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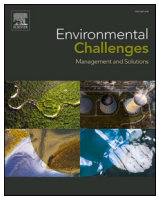

Food loss analysis in Nigeria: A systematic literature review

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ABSTRACT

The issue of food loss and waste is a complex one that must be addressed if sustainable food systems are to be achieved. In the Global South, as evidenced by Nigeria, two paradoxical trends can be observed. Firstly, substantial losses of arable crops occur during the production and distribution stages. Secondly, Nigeria is affected by food scarcity, which is in part a consequence of losses occurring at these stages. In terms of food availability, Nigeria ranks 26th among African countries. In light of this context and the government's expressed interest in identifying sustainable solutions to this problem, a systematic review was conducted with the objective of consolidating the fragmented studies on food loss in the region. This review provides a foundation for understanding the causes of food loss, the preventive and reduction strategies required, and for identifying promising areas for future research. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Checklist 2020. Following the application of inclusion and exclusion criteria, 23 studies were selected for review. A thematic synthesis was employed to integrate and examine the findings of the studies. The findings indicated that maize, rice, and cassava continued to be the most prevalent food crops in Nigeria, with cultivation occurring across the entire country. We differentiate the critical loss points for different crops, which arise between the production and distribution stages. In conclusion, this review reveals that food loss in Nigeria is a multifaceted issue requiring integrated solutions that address the natural, social, and material dimensions. Further empirical research, especially qualitative studies that focus on the perspectives and practices of food system actors, is essential for developing effective interventions and policies. This approach will help achieve sustainable development of food systems and advance global food security goals.

1. Introduction

Food loss and waste are complex issues that must be addressed to achieve a sustainable food system (Kör et al., 2022). The complexity of this issue is compounded by the fact that there is no consensus on the definitions of the relevant concepts (Spang et al., 2019). Reducing food loss and waste has become a top priority for academics and governments worldwide (Koester, 2014). An increasing number of academic publications have provided definitions of this topic (Cattaneoet al., 2021). Shee et al. (2022) compiled at least twelve definitions for these terms. Typically, a researcher's interpretation of these terms varies based on their goals and the approach used in their study (Koester, 2014).

In accordance with the FAO (2011), the terms food loss and waste are defined as a decrease in the quantity of edible food within food systems. This signifies that any food that was originally intended or cultivated for human consumption, but not consumed (regardless of its alternative use), is considered food loss or waste. Food loss occurs between the production and distribution phases of the food system, whereas food waste occurs in both the retail and consumer phases (FAO, 2019). The primary driver of food waste is consumer behaviour (Redlingshöfer et al., 2017), whereas food loss occurs predominantly in pre-consumption stages (Afolabi et al., 2021; Ayeni et al., 2021; Bankole et al., 2022), which is the focus of this study. Accordingly, this study adopts the term "food loss" instead of "food loss and waste."

A further complicating factor is the discrepancy in the methodologies employed to quantify losses across diverse geographical locations and sectors (Redlingshöfer et al., 2017). For example, the extent and stage at which food loss occurs vary significantly between the crop and livestock

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sectors, with higher losses typically observed in plant-based sectors (Redlingshöfer et al., 2017). This may be attributed, at least in part to higher economic value ascribed to livestock than to crops. In the Global South, crop-based sectors experience losses of over 70 % (Afolabi et al., 2021), which is the reason why this study focuses on arable crops.

Notwithstanding the growing corpus of literature on this subject, significant gaps remain. Further investigation is required on the underlying causes, key areas of concern, and the overall extent of food loss at the regional level (Chauhan et al., 2021). Research in these areas is vital for generating relevant local and context-specific knowledge regarding the problem (Caron et al., 2018). Such an understanding is pivotal for developing sustainable reduction strategies and ultimately achieving food security (Agoda et al., 2011; Balana et al., 2021; Chiaka et al., 2022; Eruola et al., 2013).

In developing countries, significant losses of arable crops, including rice, maize, and cassava, are observed during the production, post-harvest, and storage phases (Xue et al., 2017). Nevertheless, studies on these levels are scarce (Soma et al., 2021). On an annual basis, <35 % of global studies on food loss have concentrated on these stages, and most of these studies have been conducted in the Global North (Xue et al., 2017). Equal attention and resources must be allocated to all regions to produce context-based evidence (Koester, 2014). Consequently, this study does not consider losses occurring at the retail and consumption stages.

As indicated in the Global Report on Food Crises (GRFC) (GRFC, 2022), Nigeria is among the top ten countries most severely affected by the food crises. In 2022, Nigeria was ranked 107th globally and 25th among 28 African countries on the Global Food Security Index (The Economist Impact, 2022). Furthermore, the findings of this study also revealed that food loss has a considerable impact on food scarcity. In terms of food availability, Nigeria is ranked 108th globally and 26th in Africa.

