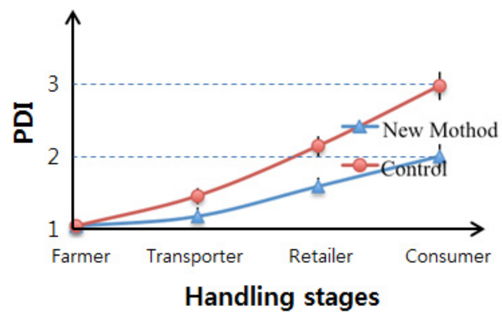

Figure 5. Changes in the physical damage index of the two bulk packaging methods: PDI-1, none (no symptoms of any physical injury); 2, slight (minor symptoms of physical injury that will not affect the retail price); 3, moderate (symptoms of physical injury are evident, and the retail price may be affected); 4, severe (serious physical injury, not marketable without a substantial price reduction); and 5, extreme (unusable, with no market value) (Kader and Cantwell 2007)

Table 2. Changes in TSS and fruit firmness under two different packaging methods

	Properties	Handling stage			
		Farmer	Transporter	Retailer	Consumer
TSS (Brix)	New method	8.57[a]	10.03[b]	15.20[a]	17.87[a]
	Conventional method (control)	9.13[a]	15.97[a]	16.00[a]	18.27[a]
Fruit firmness (N)	New method	77.73[a]	70.83[a]	52.56[a]	38.18[a]
	Conventional method (control)	79.06[a]	66.19[a]	51.67[a]	24.31[b]

Values with the same letter in the columns for the same parameter are not significantly different at $p < 0.05$

PDI of bananas at the retail stage for the control was of a moderate level (symptoms of physical injury evident with a possible affect on the retail price), whereas bananas transported using cushioning materials showed only minor signs of physical injury. Murthy et al. (2007) also reported that postharvest losses are higher in bananas at the retail stage owing to mecahnical damage. At the consumer stage, the PDI of banana fruits was maintained at a moderate level through the use of the proposed packaging method, whereas the conventional method resulted in severe physical injury. A significant difference ($p < 0.05$) in the PDI of the fruits was observed between both methods of packaging. The market price of bananas transported using an appropriate packaging method can thus be maintained at a higher level. Anwar and Malik (2006) also reported that improper packaging leads to high postharvest losses and low market prices.

Visual Quality Rating (VQR)

The quality ratings of fruits can be accounted for by taking the percentage of peel damage from the bruising, scaring, and scratching of the fruits during handling, and from mechanical damage (Al-Hosni et al., 2010). A comparison of the visual quality of banana fruits between the conventional method and the proposed method using cushioning layers is presented in Figure 6.

Using the new packaging method, the VQR of bananas was at an excellent level (essentially no symptoms of detrioration) during harvesting, and remained unchanged after transport from Thambuttegama to Colombo. However, after transport under the conventional method, the visual quality of the bananas dropped to a good level (minor symptoms). Anwar and Malik (2006) also reported that the use of proper packaging maintained the quality of bananas during the handling stage.

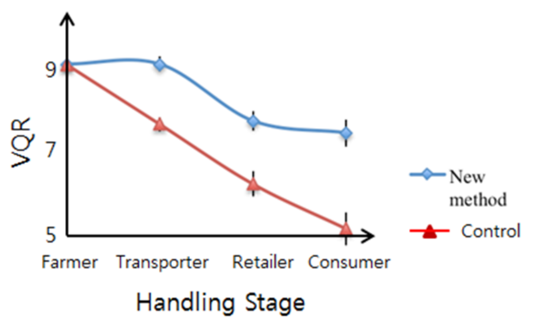

Figure 6. Comparison of visual quality of banana fruits between the control and the proposed method with cushioning layers. Visual quality ratings: 9, excellent (essentially no symptoms of deterioration); 7, good (minor symptoms of deterioration, not objectionable); 5, fair (deterioration evident, but not serious, limited salability); 3, poor (serious deterioration, limited usability); and 1, extremely poor (not usable)

At the consumer stage, the VQR of bananas transported under the newly proposed method was observed to be at a good level, whereas that of the bananas transported by the control method was fair, with evident but not serious deterioration resulting in limited marketability. The VQR of the banana fruits using the proposed packaging method maintained a significantly higher range compared to those using the control method. Previous researches have also stated that mechanical damage to fruits can affect the quality appreciation of the consumer, and that exposure of an injured area to the atmosphere leads to discoloration (Zhau et al., 2007). The VQR of bananas transported through the conventional method was categarized to be fair at the retailers, which influenced the retail price and salability, whereas the VQR remained at a good level for the produce transported using the Styroform cushioning materials. The cushioned bulk transport resulted in only minor symptoms of detrioration. This proves that the bulk transport of bananas using the proposed cushioning method minimizes the changes in visual quality along the supply chain.

