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CLIMATE CHANGE AND POST-HARVEST LOSSES OF FRUITS AND VEGETABLES IN NIGERIA: A CRITICAL REVIEW

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ABSTRACT

Agriculture, as a natural resource-based industry will be affected by climate change more than any other sector. Yet, much of the discourse on climate change has been on the mitigation of the causes of climate change like industrial CO2 emissions. This paper reviewed the consequences of climate change on post-harvest loss of fruits and vegetables in Nigeria. The specific objectives were to identify the causes of climate change; identify the causes of post-harvest losses; identify the effects of climate change on post-harvest losses; and proffer solutions to the effect of climate changes on the post-harvest losses in Nigeria. The result reveals that the causes of climate change are volcanic eruptions, ocean currents, meteorite impacts, solar variations carbon-dioxide, nitrous oxide, chlorofluorocarbon, burning of fossil fuels, gas flaring, and deforestation. Also findings revealed that the causes of post-harvest losses include biological, chemical, mechanical, physiological, microbiological, improper post-harvest handling practices, inadequate facilities and necessary infrastructure, improper temperature management, inadequate of management knowledge/skill, inappropriate packaging, inadequate transportation facilities, inadequate marketing systems and government regulations and legislations. The effects of climate change on post-harvest losses include global warming, higher temperatures, higher humidity, and unseasonal rains. To address these challenges of climate change on post-harvest losses, several mitigation strategies, such as strengthening research and development institutions, improve access to information and capacity building, improve on post-harvest practices and governments' policies improvement for postharvest loss reduction. The paper concluded that climate change seriously affect all the stages of food value chains of fruits and vegetables. The paper recommended that reducing food loss through improving storage technologies/ facilities can increase climate resilience and can reduce the vulnerability of fruits and vegetables to heat or pest infestation.

Key words: Climate-Change, postharvest losses, and Nigeria

1.0 INTRODUCTION

Climate change also known as global warming, is defined as the rise in average surface temperatures on earth due primarily to the human use of fossil fuels, which releases carbon dioxide and other greenhouse gases into the air, which can have a series of effects on ecosystems causing adverse effect on agricultural production as well as agricultural produce (Ashaye, 2018).

According to Adebisi-Adelani and Oyesola (2014), climate change threatens agriculture production and produces through rising temperatures, changes in rainfall patterns or the increase of drought. The effect of climate change on postharvest value chains cannot be ignored in Nigeria. This is not distinct to different reports of annual enormous amount of food losses along the post-harvest value chain.

Fruits and vegetables are delicate commodities and highly susceptible to physiological deterioration in the supply chain, which is the primary reason of high post-harvest loss experienced in their production (Singh and Sharma, 2018). Due to the physiological nature of fruits and vegetables, they deteriorate easily in transit and storage, especially under conditions of high temperature and humidity and as a result, heavy losses occur in these crops (Murtala *et al*., 2021). However, generally about 30% fruits and vegetables are rendered unfit for consumption due to spoilage after harvesting (Mohammed and Usman, 2023). Losses between farms and consumers are common in Nigeria where there is inadequate knowledge; skills, technologies, techniques, and facilities for produce handling and processing. Post-harvest losses have the potential to discourage farmers from venturing into commercial production and marketing of fresh produce and thus affecting the availability and consumption of fruits and vegetables in mostly urban areas.

Climatic factors are seen as the most significant and important elements that affect post-harvest losses. These factors comprise of temperature, light intensity, humidity and the proportion and composition of aeration gases, with temperature being the most important determinant factor of the time span of perishable agricultural produce (Workineh and Enyew, 2021). Based on the above evidence, it is clear that there is a need to address the effects of climate change on post-harvest losses especially fruits and vegetables. Therefore, the paper seeks to address that with the following specific objectives to: identify the causes of climate change; identify the causes of post-harvest losses; determine the effects of climate change on post-harvest losses and proffer solutions to the climate change on the post-harvest losses.