Furthermore, Nigeria ranks among the top ten countries with the highest number of case studies on food loss conducted between 2016 and 2022 (Rolker et al., 2022; Xue et al., 2017). Despite significant food loss, millions of individuals in Nigeria suffer from hunger, particularly in rural areas where food production occurs. Given this context and the government's expressed interest in identifying sustainable solutions, it is imperative to collate the disparate studies on food loss in this region. To our knowledge, no systematic review has focused on the pre-consumption stage of Nigeria's food system. This review is essential in that it provides knowledge and serves as a foundation for understanding the root causes of food loss, developing effective strategies for prevention and reduction, and identifying promising areas for future research. This systematic literature review (SLR) aims to address this gap by identifying food loss based on specific crops, where food loss is most prevalent, and the causes, consequences, and necessary interventions and policies to reduce food loss.

2. Material and methods

A systematic literature review (SLR) is a rigorous and comprehensive examination of the extant literature, conducted in accordance with systematic, explicit, and transparent methods (Gough et al., 2012). It serves multiple purposes, including providing a comprehensive overview of the current state of knowledge in a particular field, identifying research priorities, revealing problematic areas, and offering detailed explanations of the root causes of these phenomena (Page et al., 2021). The methodology employed in this SLR was informed by the approaches described in the studies by Chauhan et al. (2021); Oliveira et al. (2021), Van Der Werf and Gilliland (2017), and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Checklist 2020.

The studies were retrieved from the Web of Science (WoS). This database is accessible to researchers, particularly those based in developing countries (Li et al., 2018). Moreover, as one of the most established databases with vast coverage, it encompasses valuable old publications that might otherwise be overlooked (Norris and Oppenheim, 2007). Some criteria were employed to include and exclude papers, to ensure consistency, and to define the scope of eligible studies. In alignment with the background outlined in the introduction, we present studies that included papers from Nigeria and focused on the plant-based agricultural sector. Only papers written in English and published up to 2023 were included. Furthermore, the boundaries of the food system were delineated, with only papers on the production-to-distribution phases included. Studies that did not present the results in the abstract or that did not meet the pre-established inclusion criteria were excluded from the analysis. The search terms employed were "food loss," "food waste," and "Nigeria." These keywords were combined with Boolean logic connectors "OR" and "AND" to form search strings including "food loss AND Nigeria" and "food waste OR Nigeria". The search was conducted without any date restrictions in alignment with the methodology employed by Li et al. (2022).

The initial search yielded 141 studies. The authors screened the titles to identify articles pertinent to the subject matter, resulting in the exclusion of 59 studies deemed irrelevant to this topic. A total of 82 articles were subjected to abstract screening. After this process, 33 articles were excluded on the grounds that they focused on land use, household waste, nutrition, and rural health. Of the 49 articles identified for full-text screening, one was identified as duplicate and four were not accessible. Consequently, 44 articles underwent a full-text screening. During this process, 21 articles were excluded because they focused on topics such as income, weight, and farmland loss. In conclusion, 23 articles were selected for review.

A synthesis of the data was conducted in order to provide a summary of the key findings of the selected studies. Specifically, a thematic summary, which is a non-statistical synthesis method, was employed. This method entails a comprehensive analysis of the findings presented in the text, to organize them into coherent themes for comparison. These themes are subsequently presented as results (Gough et al., 2012; Snyder, 2019). A comprehensive thematic summary is essential, as the primary objective of this review is to gain insight into a phenomenon, rather than to propose new theories (Gough et al., 2012). This method is commonly used to consolidate information and elucidate historical trends by integrating the extant body of knowledge and evidence on a specific topic (Snyder, 2019). Moreover, other forms of analysis, such as meta-analysis, are not applicable in this case, as they require comparable statistical analyses across selected studies (Snyder, 2019) and the quantification of food loss was not the aim of this study.

Although this study did not involve a statistical synthesis, the robustness of the results was tested by adhering meticulously to the recommendations set forth by Gough et al. (2012). They stipulated that the results and findings of the synthesis should address the review questions. Furthermore, only those findings that met the specified selection criteria were included to reduce to minimise bias. These criteria were defined and documented in advance, and the full texts were screened multiple times prior to data extraction. As noted in Appendix Table A1, the majority of studies focus on the southern region of Nigeria. Of the identified articles, only five employed qualitative research techniques. The food crops in Nigeria encompass a diverse range of species, including grain crops (rice, maize, and sorghum) to root crops (cassava and yam), fruits, and vegetables. To date, plantain is the only perennial food crop that has been identified. The predominant crops in this region are maize, rice, and cassava. Maize and rice are cultivated throughout the country, whereas cassava is predominantly grown in humid forests and Guinea savannah (Zhang et al., 2018). Chiaka et al. (2022) observed that these food crops are consumed extensively throughout the country. Nevertheless, roots and tubers account for the majority (>60 %) of annual food loss in Nigeria (Afolabi et al., 2021).

3. Results

The findings of the selected studies were subjected to analysis, and

the identified themes were employed to categorize the findings into distinct groups. This method was also adopted by Chauhan et al.(2021); Li et al. (2022), and Oliveira et al. (2021). The information extracted from the 23 studies was divided into three major categories as illustrated in Table 1: (1) stages of food loss, (2) causes of food loss, and (3) consequences of food loss and associated policies and interventions. The synthesis of these categories is explained in this results section.

