International Journal of Agricultural Science, Research and Technology in Extension and Education Systems (IJASRT in EESs)
Available online on: http://ijasrt.iau-shoushtar.ac.ir
ISSN: 2251-7588 Print
ISSN: 2251-7596 Online
2022: 12(4):225-233, *DOR: 20.1001.1.22517588.2022.12.4.5.0*

Received: 15 July 2022
Reviewed: 01 September 2022
Revised: 10 September 2022
Accepted: 20 October 2022

Post-Harvest Losses and Reduction Techniques in Crop Production: A Review.

Ogedebgbe Tolulope Comfort[1]., Malomo Olorunfemi James[1]., Akanji Nike Elizabeth[2]

[1]*Department of Agricultural Extension and Rural Development, Faculty of Agriculture, University of Ilorin, Kwara State, Nigeria*
[2]*Department of Agricultural Extension and Rural Development, Faculty of Agriculture, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria*

Abstract

Post-Harvest Losses are fast becoming a major problem causing huge losses for farmers and various countries at large. This challenge has resulted in various attempts to reduce the losses as much as possible. Crop production is essential to food security sustenance, hence post-harvest losses are undesirable as it results in a threat to life and a reduction in Farmers income. This study reviews post-harvest losses, with the focus on developing countries, as they are mostly affected. It is imperative to study post-harvest loss taking cognizance of its ability to pose threat on food security most especially in the developing countries where a high post-harvest loss occurs during storage. The post-harvest losses in vegetables, fruits, and cereals were studied. Measures and technologies that can be adopted to reduce post-harvest losses has been discussed. Many developing countries are still struggling to minimize post harvest losses because of lack of modern techniques, technologies and approaches, and this has continued to cause food insecurity across many developing nations. Smart farming techniques like the internet of time (iot), extension trainings and the use of various advance storage structures has been identified as measures for reducing post-harvest losses of crops. The application of these measures will drastically reduce post-harvest losses and this reduction will definitely result in a wider advantage.

Keywords:
Crop, Farmers, Losses, Post-harvest, technology

1. Introduction

Postharvest loss occurs within the farm-to-market period during harvesting, handling, storage, and distribution of food. Postharvest loss includes the food loss across the food supply chain from harvesting of crop until its consumption (Aulakh et al., 2013). Food losses are mainly due to physical damage (through rough handling, unsuitable environmental conditions, poor quality containers used for transport and storage), poor temperature management after harvest, lack of access to facilities and equipment for proper cooling, food processing, or storage (Kitinoja, 2016). These losses lead to global hunger by reducing food supply and the purchasing power of farmers and thereby reducing financial gains from crops (Kitinoja, 2016).

Food security has been defined as the situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2011). One third of food crops is lost yearly in the world. World population has been predicted to increase to 9·1 billion by year 2050, hence, a 70 per cent increase in food is needed in the future (FAO, 2009). Therefore, it's necessary to give more attention to post harvest loss considering the increase in food demand from the ever increasing world's population. Reducing food loss is an important part of ending hunger.

The hit of COVID-19 pandemic on the agricultural sector of most developing countries has resulted to a decline in production (Adebisi et al., 2021), hence the lesser quantity produced should be protected from post harvest loss if food security must be achieved. The availability of sufficient food is related to the overall ability of the agricultural system to meet the demand for food (Dharmathilake et al., 2020). The current practice of producing nearly twice as much food each year as necessary for consumption, then throwing half of it away is detrimental to human survival. Whenever food is wasted, so are the land, seeds, agricultural inputs, water, energy, and labor resources that went into producing it wasted (Kitinoja, 2016). Food security requires more than increasing production and total food supply, it also involves the act of preserving the quality and quantity of the available food for human consumption.

Undoubtedly, the reduction of post-harvest losses is a viable strategy for improving livelihoods of farmers as the more wastages is prevented, the higher the income that will be realized. Post-harvest loss contributes to the supply chain, hence, leads to high food prices in the market and thereby hightens food security (Sisay, 2022).

In developing countries, citizens make the best use of the food produced; however, a significant amount of produce is lost in postharvest operations due to a lack of knowledge, inadequate technology and/or poor storage infrastructure. On the contrary, in developed countries, food loss in the middle stages of the supply chain is relatively low due to availability of advanced technologies and efficient crop handling and storage systems (Figure 1). However, a large portion of food is lost at the end of the supply chain, which is known as food waste. Food waste can be defined as food discarded or alternatively the intentional non-use of food due to spoilage/expiration of food (FAO, 2014).

