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Assessment of Postharvest Handling of Banana Fruits and Associated Fungi in Ganmo Market, Kwara State, Nigeria

[*1]Garuba, T., [1]Atolagbe, B., [1]Yusuff, R. A., [2]Lawal, B. Y. and [3]Ishola, T. J.
[1]Department of Plant Biology, Faculty of Life Sciences, University of Ilorin, Ilorin.
[2]School of Science, Federal College of Education (Special), Oyo
[3]Salco Limited, Idu, Abuja
***Corresponding author:** garuba.t@unilorin.edu.nng**;** +2347030200083

Abstract
Banana fruit is vastly perishable and needs to be handled with cares to ensure its safety and reduce the loss. This study aimed at assessing various postharvest practices of banana fruits with associated fungi in Ganmo market, Kwara State, Nigeria. The study was done by purposive sampling for the selection of the study area. Pretested questionnaires were administered to gather pertinent information on the postharvest handling practices of the fruits within the study area. Fungi were isolated and identified from the apparently diseased fruits using the standard method. The results showed that loss of banana fruits is not restricted to a particular member of agricultural supply chain but occurs at all phases spanning from farmers through the wholesalers to the retailers. It was deduced that practices like poor sanitation, absence of temperature monitoring system, unsuitable packaging system and inappropriate transport system are responsible for the postharvest loss of the fruits. The highest fruit damage (62.5%) was observed in the samples from retailers. The same handlers also had the highest disease incidence (37.5%) and severity (15.63%). *Fusarium oxysporum*, *Saccharomyces cerevisae*, *Pichia kudriavzevii* and *Alternaria alternata* were frequently isolated from the deteriorated banana fruits. Good postharvest practices should be fostered and agricultural extension agents should promptly disseminate useful information to all fruit handlers.

Keywords: Banana; Damage; Fungi; Market; Postharvest loss

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Introduction

Banana is one of the oldest tropical fruits chiefly traded commercially and a major staple food crop grown in over 140 countries in the subtropics and tropics with an annual production of around 148 million metrics, feeding about 500 million people (FAOSTAT, 2016). It belongs to the Family Musaceae. More than 1000 varieties of bananas are in existence worldwide (FAO, 2020). The origin of the common name "Apple of Paradise" for bananas comes from reports from the Mesolithic era, when it was said that Eve covered her modesty in the Garden of Eden, also called the Garden of Paradise, with the leaves of the banana plant (De Langhe *et al.,* 2009; D'hont *et al*., 2012). Most cultivated species are seedless, and it is vegetatively propagated by suckers and rhizomes. Bananas are a crop that thrives in a variety of environments, bounces back fast from natural disasters, and can be grown in mixed and intercropping environments (Isreali and Lahav, 2017). *Musa* sp. grows

successfully only under constant high temperatures and in lowland humid conditions with continuous annual rainfall (De Langhe, 2007).

One of the utmost ten global food crops that support both food and cash crops in the tropics and subtropics is banana fruit (Jideani, 2019). After potatoes and tomatoes, bananas were the third most popular fresh food product in the world in 2013 with an aggregate annual fruit production of 144.5 million tonnes (Isreali and Lahav, 2017). Second only to cassava and taro (cocoyam), it is a highly significant staple food in Africa, Asia, Central America, and the Pacific islands (Isreali and Lahav, 2017). The high calorie and nutritional content of bananas makes them special. Compared to many other fruits, it is highly nutritious and easily digested. According to Mohapatra *et al*. (2010), the digestion time is 105 minutes longer than Apple's. They are also rich in vitamin B6, ascorbic acid and Potassium. Several indigenous and regional agro-based industries utilize banana fruits as the main raw material for the production.

Despite their importance, banana cultivation is threatened by various biotic and abiotic factors including pests, diseases, and environmental stressors. Among the biotic factors, fungal diseases are the most severe and widespread, causing significant economic losses to banana farmers globally (Ploetz, 2015). Owing to their high nutrient reserve and moisture content, bananas are especially vulnerable to various pathogenic fungi during the harvest and consumption period (Alemu, 2014). Various fungal pathogens can infect bananas at different stages of production and storage, including *Fusarium oxysporum*, *Colletotrichum musae*, and *Mycosphaerella fijiensis*, which cause *Fusarium* wilt, anthracnose, and Black Sigatoka, respectively (Wang *et al*., 2020). The black sigatoka leaf spot disease, which is caused by *Mycosphaerella fijiensis*, seriously hinders plantain and banana output in Sub-Saharan Africa. *Fusarium* wilt that is popularly called 'Panama Disease' is caused by *F. oxysporum* f. sp. *cubense* and the fungus was an impeding factor in banana industries (Vuylsteke *et al*., 1993).

