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Pre- and postharvest losses and their correlates in the millet value chain in Nigeria

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Food losses continue to constrain food security, rural incomes, and agrifood system efficiency in sub-Saharan Africa, yet comprehensive micro-level evidence across entire value chains remains scarce. This study provides a detailed assessment of pre- and postharvest losses along the millet value chain in northwestern Nigeria, focusing on producers, aggregators, and processors in Sokoto and Zamfara states—two major millet-producing regions. Millet is a nutritionally rich and climate-resilient staple that plays a critical role in Nigeria, making loss reduction in this value chain particularly important for food system resilience.

The analysis draws on a purposefully designed baseline survey conducted in 2024, covering 595 millet producers and downstream value chain actors. The study applies a novel attribute-based loss measurement methodology that captures both quantitative losses (physical grain loss) and qualitative losses (quality degradation and associated price penalties), allowing estimation of losses in both volume and value terms across multiple nodes of the value chain. In addition to descriptive loss accounting, econometric models are employed to identify factors correlated with the incidence/likelihood and intensity of preharvest and postharvest losses at the producer level.

The results show that millet losses are widespread and concentrated at early stages of the value chain. Nearly all producers experience losses, with preharvest and on-farm postharvest stages accounting for the largest share. Total losses along the value chain average about 9 percent of total volume of production and 6 percent of total value of production. These estimates are comparable to the findings by the African Postharvest Losses Information System of approximately 9 percent millet losses in postharvest production activities in Nigeria. Producer-level losses dominate overall losses, although processors also incur substantial losses during storage, handling, and transportation. Spillage, pest infestation, moisture exposure, and inadequate handling practices are the most frequently reported causes of postharvest losses among downstream actors, although losses by aggregators are generally low.

Loss patterns vary systematically across space and demographic groups. Producers in Zamfara experience significantly higher losses than those in Sokoto, with preharvest losses playing a more prominent role. Youth and male producers incur higher total losses than mature producers, while gender differences are also observed in the composition and timing of losses across production stages. These patterns underscore the importance of spatially targeted and demographically sensitive loss-reduction strategies.

Econometric results highlight the central role of technology adoption, asset ownership, and management practices in loss reduction. Higher education levels, greater asset ownership, and larger farm size are associated with lower loss intensity, while preharvest shocks significantly exacerbate postharvest losses. The use of improved transportation, winnowing, and storage technologies substantially reduces postharvest loss intensity, whereas higher rainfall and temperature during postharvest periods increase losses.

Overall, the study demonstrates that food losses in Nigeria's millet value chain are systemic but largely preventable. Effective loss reduction requires integrated, value chain–oriented interventions that combine improved production and postharvest technologies, climate adaptation measures, infrastructure investment, and targeted support for youth and smallholders. By providing rigorous micro-level evidence across multiple value chain nodes, the study strengthens the empirical foundation for food loss reduction policies and agrifood system transformation in Nigeria.

TAKAITACCEN BAYANI

Asarar abinci na ci gaba da kawo cikas ga samar da abinci, kudaden shiga na karkara, da ingantaccen tsarin noma a yankin kudu da hamadar sahara, amma duk da haka akwai karancin shaida a kan dukkan sarkar darajar. Wannan binciken ya yi bayani dalla-dalla kan asarar da aka yi kafin girbi da bayan girbi a kan sarkar darajar gero a yankin arewa maso yammacin Najeriya, inda aka mayar da hankali kan masana'antun da masu hada-hada da masu sarrafa kayayyaki a jihohin Sokoto da Zamfara—yankuna biyu masu noman gero. Gero abinci ne mai wadataccen abinci mai gina jiki kuma mai jure yanayin yanayi wanda ke taka muhimmiyar rawa a arewacin Najeriya, yana yin raguwar asara a wannan sarkar darajar musamman ga juriyar tsarin abinci.

Binciken ya zana kan wani bincike na asali da aka ƙera da niyya wanda aka gudanar a cikin 2024, wanda ya ƙunshi masu kera gero 595 da ƴan wasan sarkar darajar ƙasa. Binciken ya yi amfani da sabon tsarin auna asarar sifa wanda ke ɗaukar asarar ƙididdigewa biyu (asarar hatsi ta zahiri) da asarar ƙima (lalacewar inganci da hukunce-hukuncen farashi mai alaƙa), yana ba da izinin ƙididdige hasara a cikin duka girma da ƙimar ƙima a cikin kuɗaɗe da yawa na sarkar darajar. Baya ga lissafin asarar da aka siffanta, ana amfani da tsarin tattalin arziki don gano abubuwan da ke da alaƙa da aukuwa/yiwuwa da tsananin asarar girbi da bayan girbi a matakin masu samarwa.

Sakamakon ya nuna cewa asarar gero ya yaɗu kuma yana mai da hankali a farkon matakan sarkar darajar. Kusan duk masu kera suna fuskantar asara, tare da girbi kafin girbi da kan gonaki bayan girbi sune ke da mafi girman kaso. Jimlar asara tare da matsakaicin sarkar darajar kusan kashi 9 cikin ɗari na jimlar yawan samarwa da kashi 6 cikin ɗari na jimlar ƙimar samarwa. Asarar matakin masu samarwa sun mamaye asara gabaɗaya, kodayake masu sarrafawa kuma suna haifar da asara mai yawa yayin ajiya, sarrafawa, da sufuri. Zubewa, kamuwa da kwari, damshi, da rashin isassun hanyoyin sarrafa su ne mafi yawan rahotannin da ke haifar da asarar bayan girbi a tsakanin ƴan wasan kwaikwayo na ƙasa, kodayake asarar masu tarawa ba ta da yawa.

Hanyoyin hasara sun bambanta da tsari a cikin sararin samaniya da ƙungiyoyin alƙaluma. Furodusa a Zamfara sun fi samun asarar fiye da na Sokoto, tare da asarar girbi kafin girbi yana taka rawa sosai. Masu samar da matasa suna haifar da hasara mafi girma fiye da manyan masu samarwa, yayin da ake lura da bambancin jinsi a cikin tsari da lokacin asara a cikin matakan samarwa. Waɗannan alamu suna nuna mahimmancin dabarun rage asara da aka yi niyya a sararin samaniya da ƙima.

Sakamakon tattalin arziƙin yana nuna babban matsayin ɗaukar fasaha, mallakar kadara, da ayyukan gudanarwa wajen rage asara. Matakan ilimi mafi girma, mallakin kadara, da girman gonaki suna da alaƙa da ƙarancin asara, yayin da girgizar ƙasa kafin girbi ke ƙara tsananta asarar bayan girbi. Amfani da ingantattun hanyoyin sufuri, winning, da fasahar ajiya na rage yawan asara bayan girbi, yayin da yawan ruwan sama da zafin jiki a lokacin girbi na ƙara asara.

Gabaɗaya, binciken ya nuna cewa asarar abinci a sarkar darajar gero na Najeriya tsari ne amma ana iya yin rigakafi. Ingantacciyar raguwar asara tana buƙatar haɗaɗɗiyar sarkar ƙima-madaidaita shisshigi waɗanda ke haɗa ingantaccen samarwa da fasahar girbi bayan girbi, matakan daidaita yanayin yanayi, saka hannun jarin ababen more rayuwa, da tallafi da aka yi niyya ga matasa da masu karamin karfi. Ta hanyar samar da ƙwaƙƙwaran ƙaƙƙarfan shaidar ƙarami a cikin kuɗaɗen sarƙoƙi masu ƙima, binciken yana ƙarfafa ƙwaƙƙwaran tushe don manufofin rage asarar abinci da canjin tsarin noma a Najeriya.

1. INTRODUCTION

1.1 GENERAL BACKGROUND

Food losses are not a new phenomenon, with evidence of food losses spanning as far back as ancient Egyptians (Baines and Malek 2000; Samuel 1999). Policy attention on food losses started gaining traction following the global food crisis of the mid-1970s, when the United Nations identified postharvest food loss reduction in developing countries as a priority (The United Nations Food and Agriculture Organization (FAO) 1981; Hodges 2012). Interest resurged following the food price crises of 2007/08, prompting renewed efforts by the FAO to measure losses, promote mitigation technologies, strengthen institutional capacity, and launch initiatives such as the Global Initiative on Food Loss and Waste Reduction (Save Food) in 2015. Momentum further increased with the establishment of APHLIS in 2009, the inclusion of postharvest loss targets in the Malabo Declaration under the Comprehensive African Agricultural Development Programme in 2014, and the adoption of food loss targets in the Sustainable Development Goals (SDGs) in 2015 (World Bank 2011; Affognon et al. 2015; Sheahan and Barrett 2017; Delgado et al. 2021).

However, studies that systematically measure the extent of food losses are relatively recent, and remain scarce, with most focusing on losses during post-harvest stages of crop production (Adams 1977; APHLIS 2025a) rather than taking a value chain approach. In addition, studies dealing with the policy considerations of post-harvest losses are a recent phenomenon.[1]

This study assesses pre- and postharvest losses along the millet value chain in northwestern Nigeria, focusing on producers, aggregators, and processors in Sokoto and Zamfara states. It contributes to the literature by combining micro-level measurement across multiple value chain nodes with econometric analysis of correlates of losses.

Several factors are reinforcing efforts to reduce PHL in sub-Saharan Africa (SSA). Rapid population growth requires substantial increase in food production alongside significant reductions in food losses (AGRA 2022; IFPRI 2020). Loss reductions could also help address the rising prevalence of moderate or severe food insecurity since 2014—exacerbated by global crises that disrupted food supply chains—and support progress toward achieving SDG 2 (Zero Hunger) by 2030. At the same time, climate change and increasing extreme weather events are making food production and rural livelihoods precarious, affecting not only crop growth but also postharvest outcomes. Reducing food losses is therefore central not only to improving food availability but also to lowering the environmental costs associated with using land, water, energy, and other inputs to produce food that is ultimately not consumed (AGRA 2022; IFPRI 2020; Stathers et al. 2015; World Bank 2011). Loss reduction can further improve farm productivity, expand marketed supply, and improve the profitability and incomes of smallholder farmers who dominate food production in SSA.

Globally, food losses are estimated to be substantial (APHLIS 2013; FAO 2011; Lipinski et al. 2013). FAO (2011) has estimated that roughly one-third of all food produced for human consumption—roughly 1.3 billion tons annually—is lost or wasted worldwide. Losses occur at different stage of value chains across countries: in higher-income countries, waste primarily occurs at the consumer level, while in low-income countries, losses are concentrated in early and intermediate stages of supply chains.

In sub-Saharan Africa (SSA), food losses are estimated at about 100 million metric tons (MT) annually. Of this figure, grain losses are valued at about US$4 billion (2007 prices), which exceeds the annual value of grain imports into Africa and the value of total food aid received in SSA over the 2008-2018

[1] See section 2.1 for precise definitions of concepts and terms used in this study.

decade (African Union 2018). In 2017, the African Postharvest Losses Information System (APHLIS) reported cereal postharvest losses of nearly 17 percent of total production (APHLIS 2025b).

However, important evidence gaps remain in the measurement and assessment of food losses. Early estimates of food losses were derived from macro-level assessments with limited micro-level analyses and often relied on tenuous assumptions and outdated or inappropriate data (Affognon et al. 2015; Kaminski and Christiaensen 2014). Evidence remains lacking on the relative importance of quantitative and qualitative losses in production, postharvest production, and the downstream nodes of value chains. Given the diverse agroecologies, crop cultures, and production systems in SSA, more precise measurement of losses across production and postharvest stages is required.

Even today, studies that systematically measure the extent of food losses remain scarce, with most focusing on losses during postharvest stages of crop production (Adams 1977; APHLIS 2025a) rather than taking a value chain approach. Measuring and addressing postharvest losses requires a broader value chain perspective that expands the focus from losses at a single stage. Most interventions target storage losses, yet significant losses occur in harvesting, drying, transportation, processing, and marketing. Relatively few studies track losses comprehensively along the entire value chain in SSA. Moreover, loss-reduction strategies must account for the region's technological and institutional context, which is characterized by low input use, limited mechanization, weak service infrastructure, and underdeveloped markets and institutional support. These limitations reduce incentives for adopting improved practices (Chatterjee 2018). A more holistic, value-chain-oriented and technology-sensitive approach is therefore needed for both research and policy. Recent empirical studies have begun filling these gaps, showing that mechanization of harvesting and threshing can significantly reduce losses (Daum 2023; Minten et al. 2021), while poor handling, delayed harvesting, and weak transport and market access contribute substantially to total losses (Delgado et al. 2017; 2021; Minten et al. 2021; Ssajjabbi et al. 2025). Studies dealing with the policy considerations of postharvest losses are also a recent phenomenon.