2. Extensive Review

2.1 Overview of crop production and post-harvest losses

The loss of quality and quantity of crops after harvest is conversant with both developed and developing countries. Loss of product quantity which refers to quantity losses is rare in developed countries but common in developing countries (Alavi et al., 2012)**.** While, loss of calorie content, nutritional composition, acceptability and digestibility of food product refer to quality loss (Abass et al., 2014). Loss of quality, nutritional value and deterioration, loss of viability and commercial losses are generally referred to as post-harvest losses (FAO, 2017). Postharvest loss accounts for direct physical losses and quality losses that reduce the economic value of crop, or may make it unsuitable for human consumption. In severe cases, these losses can be up to 80% of the total production (Fox, 2013). Post harvest loss has been known to cause wastage of 10-15% of primary horticultural crops in developing nation's and about 20-40% in underdeveloped ones (Nita and Aradhita, 2022).

In African countries, these losses have been estimated to range between 20% and 40%, which is highly significant considering the low agricultural productivity in several regions of Africa (Abass et al., 2014). According to the World Bank report, sub-Saharan Africa (SSA) alone loses food grains worth about USD 4 billion every year (Zorya et al., 2011).

2.2 Post-harvest Loss in Cereals

Wheat, rice, and maize among other grain cereals are the most popular food crops in the world, and are the basis of staple food meant for consumption in most of the developing countries. Reducing cereal's post harvest losses would definitely be an efficient way that can help in promoting food security, sustainably fighting hunger, reducing the agricultural inputs needed for production, rural development, and improving farmers' livelihoods.

The process of grain deterioration is primarily driven by aerobic respiration of fungi as they consume carbohydrates in the kernel giving of CO2, H2O and heat. Mycotoxins are produced by some types of storage mould. The common types which pose a risk to human and animal health are Deoxyvalenol, Ochratoxin, Aflatoxin, Zearalenone, Fumonisin (Ileleji, 2010).

Insect pest was considered as main source of grain loss during storage in three -Saharan African countries, Uganda, Tanzania and Malawi, and at farm level the loss was estimated at 1.4 to 5.9 per cent (Kaminski and Christiaensen, 2014). Insect infestation was reported to have caused over 50% loss of maize in Ghana (Boxall, 2002). Rodents and fungal disease during storage is the main cause of post-harvest losses in maize in Vietnam (Alavi et al., 2012). Yearly, the loss of food grains in India is equal to the food demand of 1/3 or the population which is 12-16 million metric tonnes (Nagpal and Kumar, 2012). In Nigeria, the estimated loss of rice during food supply chain was 56.7 billion Nigerian naira. Rice losses ranges from 8 to 26 percent in China (FAO, 2017a; Majumder et al., 2016). In order to achieve effective storage of some cereals, in the last few years, various hermetic storage options such as purdue improved cowpea storage, super grain bags, metallic soils etc. has been widely promoted which is cost-effective storage technology and popular in several countries.

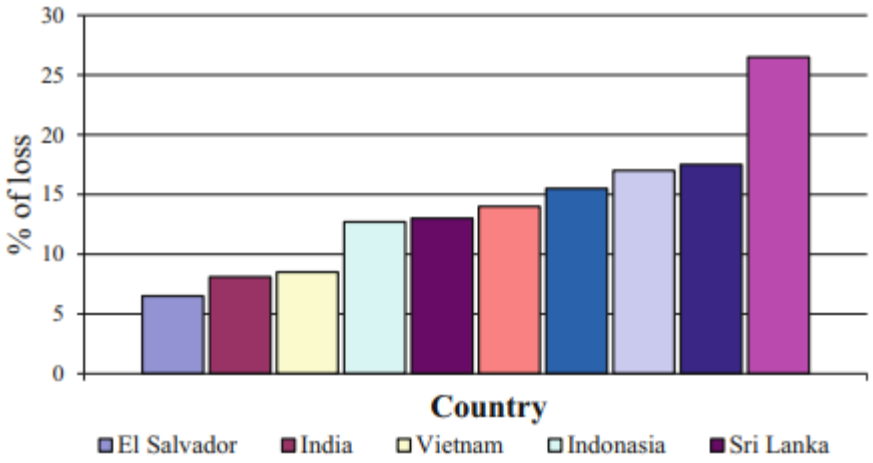

Figure 1. Post-harvest losses in the rice value chain in various countries according to FAO (2017a, 2017b)

2.2.1 Micro-organisms and Cereals Loss

Microbial spoilage of grains is majorly caused by filamentous fungi. The rate of damage is determined by microbial density, diversity, moisture content, percentage of damaged grain, the gas composition of storage, time span, etc. Microbial spoilage causes a reduction in nutritive value, off odour, abnormal coloration, deterioration in milling and baking property (Schmidt et al., 2018).