Postharvest loss is a major problem of fruit growing countries of the world (Khan and Rafat, 2018). Poor postharvest practices including mishandling, transportation, improper sanitary measures, inadequate storage facilities and poor marketing practices (especially by retailers) are major causes of the post-harvest loss and are a serious threat to the availability of banana fruits. The fruit is perishable and any injury or damage to the fruit peel brought on by postharvest practices makes bananas more susceptible to pathogens. It was observed during preliminary survey that large percentage of banana fruits is lost before it gets to the consumer. The cause of the loss is multifaceted and cannot be narrowed down to a singular source. In other to make plan for disease control, it is important to have knowledge of pathogenic organism associated with fruit during storage period (Khan and Rafat, 2018). Hence, it becomes necessary to provide germane information on the various postharvest handling practices that contribute to the loss of market values of banana fruits along agricultural value chain. Therefore, this study aimed at assessing and evaluating practices that influence postharvest loss and isolate the fungi that may be accountable for the deterioration of banana fruits in the area of the study.

Materials and Methods

The study Area

The evaluation was done in Ganmo Market, Ifelodun Local Government Area, Kwara State (8° 25′ 08.96″ N, 4° 36′ 25.64″ E). Ganmo market is one of the cheapest food markets in the state. The market operates everyday but it is populated both with buyers and sellers every 5 days. Most traders (farmers, wholesalers and retailers) display the fruits on bare ground by the road side; some display them on long benches, aluminium bowl (mostly rusted). Others place them on large aluminium trays while it is hawked by some from one point to the other.

Banana Fruits Handling Practices in Ganmo Market.

Banana fruit handling practices were assessed using the method of Kuyu and Tola (2018). Retailers, wholesalers and farmers were assessed and interviewed using purposively structured questionnaires. Specific banana vendors and dealers in the research area were chosen using two-stage sampling approaches. In the first procedure, the Ganmo marketplace was advertently chosen because it is one of the places in the state where the fruits are majorly traded, almost all varieties of banana are available and all the individuals involved in the banana channel of distribution are available in this market. In the second approach, a simple random sampling method was used, and out of 100 respondents, 23 farmers, 33 wholesalers and 44 retailers selling banana fruits in the open market were selected using Yamane (1967) sample size determination formula. Interviews concerning postharvest practices, market cleanliness, and storage procedures were conducted with the chosen respondents via a self-administered questionnaire technique. In addition, during the period of data collection, the temperature of the marketplace was noted for five (5) consecutive days, and the average temperature was recorded for each day.

Fruit Damage, Disease Incidence and Severity Assessment

The assessment of damaged fruits, disease incidence and severity was done using the method of Kuyu and Tola (2018). For the fruit damage, 48 fruits (both injured and seemingly healthy fruits) were purposefully sampled based on the volume sold from the farmers selling fruits in the open market (n = 16), wholesalers (n =16), and retailers (n = 16) with three replicates for each. Using the bus, all of the sampled fruits were brought to the laboratory and kept at room temperature for further evaluation. Percentage of damaged fruits was determined using the formula stated below:

$$\text{Percentage fruit damage} = \frac{\text{Number of damaged fruits}}{\text{Total number of fruit samples}} \times 100$$

Percentage disease incidence was determined using the method of Ogbo and Oyibo (2008) as shown below:

$$\text{Percentage disease incidence} = \frac{\text{Number of infected fruits}}{\text{Total number of fruit samples}} \times 100$$

The severity of disease was evaluated following the method of Duamkhanmanee (2008) and Kuyu and Tola (2018). The assessment was conducted by examining fungal symptoms of a disease on the infected region of the fruit. It was measured on a 1–6 scale in which no infected surface area scored 1, whereas the infected surface areas of >0%–5%, >5%–25%, >25%–50%, >50%–75%, and >75% scored 2, 3, 4, 5, and 6, respectively. The percent severity index of fungal infection was then estimated from the numerical ratings of the total samples using the following formula.

$$\text{Percentage severity index} = \frac{\text{Sum of numerical ratings}}{\text{Total number of fruit examined} \times \text{Maximum grade}} \times 100$$

Isolation and Identification of Fungi Associated with Banana Fruit.