3.1. Stage of food loss

Food loss can be identified at various points along the food chain. The critical point of food loss in Nigeria is frequently situated between the agricultural production and postharvest stages (processing, storage, and distribution). The majority of arable crop farmers experience losses at any point during these stages (Afolabi et al., 2021). However, the extent of loss differs according to the type of food and stage of the food system. For instance, the highest losses are incurred by fruits and vegetables, as well as root and tuber crops during the distribution stage. One reason for this is that immediately after harvest, these perishable crops are transported and sold at the markets without adequate packaging, cooling, or favourable environmental conditions. In most cases, these crops are sold in informal markets including the community markets, where commodities are displayed on bare floors.

The absence of standardized and sustainable storage management techniques has resulted in significant losses. The practice of farm storage remains a traditional one (Umeh, 1994). The storage materials, namely sacks, jute bags, and rhumbu, lack the capacity to provide a sustainable protective environment for crops. In the event of unfavourable climate conditions, these storage technologies are susceptible to mycotoxin infestation and other disease pathogens, which ultimately result in food loss at the storage stage (Ayeni et al., 2021). Most of the time, the initial contamination of pathogens occurs at the production stage, subsequently manifesting throughout the subsequent stages. For instance, aflatoxins in maize affect the leaves during production and after maturation, and they continue to affect the grains during storage (Bankole et al., 2022)

Prolonged dry spells and delayed rains make agricultural production difficult. Water sources are either dry or insufficient to bring crops to maturity. As a result, farmers suffer losses during production (Emeribe et al., 2020). Similarly, during extreme weather conditions, flood-prone areas experience losses that can affect all stages of the food system.

Table 1
Categorised themes and selected articles.

Category		Studies
1.	Stage of food loss	Afolabi et al. (2021); Ayeni et al. (2021); Bankole et al. (2022); Emeribe et al. (2020); Enete et al. (2016); Rabiu and Rose (2007); Umeh (1994).
2.	Causes of food loss (natural, social, and material)	Abdulsalam et al. (2021); Afolabi et al. (2021); Agoda et al. (2011); Amaechina et al. (2022); Aworh (2015); Ayeni et al. (2021); Balana et al. (2021); Bankole et al. (2022); Castelein et al. (2022); Chiaka et al. (2022); Emeribe et al., 2020; Enete et al., 2012; Eruola et al. (2013); Idris-Adeniyi et al. (2022); Morris et al. (2018); Okechukwu et al. (2008); Takeshima et al. (2023); Umeh (1994); Verma et al. (2019); Wada et al. (2002); Zhang et al. (2018).
3.	Consequences of food loss and associated policies and interventions	Afolabi et al. (2021); Agoda et al. (2011); Balana et al. (2021); Bankole et al. (2022); Castelein et al. (2022); Chiaka et al. (2022); Emeribe et al. (2020); Enete et al. (2012), (2016); Eruola et al. (2013); Idris-Adeniyi et al. (2022); Okechukwu et al. (2008); Rabiu and Rose (2007); Takeshima et al. (2023).

Enete et al. (2016) reported that in flood-prone areas, >80 percent of stored food products could be lost. Rodents such as *Arvicanthis niloticus* (African grass rat) and *Mastomys natalensis* (African common rat) are important agricultural pests. They cause damage to crops in both the nymphal and adult stages. However, they cause more damage in the later stages. The longer the crop remains in the field (late maturing), the greater the susceptibility to rodent infestation. Losses in rice and wheat before ripening can be greater than 40 percent after maturation. Rodents cause more than one million dollars worth of damage to crops each year (Rabiu and Rose, 2007).

3.2. Causes of food loss

Most of the literature included in this SLR focused on the causes of food loss. A distinction can be made between natural/environmental causes, social causes, and material causes.

3.2.1. Natural causes

Seedborne diseases are common in crops propagated by seeds, such as cereals, legumes, and some vegetable crops. Various pathogens affect these crops during the anthesis, seed development, and maturation stages. They cause cob rot in maize, head smut in wheat, seed rot in sorghum, rice blast, mottle in cowpeas, and late blight in tomato (Wada et al.2002).

In addition, several plant-parasitic nematodes threaten the production and increase the yield of cereal crops in Nigeria (Abdulsalam et al., 2021). Although other types of nematodes can infect maize, the most prevalent are root-knot nematodes (*Meloidogyne* spp.) and root-lesion nematodes (*Pratylenchus* spp.). These nematodes also attack wheat plants. They cause various forms of damage, including wilting, stunted growth and/or roots, and leaf chlorosis. Similarly, >50 species of nematode cause various types of damage in both upland and lowland rice varieties. One of the important symptoms is the reduction of chlorophyll content in cultivated rice leaves, which ultimately leads to low yield.

Zhang et al. (2018) identified >50 insect pests. They found that different insects are associated with specific crops. For instance, cassava grasshoppers, rice/sorghum-African rice gall midge, *Orseolia oryzivora,* maize/millet stems, and pod borers. The increasing prevalence of these pests has increased the use of pesticides as a critical method of pest and disease reduction and control.