2.3 Post Harvest Loss in Fruits and Vegetables

Improper handling, storage, preservation techniques and microorganism spoilage increase the postharvest losses in fruits and vegetables up to 40 per cent (Singh et al., 2014). Due to high water activity, fruits and vegetables are considered more perishable and nearly 33 per cent of total fruits and vegetables produced get spoilt during harvesting to marketing (Kader, 2005). Total of 30-40 per cent fruits and vegetables wastage occurs within harvesting to consumption (Salami et al., 2010). Market demand determines the time of harvesting vegetables among rural vegetable farmers because they lacked the proper storage facilities, therefore they harvest vegetables base on market demand (Ogedengbe and Akanji, 2022).

In developed and developing countries, the losses of fruits and vegetables are estimated to be around 5-30 per cent and 20- 50 per cent, respectively (Kader, 2002). However, with the help of modern techniques and approaches, developed countries have minimize postharvest losses to some extent due to less mechanized methods, but developing countries are still facing a big challenge (Hodges et al., 2011; Nayak et al, 2018). The level of post harvest loss of fruits depends on the marketing channel being assessed, which includes variables such as time taken to market the crop i.e. delays in marketing as well as the distance to market i.e. damage during transport (Sreenivasa et al, 2009). Tomatoes and fresh radishes are sold as hastily as possible because they are highly perishable, while the likes of cabbage and cauliflower can be kept much longer and are often transported to distant markets for sale (Kitinoja, 2016). According to findings, the levels of reported losses worldwide for fruits and vegetables doesn't seemed to have changed much between the 1970s (when the 30 to 40% losses estimate was first published by the National Academy of Sciences) and the present time (Kitinoja, 2016).

From table 1 above, the post-harvest loss of vegetable crops was higher than those of fruit crops. Tomatoes had the highest percentage of physical loss experienced on the farm, while more cabbages were lost to mechanical damage on the farm (54%), as compared to other fruits and vegetables. The percentage of Amaranths lost at the wholesale market was ridiculously high compared to others, this may be as a result of lack of/poor storage facility. This definitely would lead to poor or no profit gained by the wholesaler. Post-harvest loss of Tomatoes was high in Ghana compared to Benin, Rwanda and India, this may be as a result of agricultural practices, poor post-harvest handling or lack of proper storage facilities. The highest level of post-harvest loss of most fruits was experienced at the wholesale Market, followed by the retailers. This may indicate that the farmers harvested the fruits before they are ripe or as soon as they are ripe and push them to the wholesalers who later bears the brunt of post-harvest loss.

Table 1. Postharvest losses of fruits and vegetables in Ghana, Benin, Rwanda and India at the farm (F), wholesale market (WS) and retail market (R).