This study contributes to addressing these evidence gaps. It contributes to the literature by combining micro-level measurement across multiple value chain nodes with an econometric analysis of correlates of losses. The study describes millet production, aggregation, and processing activities; the socioeconomic and demographic characteristics of value chain agents; and the relevant policy environment in Nigeria. In doing so, it contributes micro-level evidence on food losses in SSA while providing a comprehensive view of the millet value chain—an important source of income and food security in Nigeria. The study also conducts econometric analyses to investigate the correlates of losses among producers during production and postharvest stages. By linking production and postharvest technologies and practices to observed loss levels along the value chain, the analysis helps address a key knowledge gap and provides evidence relevant for policy design.

This study examines millet losses in Nigeria as part of a broader research effort using purposefully collected data on food losses across three SSA countries—Kenya, Nigeria, and Rwanda—which differ in agroecological conditions, levels of economic and agricultural development, and crop focus. The analysis employs a recently developed data collection and measurement methodology (Delgado et al. 2021). The study aims to characterize food losses at different stages of the value chain and address the evidence gaps identified in the literature. Specifically, it measures quantitative and qualitative losses at multiple points along the millet value chain in northwestern Nigeria, identifying the production stages and processes where losses occur and their relative importance.

The detailed assessment of pre- and postharvest losses along the millet value chain in this report was conducted as part of the Strengthening Food Systems to Promote Increased Value Chain Employment Opportunities for Youth (SFS4Youth) project. The project is a collaboration of IFPRI, the Mastercard

Foundation, and its implementing partner. The project's overall objective is to provide tested options for creating innovative, digitally savvy livelihood opportunities for youth, especially young women, while reducing postharvest losses across agrifood systems. Consistent with this project's objective, IFPRI and partners are conducting a series of studies to measure pre- and postharvest losses among producers and downstream value chain agents, namely aggregators and processors.

1.2 IMPORTANCE OF MILLET IN NIGERIA

Agriculture represents a cornerstone of Nigeria's economy, contributing nearly one-quarter of the country's gross domestic product (NBS 2025; ITA 2025). Small-scale farmers constitute roughly four-fifths of the farming population and produce approximately 90 percent of the agricultural output. The sector directly engaged about 35 percent of Nigeria's workforce in 2022, while an additional 32.6 percent found employment in agrifood system activities beyond the farm gate (Bachewe et al. 2025).

Millet is an important staple crop in Nigeria: most of the country's pearl millet is cultivated in the northern region, and nearly 54 percent of households consume millet, though this share is even higher (nearly 86 percent) in the northwestern region that is the focus of our study. Despite millet's superior nutritional value compared to other cereals, consumption is largely limited to subsistence farmers and lower-income households due to its affordability, as well as its limited value chain development and cultural perceptions that associate it with poverty. Millet is highly resilient, known for its drought tolerance and pest resistance, and it can thrive in harsh and variable climate conditions (Choudhary et al. 2023; Srivastava and Arya 2021). It also releases relatively low greenhouse gas emissions compared to other cereals, giving it significant potential for sustainable agriculture (Saxena et al. 2019). Finally, millet requires less time to mature than other staples, ranging from 60 to 90 days for some cultivars (Kaminski and Christiaensen 2017). The FAO designated 2023 as the International Year of Millets (IYM 2023) in acknowledgement of these beneficial qualities and with the aim of revitalizing global millet production and consumption, boosting awareness of production potential, and promoting policies to maximize its nutritional and health benefits.

Table 1.1 summarizes trends in the area cultivated under millet and total production in Nigeria from 2009 to 2024. From 2009 to 2016, the country experienced relatively low yields averaging less than 0.9 MT per hectare (ha). However, yields improved after 2016, rising to 1.2 MT/ha during the 2017–2022 period. On average, millet accounted for approximately 5 percent of Nigeria's total cultivated land from 2009 to 2023. However, its relative importance declined from an average of 6 percent in the 2009–2015 period—peaking at more than 9 percent in 2009—to approximately 4 percent in 2016–2023. Despite this reduction in land cultivated, about 22 percent of crop-producing households in Nigeria cultivate millet in the main season (NBS 2023).

However, Nigeria faces particularly acute challenges with food loss. Estimates indicate that the country loses more than one-third of its food production annually, with significant implications for land, water, and resource use efficiency (Haruna et al. 2023). At least 20 percent of these losses come from the production of grain, roots, and tubers, though losses are even higher for fruits and vegetables, with substantial losses occurring in both the pre- and post-storage stages (Abbas 2018). According to APHLIS data for 2022, Nigeria experienced a 9.5 percent loss in millet postharvest, which amounts to 315,000 MT of millet per year—enough to feed 1.3 million people annually, or more than 16 percent of the nation's children (APHLIS 2025c).

Table 1.1. Area cultivated, quantity produced, and yields of millet in Nigeria, 2009–2024

Year	Total cultivated area (000 ha)	Area planted (000' ha)	Quantity produced (MT)	Yield (MT/ha)
2009	43,298	4,048	4,908	1.2
2010	42,335	2,878	1,381	0.7
2011	42,262	2,889	1,271	0.7
2012	42,384	2,894	1,281	0.7
2013	42,078	1,992	1,465	1.0
2014	42,092	1,846	1,635	0.9
2015	42,188	1,808	1,477	0.8
2016	42,274	1,738	1,487	0.9
2017	42,425	1,677	1,784	1.1
2018	42,896	1,734	1,973	1.1
2019	43,351	1,748	2,021	1.2
2020	43,668	1,762	2,001	1.1
2021	43,742	1,767	2,023	1.1
2022	44,015	2,020	1,941	1.0
2023	44,226	1,543	1,549	1.0
2024	-	1,548	1,546	1.0

Source: FAO (2025); NAERLS Data (2024).
Note: ha = hectares; MT = metric tons.

Box 1: Nigeria’s agricultural policies

In recognition of the damaging impact of food losses on Nigeria’s food security and economic stability, the 2011–2015 Agricultural Transformation Agenda (ATA) marked a pivotal policy shift toward strengthening agricultural value chains. The ATA aimed to improve farmers’ access to quality inputs, establish staple crop processing zones (SCPZs), and promote backward integration across the sector. The SCPZs were particularly significant, as they aimed to locate processing facilities close to production areas, thereby reducing the perishability of crops and minimizing postharvest losses caused by transportation delays and inadequate storage. In this way, the ATA provided one of Nigeria’s earliest institutional mechanisms for directly addressing food loss through value chain infrastructure development. Building on this foundation, the 2016–2020 Agricultural Promotion Policy (APP)—often known as The Green Alternative—further advanced the transformation agenda by emphasizing food self-sufficiency, private sector participation, and value chain efficiency. The APP underscored the need to strengthen processing, storage, and logistics systems to reduce food losses and waste, while promoting a transition from subsistence farming to agribusiness-oriented production. By linking improved postharvest handling to national food security objectives, the policy reinforced the role of value addition and system efficiency as essential components of Nigeria’s agricultural development strategy.

As a successor to the APP, the National Agricultural Technology and Innovation Policy (NATIP) 2022–2028 represents Nigeria’s contemporary food systems approach, integrating principles of climate resilience, technological innovation, and inclusivity. The NATIP explicitly highlights the importance of innovative technologies for improving storage, processing, and logistics, alongside investments in rural infrastructure such as feeder roads and cold chain systems. By promoting agribusiness-led growth and rural industrialization, the NATIP envisions a modern agricultural sector that not only enhances productivity but also reduces postharvest losses while strengthening sustainability and livelihoods. Institutionally, a major innovation in the current policy landscape was the establishment of the Presidential Food Systems Coordinating Unit (PFSCU) in 2024. Situated within the Office of the Vice President, the PFSCU is mandated to coordinate national food security strategies, promote agricultural exports, and facilitate job creation through agribusiness development. With its cross-sectoral mandate and high-level oversight, the PFSCU is strategically positioned to play a central role in shaping Nigeria’s future food loss reduction strategies by improving governance, enhancing policy coherence, and ensuring better alignment across ministries and programs. Complementing these policy and institutional developments, the federal government of Nigeria recently launched the Nigeria Postharvest Systems Transformation Programme to ensure a resilient, efficient, and inclusive postharvest handling and storage system that reduces losses, enhances incomes, and achieves food sovereignty (Federal Ministry of Agriculture and Food Security 2025).

The rest of this study is organized as follows: Section 2 discusses the study’s conceptual framework and defines key concepts. Section 3 describes the methodology used to measure losses in the millet value chain and the econometric methods used to investigate correlates of losses at production and postharvest stages, with a subsection focused on the baseline survey data. Section 4 characterizes value chain agents and activities. Section 5 presents the frequency, magnitude, and causes of losses. Section 6 presents econometric results on correlates of losses. Section 5 presents the frequency at which value chain agents experience losses, the share and nodes at which losses occur, and sources that contribute significantly to these losses. Section 6 presents the results of the econometric analyses on correlates of losses during millet production and postharvest production.

2. CONCEPTUAL FRAMEWORK AND DEFINITIONS

This section defines key concepts used in the study and presents the conceptual framework guiding the analysis. The framework situates food losses along the millet value chain, from production through aggregation and processing, and links loss points to the survey modules and empirical analysis.

2.1 DEFINITIONS AND CONCEPTS

This section defines concepts related to food losses in crop value chains. Given the FAO's leadership in measuring food loss and waste, these definitions are largely derived from its methodological publications or affiliated institutions and authors.

Value chains comprise "a full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services); delivery to final customers; and final disposal after use" (Kaplinsky and Morris 2002, p. 4). More specifically, agricultural value chains comprise "the input supply, production, postharvest, storage, processing, marketing and distribution, food service and consumption functions along the "farm-to-fork" continuum for a given product" (FAO 2018, p.9).

Agricultural value chains primarily produce food, which the FAO and the World Health Organization (2023, p. 7) define as "any substance, whether processed, semi-processed, or raw, which is intended for human consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of 'food' but does not include cosmetics or tobacco or substances used only as drugs." The production of food in agriculture involves joint production of edible and inedible components of food. The edible part refers to that element of food that a population of a specific cultural or economic group traditionally consume (Fabi and English 2019). On the other hand, the inedible portions of the crop, such as stalks, hulls, and leaves, are not food. Crops for consumption by animals are not considered food (FAO 2018).

Agricultural food value chains involve several stages. Kaplinsky and Morris (2002) define the preharvest stage of crop production as "the time frame between maturity and harvesting." However, in the context of crop losses, we define the preharvest production stage more broadly to cover the full production cycle—from land preparation through harvest—to capture all factors and processes that contribute to losses. Harvesting is defined as "the deliberate act of separating the food material from the site of immediate growth or production, for instance reaping of cereals, picking of fruits, etc." (FAO 2018, p.13). Postharvest is the period after separation from the site of immediate growth or production. Moreover, the stage of production that comprises harvest and postharvest operations is defined as postproduction (FAO 2018).

Food loss is defined as "all the crop and livestock human-edible commodity quantities that, directly or indirectly, completely exit the postharvest production/supply chain by being discarded, incinerated or otherwise, and do not re-enter in any other utilization (such as animal feed, industrial use, etc.), up to, and excluding, the retail level. Losses that occur during storage, transportation and processing, also of imported quantities, are therefore all included. Losses include the commodity as a whole with its non-edible parts" (Fabi and English 2019, p.6). The FAO (2018) qualifies this definition of food losses as the measurable decrease of food produce which may be quantitative or qualitative and something that causes any change in the availability of food and in the edibility, wholesomeness, or quality of food that reduces its value to humans. Specifically, losses in grains may be characterized as direct, indirect, quantitative, qualitative, and economic.