2.0 METHODOLOGY

Literature materials climate change, fruits , vegetables and post harvest lossess were sourced from journals , conference papers bulletins , books ert, they were collated, reviewed and discussed

3.0 REVIEW AND DISCUSSION

3.1 Causes of Climate Change

The causes of climate change in Nigeria are categorized into anthropogenic (man-made) and natural causes.

Natural Causes

According to Workineh and Enyew, (2021 and Badru, (2020) the following are the natural causes of climate change.

Volcanic Eruptions

The major effect volcanoes on the climate change are short-term cooling. Volcanic eruptions propel out clouds of dust and ash, which blocks out some sunlight. The ash particles are heavy; they fall to the ground within three months. Volcanoes influence the climate through the gases, and dust particles thrown into the atmosphere during eruptions. The effect of the volcanic gases and dust might warm or cool the earth's surface, depending on how sunlight relates with the volcanic materials.

Ocean currents

The oceans are the main factor of the climate system. Ocean currents are located at the ocean surface and in deep water below 300 meters (984 feet). They can shift water horizontally and vertically and take place on both local and global scales. Ocean currents take heat around the earth. The direction of these currents can shift so that different areas become warmer and cooler. Oceans hoard a large amount of heat, so that small changes in ocean currents can have a large consequence on coastal and global climate.

Meteorite impacts

Meteorite impacts have contributed to climate change by releasing some influential materials into the atmosphere. These materials shield the earth from solar radiation and cause global temperature to fall, the influenced can last for a few years. After the materials released such as dust and aerosols will fall back to earth, the greenhouse gases (Carbon-di-oxide, water, methane etc.), caused by the interaction of the impact remain in the atmosphere and can cause global temperature to increase, the effects can last decades.

Solar variations

Solar is the source of energy for the earth's climate structure. Although the sun's energy output appears constant from an everyday point of view, small changes over an extended period of

time can lead to climate changes. It is sensible to assume that changes in the sun's energy output would cause the climate to change, since the sun is the fundamental source of energy that drives our climate system.

Anthropogenic (Man-Made) causes

Carbon-dioxide CO_2

Carbon dioxide is a component of the atmosphere which is released through natural processes such as respiration and volcanic eruptions and through human activities such as deforestation, land use changes, and burning of fossil fuels. The concentration of carbon dioxide in the atmosphere has increased through human activities and industrial works (Badru, 2020). However, carbon dioxide (CO_2) has been identified as the gas which singularly contributes the most to climate change (Badru, 2020). The instant question which then comes to mind is: what are the elements of carbon dioxide? With particular respect to Nigeria, the sources of carbon dioxide (CO_2) are: the burning of fossil fuels; deforestation and gas flaring. According to Nemeskéri and Helyes (2019), who conducted a study in the recent years concluded that CO_2 might have both positive and negative role in maintain the postharvest quality of vegetable crops. For example, elevated carbon dioxide (CO_2) concentrations can increase the photosynthesis, biomass production, and increase the use efficiency of light, water, and nutrient and thereby increase the overall yield (Prasad *et al.*, 2023). In other hand, reduction of plant growth, physiological parameters and alteration of some of the fruit qualities such as total soluble solid, acidity as a result of increased in carbon dioxide (CO_2) (Dong *et al*. 2020)

~~B~~urning of fossil fuels

The components of fossil fuels are oil, coal and natural gas. The actual combusting of these components cause excessive carbon dioxide to flow into the atmosphere, thus, causing pollution of the atmosphere which inevitably results into climate change.

Gas flaring

Gas in this context relates to the associated gas in oil production process. This associated gas could be harnessed to the benefit of the country when employed for domestic use and export. Unfortunately, in Nigeria, associated gas is extravagantly flared into the atmosphere, channeling ways for climate change to surface. Nigeria has been reported to be flaring an estimated 2.5 million cubic feet of gas each day which amounts to almost 40% of the total gas consumption in Africa

(Badru, 2020). Additionally, Nigeria is responsible for one sixth of the entire gas flared in the world as it pumps over 400 million tons of carbon dioxide into Nigeria's environment. With all these statistics, Nigeria has been held as the country which flares gas the most in the world.