Enete et al. (2012) observed that erratic rainfall patterns and long dry spells contribute to soil degradation, low fertility, and the incidence of pests and diseases. The physiological nature of some crops makes them susceptible to disease and pest infestation. For instance, maize's low capacity to extract water from the soil means that erratic weather conditions predispose it to pest and disease infestations that ultimately cause damage (Agoda et al., 2011). Due to extreme weather conditions, there has been a considerable increase in the incidence of pests and diseases among arable crop farmers in Nigeria, resulting in poor yields. Root rot disease is a major challenge in the production of tuber crops, such as cassava. Okechukwu et al. (2008) reported that no region in Nigeria has a fully resistant plant variety. The longer the cassava tuber remains in the soil, the greater the chance of exposure to root rot disease. The prevalence and stage of the disease vary across different agroecological zones of the country.

During storage, crops, such as cereals and pulses, are exposed to attack by various mycotoxins such as aflatoxins and trichothecenes. Some mycotoxins catalyse the growth of pests and inevitably cause food contamination (Ngoma et al., 2024). They are often found in stored grain due to the presence of toxigenic fungal spores. In addition to weather instability, which has increased the prevalence of postharvest mycotoxin infestation in cereals, suboptimal stored grains are more susceptible to mycotoxin infestation (Ayeni et al., 2021).

In addition, during storage, instability and/or lack of adequate temperature in storage materials or conditions leads to the development

of mould and various pest and disease infestations. Rodents also cause on-farm and off-farm losses in cereal crops, such as maize. Rodent species, such as *Rattus rattus* (black rat), *Rattus norvegicus* (brown rat), *and Mus musculus* (house mouse), contaminate stored grain with their urine and faeces. They also bore holes in the grain, causing a loss of quality and nutritional value. In other cases, they cause leaks in storage materials, such as bags, resulting in grain spillage and loss of volume. Other factors also contribute to pest and disease problems during storage. For example, damaged areas on grains due to post-harvest handling and/or pest infestation (rodent, insect) act as entry points for mould and disease. Moreover, poor hygiene and the use of traditional storage techniques, such as sun-drying expose grains to pests and diseases (Agoda et al., 2011).

Another important environmental cause of food loss is climate change, a critical interwoven factor causing food loss in Nigeria (Eruola et al.2013). Although the degree extent and period duration of the effects differ, most farmers have experienced the impacts of climate change and extreme weather conditions. These effects include prolonged droughts, delayed rains, increased ambient temperatures, and low soil moisture (Enete et al., 2012).

Over the last decade, temperatures have increased by an estimated 0.5 °C. This is having an unprecedented impact on production and yields. In the case of cassava, drought impairs its stem and root development (International Atomic Energy Agency, 2018). Climate variability has partly contributed to the postharvest loss of maize from 819, 676 tonnes in 2001 and approximately 2 million tonnes in 2021 (African Postharvest Losses Information System (APHLIS), 2024). Unpredictable rainfall patterns remain the main cause of poor food production. Farmers are unable to know when to plant or plan for other farm activities, such as the use of machinery and the application of pesticides and fertilizers. Weather variability hampers the efficiency of food systems and leads to food loss (Eruola et al., 2013).

Erratic climatic conditions make food storage difficult and can lead to food loss (Afolabi et al., 2021). Flooding is one of the effects of climate change in Nigeria. This affects the livelihoods of farmers, as they experience a loss of yield, investments, and an increase in food prices (Amaechina et al., 2022). Enete et al.(2016) revealed that >70 percent of rice farmers experienced flood-induced losses. >80 percent losses were recorded for rice, cassava, and maize at different stages from production to storage. In contrast, some regions in northern Nigeria experience long periods of drought due to low rainfall resulting in low soil moisture content (Emeribe et al. 2020).

3.2.2. Social causes

A dominant social cause, as described in the literature, is the competencies of farmers. Arable crop farmers in Nigeria are predominantly subsistence farmers and are characterized using traditional farming methods (Chiaka et al., 2022). There is strong evidence that these methods predispose crops to pathogenic infections, leading to the loss of most arable crops (Abdulsalam et al., 2021). Farmers face various technological constraints that lead to poor agricultural practices and the use of outdated crop production methods and techniques (Afolabi et al., 2021). In particular, grain drying is an important aspect of safe grain storage, but farmers still fail to analyse moisture content before and after drying. They base their decisions on their perceptions. In Nigeria, traditional drying methods, such as sun drying and spilling on the ground, remain popular. However, these traditional methods have several limitations. During the rainy season, the grains may not have been properly dried. The consequences of these methods are severe, leading to pathogen and pest infestations (Ayeni et al., 2021).

Most farmers lack appropriate management techniques, which are essential to reduce the incidence of pests and diseases. Farmers rarely source disease-resistant varieties during pre-planting preparation. They buy planting materials from informal sources such as open markets or from friends and family, rather than from reputable agricultural outlets (Kilwinger et al., 2020; Mariel et al., 2024). They also neglect the practice of crop rotation. Instead, they plant the same crop each season on similar hectares of land. They also fail to ensure adequate seed treatment (Bankole et al., 2022). Although there are direct causes of food loss, such as mechanical damage and pest and disease infestations, farmers and other stakeholders have placed little or no emphasis on indirect causes. These are primarily the result of human decisions, such as suboptimal planting and post-planting handling strategies, that lead to food loss (Morris et al., 2018). Most traditional storage methods are inadequate for controlling insects, rodents, and other pathogens. Besides, climate change persists, and traditional practices are inadequate. Unfortunately, these methods remain prevalent among most arable crop farmers in Nigeria (Agoda et al., 2011).