The isolation was done following the procedure of Garuba et al. (2022). After surface sterilizing the samples of spoiled banana fruits for two minutes using a swabbing technique with 70% ethanol, they were rinsed multiple times with sterile distilled water and blotted dry with sterile filter papers. The pre-sterilized fruits were placed in a desiccator enclosing a sterilized cotton wool, soaked with distilled water to generate a micro-humidity chamber of 100% relative humidity. This was done to promote the growth of fungi. Apparently diseased areas in the banana fruits were cut and aseptically inoculated into petri-dishes containing Potato Dextrose Agar that was previously supplemented with streptomycin. The plates were incubated at 25 ± 2 °C. After series of subculturing, pure cultures for each fungal isolate were gotten from emerging mycelial colonies and maintained on PDA

slant in McCartney bottles. The McCartney bottles were kept and maintained at 4 ºC.

All the fungal isolates were identified based on macromorphological and micromorphological features of the pure cultures. The macromorphological features observed were the pattern of growth (whether filamentous or colonial), the superficial colour of the colony, and the colour of the opposite side of the plates. The type of the hyphal wall (thick or thin and shape), the nature of the spores, the colour of the hyphae, presence or absence of septa, type and nature of reproductive structure (sporangiophore or conidiophore), shape and colour of the spore were examined microscopically (Fawole and Oso, 2007). The manual and reference books were used as a guide for identification (Cambell and Stewart, 1980; Barnett and Hunter, 2010).

Results and Discussion

Socio-demographic Characteristics of Banana Fruits Vendors in Ganmo Market.

Among 100 banana traders questioned, their sex, age, and levels of education were measured as shown in Table 1. It was observed that 23% of respondents were male and 77% were female in the group of gender. This testified to the report of Kayu and Tola (2018) who affirmed that more females engaged in banana fruit selling than males.

In the age groups, least percentage (12%) was found in age group less than 25 years. The maximum of (36%) interviewees were between 35 and 45 years of age. It was deducted from the results that about 70% of banana handlers in the study area fall within the range of the age group of 25-45 years. Findings on literacy levels revealed that 31% of banana handlers did not attend any former school (illiterates), 69% of them acquired formal education (literates). All respondents under literate category are aware of consequential effects of poor postharvest activities of agricultural produce especially banana fruit. Education plays a significant role in increasing awareness and understanding the postharvest handling practices in the banana vending business but individuals with secondary level of education tend to comprehend handling practices more effectively than those with primary education (Ploetz, 2015). Additionally, Ortega and Ruiz (2018) noted that education empowers individuals to comprehend the significances of handling practices, especially in comparison to those who are illiterate. Education makes it possible to comprehend how handling methods affect agricultural produce after harvest and encourages better handling methods than illiteracy (Babalola, 2011).

Banana Fruits Postharvest Practices in Ganmo Market

In Ganmo market, series of improper handling techniques that lead to postharvest loss of fruits were found during the examination of banana fruit handling procedures. These practices highlight the need for improved postharvest handling methods to mitigate loss and enhance the overall quality of banana fruit in the market.

Table 1: Socio-demographic data of banana fruits sellers in Ganmo market.

Socio-demographic characteristics of banana Fruit vendors		Frequency	Percentage
Sex	Male	23	23%
	Female	77	77%
Age	<25	12	12%
	25-35	34	34%
	35-45	36	36%
	>45	18	18%
Level of Education	Literate	69	69%
	Illiterate	31	31%

Mode of banana fruits transportation to the market and packaging material

Banana fruits in Ganmo usually use bus, car, truck, and bike (motorcycle) as a means of transportation to convey their goods to the market. The findings indicated that 43 (43%) of the respondents used a bus to deliver their banana fruits to Ganmo Market, 17 (17%) used a car, 31 (31%) used a bike, and the remaining respondents either carried the fruit on their head or used a truck (Figure 1). The few that carries it on their head are mostly retailers that had probably gotten it from farmers living in places very close to the market. It was observed that the mode of transportation depended on the distance to the market where the fruits would be sold (Adewoyin *et al*., 2021).