Deforestation

This is a process of clearing of forests, by cutting down or burning all the trees grown in such forest. Nigeria also leads the world in deforestation as the thick forests have been wantonly cleared for logging, timber export, wood fuel, agriculture etc. It has been reported that between 2000 and 2005, the country cleared 55.7% of forests. Sadly, these trees which are cut down serve as a major absorbent of carbon-dioxide ($C0_2$) through the process of photosynthesis. Thus, by the reckless removal of trees for economic and domestic utilization, the atmosphere is substantially deprived of the instruments which should protect it against carbon-dioxide ($C0_2$) effects.

Methane

This is a hydrocarbon gas produced through both natural sources and human activities including the decomposition of works in landfills, agriculture, ruminant digestion and manure management associated with domestic livestock.

Nitrous Oxide

Nitrous Oxide is a powerful greenhouse gas which is produced through soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuels combustion, nitric acid production and biomass burning.

Chlorofluorocarbon (CFCs)

They are gases of industrial origin used in a number of applications, but now largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to destruction of the ozone layer.

3.2 Causes of Post Harvest Losses

According to (Workineh and Enyew, 2021) the cause of post-harvest losses can be classified into primary and secondary causes.

Primary causes of post-harvest losses are those which affect the food directly. They can be categorized into the following groups:

Biological factor

The rate of biological deterioration depends on several environmental (external) factors, including temperature, relative humidity, air velocity and atmospheric composition (concentrations of

oxygen, carbon dioxide and ethylene) and sanitation procedures. Damage can be due to consumption by either large or microscopic organisms, such as monkeys, rodents, birds, insects, fungi and bacteria, causing direct food loss. The damage also could come from contamination of food by the excreta or toxic substances produced by the organisms, causing rotting or other defects, thus rendering the food unfit for human consumption. When fruits and vegetables are packed into boxes, crates, baskets, or trucks upon harvesting, they usually become subjected to cross-contamination by spoilage microorganisms from the containers and also from other fruits and vegetables. Biological spoilage stands out as the main cause of postharvest loss in developing countries (Akanbi and Ajala, 2021).

Chemical factor

In the case where deterioration is brought about by reactions caused by biochemical or chemical agents, there is usually a significant loss of nutritional value of both the intermediate and final products, resulting in undesirability of whole fruit or vegetable (Akanbi and Ajala, 2021). One such reaction is the "maillard reaction'' that causes browning and decolouration in dried fruits and vegetables. This chemical reaction is highly triggered by exposure of agricultural produce to high temperatures and exposure to the high radiation of sunlight. Also, high application of chemical fertilizers and chemical pesticides can equally result in postharvest losses (Workineh and Enyew, 2021). Food may become unfit for consumption by contact with chemical substances such as pesticides, preservatives, oil, or chemical constituents naturally present in stored foods. Postharvest losses of vegetables can also be as result of contamination by noxious substances including pesticides during handling (Kader, 2002).

Mechanical factors

Mechanical factors refer to the inappropriate ways of handling agricultural produce in all the value chain processes from harvesting to storage. It involves the ruthless, careless and rough handling of the fruits and vegetables (Antunes *et al*., 2007) that exposes them to all forms of bruises, cracks, peeling of surfaces and soft textures of fruits, cuts, abrasion, scuffing and scratches (Munhuweyi, 2012). These cause mechanical damage in the form of cuts, cracks, punctures, abrasion, scuffing and scratches with the predominant form being bruising (the darkened area visible under the surface of many vegetables and fruits). Bruising usually detracts from the quality of the produce and may decay (Bollen, 2006; Opara, 2007). The skin of horticultural products is an effective

barrier to most of the opportunistic bacteria and fungi that cause rotting of tissues. Breaking of the skin also stimulates physiological deterioration and dehydration (Atanda *et al*., 2011). The possibility that fruits and vegetables encountering maximum mechanical damage during harvesting is very possible if proper means of picking and harvesting are not adopted (Yahaya and Mardiyya 2019). Longer shipment and distribution period eventually caused heavy losses.