3.2.3. Material causes in the food system

Starting with the material causes, this review identified the lack of financial and rural infrastructure as the main cause. Inaccessibility to the required technologies poses a challenge to the sustainable transformation of Nigeria's food system (Afolabi et al., 2021). Lack of finance, infrastructural facilities such as electricity, durable roads, and effective storage facilities have a huge impact on the storage, marketing channels, and mode of distribution of crops. The prevalence of these issues has accelerated food losses (Afolabi et al., 2021), and it continues to hinder the transition from small-scale subsistence farming to medium or large-scale production (Aworh, 2015)

Due to the lack of rural infrastructure and amenities, smallholder farmers seek to use methods or techniques that are available to them, rather than advanced technology. These include the use of human labour during planting, simple farm implements such as cutlasses for harvesting, drying in open areas or on bare floors, and the use of traditional methods of grain storage, such as jute bags and rhumbu. However, these storage methods are not suitable for long-term crop storage because they predispose the stored crops to various contaminants (Ayeni et al., 2021).

The adoption of postharvest technologies, such as simple reusable plastic crates technology, minimizes food loss in tomatoes and consequently increases the return on farmers' investment (Balana et al., 2021). However, there is a large yield and profit margin between manual and mechanical rice production. It also has significant climatic advantages (Castelein et al., 2022). However, these technologies have low adoption rates among smallholder farmers. They perceived that such technologies were not affordable to procure and maintain (Balana et al., 2021).

Technologies such as cold storage systems are important for preserving and storing horticultural crops, but farmers cannot afford the cost of electricity supply (or solar inverters) (Takeshima et al., 2023). Credit constraints among leafy greens farmers have limited their ability to procure adequate storage amenities, resulting in severe losses (Idris-Adeniyi et al., 2021). Higher losses are mostly recorded for perishable crops, such as vegetables, roots, and tubers (Morris et al., 2018). Despite the significant contribution of smallholder farmers to food production in Nigeria, they continue to experience limited welfare support in terms of technology, such as pesticides and fertilizers (Chiaka et al., 2022). These factors will continue to drive farmers to produce food at a subsistence level and below the required quantity to achieve food security (Chiaka et al., 2022).

3.3. Consequences of food loss and associated policy and interventions

Agricultural production remains insufficient to feed Nigeria's growing population. Reducing food losses is an effective strategy for overcoming food inaccessibility (Balana et al., 2021). Annual yields of crop groups, such as cereals, continue to decline, leading to food shortages and high food costs (Chiaka et al., 2022). Food losses from cereals and other food crops indicate that the resources invested in production and other value-addition activities have been lost(Agoda et al., 2011). Factors such as poor agricultural practices, climate change,

pests, and disease outbreaks continue to cause crop failures and low-yield. This culminates in the prevalence of hunger among the population and, consequently, rural-urban migration, especially among rural youth (Eruola et al., 2013).

Food losses in the pre-consumption stage remain high compared to the consumption stage of the food system in Nigeria. One reason for this is that the majority of the population lives below the poverty line. Little to no income makes it difficult for households to waste food. Furthermore, some cultural and religious beliefs frown upon food waste. It is therefore important that interventions and policies focus strongly on reducing food loss at the pre-consumption stages (Afolabi et al., 2021). In order to transform the Nigerian food system, there is a need for policies, and regulations specifically aimed at reducing food loss. This is critical to ensuring the multiple benefits of food loss reduction (Afolabi et al., 2021). The findings of the studies analysed for the SLR identified interventions that include knowledge about the nature of food loss, the social dimension, and finally, finance, technology, and infrastructure – hence, a material dimension.

3.3.1. *Knowledge about the nature of food loss*

Plant pathogens are evolving, but there is little or no data on emerging disease parasites, making it difficult to develop disease-resistant crop varieties. The lack of appropriate data has limited opportunities for innovative and impactful research (Abdulsalam et al., 2021). This has made it difficult to develop appropriate and sustainable technologies (Ayeni et al., 2021). This has led to inefficiencies in the country's food system and high levels of food loss. Afolabi et al. (2021) add that inadequate and unreliable data has hindered the design of appropriate policies and intervention programmes in the country, and if food loss is not adequately measured, it cannot be adequately managed.

Most studies that have attempted to estimate food losses have failed due to the lack of data. Chiaka et al. (2022) documented that assumptions were made in some parts of their studies due to the lack of primary data from farmers. Around two decades ago, Umeh (1994) lamented that record-keeping and documentation were not popular management practices for smallholder farmers subsistence farmers in Nigeria. This means that the true reality of farming activities is unknown and leaves room for various assumptions.

There is therefore an urgent need for complete and reliable agricultural data (Mmereki et al., 2024). This is essential for monitoring and evaluating the impact of interventions aimed at reducing food loss. Most importantly, these data provide a clear understanding of policy gaps and other activities that lead to food loss (Afolabi et al., 2021). It also provides an understanding of the most appropriate practices and technologies that are currently working and those that farmers are willing to adopt (Enete et al., 2012).