Quantitative loss is the decrease in the physical substance of food that would have been eaten had it remained in the food chain. This type of loss is usually quantifiable and assessed through direct measurement. Quantitative loss is closely related to direct losses, defined as the disappearance of food by spillage or consumption attributed to insects, rodents, birds, mold, fungi, or others. However, quantitative loss more broadly refers to a reduction in the physical substance of food (by weight or volume) and reflects direct losses as well as other factors such as moisture loss, contamination, and spoilage (Shahbazi et al. 2025; FAO 2018; Aulakh et al. 2013).

Qualitative loss refers to the deterioration of food quality attributes, which may reduce a food's nutritional value, appearance, or other characteristics that make it less desirable for consumption or processing. Qualitative losses could result from food damage, which refers to changes in the appearance and structure of food, such as crushing or breaking produce, which makes it less usable but not necessarily unfit for consumption. This is different from food loss, where food is rendered inedible. Qualitative losses and food damage could result in nutritional loss, which is loss in the nutritional value or reduction in nutrients to the human population. This happens because damage and quality degradation mostly affect the food's nutrient content, as pests often target the most nutritious parts (Shahbazi et al. 2025; FAO 2018; FAO 2014; Aulakh et al. 2013).

Qualitative losses also cause reduced marketability and higher rejection rates of food that is less attractive to consumers. Value chain agents bear increased costs of handling, storing, and transporting food that has been damaged or has a shorter shelf life. Lower quality food fetches lower prices, which directly affects the incomes of value chain agents, particularly producers. These translate into economic losses (Shahbazi et al. 2025). In this study, we collect price data to measure the value of both qualitative and quantitative losses.

Food losses usually involve an unintentional reduction in food quantity or quality before consumption. Such losses mostly occur in the earlier stages of the food value chain, including during preharvest, harvest, and postharvest. Preharvest losses occur before the harvest begins and may be the result of attacks by insects, rodents, birds, weeds, or diseases afflicting crops. Harvest losses occur during harvesting and may be the result of shattering, mechanical damage, and shedding of the grain from the ears to the ground (FAO 2018). Losses can also occur during wholesale and retail.

In this study, we define postharvest losses as losses that occur after the crop is harvested, which excludes harvesting losses from postharvest losses. This definition is consistent with Delgado et al (2021, p.2), who argue that “PHL (post-harvest losses) is an element of food losses and excludes losses at the production level, although losses during harvest are sometimes misleadingly included in the concept.” In this study, losses during harvesting are included within preharvest production losses (and excluded from postharvest losses), while a third category—left in the field—accounts for losses due to unharvested crop and is included as a component of food losses.

A concept related to food losses is food waste, which is most common toward the end of the value chain at the retail and household level. Food waste refers to “food that is of good quality and fit for human consumption but that does not get consumed because it is discarded – either before or after it spoils. Food waste typically, but not exclusively, occurs at the retail and consumption stages in the food value chain and is the result of negligence or a conscious decision to throw food away” (Lipinski et al. 2013, p.4). As mentioned earlier, food waste is largely concentrated in high-income countries, accounting for

60 to 70 percent of total food loss and waste in these countries, or 25 to 35 percent of food available for human consumption (United Nations Environment Programme 2021; FAO 2011). Food losses are more common in low-income countries and affect food security negatively. Specifically, food losses affect food availability, which is an important dimension of food security, because food losses reduce the total quantity or quality of food produced, brought through market mechanisms, held by traders and in government reserves, and supplied by the government and/or aid agencies linked to losses (FAO 2018; Kör et al. 2022).

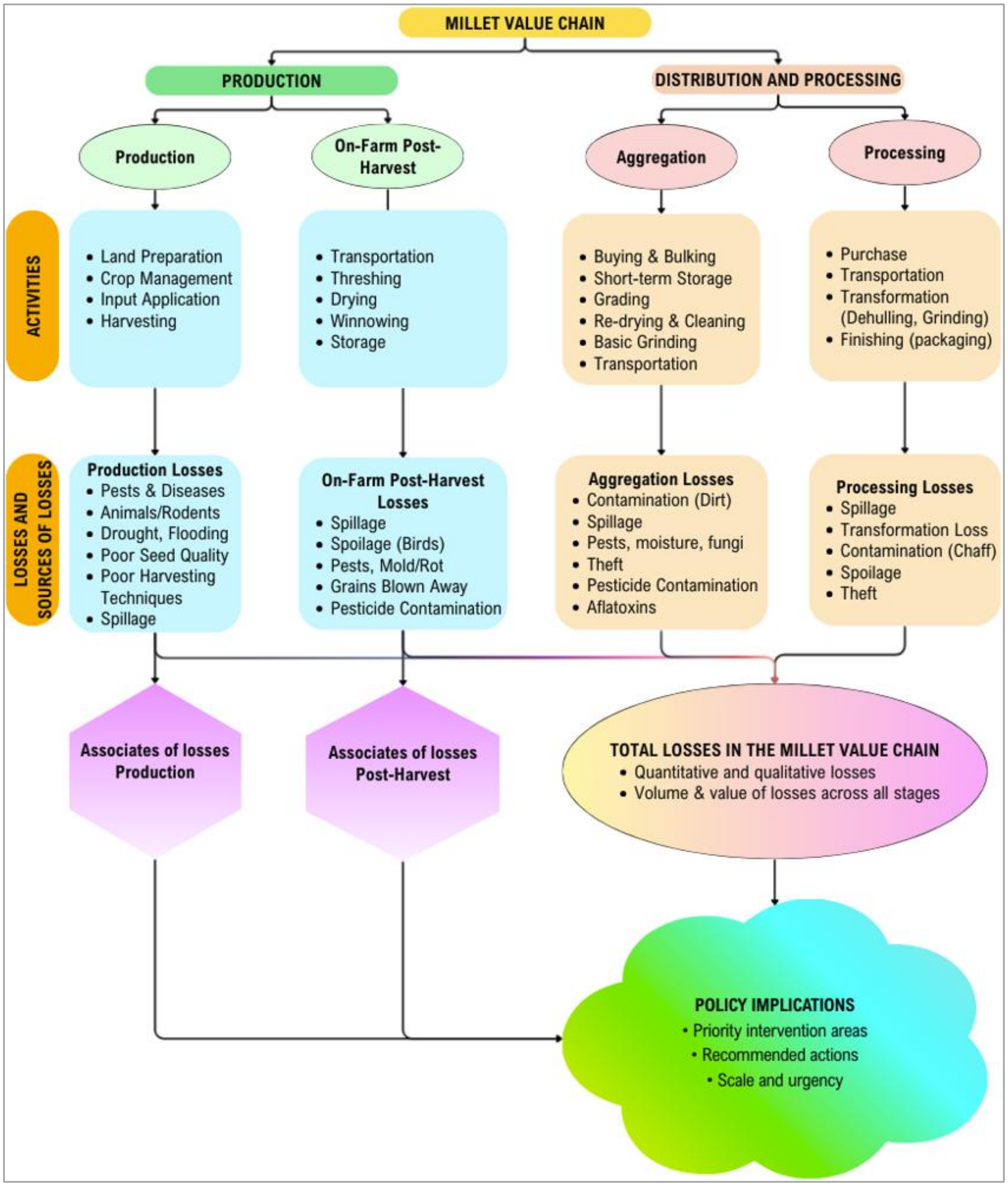
2.2 CONCEPTUAL FRAMEWORK

Figure 2.1 illustrates the conceptual framework guiding this study. This framework situates food losses within the structure of the millet value chain, spanning from production to processing. The data collected in this study trace the flow of millet from its production on the farm to its final transformation. Accordingly, the conceptual framework captures how the activities undertaken at each stage generate distinct types of quantitative and qualitative losses and how these losses accumulate to determine the total volume and value of millet lost across the value chain.

The conceptual framework displays how the data collected in different sections and subsections of the paper were used consistently with the objectives of the study. The four major columns of the conceptual framework depict the different components associated with production and on-farm postharvest handling activities (performed by producers), and the aggregation and processing activities performed by the respective value chain agents. Section 4 of the study characterizes producers, aggregators, and processors across demographic and spatial variables (section 4.1) before describing activities in the four nodes of production, on-farm postharvest, aggregation, and processing.

At the initial stage of the value chain, producers undertake the core production activities that start with land preparation and end at harvesting. Following harvest, millet producers perform a sequence of on-farm postharvest operations including transporting the harvested millet from the field, storing harvested millet, and/or selling it. Aggregators' activities involve the purchasing, bulking, grading, occasional processing, transporting, and selling of millet. Millet processors engage in purchasing, transporting, dehulling, grinding, and processing millet into different products.

Figure 2.1. Conceptual framework of the millet value chain



Source: Authors' illustration.

Each of these activities exposes the millet to numerous loss-inducing factors. The third level of the conceptual framework corresponds to section 5 of the study, where we measure losses, indicate where losses occur, and describe the sources of losses. Losses at the production stage are likely to arise for multiple reasons, including pests and diseases, animal and rodent attacks, drought and flooding, poor seed quality, and suboptimal harvesting techniques. Losses at postharvest production activities result from spillage, bird damage, pest infestation, and mold and rot, among other causes.

This study treats losses at preharvest and postharvest as analytically distinct. However, both stages are the focus of the econometric analysis of correlates of losses. At the aggregation stage, losses could result from contamination of millet with dirt, spillage during handling, pests and moisture-induced deterioration, and pesticide contamination or chemical off-flavors. Finally, processor-level losses could result from spillage, transformation inefficiencies, contamination with chaff, and spoilage.

Losses occurring at all four nodes collectively determine the total losses in the millet value chain, comprising both quantitative losses (physical grain loss) and qualitative losses (deterioration of grain quality). The framework also emphasizes that the study measures both the volume and value losses, thereby capturing their full economic implications.

The econometric analysis component of the study aims to identify factors that contribute to millet losses during production and postharvest production and thereby point to important policy implications to reduce losses at this important stage of the value chain, which likely has positive impacts on subsequent nodes of the value chain as well as spillover benefits for downstream nodes.

The analyses in this study provide a sound basis for identifying actionable policy pathways. By mapping where and how losses occur, this work highlights priority intervention points along the value chain; the types of technical, behavioral, or institutional responses required; and the scale and urgency of potential interventions. These insights aim to support evidence-based policymaking targeted at reducing millet losses, improving value chain efficiency, and strengthening food system resilience.

3. EMPIRICAL FRAMEWORK

This section first describes the methodologies used for our food loss and econometric analysis. In the second subsection, the study's pre- and postharvest loss data are described, specifically the data collected in the baseline survey.

3.1 ESTIMATION METHODS

3.1.1 Measurement of losses

This study follows the food loss measurement methodology of Delgado et al. (2021), which implements three alternative methodologies for measuring food losses, in addition to the traditionally used method of aggregate self-reported loss measurement. The three alternative methodologies measure losses at different stages of the value chain and are comparable across crops and regions/countries. These methodologies are implemented using data collected through representative surveys. In this study, we use data collected along Nigeria's millet value chain through a survey of producers, aggregators, and processors (described in section 3.2). These surveys allow the characterization of input use and practices of each agent during the production, postharvest, aggregation, and processing stages and allow estimation of the quantity, quality, and value of output as well as losses as the product travels along the value chain.

This study specifically uses the "attribute method," which involves the evaluation of a crop according to inferior visual, tactile, and olfactory product characteristics. This method improves on existing methodologies by (1) following a sampling procedure that captures food losses in areas with considerable importance in each value chain; (2) accounting for losses across multiple stages of the value chain—preharvest and postharvest production through the aggregation and processing stages; and (3) measuring quantitative food losses while also accounting for losses resulting from qualitative deterioration in food.

The attribute-based methodology estimates total losses as the sum of the amount of food entirely lost (quantitative loss/degradation) and losses due to food that is affected by quality deterioration (qualitative loss/degradation), as distinct from quantitative loss/degradation. These losses are measured at the three broad nodes of the millet value chain in Nigeria for which data were collected using detailed survey questionnaires.

We estimate quantitative and qualitative losses during millet production and on-farm postharvest handling using data collected in the millet producer baseline survey, which pertains to the harvest and immediate postharvest period of the major millet season in 2024. Data collected from the aggregators' and processors' surveys are used to estimate food losses that occurred from millet purchases to sale during a one-month period prior to the survey. Due to the heterogeneity of transformation processes at later stages in the value chain, only the aggregate self-reported measurement method is used at the processor level.