Physiological factors

Physiological deterioration of fresh produce happens since fruits and vegetables are living tissues (Sitorus *et al*., 2018). So, as lively tissues the produce continues to transpire, respire and further ripen even after they have been detached from the mother plant during harvesting (Gupta and Dubey, 2018). Natural respiratory losses which occur in all living organisms account for a significant level of weight loss and moreover, the process generates heat. High temperature and relative humidity increase the decaying of fruits and vegetables, while decrease in temperature slow down the rate of microbial attack on different crops especially when it is below 5 °C (Yahaya and Mardiyya 2019).

Microbiological factors

Fruits and vegetable are susceptible to attack by bacteria and fungi, with pathological breakdown (Workineh and Enyew, 2021). Fresh produce can become infected before or after harvest by diseases widespread in the air, soil and water. The succulent nature of fruits and vegetables makes them easily invaded by these organisms. Damage so produced is probably the major cause of loss of fresh produce (Elias *et al.,* 2010; Kader, 2013). Horticultural crops can be contaminated with different microbial and chemical contaminants during handling and processing and become source for infectious microorganisms (Moy, 2005).

Secondary causes: These are those factors that lead to conditions that encourage a primary cause of loss. Secondary causes of post-harvest losses that encourage a primary causes (Workineh and Enyew, 2021); Zenebe *et al*.,2015).

Improper post-harvest harvesting practices and time

Improper harvesting practices result in loss due to spoilage of the produce before reaching the consumers along with the loss in quality of the produce such as deterioration in appearance, taste and nutritional value (Devkota *et al*., 2014). Harvest techniques can also cause losses (Kasso & Bekele, 2016). In addition, the use of improper machinery and equipment's in mechanical

harvesting cause serious losses. While harvesting of fruits and vegetables during rain or immediately after rains creates conditions favorable for decay organisms. But harvesting during hotter part of the day results in faster senescence, shriveling and wilting of fruits and vegetables as compared to produce harvested in the early morning or later afternoon (Yahaya,2005).

Inadequate facilities and necessary infrastructure

Inadequate storage and transportation facilities, drying equipment and smooth marketing systems are the main–factors that facilitate post-harvest losses in Nigeria (Martin, 2017). Majority of farmers from Africa use wooden crates and woven baskets with hard and sharp surfaces which cause mechanical injuries to the harvested fruits. Furthermore, inadequate storage facilities at the producing or marketing centers, exposes the produce to the natural causes of losses ie. damage by micro-organisms, respiration, transpiration and other biochemical reactions (Yahaya and Mardiyya 2019). Longer shipment and distribution period eventually caused heavy losses. Even with the mechanization of some of these food processing methods, Nigeria still loses2.7 trillion naira annually as a result of Post harvest food losses due to climate change and obsolete infrastructural facilities .(Ashaye, 2018; Ogugbuaja, 2017)

Improper temperature management and relative humidity

Temperature in both extremes is the main causative agent in affecting the postharvest period of horticultural perishables (Workineh and Enyew, 2021). The high temperature and relative humidity favour the growth of micro-organisms which result in serious damage to the produce. Thus, amount of temperature in the horticultural produce during harvesting, handling, transport and marketing is much higher than those recommended for quality maintenance of the produce due to continuous and high rate of respiration and other related biochemical reactions of the produces. Higher temperature is favourable for growth of many fungi and mould which produces mycotoxin that are hazardous to human being. At very high temperature some vegetable crops get too dried on the other hand unfavourable damp weather during the drying can lead to poor
quality of stored vegetables (Prasad *et al.*, 2023).

Lack of management knowledge/skill

High postharvest losses can occur as a result of inefficient human, economic, and technical resources for developing programs aimed at prevention and reduction of post-harvest food losses; unknown knowledge of technical and scientific technologies associated with preservation,

processing, packaging, transporting, and distribution of food products; and inefficient commercialization systems, and absent or inefficient government agencies in the production and marketing of commodities, as well as a lack of credit policies that address the needs of the country and participants (Akanbi and Ajala, 2021). The human element in postharvest handling of horticultural commodities is extremely important. Most handlers involved directly in harvesting, packaging, transporting and marketing have limited knowledge, ineffective and far reaching educational programme on how to maintain quality (Kader, 2005). Due to the lack of knowledge on commodity compatibility, farmers often times transport ethylene sensitive commodities together with ethylene generators (Atanda *et al*.,2011). Transporting of green leafy vegetables such as lettuce, cucumbers, broccoli, Kales, Spinach, matured green tomatoes and carrots that are ethylene sensitive commodities with high level producing ethylene agricultural produce such as apples, mangoes, pears, bananas, tomatoes and peaches result in great post-harvest losses (Silva, 2008).