Country	Commodity	Method Used	Physical Losses (% sorted out and discarded)	Quality Losses (% mechanical damage)	Quality Losses (% decay)
Ghana	Tomatoes	Sampling	25.1 (F), 21.5 (WS), 3 (R)	33.5 (F), 21.5 (WS), 10.5 (R)	17 (F), 14 (WS), 11.5 (R)
Ghana	Cabbage	Sampling	20.1 (F), 6.5 (WS), 28.1 (R)	54 (F),32 (WS), 45 (R)	13 (F), 8 (WS), 5 (R)
Ghana	Eggplants	Sampling	13.9 (F), 11.3 (WS), 16.2 (R)	22 (F),19 (WS), 9.5 (R)	2.8 (F), 2 (WS), 0 (R)
Ghana	Mangoes	Sampling	6 (F), 10.4 (WS)	2.3 (F),5 (WS), 8 (R)	2.5 (F), 0.4 (WS), 1 (R)
Ghana	Okra	Sampling	16.6 (F), 2.3 (WS), 6.3 (R)	28 (F),4.5 (WS), 15 (R)	6 (F), 0 (WS), 8.5 (R)
Benin	Tomatoes	Sampling	23 (F), 31.2 (WS), 26.4 (R)	29 (F),27.5 (WS), 31.2 (R)	24 (F), 21.2 (WS), 27.5 (R)
Benin	Peppers	Sampling	5.9 (F), 6.2 (WS), 11 (R)	15 (F),7 (WS), 10 (R)	24 (F), 18 (WS), 8 (R)
Benin	Amaranths	Sampling	17.3 (F), 17.3 (R)	34.5 (F), 89.5 (WS), 79 (R)	47 (F),
Benin	Oranges	Sampling	10 (F), 11.6 (WS), 10.9 (R)	15 (F),41 (WS), 51 (R)	5 (F),16.4 (WS), 6.5 (R)
Rwanda	Tomatoes	Sampling	7.8 (F), 10.7 (WS), 14.7 (R)	2 (F), 11 (WS), 12.5 (R)	6 (F), 7 (WS), 6.5 (R)
Rwanda	Amaranths	Sampling	8.3 (F), 2 (WS), 25 (R)	18.5 (F),15 (WS), 32 (R)	7.5 (F), 12.5 (WS), 13.5 (R)
Rwanda	Bananas	Sampling	14.8 (F), 35.1 (WS), 30.1 (R)	7.5 (F),19 (WS), 25 (R)	0 (F), 9.5 (WS), 0 (R)
Rwanda	Pineapples	Sampling	10.4 (F), 17 (WS), 15.9 (R)	11.8 (F), 20 (WS), 21 (R)	0 (F), 2.9 (WS), 2 (R)
India	Tomatoes	Sampling	8.7 (F), 15.1 (WS), 16.4 (R)	10.5 (F),7.5 (WS), 16 (R)	5 (F), 7 (WS), 8.5 (R)
India	Cucurbits	Sampling	12.7 (F), 3.8 (WS), 9.2 (R)	9 (F), 6 (WS), 5 (R)	4.5 (F), 7 (WS), 5 (R)
India	Okra	Sampling	18.5 (F), 7.9 (WS), 10 (R)	8.8 (F), 3.8 (WS), 6 (R)	2.6 (F), 2 (WS), 8.8 (R)
India	Mangoes	Sampling	6.5 (F), 7.9 (WS), 7.1 (R)	6.5 (F),6 (WS), 9.5 (R)	5 (F), 7 (WS), 7.5 (R)
India	Litchis	Sampling	9.8 (F), 11.4 (WS), 10.1 (R)	14 (F),6 (WS), 10 (R)	8.5 (F), 8 (WS), 8.7 (R)

Source: Kitinoja (2016)

2.3.1 Micro-organisms and Fruits and Vegetable Loss

As a result of high moisture and nutrient content, fruits and vegetables are highly susceptible to microbial spoilage caused by fungi, bacteria, yeast and moulds (Naresh and Pratibha, 2021). Fungal and bacterial diseases causes a high loss of fruits and vegetables during the post-harvest period (Yahaya and Mardiyya, 2019). Species of Alternaria, Fusarium, Penicillium, Aspergillus, Geotrichum, Phytophthora as well as Botrytis have been reported as common pathogens implicated with postharvest diseases of tomato fruits, which leads to as much as 10-30% reduction in the yield of major tomato crops (Etebu et al., 2013).

Both qualitative and quantitative food losses of extremely variable magnitude occur at all stages in the post-harvest system, processing and marketing to final delivery to the consumer. Estimates of the post-harvest losses of food grains in the developing world from mishandling, spoilage and pest infestation are out at 25 percent; this means that one-quarter of crop production done with money become wasted. Fruits, vegetables and root crops are much less handy and are mostly quickly perishable, and if care is not taken in their harvesting, handling and transport, they will waste, particularly if it can economically be avoided, would be of great significant to farmers and consumers.

2.4 Other Losses from Post-Harvest Losses

2.4.1 Economic Loss:

About one-third of the world's food (about 1.4 billion tons), estimated at around USD 1 trillion, is lost annually during the post-harvest operations and post-harvest treatments (FAO, 2016). When food produce is lost, then all the expense that was incurred for the portion that wasted is lost. Furthermore, the farmers profit is reduced.