In the attributes method, product attributes are identified prior to survey implementation in collaboration with commodity experts, local experts, and value chain actors. In addition, an extensive pilot was conducted to validate the attributes. The number of attributes varies between 10 and 14, according to the commodity and country. In the survey, the producer evaluates their production and establishes the share of output that was damaged or affected by inferior attributes, both during production (immediately after harvest) and after postharvest production activities. Aggregators evaluate their product from the previous month at both purchase and sale. The producer and the aggregators declare how much of their respective produce is considered inferior and whether their buyers penalize them for these product attributes by paying a lower price. The attribute-specific price penalty is used to estimate value losses.

Total millet lost at the producer level is captured by the sum of quantity and quality degradation in volume/weight ($Weight\ loss_P$) and in value ($Value\ loss_P$) for each producer p, as given by equations 1 and 2, respectively:

$$Weight\ loss_P = Q_{Prod,p} - Q_{PH,p} + \sum_{j=1}^{J} a_{j,p} * Q_{PH,p} \quad (1)$$

$$Value\ loss_P = V_{Prod,p} - V_{PH,p} + \sum_{j=1}^{J} \overline{Pa}_{j,p} * Q_{PH,p} \quad (2)$$

where $Q_{Prod,p}$ and $Q_{PH,p}$ are the quantity of all produce after production and after postharvest, respectively, for producer p, while $a_{j,p}$ is the share of product affected by damage attribute j. Similarly, $V_{Prod,p}$ and $V_{PH,p}$ are the value of all produce after production and after postharvest, respectively, obtained as multiples of $Q_{Prod,p}$ and $Q_{PH,p}$ by the ideal price $\bar{P}_{ideal}$, whereby the ideal price, $\bar{P}_{ideal}$, is the average sales price for an ideal product. $\overline{Pa}_{j,p}$, is the average price penalty for an inferior product with damage attribute j. This is obtained as a difference between the ideal market price of the product at the producer level and the lower producer-level price associated with inferior product of damage attribute j. While the first terms of equations 1 and 2 provide the total quantity or value lost (quantity degradation) between production and postharvest, the second terms capture the quantity affected by quality loss/degradation.

At the aggregator level, the quantity and quality degradation in weight ($Weight\ loss_m$) and in value ($Value\ loss_m$) for aggregator m are given by equations 3 and 4, respectively:

$$Weight\ loss_m = Vol\ quantitative\ losses_m + \sum_{aj=1}^{J} (Q_{Purchase,aj,m} - Q_{Sale,aj,m}) \quad (3)$$

$$Value\ loss_m = Value\ quantitative\ losses_m + \sum_{aj=1}^{J} (V_{Purchase,aj,m} - V_{Sale,aj,m}) \quad (4)$$

where $Vol\ quantitative\ losses_m$ and $Value\ quantitative\ losses_m$ are the volume and value of quantitatively lost produce, respectively, at the aggregator level. $Q_{Purchase,aj,m}$ and $Q_{Sale,aj,m}$ are the quantities of millet purchased and sold, respectively, by aggregators with qualitative damage attributes of aj by aggregator m. $V_{Purchase,aj,m}$ and $V_{Sale,aj,m}$ are the values at purchase and sale of qualitatively damaged harvest with attribute aj. The respective values are obtained as multiples of the quantities affected by qualitative damages ($Q_{Purchase,aj,m}$ and $Q_{Sale,aj,m}$) by the corresponding average price penalty at purchase and sale. These, in turn, are obtained as a difference between aggregator-level ideal market price and the lower price associated with inferior product of damage attribute aj that aggregators receive from processors or consumers.

3.1.2 Correlates of incidence and severity of food losses

We conduct econometric analyses to determine the correlates of preharvest and postharvest food losses among millet producers in Nigeria. We specifically use the term *correlates* since some of the variables used as explanatory (righthand side) variables in these analyses could simultaneously be jointly determined by producers and hence could fail the criteria to be considered *determinants*. For instance, producers' labor and herbicide use decisions may jointly be made together with the occurrence and extent of losses expected prior to production. Similarly, producers' decision to use specific postharvest methods and storage infrastructure may jointly be determined with expectations on occurrence and severity of postharvest losses.

To examine both the likelihood and severity of millet losses among sampled producers, we estimate a two-equation framework combining a Probit model for the incidence of damage and a Tobit model for the intensity/percentage of damage. First, let $D_p \in \{0,1\}$ denote whether producer p experienced any crop damage, and let X_p be a vector of explanatory variables capturing household characteristics, production and marketing practices, agro-ecological conditions, and other spatial characteristics. The probability of observing crop damage at preharvest and postharvest production is modeled using a standard Probit specification:

$$\Pr\left(D_p = 1 \,\middle|\, X_p\right) = \Phi(X_p'\beta) \tag{5}$$

Where $\Phi(\cdot)$ is the standard normal cumulative distribution function and β is the parameter vector to be estimated. The log likelihood equation associated with (5) is given as:

$$l(\beta) = \sum_p D_p \cdot ln\Phi(X_p'\beta) + (1 - D_p) \cdot ln\left(1 - \Phi\left(X_p'\beta\right)\right) \tag{6}$$

We model the severity of preharvest and postharvest production millet losses using the observed percentage of loss $P_p \in [0, 100]$. The boundaries (0 and 100) naturally limit food losses that producers can experience, which dictates that we implement a two-sided Tobit model:

$$\mathrm{P_p^*} = \mathrm{X_p'\gamma + u_p}, \qquad \mathrm{u_p \sim N(0, \sigma^2)}, \tag{7}$$

$$P_p = \begin{cases} 0, & P_p^* \le 0, \\ P_p^* & 0 < P_p^* < 100, \\ 100 & P_p^* \ge 100, \end{cases} \tag{8}$$

Where P_p^* is a latent continuous damage propensity. Parameters γ and σ are estimated by maximum likelihood method using the standard Tobit log-likelihood with lower and upper bounds at 0 and 100.

Because Tobit coefficients do not directly represent effects on the observed outcome, we compute average marginal effects on the unconditional expected percentage damage, $E[P_p|X_p]$, using the standard decomposition of the Tobit model into effects on the probability of being uncensored and the expected severity among uncensored observations.

In the equations above, X_p is a vector of variables pertaining to producer p, including demographic variables (age, gender, education, household size, household wealth, and experience growing millet). We also use variables related to millet production and marketing such as area under millet, share of millet output sold, millet price gap between abundant and lean seasons, membership in agricultural cooperatives, and types of inputs used in millet production. The third group of variables include those that are specifically related to problems encountered during millet production, such as insect and disease infestations, weeds, drought, and others that represent proximate causes or biotic and abiotic stressors that directly and indirectly affect the likelihood and the severity of losses during production. Finally, we include spatial variables, such as rainfall and temperature during production season, dummy variables representing states, and whether the area is beneficiary of the Mastercard Foundation's partner interventions.

The corresponding likelihood/Probit equation of the postharvest production activities add two types of variables. First, we include the share of preharvest losses in the likelihood and severity equations of postharvest losses. This is justified given that the extent of preharvest qualitative losses affects the extent of total (qualitative and quantitative) losses at postharvest. The second type/group of variables pertain to the postharvest methods of production and equipment used by producers, which can clearly affect the extent and severity of postharvest losses. We also use weather variables that pertain to the postharvest period of millet production.

In estimating both Probit and Tobit equations, we also cluster the variance-covariance matrix across wards, the smaller administrative units in Nigeria, to adjust for within-ward correlation in the regression error terms.

3.2 DATA: BASELINE SURVEY OF FOOD LOSSES IN NIGERIA'S MILLET VALUE CHAIN

This study uses primary data collected in the baseline survey of food losses in Nigeria's millet value chain. This section discusses the study area covered in the surveys, the sample design and sample size, fieldwork, questionnaires, and limitations of the surveys.

Data were collected by interviewing the main agents in the millet value chain (namely millet producers, aggregators, and processors) through well-structured questionnaires. This involved collecting quantitative and qualitative information from participants along the millet value chain through in-person interviews. Three distinct questionnaires were prepared and administered to these value chain agents.

In the producers' survey, information was obtained from producers who cultivated millet, completed harvest, and sold all or part of their harvest during the 2023 planting season. The data collected in this part of the survey included information on farmer and household demographics and characteristics, volume and value of millet produced, information on pest and disease infestation and management strategies, preharvest losses, and harvest/postharvest handling practices.

Millet aggregators are those who purchased millet from producers for resale in larger markets or processors during the 2023 production season. The data collected in the millet aggregators' survey pertains to the last 30 days of aggregators' activities and included information on business enterprise activities, quantity and value of millet purchased from producers and other intermediaries during the 2023 planting season, price fluctuations, quality of purchased millet and associated costs, quantity and quality of millet sold and related price adjustments, and sources of damage during aggregation.

The millet processors' survey included processors that acquired millet either from the aggregators or directly from producers during the 2023 planting season. Data collected in this component of the survey pertained to the last 30 days of processors' activities and included information on the type and ownership (structure) of business, quantity, and cost of millet purchased; quality of millet acquired and price penalties associated with quality degradation; sources of qualitative losses; and quality depreciation or quantity of losses at various processing stages.

3.2.1 Study area

This study focused on millet production in the northwestern Nigerian states of Sokoto and Zamfara (Figure 3.1). These states were selected based on their strategic location in Nigeria's millet belt, their significant contribution to Nigeria's millet output, and the presence of postharvest loss interventions by Mastercard Foundation's implementing partner. Sokoto state borders the Republic of Niger to the north and shares boundaries with Kebbi state to the west and south and with Zamfara to the south and east, while Zamfara is bounded by Sokoto to the north, Niger and Kaduna states to the south, Kebbi state to the west, and Katsina state to the east. Within each state, Wammako local government areas (LGAs) (Sokoto) and Gusau LGA (Zamfara) were selected as control sites due to the absence of postharvest loss interventions there.

The importance of millet in Nigeria's agriculture sector—and specifically, in Sokoto and Zamfara—and the prevalence of food losses and waste in the country highlight the need to understand pre- and postharvest losses during production, as well as losses along downstream value chains. In so doing, this study will inform policies aimed at reducing losses during production and postharvest activities on the farm and beyond, thereby removing inefficiencies that substantially reduce available millet, with implications for food security and economic outcomes.

3.2.2 Sampling strategy

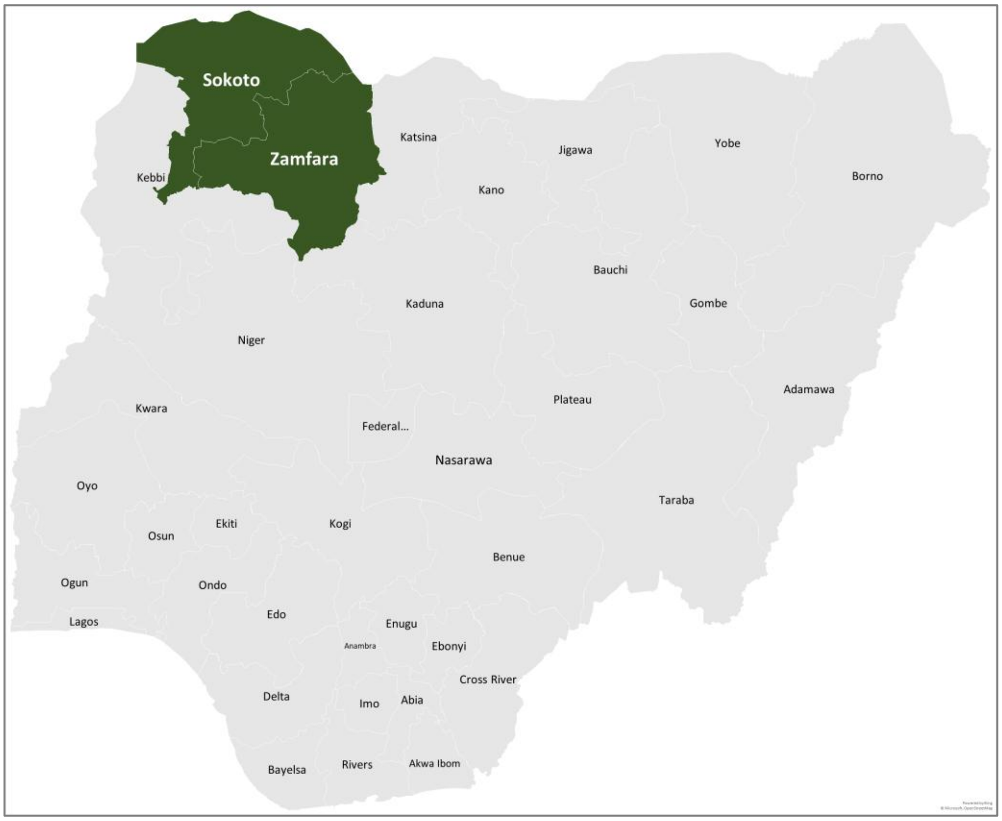
Sampling of producers

A multistage sampling technique was employed to select millet producers across the target states of Sokoto and Zamfara. In treatment[2] areas, the first stage involved the purposive selection of two LGAs in each state, determined by the operational intensity of Mastercard Foundation's implementing partner, accessibility factors, and security conditions. Accordingly, Bodinga and Wurno LGAs were selected from treatment areas in Sokoto, while Kaura Namoda and Talata Mafara LGAs were selected from the treatment LGAs of Zamfara. Among the non-beneficiary LGAs (control areas), one LGA was purposively selected from each state based on millet production capacity, rural characteristics, and prevailing security conditions. This resulted in the selection of Wammako LGA in Sokoto and Gusau LGA in Zamfara. The matching of treatment-control areas was compiled at the LGA level and considered accessibility to ensure that producers in treatment and control areas have the same level of access to markets, as well as travel times to the nearest primary or secondary road and the nearest city.