Inadequate transportation facilities

Transportation and distribution of fruits and vegetables are the most important stage of post-harvest losses. The physical and mechanical damage occur during transportation and distribution. Longer shipment and distribution period eventually caused heavy losses (Mustapha and Yahaya, 2006). Transportation places a certain period of time between production and consumption, it can be one of the main causes of losses, especially for fresh products. In developing countries, the absence of appropriate means of transport, poor roads and inefficient logistics management prevent perishable foods from being properly preserved. In addition, loading and unloading operations are carried out in these countries by unskilled and uneducated workers who generally do not carry products carefully. This causes mechanical damage in agricultural products (Azabağaoğlu, 2018). In the same vein, roads are not adequate for proper transport of horticultural crops. Also, transport vehicles and other modes, especially those suited for fresh horticultural perishables, are in short supply. Inappropriate means of transporting agricultural produce such as human labour, donkeys, public transports (Arah *et al*.,2016) leads to both primary and secondary post-harvest losses of fruits and vegetables.

Inadequate marketing systems

Growers can produce large quantities of good-quality fruits and vegetables but if they do not have ~~a~~ dependable, fast and equitable means of getting such commodities to the consumers, losses will be extensive. This problem exists in many locations within developing countries. It is accentuated by lack of communication between producers and buyers and lack of market information (Kader, 2005). The horticultural products in Nigeria are mainly produced by smallholder farmers and most of the farmers sell their products at nearby markets and a few sell both on farm and in nearby markets such that the marketing condition is unsatisfactory and discouraging (Seid., 2013). The reasons for unsatisfactory market conditions indicated that higher supply of the produce at a time causing middle men exploitation and products sell on farm and on the nearby market without good price Another finding on major postharvest loss assessment at Jimma zone in Oromia of Ethiopia, elaborated presence of highest percentage loss was sold in the open space being exposed to sun (Adugna *et al.*, 2011).

3.3 Effects of Climate Change on Post Harvest Losses

Global warming

Global warming will expand pest and disease territories due to pest outbreaks in new areas which previously were not favorable for them. Pests and diseases can increase the frequency of outbreaks of field and storage pests and disease invasions (Martin, 2017). As a result, more losses of food will occur while the crop is in the field and during storage. Studies by Martin (2017); Prasad *et al.*, 2023) documented that crop diseases reports are more frequently preceded by weeks of higher local temperature. Changes in climate translate to faster reproduction of insect pests and diseases, that is, insects would have shorter lifecycles due to higher temperatures, resulting in more rapid build-up of insects and fungi in stored commodities (Johnson, *et al.*, 2024)

Higher temperatures and humidity

Higher temperatures and humidity can cause~~d~~ shorter life cycles of insect pests and diseases, which may foster reproduction and buildup of field and storage pests and diseases. Rising mean temperature will also increase the rate of crop drying in the field, which will reduce the opportunity for pest attacks but also increases the risk of the grain becoming too dry, which makes it shriveled and hard to shell (Martin, 2017). Overly dry produce becomes brittle and can crack after threshing or during milling and thus has low viability. Generally moist, humid conditions favour growth of

mould. Furthermore, some fungi perform better at higher temperatures. This increases the risk of fungal growth and mycotoxin contamination of fruits and vegetables crops. High temperature influences the development of red colour in ripe chilli fruits. The temperature alteration interferes the ripening of melon fruits that indirectly affects the sweetness (Prasad *et al.*, 2023)

Unseasonal rains

Unseasonal rains can dampen the matured crop before harvesting and result in mould growth, which may later reduce the fruits quality, cause some of the fruit to be discarded, and increase the associated risk of contamination in fruits (Chegere (2017). The author has reported that harvesting when weather conditions are damp (compared to when the weather is sunny) correlates with higher pre -storage and storage losses. If unfavorable damp weather a condition occur during and after crop harvesting, drying becomes difficult, which may cause rotting or germination and increased risk of mycotoxin contamination (Martin, 2017).