The knowledge generated from the data will help extension education to understand the areas for training and development. It will also provide further evidence on how to develop and improve the efficiency of low-cost production and postharvest technologies (Takeshima et al., 2023). In addition, it provides evidence-based information on the factors that determine the adoption of postharvest technologies and improved practices among smallholder farmers in different regions. This knowledge can be used to design interventions aimed at changing farmers' mindsets towards the adoption of production and postharvest technologies (Morris et al., 2018).

3.3.2. *Social dimension: developing competencies*

Most smallholder farmers in Nigeria are elderly and have little or no formal education or training. The literacy rate is significant in determining the level of awareness and exposure to innovations, technologies, and improved practices that could increase productivity and minimize losses (Afolabi et al., 2021). The lack of education and training of farmers has contributed to a lack of data that could help design innovative research. Farmers lack the knowledge to keep adequate records of their farming activities and to carry out other important management practices such as seed testing and moisture content analysis (Afolabi et al., 2021; Ayeni et al., 2021).

The most vulnerable farmers who experience severe food losses are those with little or no knowledge of sustainable coping strategies (Amaechina et al., 2022). Among many other factors, low literacy due to a lack of formal and informal training through extension education is one of the barriers to smallholder farmers' adoption of postharvest technologies for sustainable production, processing, packaging, and storage of food (Balana et al., 2021)

Educational development remains a critical intervention in the quest to reduce food loss. This is because education and training affect farmers' perceptions and beliefs regarding the adoption of various management practices, techniques, and technologies to reduce food loss (Morris et al., 2018). The adoption of technologies and improved management practices will consequently increase farmers' productivity and standard of living standards (Afolabi et al., 2021; Castelein et al., 2022; Idris-Adeniyi et al., 2022). Training will also provide farmers with guidance on which technologies to invest in, given their specific characteristics and limited resources (Castelein et al., 2022).

3.3.3. *Finances, technology, and infrastructure – a material dimension*

Technologies that will help increase production and reduce losses include but are not limited to, the development and adoption of hybrid crop varieties, adapted to the local environment, such as maize, that contain multiple disease-resistance traits. Adoption of this technology by farmers will help reduce the quality losses due to mycotoxin infestation (Bankole et al., 2022). Drought-tolerant and early-maturing crop varieties are also inevitable if sustainable production is to be achieved due to rainfall variability (Emeribe et al., 2020). Early maturing crop varieties are needed (Rabiu and Rose, 2007; Okechukwu et al., 2008).

Castelein et al. (2022) found that the use of machinery instead of unskilled human labour in rice harvesting and processing increases yield per hectare by >15 % on average. It also reduces losses and greenhouse gas (GHG) emissions. It also increases farmers' revenue (Castelein et al., 2022). In addition, reusable plastic crate technology has the potential to reduce food loss in fruit and vegetable crops (Balana et al., 2021). The challenge for farmers in adopting these technologies is their inability to meet the cost of renting or purchasing them. Therefore, it is imperative to develop incentives (loans or access to credit access) for farmers to meet the initial investment requirements for different types of machinery. In addition, lack of credit and training increases farmers' risk of food losses. This underscores the need for government and policymakers to ensure the training of farmers, the formation of farmers' cooperative groups, empowerment programmes among farmers (Enete et al., 2016), and the development of low-cost technologies to help prevent food loss (Eruola et al., 2013)

The most significant post-harvest challenge for smallholder farmers after harvesting is the lack of infrastructure. The perishable nature of some crops, such as vegetables, means that they require adequate processing, storage, and transportation (Idris-Adeniyi et al., 2022). This requires investment in infrastructure, such as stable electricity and motorable road networks, from farms to markets, and from rural areas to urban areas (Eruola et al., 2013). Emerging refrigeration, such as cold rooms, have become important for food storage and the prevention of food loss. However, access to and affordability of stable sources of electricity sources remain major constraints for farmers. This calls for investment in alternative sources of electricity, such as solar-powered electricity systems (Takeshima et al., 2023). Weather instability and long dry spells have made it important for governments and policymakers to invest in irrigation facilities. This will ensure food production throughout the year, especially in areas with proven water deficits (Chiaka et al., 2022; Eruola et al., 2013).

Overall, interventions and policies must be appropriate to the identified problem, culture, and environment of the target population and community. Differences in agroecological characteristics indicate that smallholder farmers sometimes face different challenges at different

stages of their food systems. Therefore, intervention programmes should be context-specific (Afolabi et al., 2021) to suit the environmental characteristics of each region (Chiaka et al., 2022).

4. Discussion

The findings of this systematic literature review demonstrate that food loss in Nigeria is shaped by the multifaceted interaction of natural, social, and material dimensions. Nevertheless, despite the acknowledgement of the issue, there seems to be a paucity of evidence indicating the implementation of a comprehensive and coordinated approach to effectively addressing these challenges. This section presents a critical evaluation of the current state of interventions in Nigeria, a comparison with strategies in other Sub-Saharan African contexts, and an identification of potential avenues for improvement.