[2] The terms "treatment" and "control" refer to the programmatic classification of the study areas within the baseline design. These comparisons are descriptive and are intended to highlight differences across the sampled contexts; they should not be interpreted as causal treatment effects at baseline.

The Mastercard Foundation's implementing partner provided comprehensive information about wards and communities with ongoing operations. This was used to select the second stage sampling units (that is, wards). In Sokoto, four wards were randomly selected from each of Bodinga and Wurno LGAs, totaling eight wards across the state. In Zamfara, ward selection was further influenced by security considerations, resulting in four wards being purposively selected in Talata Mafara LGA and one ward in Kaura Namoda LGA, totaling five wards from that state (Table 3.1).

Figure 3.1. Map of study area indicating focus states



Source: Authors' elaboration based on the Nigeria millet postharvest loss baseline survey (2024).

Household listing was conducted across all communities within the respective wards. Millet-producing households were then randomly selected from these lists for both treatment and control areas at the third stage of sampling. The final sample of households interviewed in the survey comprised 297 producers from treatment areas (191 in Sokoto, 106 in Zamfara) and 298 producers from control areas (174 in Sokoto, 101 in Zamfara). Table 3.1 provides a detailed distribution of the sampled millet producers in the two states.

Sampling of Aggregators and Processors

The selection of aggregators and processors followed a stratified proportional sampling design across treatment and control areas in Sokoto and Zamfara states. The sampling framework was structured hierarchically, with LGAs as primary sampling units and wards as secondary sampling units within each stratum. A snowball sampling technique was systematically implemented to identify aggregators and processors. This non-probabilistic method was particularly suited to the millet value chain context, where market participants often operate through informal networks and referral systems. Initial seed respondents were identified through key informants in each ward, who subsequently provided referrals to additional market actors within their operational networks.

Table 3.1. Sampling distribution of millet producers in Sokoto and Zamfara states, Nigeria

Sokoto				Zamfara			
LGA	**Ward**	**Community**	**Sample**	**LGA**	**Ward**	**Community**	**Sample**
Treatment							
Bodinga	Bodinga/Tauma	Gidan Bango	18	**Kaura Namoda**	Kyambarawa	Kyambarawa/KDaji	7
		Tauma	5			Zazzaqa	20
	Danchadi	Danchadi	6	**Talata Mafara**	Grabadu	Shiyar Liman	10
	Dingyadi/Badawa	Badawa	10		Kayaye/Mats ugi	B/Kasuwa Gangaren Yan Buhu	29
	Sifawa /Lukuyawa	Lukuyawa	11			Bakin Kasuwa Yamma	1
Wurno	Dankemu	Adakanta	38		Morai/Sado	Shiyar Galadima	17
	Dinawa	Gangu Dabagi (Dabagin Rama)	21			Shiyar Magaji	2
	Magarya	Magarya	53		Take Tsaba Makera	Shiyar Marafa/Makera	20
	Marafa	Rugagawa	29				
Total			**191**	**Total**			**106**
Control							
Wammako	Arkilla	Arkilla Liman	35	**Gusau**	Galadima	Gadarbager	27
	Bado/Kasarawa	Badon Barade	6			Audu Kafinta	4
	Dundaye/Gumbu-rawa	Gidan Dan Iddi	22		Madawaki	K/Bayan Massallaci Jummat	18
		Dundaye Filing Datsa	12			Mai Angwar/K/Sauki	18
	G/Hamidu/G/Kaya	Rujin Gazau	6		Sabon Gari	Garkar Mai Katobara	34
		Gidan Yumfa	9				
		Unguwar Ruwa	12				
	Gumbi/Wakaje	Wajekke	22				
	Gwamatse	Gidan Kaduna	28				
	Kalam-baina/Girabshi	Kalambaina	7				
	Kammato	Lokobi Mana	3				
	Wammako	Boyen Mari	12				
Total			**174**	**Total**			**101**

Source: The baseline survey of food losses in millet value chain of Nigeria (2024).
Note: LGA = local government area.

Aggregators

In treatment locations, a total of 45 aggregators were selected in Sokoto across two LGAs (eight wards) through a snowball sampling method. More aggregators were sampled in treatment communities in Wurno LGA than in Bodinga LGA. In Zamfara, a total of 31 aggregators were selected from five wards across two LGAs: Kaura Namoda and Talata Mafara. In Sokoto, the control sample was exclusively drawn from Wammako LGA across nine wards, while in Zamfara, 30 aggregators were sampled from Gusau LGA across three wards. Table 3.2 shows the distribution of the 158 aggregators sampled across states, LGAs, and treatment and control areas.

Table 3.2. Sampling distribution of millet aggregators in Sokoto and Zamfara states, Nigeria

Sokoto			Zamfara		
LGA	**Ward**	**Sample**	**LGA**	**Ward**	**Sample**
Treatment					
Bodinga	Bodinga/Tauma	6	**Kaura Namoda**	Kyambarawa	8
	Danchadi	1	**Talata Mafara**	Grabadu	8
	Dingyadi/Badawa	2		Kayaye/Matsugi	5
	Sifawa /Lukuyawa	3		Morai/Sado	5
Wurno	Dankemu	9		Take Tsaba Makera	5
	Dinawa	5			
	Magarya	13			
	Marafa	6			
Total		**45**	**Total**		**31**
Control					
Wammako	Arkilla	9	**Gusau**	Madawaki	14
	Bado/Kasarawa	2		Sabon Gari	10
	Dundaye/Gumburawa	8		Galadima	6
	G/Hamidu/G/Kaya	7			
	Gumbi/Wakaje	5			
	Gwamatse	7			
	Kalambaina/Girabshi	5			
	Kammato	3			
	Wammako	6			
Total		**52**	**Total**		**30**

Source: The baseline survey of food losses in millet value chain of Nigeria (2024).

Processors

In the treatment areas of Sokoto, 25 processors were sampled, with a higher concentration of these processors in Wurno LGA. In the treatment areas of Zamfara, 14 processors were sampled. In control areas of Sokoto, 28 processors were sampled exclusively from Wammako LGA, while 11 processors were sampled in Zamfara. Table 3.3 below shows the distribution across states and LGAs of the 78 sampled processors (39 from treatment areas and 39 from control areas).

Table 3.3. Sampling distribution of millet processors in Sokoto and Zamfara states, Nigeria

Sokoto			Zamfara		
LGA	Ward	Sample	LGA	Ward	Sample
Treatment					
Bodinga	Bodinga/Tauma	3	**Kaura Namoda**	Kyambarawa	4
	Danchadi	1	**Talata Mafara**	Grabadu	4
	Dingyadi/Badawa	1		Kayaye/Matsugi	3
	Sifawa /Lukuyawa	1			
Wurno	Dankemu	1		Morai/Sado	3
	Dinawa	6			
	Magarya	4		Take Tsaba Makera	-
	Marafa	8			
Total		**25**	**Total**		**14**
Control					
Wammako	Arkilla	5	**Gusau**	Madawaki	3
	Bado/Kasarawa	2		Sabon Gari	5
	Dundaye/Gumburawa	4		Galadima	3
	G/Hamidu/G/Kaya	3			
	Gumbi/Wakaje	3			
	Gwamatse	3			
	Kalambaina/Girabshi	2			
	Kammato	3			
	Wammako	3			
Total		**28**	**Total**		**11**

Source: The baseline survey of food losses in millet value chain of Nigeria (2024).

3.2.3 Survey instruments, key modules, and questions

We developed three comprehensive survey tools covering various aspects of the millet value chain, which can be used in the producer, aggregator, and processor surveys. The survey tools allow for quantifying food loss throughout the value chain, using standardized approaches that can be used to compare data collected across different commodities and regions. Additionally, they allow us to characterize the nature of food loss, particularly identifying the production and postharvest stages and specific processes during which losses occur.

The producer survey tool consists of several modules, each serving a unique purpose (Figure 3.2):

Roster and Producer Identification (Module 1): Used to identify and register the producer. This collects information on age, sex, and education, as well as household and locational/geographic characteristics.

Asset and Production Characteristics (Modules 2 and 3): Data related to assets and production characteristics (such as input use, technology adoption, and outputs).

Preharvest Losses (Module 4): Measurement of the quantity of millet lost during the preharvest stage and identification of the sources of these losses, as well as value losses due to qualitative degradation, thereby capturing producers' incentives to improve the quantity and quality of production.

Figure 3.2. Producer survey questionnaire modules

Roster and Producer Identification (Module 1)

- Producer identification (name, age, telephone)
- Education and household members
- Location

Productive assets (Module 2)

- List of the specific assets
- Quantity and price (value)

Production characteristics (Module 3)

- Area
- Technology
- Labor
- Fertilizer use (type, time, quantity, costs)
- Production issues (insects and worms, diseases, weeds)
- Pesticide and fungicide usage (type, times, quantity, costs

Pre-harvest losses (Module 4)

- Reasons for loss
- Quantity of affected product and value
- Quantity of totally lost product and value

Millet left in the field (Module 5)

Reasons for left in the field

- **Area**
- **Quantity**

Value

Harvest and Quality Assessment (Module 6)

Quantity produced

Quantity damage by attributes

Harvest and post-harvest losses (Module 7)

Specific Activities

For each activity:

- Quantity of affected product and value
- Quantity of totally lost product and value

Reasons for losses

Product destination and Sale attributes (Module 8)

For each type of use:

- Quantity and value
- Quantity of affected product and value
- Quantity of totally lost product and value

For sale:

- Quantity damaged by attributes
- Penalization of produce by attributes

Price in scarcity and in abundance time

Source: The baseline survey of food losses in millet value chain of Nigeria, 2024.

Millet Left in the Field (Module 5): Record of the quantity of good quality millet that remains in the field after harvest and the reasons.

Harvest and Quality Assessment (Module 6): Data on the total production harvested, as well as the qualities, attributes, and prices associated with the harvest.

Harvest and postharvest Losses (Module 7): Information on the quantity affected by quality degradation[3] and the total quantity lost[4] during postharvest activities, such as winnowing, threshing, grading, transporting, and packaging. This module also captures postharvest handling and storage techniques that contribute to food losses and measures the value lost due to qualitative degradation and quantitative losses, gauging producers' incentives to improve the quantity and quality of production.

Product Destination and Sale Attributes (Module 8): Product's destination, whether it is for consumption, sale, donation, or other purposes. This also records attributes related to the quantity intended for sale.

The aggregators' survey questionnaire comprises four distinct modules (Figure 3.3):

Roster and Aggregator Identification (Module 1): Identification and registration of the aggregator. This collects information on age, sex, and education, as well as geographical location.