2.4.2 Environmental Loss:

In addition to economic and social implications, postharvest losses also impact the environment, as the land, water and energy (agricultural inputs) used to produce the lost food are also wasted along with the food. Unutilized food also results in extra CO2 emissions, eventually affecting the environment. A report from the Food and Agriculture Organization of the United Nations (FAO) using the life cycle perspective, estimated about 3.3 Gtonnes of CO2 equivalent emissions due to food that was produced but not eaten, without even considering the land use change (FAO, 2013). The blue water footprint (water use during life cycle of food) for the wasted food globally was estimated to be about 250 km3 (Fox, 2013). Similarly, the land used to grow the food is another valuable resource that goes to waste due to these losses. A study conducted on rice postharvest losses in Nigeria estimated that the lost paddy accounted for 19% of the total cultivated area (Gesellschaft, 2014). On the global scale, about 1.4 billion hectares of land was wasted by growing food that was not consumed in the year 2007, an area larger than Canada and China (FAO, 2013).

2.5 The Need for Proper Storage Facility

Losses like calories loss, quantity loss, and quality loss are faced by farmers as a result of lack of proper storage facilities after crop's harvest. However, with appropriate storage methods, these losses can be reduced by 1-2 per cent (Obiedzińska, 2017). The use of scientific storage methods can reduce post-harvest losses by up to 1–2% (Obiedzińska 2017). As a result of advance technology, middle stage supply chain losses are low in developed countries than developing countries (Gill and Sharma, 2021).

2.5.1 Technology for Post-Harvest Loss Reduction

Post-harvest losses during storage of plant produce can be reduced by using efficient storage technology, updated infrastructure and good storage practices. Losses associated with storage of plant raw materials can be reduced with effective storage technology (Jagjeet and Surabhi, 2021). The World Food Programme (WFP), in collaboration with governments and nongovernmental organizations (NGOs), carried out operation trials in Uganda and Burkina Faso to investigate the impact of improved postharvest management practices and the application of new storage technologies to crop losses after harvest (Costa 2014). Irrespective of the duration of cultivation or storage, the use of improved practices and new technologies contributed to reducing the food loss by around 98% (Abedin et al. 2012). The University of Guelph, Canada invented a patented technology using a safe, plant-derived chemical compound (hexanal) that reduces postharvest losses. Also, researchers in Israel announced at the AgriTech 2015 Conference on Global Food Losses and Waste that they are commercializing an edible coating that can reduce food losses at ambient temperature and protect fresh produce from water loss and decay for up to one month (Kitinoja, 2016). Tamil Nadu Agricultural University in India has also developed a nano-film to extend the shelf life of fruits and vegetables, and the Industrial Technology Institute in Sri Lanka has a bio-wax formulation that helps to reduce postharvest damage. (Kitinoja, 2016).

● Smart Farming Techniques:

Internet of Things (IoT); is very helpful to reduce post-harvest losses in storage and in supply chain (Parfitt et al, 2010). It can help to collect data to monitor and manage practices so as to reduce losses from seedling to harvest (Fox T, 2013). IoT helps in knowing the weather and other climatic conditions and also process data for remote farms (FAO, 2014). The technology was introduced in the year 2010 in agriculture and showed incredible potential and growth (Hodges et al).

● Extension Trainings

Education and skill-building initiatives by extension agents will be helpful to small scale farmers in reducing post-harvest loss. An effective tool for encouraging smallholder farmers to reduce food waste is to teach them how to determine the costs and benefits of potentially useful postharvest innovations. Also, informing the farmers on the available postharvest technology and it cost-effective allows them to better assess their individual situation and move beyond believing that postharvest losses are out of their control (Kitinoja, 2016).

It is imperative to know that the training of service staff is necessary, the training should not be limited to only large warehouse owners but also small store owners, this is equally necessary in the distribution of storage technology (European Commission 2016a; FAO 2017b). In a bid to make these post harvest losses technologies available, it is advised that government agencies and organizations should ensure the development of devices providing information and training on the use and maintenance of these technologies for effective usage (European Commission 2016b; FAO, LEI 2015; Godfray et al. 2010).