An evaluation of the current interventions reveals that, while there are several policy initiatives and programmes aimed at reducing food loss in Nigeria, such as efforts to promote improved storage techniques and postharvest management practices, the implementation of these measures remains inconsistent (Afolabi et al., 2021). Our review identifies significant deficiencies in infrastructure, technology adoption, and farmer education that continue to impede progress. For example, although some initiatives have been implemented to introduce modern storage facilities, many smallholder farmers continue to rely on traditional methods, which results in significant losses at the postharvest stage (Ayeni et al., 2021). Moreover, the lack of access to affordable credit and extension services constraints farmers' capacity to adopt innovative technologies that could mitigate losses (Chiaka et al., 2022; Takeshima et al., 2023)

A comparison with other sub-Saharan African contexts reveals that Nigeria presents distinctive challenges and opportunities to address food loss. By way of illustration, in contrast to the situation in countries such as Kenya or Ethiopia, where agricultural cooperatives play a prominent role in the reduction of postharvest losses, the cooperative movements in Nigeria are less developed and frequently lack the requisite support and coordination (Aworh, 2015). Furthermore, Nigeria's diverse agroecological zones present distinctive challenges, including varying pest and disease pressure and disparate climate-related risks. These necessitate region-specific strategies that are currently underdeveloped (Zhang et al., 2018; Emeribe et al., 2020). However, Nigeria also presents a number of distinctive opportunities. Nigeria's position as a regional leader in West Africa provides a platform from which innovative, cross-border solutions to food loss can be spearheaded, leveraging the country's large market size and strategic partnerships. Additionally, nascent local initiatives, such as farmers-led postharvest management practices and innovative applications of digital technologies for market access, have the potential to be scaled up and implemented on a larger scale, thereby reducing losses across the food system (Balana et al., 2021; Castelein et al., 2022).

In order to achieve meaningful progress in reducing food loss, Nigeria must adopt a more integrated approach that addresses the problem's natural, social, and material dimensions. This entails the investment in low-cost technologies for enhanced storage and transportation, the promotion of farmer education programmes to improve postharvest handling practices, and the fostering of public-private partnerships for the development of infrastructure that supports food preservation and distribution (Idris-Adeniyi et al., 2021; Rabiu and Rose, 2007). Furthermore, there is a necessity for more context-specific research to gain a deeper understanding of the underlying causes of food loss at various stages of the food system. For example, qualitative studies focusing on the experiences and practices of farmers, traders, and other stakeholder could provide valuable insights into the barriers to adopting improved technologies and practices (Chauhan et al., 2021; Morris et al., 2018). Such research could inform the design of more targeted interventions that consider the specific socioeconomic and cultural contexts in which they are to be implemented. In conclusion, although some measures are being implemented to tackle food loss in Nigeria, these initiatives are frequently fragmented and inadequately targeted. Adopting a more holistic approach that integrates technical, social, and policy solutions could enable Nigeria to serve as a model for other countries in sub-Saharan Africa facing similar challenges.

5. Conclusions

This study offers a comprehensive examination of the factors contributing to food loss in Nigeria, demonstrating that the issue is complex and encompasses natural, social, and material dimensions. The review highlights the necessity for integrated solutions that address these multiple dimensions concurrently to achieve substantial reductions in food loss and contribute to more sustainable food systems. The findings indicate that while there are existing policies and initiatives aimed at mitigating food loss in Nigeria, there are significant gaps in their implementation and effectiveness. It is imperative to prioritize the enhancement of rural infrastructure, the expansion of access to affordable technologies, and the implementation of targeted educational and training programmes for farmers (Afolabi et al., 2021; Takeshima et al., 2023). Furthermore, the absence of comprehensive and reliable data on food loss at the regional and local levels continues to impede the development of effective policies (Mmereki et al., 2024).

Nigeria's status as a regional leader in West Africa affords the country considerable potential to adopt and implement innovative strategies that could serve as a model for other countries in the region and beyond. This includes the fostering of partnerships across the public and private sectors, the investment in infrastructure, and the support of community-based initiatives that integrate local knowledge with modern technologies (Castelein et al., 2022; Chiaka et al., 2022). To progress, it is vital to prioritize data collection and research, particularly qualitative studies that capture the perspective of diverse food system actors (Chauhan et al., 2021; Morris et al., 2018). This will facilitate a more nuanced understanding of the obstacles to food loss reduction and enable the design of more effective, context-specific interventions. In conclusion, the reduction of food loss in Nigeria necessitates a multifaceted and integrated approach that is aligned with the local context and needs. By enhancing the collection of data, encouraging the implementation of targeted interventions, and cultivating collaborative relationships, Nigeria can make considerable progress towards attaining sustainable food systems and contributing to global food security objectives.

CRediT authorship contribution statement

Ifeoluwa Abulude: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Stefan Wahlen:** Writing – review & editing, Supervision, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix

Table A1

Table A1
Characteristics of selected articles.