Purchase Details (Module 2): Information about the quantity, quality, value, and attributes of the total product purchased during a specified period.

Postharvest Losses (Module 3): Quantification of the quantity and value of affected product and the total loss and value incurred during postharvest processing activities for millet.

Sales Information (Module 4): Quantity, quality, attributes and value of the total product sold within a defined period, tailored to Nigeria.

Figure 3.3. Aggregator survey questionnaire modules

Roster and Aggregator (Module 1)	Purchase details (Module 2)	Post-harvest losses (Module 3)	Sales information (Module 4)
- Intermediary identification (name, age, telephone) - Location - Type of business	- Total quantity purchases from producers and other intermediaries and values - Average quantity purchase in one day and the value - Reaction to quality constraints - If penalized, how much per attribute - Quality attributes of the product at purchase	- For each activity: Quantity of affected product and value - Quantity of totally lost product and value - Reasons for losses	- Total quantity sale - Average quantity sale in one day and the value - Reaction to quality constraints - If penalized, how much per attribute - Quality attributes of the product at sale

Source: The baseline survey of food losses in millet value chain of Nigeria (2024).

[3] Affected product: Product with lower quality but can still be used.

[4] Totally lost: Product that is completely lost and cannot be used.

The processor survey consists of three key modules (Figure 3.4):

Roster and Processor Identification (Module 1): Identification and registration of the processor.

Purchase Details (Module 2): Information regarding the quantity, quality, and attributes of the total product purchased during a specified period, which may vary depending on country context.

Processing Steps (Module 3): Information about the steps involved in transforming the acquired product into the final product intended for consumption, including losses and their value at each step.

Figure 3.4. Processor survey questionnaire modules

Roster and Processor (Module 1)	Purchase details (Module 2)	Processing steps (Module 3)
- Processor identification (name, age, telephone) - Location - Type of business	- Total purchases from producers and aggregators - Average quantity purchase in one day and the value - If penalized, how much per attribute - Attributes at purchase	- For each activity: Quantity of affected product and value - Quantity of totally lost product and value - Reasons for losses

Source: The baseline survey of food losses in millet value chain of Nigeria (2024).

In the attributes section of each survey, producers, aggregators, and processors are asked to evaluate the physical or chemical characteristics of the crops. These characteristics, specific to millet in Nigeria, were identified in collaboration with value chain actors and millet experts. In our surveys, crop damage is determined by factors such as texture, size, moisture, and the presence of fungus or insects, among others. We further validate this through expert consultations and the price penalty that each type of crop damage entails in the different market locations.

3.2.4 Survey implementation

The implementation of the baseline survey was comprehensive and phased. In the following section, we briefly discuss the major activities accomplished by IFPRI and the Sahel Consulting Company (Sahel) on the ground in Nigeria.

Translating survey instruments

The survey instruments were initially developed in English and reviewed to ensure alignment with the study's objectives. After the review, a local translator was contracted to translate the tool into Hausa, the commonly used language in our survey areas. The translated version underwent a joint review process involving IFPRI and Sahel researchers, field supervisors, and enumerators to ensure that the local language accurately reflected the original questions' intended meaning.

Once finalized, the Hausa version was digitized and programmed into the SurveyCTO platform to support field deployment. The digital format enabled pre-testing, enumerator training, and live data collection. All technical issues identified during the pre-survey phase were addressed to ensure a seamless and error-free field operation.

Recruitment of supervisors and enumerators

This process started with the recruitment and training of qualified field personnel, followed by deployment and continuous monitoring during data collection. Recruitment of field data collection officers and enumerators followed standard procedures regarding educational level, language fluency, numeracy/logical reasoning, and work experience requirements. A total of four field data collection officers and 12 enumerators were engaged in the baseline millet value chain postharvest loss survey in Nigeria.

Training of field supervisors

Supervisors participated in a five-day training session. The sessions were facilitated by IFPRI and supported by Sahel at the Sahel Consulting office in Abuja. The supervisors' training covered project objectives and different sections of the data collection instrument prepared for each category of respondents.

After the training, the supervisors, IFPRI, and Sahel jointly reviewed the English and Hausa versions of the instrument to ensure that the supervisors accurately captured and understood the translation.

Training of field enumerators

Enumerators underwent a separate five-day training session in Sokoto. All team members from both Sokoto and Zamfara were accommodated at the training venue. The training included six sections:

- Overview of research objectives
- Core data quality practices
- Survey administration techniques
- Approaches for resolving field-level issues
- Roleplaying of all survey sections
- Shortlisting of enumerators, which was finalized after the training and based on performance

Field monitoring and data quality management

A two-way communication structure between enumerators and supervisors ensured real-time feedback and guidance during data collection. Supervisors used field tracking and observational reporting tools to monitor team performance and submit daily updates.

To ensure data quality:

- A dedicated data checker monitored supervisor-approved submissions daily
- Random back-check surveys were conducted to verify data integrity
- The survey coordinator conducted unannounced field visits to assess compliance with established field protocols
- A real-time tracking system was set up, allowing IFPRI and the Sahel backend access to monitor ongoing data collection

3.2.5 Survey limitations

Sokoto and Zamfara states are purposefully selected for the millet value chain surveys, in part due to the intensity of intervention activities conducted by the Mastercard Foundation's implementing partner in these areas. As a result, the estimates are representative of the sampled study areas and respondent groups but should not be interpreted as nationally representative of all millet value chain actors in Nigeria.

4. DESCRIPTIVE STATISTICS

This section first describes value chain agents (that is, producers, aggregators, and processors) in the millet value chain in Nigeria. The second subsection describes the different activities engaged in by these value chain agents across the respective nodes of the value chain. Comparisons across different spatial groups (states and treatment status) and demographic groups (gender and age) refer only to statistically significant differences.

4.1 CHARACTERISTICS OF VALUE CHAIN AGENTS

Tables 4.1 and 4.2 show the demographic and socioeconomic operational characteristics of the three key value chain actors across spatial disaggregates. Annex Table 1 provides a similar summary across gender and age categories.

The data reveal distinctive gender patterns across the value chain. Men dominate millet production and aggregation, accounting for at least 95 percent across all subgroups. However, this difference is statistically significant only across states; the share of men in Sokoto is higher than in Zamfara. Women constitute the majority of processors (84 percent). Youth value chain agents (15–35 years old) account for 34 percent of producers, 38 percent of aggregators, and 57 percent of processors. Average producer age is 42 years, with only slight and statistically insignificant spatial differences (Tables 4.1 and 4.2). However, women producers are generally younger (36 years) relative to men (42.3 years) (Annex Table 4.1). The average age of aggregators is 41 years. Millet processors, however, are relatively younger, with an average age of 35.4 years. The majority, 84 percent, of processors are women. This may be because entering millet production may be difficult for youth, particularly young women, due to the lack of access to land. This implies that millet processing may provide an opportunity for youth engagement and thereby contribute to agrifood system transformation in Nigeria, an implication consistent with that of other studies (Bachewe et al. 2025; Abay et al. 2025).

Most of Nigeria's producers are literate, with less than 1 percent of producers being illiterate (Table 4.1). Although this number is considerably less than the rate of adult illiteracy in Nigeria (22 percent),[5] methodological differences in defining literacy may contribute to the divergence, especially related to the more informally, mostly Qur'anic educated producers in the study areas. A third of producers completed secondary education, followed by 29 percent completing informal education, and 24 percent completing primary education. Only 13 percent advanced beyond secondary education. A relatively higher share of producers in control areas are informally educated; the share of those in Sokoto with primary education is considerably higher than those in Zamfara, while the share in Zamfara with secondary or higher education is relatively higher than in Sokoto. Overall, producers had 10 years of education on average (11.5 years in Zamfara, 9 years in Sokoto).

Value chain experience averaged 17.5 years among producers, 15.6 years among aggregators, and 12 years among processors. Producers and aggregators in Sokoto are more experienced than those in Zamfara, while the reverse is true among processors. Socioeconomic indicators show that producers maintain relatively large households (nearly 10 members). Households in the treatment group are larger than those in control areas, and households with mature heads are nearly twice in size relative to youth-headed households. The total current value of household assets averaged more than 270,000 Nigerian

[5] https://www.verivafrica.com/insights/bridging-the-literacy-gap-in-nigeria#:~:text=A%202024%20survey%20shows%20that,by%2013.9%25%20to%2077.62%25.

naira, which is approximately US$162.[6] Significant variations exist in household assets: average asset value among households in the control group was 80 percent higher than for those in the treatment group, and asset ownership among households in Sokoto was 150 percent higher than in Zamfara. Mature-headed households own more household assets than youth-headed households, which is consistent with the accumulation of such assets over time.[7] Although the value of household assets owned by male-headed households is nearly twice that of female-headed households, the difference is not statistically significant (Annex Table 1). These disparities suggest important regional and demographic economic differences that may influence value chain dynamics.

Table 4.1. Characteristics of millet producers, spatial distribution

		Total		Treatment		Control			Sokoto		Zamfara		
Variable	**Measure**	Mean	SD	Mean	SD	Mean	SD	**Sig. test**	Mean	SD	Mean	SD	**Sig. test**
Observations	Number	595		297		298			392		203		
Gender of head (=1 if male)	%	96.6	18.0	96.0	19.7	97.3	16.2		97.7	15.0	94.6	22.7	*
Age (years)	Years	42.1	11.2	42.1	10.8	42.1	11.5		42.5	11.0	41.3	11.5	
Experience in years	Years	17.5	10.37	19.29	10.07	15.7	10.38	***	19.53	10.18	13.52	9.58	***
Education category	Illiterate	0.3	5.8	0.7	8.2	0.0	0.0		0.3	5.1	0.5	7.0	
	Informal	28.9	45.4	23.9	42.7	33.9	47.4	**	27.0	44.5	32.5	47.0	
	Primary	24.2	42.9	23.2	42.3	25.2	43.5		33.9	47.4	5.4	22.7	***
	Secondary	33.3	47.2	36.7	48.3	29.9	45.8		30.1	45.9	39.4	49.0	*
	Secondary	13.3	34.0	15.5	36.2	11.1	31.4		8.7	28.2	22.2	41.6	***
Education in years	Number	9.8	3.9	10.1	3.8	9.6	3.9		9.0	3.6	11.5	3.7	***
Household size	Number	9.8	4.8	10.7	5.1	9.0	4.4	***	9.9	4.8	9.7	5.0	
Household assets	000 Naira	270.2	440.9	190.3	330.7	349.8	516.9	***	340.1	499.4	135.3	247.2	***
Main occupation is farming	%	94.1	23.6	95.6	20.5	92.6	26.2		96.2	19.2	90.2	29.9	**
Main occupation is non-farming	%	5.9		4.4		7.4			3.8		9.9		

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

We collected data on the major occupation of producers, as well as on types of business activities and roles in the businesses of aggregators and processors. Farming constitutes the primary occupation for 94 percent of producers, followed distantly by petty trading (4.7 percent). The percentage engaged in farming was higher in Sokoto (96 percent) compared to Zamfara (90 percent). Business structure analysis reveals distinct patterns across the value chain: nearly 11 percent of aggregators operate as formal businesses, with significant variation across states (Table 4.2). Only 3 percent of aggregators in Sokoto operate formally, compared to 24.6 percent in Zamfara. Formal aggregator business operations remain consistently low across age groups (Annex Table 1).

[6] The exchange rate between the Nigerian Naira and the US dollar (US$) at the time of the survey was 1 NGN to 0.0006 US$.

[7] In the context of this study, a "mature" individual is defined as a non-youth who is above the age of 35 years.