●Use of Advanced Storage Structures

The use of technologically advanced storage structures can result in food loss reduction up to about 98% (Abedin et al., 2012). An example is the use of plastic/metal silos and super grain bags for food preservation. These reduced food losses drastically when compared with the traditional methods of food preservation (Figure 2). Hence, when farmers and other farm staff are well trained on the techniques and process of such store usage up to small farmers level, food loss would drastically reduce (Kitinoka, 2013; FAO, 2017b). It is therefore important that the government encourage the development and adaptation of such technologies for a drastic reduction of food losses (Godfray et al., 2010)

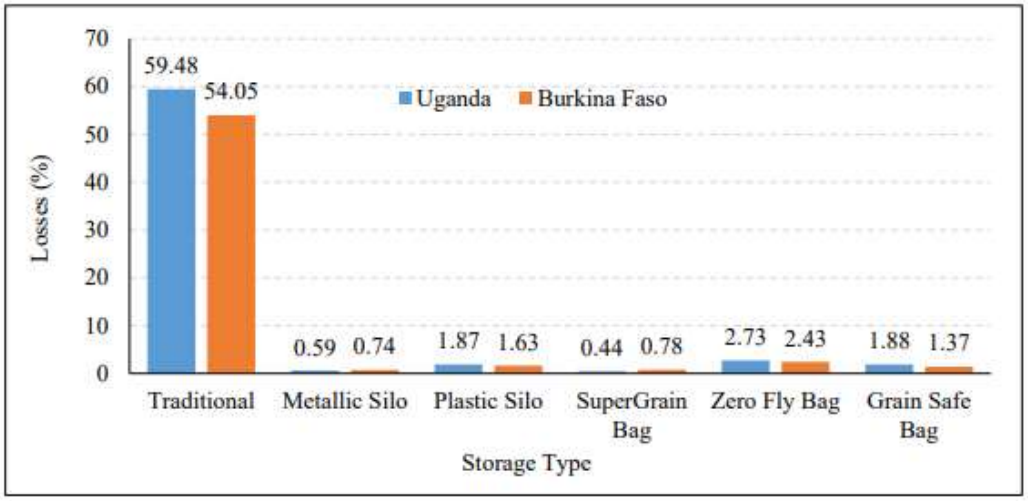

Figure 2. Losses in maize grain after 90 days of storage in various storage structures (Costa, 2014)

2.3 Influence of production practices on post-harvest losses in production

Pre-harvest production practices seriously affect post-harvest returning quality and quantity and results in the rejection or downgrading of produce at the time of save.

2.3.1 Water supply (irrigation)

Growing plants need a continuous water supply for both photosynthesis (process by which plants convert light to chemical energy and produce carbohydrate from carbon dioxide and water) and transportation.

Bad effects can be caused by;

1. Too much rain irrigation, which can lead to brittle and easily endangered leafy vegetables and increased tendency to decay.
2. Lack of rain or irrigation, which can lead to low juice content and thick in citrus fruit.
3. Dry conditions followed by rain or irrigation which can give rise to growth cracks or secondary growth in potatoes or growth cracks in tomatoes.

2.3.2 Soil Fertility/Use of Fertilizers

Lack of plant foods in soil can seriously affect the quality of fresh produce at harvest, on the other hand, too much fertilizers can harm the development and post-harvest condition of produce. Some of the effects are;

- Lack of nitrogen leads to stunted growth or yellowish discoloration of leaves in green vegetables e.g. cabbage.
- Lack of potash can bring about poor fruit development and abnormal ripening.
- Calcium moisture imbalance can cause blossom end rot in tomatoes and bitter pit and applies.
- Boron deficiency can lead to impurities in papaya, hollow stem in cabbage and cauliflower, the cracking of outer skin in beets,

2.3.3 Cultivation Practices

Good crop husbandry is important in achieving good yields and quality of fresh produce. Certain aspects are particularly important such as;

- Weed Control: weeds are common hosts for crop diseases and pests. Weeds also complete with crops for nutrients and soil moisture, which therefore reduces the quality of crop produce.
- Crop hygiene: decaying plant residues, dead wood and decaying plants are all reservoirs of infections

4. Conclusion and Recommendation

In this study, the causes and possible solutions to post-harvest losses have been discussed in details. Post-harvest loss can be reduced to a great extent provided the necessary measures are put in place by farmers and other stakeholders. If the possible solutions discussed in this reviewed are considered. Food security would be ensured as post-harvest losses would be reduced, thereby ensuring the availability of food for all. It is recommended that farmers and all concerned parties be trained on new technologies for post-harvest loss reduction. More research should however be carried out to discover easier ways to access and use technologies, most especially for rural farmers in order to reduce post-harvest losses of various food crops.

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