Cost analysis

A cost benefit analysis was conducted to determine the economic feasibility of both packaging methods during transport from Thambuttegama to Colombo (Table 3).

Table 3. Cost-benefit analysis for Embul bananas using the proposed packaging method

Fixed cost	New method	Control
Packaging materials (Styrofoam sheets) (Rs/kg of bananas)	0.67	0
Operational cost		
Unit load per journey (kg)	1	1
Buying cost (Rs/kg)	32.00	32.00
Transport cost (Rs)	3.43	3.43
Handling (labor) cost (Rs)	0.51	0.34
Total operational cost (Rs)	4.16	3.77
Total cost per journey (Rs)	**36.38**	**35.77**
Weight loss (%)	5.10	9.82
Total weight loss (kg)	0.051	0.098
Net weight sold (kg)	946	902
Selling price (Rs/kg)	43.00	43.00
Total revenue (Rs)	**40.81**	**38.70**
Net profit per journey (Rs/kg)	**4.43**	**2.93**

The total packging cost for a single journey when using the 8-mm Styrofoam sheets was Rs 175.50 (1.26 $), whereas there was no additional cost for the coventional packaging (Table 3). The postharvest loss of bananas from mechanical damage during transport can be reduced from 9.8% to 5.1% using the proposed cushioning material. These results further show that the net profit is increased by 51.2% per journey when bananas are transported using the new method.

Conclusion

Mechanical damage can be reduced from 26.3% to 12.9% using 8-mm thick Styrofoam sheets as a cushioning material between banana bunch layers for the bulk packaging of bananas placed onto trucks for long-distance transport in comparison to the present conventional transport method. This field-level study further indicated that the use of the newly proposed packaging method reduces the physiological loss in weight, changes in fruit firmness, total soluble solids, and physical damage index. Further, it preserves the visual quality of the fruits during the distribution from the farmer to the consumer, which is one of the main factors affecting consumer preference and retail price. The additional cost for the new method per 1 kg of *Embul* bananas for a single journey is Rs 0.61, assuring an additional income of Rs 1.50. Therefore, the present net profit can be increased by 51.2% per journey by adopting the proposed packaging method.

Conflicts of Interest

The authors have no financial or other conflicting interests.

References

Al-Hosni, A. S., I. K. Al-Busaid, M. Al-Farsi, M. Al-Jabri and H. Al-Azri. 2010. Postharvest characteristics and qualities of selected banana (Musa spp.) cultivars in Oman. Proceedings of International Conference of Banana and Plantain in Africa, Acta Hort 879:407-411.

Anwar, M. and A. U. Malik. 2006. Hot water treatment affects ripening quality and storage life of mango (*Mangifera indica* L.), Pakistan Journal of Agriculture Science 44:23-30.

Armstrong, P. R., M. L. Stone and G. H. Brusewitz. 1997. Peach firmness determination using two different nondestructive irrational sensing instruments. Transactions of ASAE 40(3):699-703.

Dadzie, B. K. and J. E. Orchard. 1997. Routing postharvest screening of banana/plantain hybrids: criteria and methods. INIBAP technical guidelines No. 2. INIBAP, Montpelier.

Dharmasena, D. A. N. and K. H. Sarananda. 2012. Present status, issus, and future trends in fruit and vegetable handling, distribution and marketing in Sri Lanka. Workshop on postharvest technology and cold chain management. 20-22 March 2012. Amity International Centre for Postharvest Technology and Cold Chain Management, Noida, India. Available at http://www.fruits.soton.ac.uk/?page_id=111.

Ekanayake, S. and L. Bandara. 2002. Development of banana leather. Annals of the Sri Lanka Department of Agriculture 4:353-358.