Table 4.2. Characteristics of aggregators and processors of millet, by region

Variable	Measure	Total		Sokoto		Zamfara		Sig. test
		Mean	SD	Mean	SD	Mean	SD	
Aggregator								
Observations	Number	166		105		61		
Gender (=1 if male)	%	97.6	15.4	96.2	19.2	100.0	0.0	
Age	Years	41.0	10.1	40.7	11.0	41.5	8.6	
Experience in years	Years	15.6	9.8	16.8	10.8	13.6	7.5	*
Share of formal business	%	10.8	31.2	2.9	16.7	24.6	43.4	***
Business type								
Has no store	%	31.9	46.8	22.9	42.2	47.5	50.4	***
Has store	%	68.1	46.8	77.1	42.2	52.5	50.4	***
Role in Business								
Owner	%	83.7	37.0	98.1	13.7	59.0	49.6	***
Boss/Manager	%	2.4	15.4	1.9	13.7	3.3	18.0	
Employee/Assistant	%	4.2	20.2	0.0	0.0	11.5	32.1	***
Member of cooperative	%	9.6	29.6	0.0	0.0	26.2	44.4	***
Processors								
Observations	Number	81		55		26		
Gender (=1 if male)	%	16.1	36.9	16.4	37.3	15.4	36.8	
Age	Years	35.4	12.5	34.2	12.7	37.9	12.0	
Experience in years	Years	12.1	7.7	10.6	6.9	15.1	8.7	*
Business type								
Formal	%	7.4	26.4	0.0	0.0	23.1	43.0	***
Informal	%	92.6	26.4	100.0	0.0	76.9	43.0	***
Role in Business								
Head	%	96.3	19.0	96.4	18.9	96.2	19.6	
Employee	%	1.2	11.1	0.0	0.0	3.9	19.6	
Boss	%	2.5	15.6	3.6	18.9	0.0	0.0	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Similarly, nearly 93 percent of processors operate informally. Formal businesses are more prevalent in Zamfara (23 percent), whereas all processors operate informally in Sokoto. Physical business infrastructure varies significantly. While 68 percent of aggregators operate from stores in the overall sample, the share is higher among aggregators in Sokoto (77 percent) than in Zamfara (52.5 percent). No statistically significant differences exist across gender and age categories in the formality of businesses and ownership of stores (Annex Table 1). At least 96 percent of the respondents in the processor survey owned their businesses. Of those included in the aggregator survey, 84 percent owned their businesses. There is a clear distinction in ownership across states: almost all aggregators surveyed in Sokoto (98 percent) owned their businesses, compared to only 59 percent of aggregators in Zamfara. For cooperative membership, the reverse was true. A sizeable share (26 percent) of aggregators in Zamfara were members of cooperatives, while there were no cooperative members in Sokoto.

4.2 MILLET VALUE CHAIN ACTIVITIES

In this section we describe the input use and production activities of producers, aggregators, and processors. Table 4.3 summarizes producers' preharvest activities—disaggregated spatially—while Table 4.4 summarizes their postharvest activities. Annex Tables 2 and 3 provide a corresponding summary across gender and age categories. Tables 4.5 and 4.6 provide spatially disaggregated summaries of the activities of aggregators and processors, while Annex Table 4 summarizes processors' activities across demographic groups.[8]

4.2.1 Millet preharvest production activities

Outputs and yields

Millet production averages 2.8 MT per producer, while average yield is 1.3 MT/ha—slightly higher than national millet yields (Table 1.1). Producers in treatment areas achieve significantly higher yields than those in control areas. Regionally, producers in Sokoto record significantly higher output and yield than those in Zamfara. Female producers achieve significantly higher yields (2.0 MT/ha) than male producers (1.3 MT/ha), while mature producers record both higher total output (3.2 MT) and higher yields (1.4 MT/ha) than youth producers (2.0 MT and 1.2 MT/ha) (Annex Table 2).

Land use and management

The average producer operates 2.8 ha, of which 2.2 ha are allocated to millet, underscoring the crop's importance. Producers in Zamfara operate and rent in larger land areas, while producers in control areas rent in more land (Table 4.3). Female producers rent in or sharecrop nearly twice as much land as male producers, possibly reflecting gender disparities in land ownership rights. Mature producers operate significantly larger land areas than youth producers, reflecting entry barriers faced by younger farmers (Annex Table 2).

Use of mechanical equipment was reported by more than 40 percent of producers. However, manual soil preparation is the dominant method, used by 62 percent of producers.

Variable input use

Seeds

Millet seed application averages 12.3 kg/ha and is slightly higher in control areas and Zamfara. Improved seed varieties are used by 43 percent of producers, with significantly higher uptake in treatment areas and Zamfara (79 percent) compared to Sokoto (24 percent).

Fertilizer and crop protection

Organic fertilizer is used by 67 percent of producers, with higher adoption in treatment areas and Sokoto. Female producers adopt organic fertilizer at significantly higher rates than male producers. Ninety percent

[8] Note that the data for aggregators are not collected across control areas as their activities is largely nonstationary. Moreover, among aggregators surveyed, only four (less than 3 percent) were women. Therefore, we decided not to summarize the data across gender of aggregators.

Table 4.3. Millet preharvest production and input use, spatial distribution

Variable	Measure	Total		Treatment		Control		Sig. test	Sokoto		Zamfara		Sig. test
		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Produced/harvested millet	%	100.0	0.0	100.0	0.0	100.0	0.0		100.0	0.0	100.0	0.0	100.0
Outputs													
Total output harvested	kgs	2784.5	2278.4	3429.7	2496.5	2141.6	1827.5	***	3162.4	2403.0	2054.9	1810.0	***
Yield	kgs/ha	1338.1	826.0	1630.9	906.8	1046.4	611.5	***	1509.6	868.0	1007.0	617.1	***
Land													
Total area operated	Ha	2.8	1.9	2.9	1.9	2.7	1.8		2.6	1.8	3.1	2.0	**
Area rented/sharecropped	Ha	0.5	0.9	0.3	0.8	0.6	1.0	**	0.1	0.4	1.1	1.2	***
Total millet area	Ha	2.2	1.4	2.3	1.4	2.1	1.4		2.3	1.4	2.2	1.5	
Used mechanical equipment	%	40.5	49.1	55.9	49.7	25.2	43.5	***	23.0	42.1	74.4	43.8	***
Tilling type used													
Manual	%	61.9	48.6	46.8	50.0	76.9	42.3	***	84.7	36.1	17.7	38.3	***
Animal	%	4.7	21.2	9.4	29.3	0.0	0.0	***	0.3	5.1	13.3	34.0	***
Mechanized	%	2.5	15.7	0.3	5.8	4.7	21.2	***	0.0	0.0	7.4	26.2	***
More than one method	%	30.9	46.3	43.4	49.7	18.5	38.9	***	15.1	35.8	61.6	48.8	***
Variable inputs													
Seed use	kgs/ha	12.3	5.6	10.7	4.6	13.9	6.1	***	11.6	4.5	13.8	7.1	***
Improved seed used	%	42.7	49.5	65.3	47.7	20.1	40.2	***	23.7	42.6	79.3	40.6	***
Applied organic fertilizer	%	67.1	47.0	76.8	42.3	57.4	49.5	***	73.0	44.5	55.7	49.8	***
Applied chemical fertilizer	%	89.6	30.6	96.0	19.7	83.2	37.4	***	88.5	31.9	91.6	27.8	
Chemical fertilizer application	Number	2.0	0.6	2.1	0.4	1.8	0.6	***	2.0	0.6	2.0	0.5	
Rate of fertilizer application	kgs/ha	454.1	885.7	519.7	934.7	388.6	830.4		576.6	1049.7	217.5	297.2	***
Crop protection	%	35.5	47.9	30.6	46.2	40.3	49.1	*	17.1	37.7	70.9	45.5	***
Chemical insecticide	%	19.7	39.8	11.5	31.9	27.9	44.9	***	12.2	32.8	34.0	47.5	***
Biological insecticides	%	3.0	17.1	0.3	5.8	5.7	23.2	***	0.8	8.7	7.4	26.2	***
Herbicides	%	23.2	42.2	21.6	41.2	24.8	43.3		7.1	25.8	54.2	50.0	***
Fungicides	%	5.6	22.9	0.3	5.8	10.7	31.0	***	5.6	23.1	5.4	22.7	
Biological pest control	%	4.2	20.1	0.7	8.2	7.7	26.7	***	0.3	5.1	11.8	32.4	***
Integrated pest management	%	2.5	15.7	0.3	5.8	4.7	21.2	***	0.3	5.1	6.9	25.4	***
Value of modern inputs applied	000N./ha	68.4	37.3	76.1	35.2	60.6	37.9	***	60.3	32.1	84.0	41.6	***
Harvesting	%	100	0.0	100.0	0.0	100	0.0		100	0.0	100	0.0	
Harvesting Method													
Manual	%	93.1	25.4	99.7	5.8	86.6	34.2	***	100	0.0	79.8	40.3	***
Mechanical	%	1.0	10.0	0.0	0.0	2.0	14.1	*	0.0	0.0	3.0	17.0	***
Both	%	5.7	23.2	0.0	0.0	11.4	31.9	***	0.0	0.0	16.8	37.4	***
Other inputs													
Used hired labor	%	93.5	24.8	93.9	23.9	93.0	25.6		94.6	22.6	91.1	28.5	
Used irrigation	%	2.5	15.7	0.0	0.0	5.0	21.9	***	3.3	17.9	1.0	9.9	
Used formal credit	%	43.2	49.6	46.1	49.9	40.3	49.1		35.7	48.0	57.6	49.5	***
Used informal credit	%	2.4	15.2	3.7	18.9	1.0	10.0	*	0.0	0.0	6.9	25.4	***
Member of agricultural coops.	%	6.7	25.1	7.4	26.2	6.0	23.9		8.2	27.4	3.9	19.5	
Used agricultural services	%	16.0	36.7	11.5	31.9	20.5	40.4	**	2.8	16.5	41.4	49.4	***
Barriers towards													***
Accessing input/service markets	%	10.3	30.4	13.5	34.2	7.1	25.6	**	4.1	19.8	22.2	41.6	***
Reaching markets/buyers	%	9.1	28.8	13.1	33.8	5.0	21.9	***	2.8	16.5	21.2	41.0	***

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

of producers apply chemical fertilizer. Treatment-area producers apply fertilizer more frequently than control-area producers. Similarly, female producers apply chemical fertilizer more frequently than male producers. Average fertilizer application rates exceed 450 kg/ha, with farmers in Sokoto applying more than twice the rate of those in Zamfara.

Crop protection methods are used by 35 percent of producers. Chemical insecticides are used by 20 percent of producers, herbicides by 23 percent, fungicides by 6 percent, biological pest control by 4 percent, and integrated pest management by 2.5 percent. Adoption of crop protection methods is generally higher in Zamfara and control areas.

The value of modern inputs applied averaged 68,364 naira/ha, with higher investments among farmers in treatment areas and in Zamfara compared to those in Sokoto.

Millet harvesting

Harvesting is conducted by all producers and is predominantly manual (93 percent). However, significantly more farmers in control areas and Zamfara use mechanical or mixed harvesting methods. Approximately 25 percent of farmers received harvesting training, with higher shares in control areas

Other inputs/services

More than 93 percent of producers use hired labor. Irrigation use is limited to 2.5 percent of producers, with almost all of it in control areas. Formal credit is accessed by 43 percent of producers, with higher access in Zamfara. Informal credit use is low (2.4 percent). Cooperative membership remains below 7 percent. Agricultural services are used by 16 percent of producers, more commonly in control areas and Zamfara.

Only 10 percent of producers report barriers to accessing input markets, and 9 percent report barriers to output markets, with higher shares in Zamfara and among youth and female producers

4.2.2 Millet postharvest production activities

Millet transportation, threshing, and winnowing

Most producers (99 percent) transport the harvest from the fields. In treatment areas, a higher proportion of producers use a mechanical mode of transportation; in Sokoto, more producers use manual methods, and those in Zamfara use manual and mechanical modes.

All producers thresh their harvest, mostly manually; this is particularly the case in treatment areas and in Sokoto. A higher share of producers in control areas and Zamfara combine manual and mechanical methods. More than 95 percent of farmers practice drying, mostly manually. A higher share of farmers in control areas and Zamfara use mechanical and manual methods jointly. Most producers (85 percent) winnow, sift, and sort, mostly manually.

Millet storage and related activities

Storage facilities and pre-storage activities are important factors that influence the extent of damage during storage. More than 98 percent of producers store millet harvest; the storage period averages 93 days. Treatment area and mature producers stored their harvest for longer. Stored millet averages 2.4 MT of harvest. Producers in treatment area and Sokoto stored a larger quantity. Mature producers store considerably higher quantities, and for longer periods, consistent with their higher total production.