Increase the cost of management post-harvest produce:

According to studies conducted (Stathers *et al.*, 2013 and Martin, 2017), the following various climate change events may increase the cost of fruit and vegetables management in different forms:

(i) damage to storage structures, which cannot withstand the new and erratic weather conditions and increased cost of improving storage structures to suit the new weather conditions;

(ii) the need for re-drying when the harvest gets wet during harvesting due to unseasonal rains;

(iii) the need for re-sorting and repeating treatment with protectants in the midpoint of storage due to increased pest reproduction and mobility; and increased difficulty in predicting the likely storage duration and planning for post-harvest management investment.

3.4 Suggested Solutions to Post-Harvest Losses due to eEfect of Climate Change

Strengthening Research and Development (R&D)Institutions;

- appropriate agricultural inputs for producing quality produces,
- study perishable agricultural produces within the context of its processing and market potential,

- develop farmers' friendly maturity indices and recommend appropriate harvest tools and methods ,
- establish grading, sorting and packing protocols for different commodities and research focus on temperature,
- relative humidity for different commodities under storage will help reducing the effects of climate change on post-harvest losses (Martin, 2017).

Improved access to information and capacity building

- Capacity building and working directly with farmers, traders and other value chains' stakeholders to accept and promote improved post-harvesting practices,
- capacity building on proper cold chain management,
- encourage simple agro-processing methods in the villages and establishing regional post-harvest management and
- losses reduction information networking system are crucial in reducing climate change effects on post-harvest loss of fruit and vegetables (Workineh and Enyew, 2021).

Improve on harvesting practices

- Improve on-farm hygiene and packing practices,
- support small scale farmers in the basic infrastructures such as packing house, cool storages development with helping producers in value adding activities/technology are the most important practices to decrease the effects of climate change on post-harvest of fruits and vegetables (Martin, 2017).

Governments' policies improvement for post-harvest loss reduction

- Support the development and adaption of applicable postharvest management technologies as well as implement and monitor postharvest management standards (safety, maturity, grading and sorting) for domestic and export markets with develop contract farming and
- linkages among producers, processors, and traders (PPTs) and make strong collaboration between producers, governments' agencies (ministry of agriculture, trade etc.), researchers and donors agencies for establishing priority projects and with increase public awareness campaigns to reduce postharvest losses in the consumption stages can never be overemphasis in copping the effects of climate change on post-harvest loss. (Workineh and Enyew, 2021).

Increase investment to develop infrastructures

Government and non-governmental organizations should build collection centers in the rural areas near production places and equipped with sorting, grading, packaging, sanitation and storage facilities, build roads from farms to collection centers, storages and market places, invest in the processing factories equipped with suitable processing technology, good sanitation system, suitable packaging, and appropriate food safety and quality standards and build market infrastructures and equipped with good storages and sanitation facilities (FAO, 2015)

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Climate change is seriously affecting all the stages of food chains especially in fruits and vegetables. The impacts of climate change on food systems are widespread, complex, spatially variable, and highly influenced by socioeconomic conditions. It shows that agriculture-based economic systems such as Nigeria are most adversely affected. Consequently, a lot of resources and efforts have already been used to develop adaptation mechanisms to increase fruits and vegetables production in Nigeria, but high levels of post-harvest losses through climate change effects will offset the efforts to increase food production

4.2 Recommendations

The paper recommended that reducing food losses can increase climate resilience because it is not one way only. Food loss has a lot to do with climate change. Improving storage technologies alone the value chain and proper harvesting management practices can reduce the vulnerability of harvested produce to heat or pest infestation as well as preserving nutrients, especially in highly perishable produce like fruits and vegetables. Importantly, it can also help to reverse global warming. Also, solving postharvest losses requires reliable data on where, when, why and to what extent they are occurring.

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