About 45% of the respondent used sack to package banana fruits and the remaining 55% of them used basket, cloth, and plastic as shown in Figure 2. Packaging is very crucial in mitigating loss of agricultural produce Low-quality packaging materials can hasten the deterioration of fresh produce by not providing enough protection against damage (Elik et al., 2019). Moreover, delayed transportation after packaging increases susceptibility to physical damage such as bruising and punctures which made the fruits more prone to fungal infections (Ali *et al*., 2011; Tirillini *et al*., 2011).

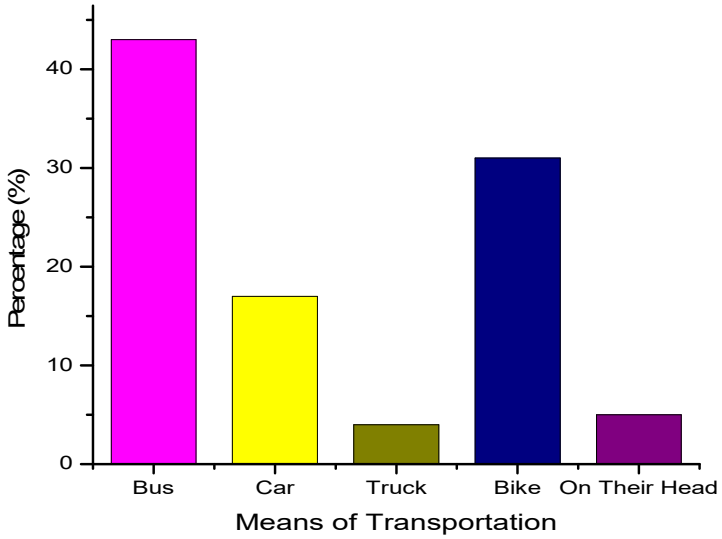

Figure 1: Percentage of respondents using different means of transportation

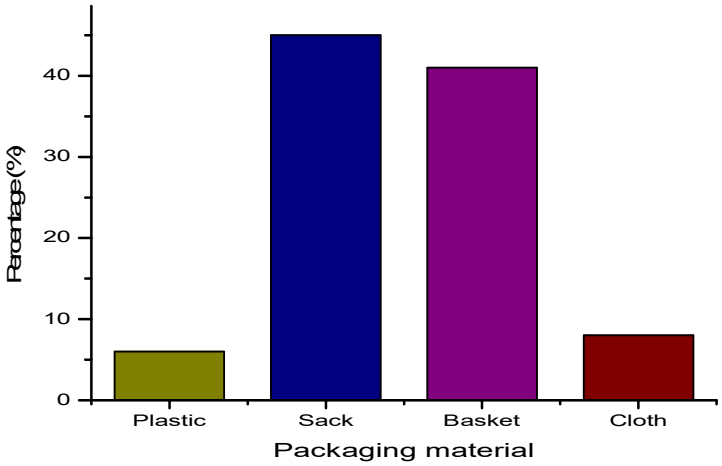

Figure 2: Percentage of respondents using different packaging materials for banana fruit

Temperature and Relative Humidity of the Market Area

The temperature of the marketplace was noted for five successive days and ranged from 26.7 to 41.1^{0}C and the relative humidity was from 36 to 50%. About 51% of the interviewees market the fruits in an open space but only 21% and 28% of them hawk and sell in the shop respectively (Figure 3). It can be inferred that 72% of the sellers exposed banana fruits to a direct sunlight (open space and hawking) which cause scotching (Hofman *et al.,* 2011). Sunburn not only affects the appearance of the fruit but also weakens the peel, making it more susceptible to fungal infections. Most of the bananas sold at Ganmo market are vulnerable to sunburn. Bananas are highly sensitive to changes in humidity. High humidity in storage areas promotes the growth of fungal pathogens, particularly *Botrytis cinerea,* which causes grey mold and encourage accumulation of surface moisture on the fruit, creating an ideal environment for fungal spores to germinate and infect the fruit (Lurie, 2017).