Ferris, S., H. Waiwright and A. K. Thompson. 1998. Susceptibility of plantains (AAB) to mechanical damage. Fruits 50:101-107.

Gast, K. L. B. and R. Flores. 1991. Post harvest management of commercial horticulture crops. The Journal of the Agriculture Research 7(2):12-18.

Ilyas, M. B., M. U. Ghazanfar, M. A. Khan, C. A. Khan and M. A. R. Bhatti. 2007. Postharvest losses in apple and banana during transport and storage, Pakistan Journal of Agriculture Science 44(3):534-539.

Jindal, S., N. R. Beniwal, N. R. Godara and R. P. Sihag. 2005. Studies on the shelf-life of sapota fruits with polyethylene packaging. Haryana Journal of Horticulture Science 34(3):253-255.

Kader, A. A. and M. Cantwell. 2007. Produce quality rating scales and colour charts. Postharvest technology research and information center, UC Davis University, CA, USA.

Kudagamage, C., G. W. J. Chandrasiri and A. M. Z. Razmy. 2002. Analysis of long-term trends in banana sector of Sri Lanka. Annals of the Sri Lanka Department of Agriculture 4:21-32.

Liew, C. Y. and C. Y. Lau. 2012. Determination of quality parameters in Cavendish banana during ripening by NIR spectroscopy. International Food Research Journal 19(2):751-758.

Maia, V. M., L. C. C. Salomao, D. L. Siqueria, R. Puschman, V.

J. G. M. Filho. and P. R. Cecon. 2011. Physical and metabolic alterations in 'Prata Ana' banana induced by mechanical damage at room temperature. Sci. Agric 68(1):31-36.

Murthy, D. S., T. M. Gajanana, M. Sudha and V. Dakshinamoorthy. 2007. Marketing losses and their impact on marketing margins: A case study of banana in Karnataka. Agricultural Economics Research Review 20:47-60.

Ram, A., S. Rajbir, J. K. Jain and K. Anil. 2008. Maturity, transportation and storage study in strawberry fruit. Journal of Food Science and Technology 45(6):540-542.

Sanford, K. A., P. D. Lidster, K. B. McRae, E. D. Jackson, R. A. Lawrence, Stark, R. and R. K. Prange. 1991. Lowbush blackberry quality changes in response to mechanical damages storage temperature. Journal of American Society of Horticultural Science 116(1):47-51.

Sarananda, K. H. 2000. Country paper - Sri Lanka. Report of the APO seminar on appropriate postharvest technologies for horticultural crops in Asia.5-9 July, 1999, Bangkok, Thailand, 230-236.

SAS. 1994. Statistical analysis of software programme packages. SAS Institute version 6.0.

Singh, Z., J. Janes. and S. Nair. 2003. Packaging materials affect physiological weight loss, fruit colour and quality of mango during storage. Acta Horticulture 553:603-604.

Sultani, M., R. Alimardani and M. Omid. 2010. Comparison of some chromatic, mechanical and chemical properties of banana fruit at different stages of ripeness. Modern Applied Science 4(7):34-41.

Thakur, K. S., V. C. M. Reddy and B. B. Kaushal. 2005. Use of polypropylene box-liners and ethylene absorbents for retention of quality of staking delicious apple during marketing. Acta. Horticulture 696:463-466.

Vursavus, K. and F. Ozguven. 2004. Determination the effects of vibration and packaging method on mechanical damage in golden delicious apples. Turkish Journal of Agriculture and Forestry 28(5):311-320.

Wasala, W. M. C. B., C. A. K. Dissanayake, D. A. N. Dharmasena, C. R. Gunawardane and T. M. R. Dissanayake. 2014. Postharvest losses, current issues and demand for postharvest technologies for loss management in the main banana supply chains in Sri Lanka. Journal of Postharvest Technology 02(01):80-87.

Wasala, W. M. C. B., D. A. N. Dharmasena. T. M. R. DIssanayake and B. M. K. S Thilakarathne. 2015. Vibration simulation testing of banana bulk transport packaging systems. Tropical Agricultural Research 26(2):355-367.

Zhau, R., S. Q. Su, L. P. Yan and Y. F. Li. 2007. Effect of transport vibration levels on mechanical damage and physiological responses of 'Huanghua' pears (*Pyrus pyrifolia Nakai, cv. Huanghua*). Postharvest Biology and Technology 46(1):20-28.