S/N	Authors	Title of article	Focus Crop	Year of publication	Type of Study	Type of Publication	Region
1.	Abdulsalam et al.	Nematode pests of some major cereals in Nigeria: Need for integration of morphological/morphometrical, biochemical, and molecular diagnostic approaches for accurate identification	Cereals: Maize (*Zea mays*), Rice (*Oryza sativa*); Sorghum (*Sorghum bicolor*); Wheat (*Triticum aestivum* and *T. durum*)	2021	Qualitative	Review article	Not Specified
2.	Afolabi et al.	Country-level assessment of agrifood waste and enabling environment for sustainable utilisation for bioenergy in Nigeria	Not specific	2021	Quantitative	Research Article	Entire country
3.	Agoda et al.	Post-harvest food losses reduction in maize production in Nigeria	Maize	2011	Qualitative	Review	Not Specified
4.	Amaechina et al.	Assessing climate change-related losses and damages and adaptation constraints to address them: Evidence from flood-prone riverine communities in Southern Nigeria	Not Specific	2022	Quantitative	Research Article	South: Anambra & Cross River state
5.	Aworh	Promoting food security and enhancing Nigeria's small farmers' income through value-added processing of lesser-known and under-utilized indigenous fruits and vegetables	Fruits & Vegetables	2015	Quantitative & Qualitative	Research Article	Not Specified
6.	Ayeni et al.	Present status and future perspectives of grain drying and storage practices as a means to reduce mycotoxin exposure in Nigeria	Grains	2021	Qualitative	Review Article	Not Specified
7.	Balana et al.	Improving livelihoods through postharvest loss management: evidence from Nigeria	Tomato	2021	Quantitative	Research Article	Southwest: Lagos State
8.	Bankole et al.	Identification of Early and Extra-Early Maturing Tropical Maize Inbred Lines with Multiple Disease Resistance for Enhanced Maize Production and Productivity in Sub-Saharan Africa	Maize	2022	Quantitative	Research Article	Not Specified
9.	Castelein et al.	Mechanization in rice farming reduces greenhouse gas emissions, food losses, and constitutes a positive business case for smallholder farmers - Results from a controlled experiment in Nigeria	Rice	2022	Quantitative	Research article	Northcentral: Nassarawa State
10.	Chiaka et al.	Smallholder Farmers Contribution to Food Production in Nigeria	Rice (*Oryza sativa*); Maize (*Zea mays*); Sorghum (*Sorghum bicolor*); Soya bean (*Glycine* max); Cassava (*Manihot esculenta*), and Yam (*Dioscorea* spp.)	2022	Quantitative	Research Article	All the Six geopolitical zones
11.	Emeribe et al.	Climatic Water Balance Over Two Climatic Periods and Effect on Consumptive Water Need of Selected Crops in the Chad Basin, Nigeria	Various crops	2020	Quantitative	Research Article	Chad Basin area. Borno & Yobe states
12.	Enete et al.	Climate change and the profitability of indigenous adaptation practices in smallholder agriculture in South East Nigeria	Not Specific	2012	Quantitative	Research Article	Southeast: Enugu & Imo States
13.	Enete et al.	Socioeconomic assessment of flooding among farm households in Anambra state, Nigeria	Not Specific	2016	Quantitative	Research Article	South: Anambra State
14.	Eruola et al.	Effect of Climate Variability and Climate Change on Crop Production in Tropical Wet-and Dry Climate	Not Specific	2013	Quantitative	Research Article	Southwest: Ibadan
15.	Idris-Adeniyi et al.	Costing postharvest losses in selected leafy vegetable marketing in Lagelu Local Government area of Oyo State, Nigeria	Leafy Vegetables	2022	Quantitative	Research Article	Southwest: Oyo State

(*continued on next page*)

Table A1 (*continued*)

S/N	Authors	Title of article	Focus Crop	Year of publication	Type of Study	Type of Publication	Region
16.	Morris et al.	Small-scale postharvest practices among plantain farmers and traders: A potential for reducing losses in rivers state, Nigeria	Plantain	2018	Quantitative	Research Article	Southsouth: Rivers State
17.	Okechukwu et al.	Root rot resistance in new cassava varieties introduced to farmers in Nigeria.	Cassava	2008	Quantitative	Research Article	Across the country
18.	Rabiu & Rose	Crop damage and yield loss caused by two species of rodents in irrigated fields in northern Nigeria	Rice and Wheat	2007	Quantitative	Research Article	Kano, Northern Nigeria
19.	Takeshima et al.	Solar-powered cold-storage and agrifood market modernization in Nigeria	Horticultural crops	2023	Quantitative	Research Article	Northeast
20.	Umeh, J. C.	On-farm storage structure inventory management - an economic appraisal of rhumbu	Grains	1994	Quantitative	Research Article	Not Specified
21.	Verma et al.	A Systems Approach to Food Loss and Solutions: Understanding Practices, Causes, and Indicators	Tomato	2019	Qualitative	Research Article	Not Specified
22.	Wada et al.	Role of seed in disease transmission and the need for effective seed health testing centres in Nigeria	Various seed crops	2002	Qualitative	Review	Not Specified
23.	Zhang et al.	Farmers' perceptions of crop pest severity in Nigeria are associated with landscape, agronomic and socio-economic factors.	Various crops	2018	Quantitative	Research Article	Northern & Southern Agroecological Zones in Nigeria

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