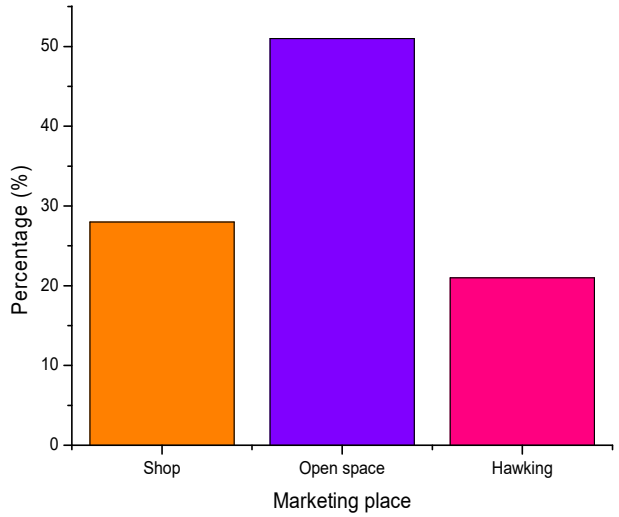

Figure 3: Percentage of respondents selling banana fruits in different marketing places in study area

Sanitation state of the marketplace

The practice of stacking all fruits in packaging materials is common among food vendors. It was observed (Table 2) that 98% of fruit vendors usually separate healthy fruits from diseased ones to avoid cross-contamination (Jennylynd, 2006). It is phytopathologically advisable and economically encouraged to maintain the practice of fruit sorting so as to minimize postharvest loss.

More than average of the respondents (64%) disclosed that market places are dusty and filthy, with 27% attested to the presence of agricultural refuse, cow dung, mud, and other solid wastes. The presence of such waste materials in marketplaces has precarious ecological, social, and economic consequences that pose health and sanitation challenges on the fruit vendors and consumers (Abadi *et al*., 2021). However, its presence in public areas, especially in marketplaces, raises sanitation and hygiene concerns. Proper waste management and sanitation practices are essential to address these challenges and ensure the cleanliness and safety of public spaces.

The respondents (63%) revealed that banana fruits are not kept with other fruits. This is observed to be a good practice in postharvest management because one fruit may be tainted by the odour giving off by another and optimal storage temperature and relative humidity for different fruits differ widely (DPIRD, 2023). Besides, Mixed-fruit storage could have harmful influence on quality, due to fluctuating ethylene sensitivities (Aurelie et al., 2020). Storing

fresh fruits and vegetables is crucial in maintaining their quality and preventing losses during transportation and storage. Storing materials or container should possess enough stacking strength to withstand crushing in a low temperature and high humid environment (Boyette *et al*., 1996). Bananas are susceptible to microbial contamination, and improper storage or handling practices can exacerbate this risk of cross-contamination (Kuyu and Tola, 2018).

Additionally, 75% of respondents disclosed that banana fruits cannot be stored for a week. This alludes to the perishable nature of bananas and the need for proper storage and handling practices. Proper storage conditions, such as refrigeration, can help extend the shelf life of banana fruits (Kusumaningrum *et al*., 2015). For example, a study found that storing bananas in moist sawdust can improve their shelf life, while refrigeration at 4℃±1 seemed to be the best suitable condition for lengthening the instigation of ripening of banana varieties used. Additionally, the use of appropriate packaging materials can help maintain the quality and storage life of banana fruits (Hailu *et al*., 2014).

The finding that 77% of respondents do not buy apparently diseased banana fruits from the market reflects consumer awareness and concern regarding the quality and safety of the produce. This observation aligns with the perishable nature of bananas and the potential risks associated with purchasing diseased or contaminated fruits. Consuming a diseased fruit can lead to various problems such as foodborne illness (Gandhi and Chinkindas, 2007). Proper handling, storage, and sanitation practices are essential to mitigate these risks and maintain consumer confidence in the fruits available in the market.

Table 2: Data on problems associated with sanitation and marketplace

Interview statements	Yes Frequency [%]	No Frequency [%]
Have you kept infected or damaged fruits and healthy fruits apart in storage?	98 (98)	2 (2)
Is there no dust or pest infestation in the surroundings or the shop?	36 (36)	64 (64)
Is there no mud, animal manure, or trash in the area?	73 (73)	27 (27)
Have you stored banana fruits with other fruits/commodities?	37(37)	63(63)
Is it possible to keep banana fruits in your store for a week?	15(15)	75(75)
Do people buy apparently diseased banana fruits from you?	23(23)	77(77)

Percentage of Fruit Damage

At the market, the percentage of fruit damage differed among the fruit sellers as shown in Figure 4. The result showed that the highest damage (62.5%) was recorded in samples collected from retailer's shop, while the sample from the farmers had the lowest damage (31.5%). Several factors may be responsible for the damage across all handlers' levels including poor transport system, improper postharvest storage and poor marketing conditions (Warton *et al*., 2000). During the study, it was noted that bunches are piled high on the ground to ripen, and that stacking one bunch on top of another may cause physical harm to bunches.

Incidence and Severity of Fungal Pathogens

The average percentage of disease incidence and severity differed among banana fruit traders (Table 3). The highest incidence (37.5%) was observed in samples obtained from retailer's shop followed by samples from wholesalers (18.75%). In a similar vein, retailer's shops had the highest mean percentage of disease severity and minimum severity was recorded in the samples from farmers. The percentage of fruit damage

recorded is consistent with the mean percentage of disease incidence and severity. This showed that mechanical injury during handling at different periods along postharvest chain exposes the fruits to microbial invasion (Hailu *et al*., 2012). The difference in respect of fruit damage, percentage disease incidence, and severity among the fruit sellers could be attributed to storing methods and ripening stage (Debela *et al*. 2011; Kuyu and Tola, 2018).

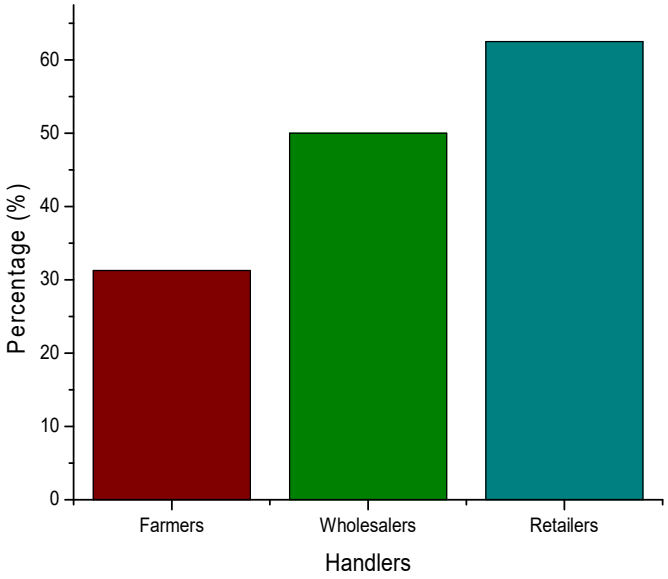

Figure 4: Percentage of fruit damage from different fruit handlers in Ganmo market.

Table 3: Percentage of Disease incidence and severity from different fruit handlers in Ganmo market

Fruit sellers	**Incidence**(%)	**Severity(%)**
Farmers	12.5	10.41
Wholesalers	18.75	11.46
Retailers	37.5	15.63
Overall mean	22.92	12.5

Isolation and Identification of Fungi from Banana Fruits

From this study, *Fusarium oxysporum, Saccharomyces cerevisae*, *Pichia kudriavzevii* and *Alternaria alternata* were frequently isolated and identified from the samples. This is in tandem with the work of Sarkar *et al*. (2009) that had previously reported all the fungi except *P. kudriavzevii. F. oxyporum* is among the most devastating soil-borne fungi that affect banana production worldwide causing Panama disease (Cumagun *et al*., 2007). It is mycotoxigenic and produced arrays of mycotoxins including fumonisins, zearalenones and deoxynivalenol (Alghuthaymi *et al*., 2020). *S. cerevisae* (yeast) is a unicellular fungus that plays a vital role in fermentation. The fungus ferments banana fruits and convert the sugar to alcohol (Alvarenga *et al*., 2011).

Conclusion

From this present investigations, it can be concluded that banana fruits are perishable and prone to mechanical injury and pathological damage. The significant loss of the fruits can be attributed to their inappropriate postharvest handling. Mishandling also exposed the fruits to fungal infection that can reduce the nutritional quality and pose a severe health challenge. Proper postharvest management should be

encouraged and pertinent information should be disseminated to the banana fruit handlers, especially retailers that recorded the highest loss. A good sanitary measure would also go a very long way to reduce postharvest loss of banana fruits.

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