Homes are used for storage by 97 percent of producers. Various storage methods are used: rhombus by 31 percent, barns by 20.5 percent, bare uncovered floor by 19.5 percent, and other storage infrastructure by 27 percent (other methods included underground at home/farm, on platforms covered/uncovered, in metallic silos, and in hermetic PICS bags). Different types of storage are dominant across treatment/control areas and states.

Most producers (96 percent) clean their storage sites. In contrast, only 43 percent reported cleaning storage sacks/bags. Ventilating the site before storage was undertaken by 51 percent of producers, and curing was reported by 35 percent. Fumigation of storage sites was common, with 75 percent of producers using this method.

Table 4.4. Postharvest activities of millet producers, spatial distribution

Variable	Measure	Total		Treatment		Control		Sig. test	Sokoto		Zamfara		Sig. test
		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Observations		595		297		298			392		203		
Received training in harvesting	%	25.2	43.5	15.2	35.9	35.2	47.9	***	27.0	44.5	21.7	41.3	
Transportation	%	99.3	8.2	99.7	5.8	99.0	10.0		99.7	5.1	98.5	12.1	
Manual	%	73.6	44.1	72.7	44.6	74.5	43.7		83.4	37.2	54.7	49.9	***
Mechanical	%	2.5	15.7	4.7	21.2	0.3	5.8	***	2.3	15.0	3.0	17.0	
Both	%	23.2	42.2	22.2	41.6	24.2	42.9		14.0	34.8	40.9	49.3	***
Threshing	%	99.5	7.1	99.3	8.2	99.7	5.8		99.7	5.1	99.0	9.9	
Manual	%	92.8	25.9	98.7	11.6	86.9	33.8	***	98.7	11.2	81.3	39.1	***
Mechanical	%	0.3	5.8	0.3	5.8	0.3	5.8		0.3	5.1	0.5	7.0	
Both	%	6.4	24.5	0.3	5.8	12.4	33.0	***	0.8	8.7	17.2	37.9	***
Drying	%	95.3	21.2	94.3	23.3	96.3	18.9		95.2	21.5	95.6	20.6	
Manual	%	93.1	25.4	93.6	24.5	92.6	26.2		94.6	22.6	90.2	29.9	*
Both	%	2.2	14.6	0.7	8.2	3.7	18.9	*	0.5	7.1	5.4	22.7	***
Winnowing, sifting, and sorting	%	84.9	35.9	72.7	44.6	97.0	17.1	***	79.3	40.5	95.6	20.6	***
Manual	%	78.0	41.5	72.7	44.6	83.2	37.4	**	79.3	40.5	75.4	43.2	
Mechanical	%	0.3	5.8	0.0	0.0	0.7	8.2		0.0	0.0	1.0	9.9	*
Both	%	6.6	24.8	0.0	0.0	13.1	33.8	***	0.0	0.0	19.2	39.5	***
Storage	%	98.2	13.5	99.0	10.0	97.3	16.2		99.5	7.1	95.6	20.6	***
Average storage period	Days	92.6	53.6	102.5	50.6	82.5	54.7	***	91.4	53.6	95.0	53.7	
Maximum quantity stored (000)	kgs	2.4	2.1	2.9	2.3	1.8	1.7	***	2.7	2.1	1.7	1.8	***
Storage location													
Home	%	97.1	16.7	97.6	15.2	96.6	18.0		98.7	11.2	94.1	23.6	**
Farm	%	0.7	8.2	1.4	11.6	0.0	0.0	*	0.3	5.1	1.5	12.1	
Storage method													
Rhombus	%	31.3	46.4	24.2	42.9	38.3	48.7	***	43.6	49.7	7.4	26.2	***
Barns at home	%	20.5	40.4	25.6	43.7	15.4	36.2	**	17.1	37.7	27.1	44.6	**
On bare floor uncovered	%	19.5	39.7	9.8	29.7	29.2	45.5	***	17.6	38.1	23.2	42.3	
All other storage methods	%	26.9	44.4	39.4	48.9	14.4	35.2	***	21.2	40.9	37.9	48.6	***
Pre-storage activities													
Cleaning storage site	%	96.5	18.5	97.0	17.2	96.0	19.7		98.7	11.2	92.1	27.0	***
Cleaning storage sacks/bags	%	43.0	49.6	24.2	42.9	61.7	48.7	***	36.7	48.3	55.2	49.9	***
Preparing site (ventilation)	%	50.9	50.0	32.0	46.7	69.8	46.0	***	54.3	49.9	44.3	49.8	*
Curing	%	35.3	47.8	23.6	42.5	47.0	50.0	***	36.7	48.3	32.5	47.0	
Fumigation of storage site	%	74.8	43.5	79.1	40.7	70.5	45.7	*	82.4	38.1	60.1	49.1	***

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

4.2.3 Millet aggregation

Millet purchases

Aggregators sourced millet from an average of 23 producers and 13.5 intermediary sellers during the 2024 harvest. Mature aggregators tend to work with more producers, while younger aggregators source from more producers. This difference reflects more established networks and greater market reach, which has been developed over time. Aggregators purchased on average 8,428 kgs of millet from producers and 4,608 kgs from intermediaries. The value of aggregators' purchases from producers averages 5 million Naira and 2.1 million Naira from aggregators. Aggregators in Sokoto purchase significantly higher-valued millet from aggregators than those in Zamfara. On a typical day, aggregators purchased 578 kgs of millet, which was valued at 0.25 million naira.

Aggregators reported that they sold millet to processors (82 percent), individual consumers (77.7 percent), other aggregators (45 percent), and stores (35 percent). However, analysis of the most recently recorded sales reveals that aggregators sell mostly to individual consumers (89 percent), processors (80 percent), and other aggregators (49 percent). Aggregators in Sokoto sell to a higher proportion of all three buyers or have more diversified buyers than those in Zamfara.

Aggregators sold an average of 6,066 kgs in the last 30 days. Mature aggregators sold significantly more than young aggregators. The total revenue of aggregators averaged 3.8 million naira over the last 30 days, with mature aggregators earning significantly more than youth. Aggregators in Sokoto sold about 38 percent more than those in Zamfara. The largest difference was in price, with Sokoto aggregators receiving 588 naira/kg compared to 464 naira/kg in Zamfara.

Activities of millet aggregators

More than 85 percent of aggregators store their millet purchases as part of their intermediary activities, with almost all aggregators in Sokoto storing millet and 64 percent in Zamfara. Aggregators stored millet for an average of 10 days, with aggregators in Zamfara storing for longer than those in Sokoto. Sacks are the main storage method (Table 45).

About 30 percent of aggregators also engage in drying, nearly 80 percent in cleaning and packaging, and 57 percent in distribution and transportation, while only 5 percent participate in grinding. The proportion of aggregators drying and grinding their harvest and engaging in distribution and transporting is considerably higher in Zamfara than in Sokoto. This variation could reflect different market structures or climatic conditions requiring additional post-handling activities by aggregators.

Millet sales and prices

Millet sales averaged 6 MT in the most recent month, with an average value of 3.8 million naira. Both the quantity of sales and their value are higher among mature aggregators than young aggregators (Annex Table 4).

Aggregators sold millet to various destinations, with Sokoto aggregators distributing larger quantities to all buyer categories compared to their counterparts in Zamfara. Overall, the quantity sold to other aggregators averaged 4,007 kg. Sales to processors averaged 5,112 kg and were significantly higher in Sokoto. Similarly, millet sold directly to consumers averaged 5,095 kg, with aggregators in Sokoto selling significantly more than those in Zamfara.

The data indicate that millet markets are characterized by seasonal purchase price fluctuations. During the abundant season, purchase prices for high-quality millet averaged nearly 404 naira/kg. Prices paid by aggregators are higher during the scarce season, averaging 551 naira/kg—a 36.4 percent seasonal

Table 4.5 Activities of millet aggregators, by state and age

Variable	Measure	Total		Sokoto		Zamfara		Sig test	Youth (15-35 years)		Mature (>35 years)		Sig test
		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Observations	Number	166	105	61		63	103						
Millet purchases: Volumes and values													
Producers sourced from	Number	22.9	24.0	24.1	25.7	19.4	17.6		19.5	15.2	25.1	28.1	
Aggregators sourced from	Number	13.5	10.1	15.0	10.1	11.2	9.8		13.6	8.5	13.3	11.1	
Purchased from producers ('000)	Kgs	8.4	9.1	8.9	9.0	7.1	9.3		7.8	9.2	8.8	9.0	
Purchased from aggregators ('000)	Kgs	4.6	3.6	5.1	3.9	3.9	2.9		4.5	3.7	4.7	3.5	
Purchased from producers ('000,000)	Naira	5.0	7.3	5.4	7.3	3.9	7.5		4.2	7.0	5.5	7.5	
Purchased from aggregators ('000,000)	Naira	2.1	2.0	2.5	2.3	1.4	1.2	*	1.8	1.8	2.2	2.1	
Quantity purchased (typical day)	Kgs	578.2	653.3	627.2	674.0	493.7	612.3		509.7	569.3	620.1	699.1	
Value purchased (typical day) ('000,000)	Naira	0.2	0.3	0.3	0.3	0.2	0.2	*	0.2	0.2	0.3	0.3	**
Millet buyers													
Aggregators	%	45.2	49.9	52.4	50.2	32.8	47.3	*	28.6	45.5	55.3	50.0	***
Stores	%	34.9	47.8	41.0	49.4	24.6	43.4	*	28.6	45.5	38.8	49.0	
Processors	%	81.9	38.6	90.5	29.5	67.2	47.3	***	82.5	38.3	81.6	39.0	
Individual consumers	%	77.7	41.7	78.1	41.6	77.1	42.4		81.0	39.6	75.7	43.1	
Activity and sales													
Intermediary activities													
Drying	%	30.1	46.0	15.2	36.1	55.7	50.1	***	30.2	46.3	30.1	46.1	
Cleaning and packaging	%	78.3	41.3	82.9	37.9	70.5	46.0		88.9	31.7	71.8	45.2	**
Storage	%	85.5	35.3	98.1	13.7	63.9	48.4	***	88.9	31.7	83.5	37.3	
Distribution and transportation	%	57.2	49.6	40.0	49.2	86.9	34.0	***	58.7	49.6	56.3	49.8	
Grinding	%	4.8	21.5	1.0	9.8	11.5	32.1	**	1.6	12.6	6.8	25.3	
Other activities	%	13.9	34.7	21.9	41.6	0.0	0.0	***	19.1	39.6	10.7	31.0	
Storage practices													
Days stored before selling	Number	9.9	8.1	8.0	6.6	11.5	8.9	*	7.2	6.1	11.7	8.8	**
Main storage methods													
Sacks	%	90.0	30.2	92.9	26.1	87.5	33.4		91.9	27.7	88.7	32.0	
Others	%	10.0	30.2	0.0	0.0	10.2	30.5		8.1	27.7	11.3	32.0	
Millet sales													
Sales volume and price (last 30 days)													
Quantity of millet sold ('000)	Kgs	6.1	6.9	6.8	7.2	4.9	6.1		5.8	7.2	6.2	6.7	*
Quantity sold to aggregators	Kgs	4007.4	7120.0	4804.9	7410.1	2634.6	6419.1		3693.7	7587.7	4199.2	6849.2	
Quantity sold to processors	Kgs	5112.4	7124.1	6170.2	7459.8	3291.6	6146.8		5046.0	7267.8	5153.0	7070.3	
Quantity sold to consumers	Kgs	5095.3	6254.2	6514.8	7000.2	2651.8	3610.1		4106.6	5435.3	5700.0	6659.2	
Total sales revenue ('000,000)	Naira	3.8	5.3	4.6	5.7	2.5	4.4	*	3.4	5.0	4.1	5.5	
Average price of millet	Naira/Kg	532.7	174.4	587.4	190.4	438.4	80.5	***	508.9	148.2	547.2	187.8	
Millet sales: Destinations													
Intermediaries	%	49.4	50.2	57.1	49.7	36.1	48.4	**	36.5	48.5	57.3	49.7	**
Processors	%	80.7	39.6	88.6	32.0	67.2	47.3	***	84.1	36.8	78.6	41.2	
Individual consumers	%	89.2	31.2	95.2	21.4	78.7	41.3	***	87.3	33.6	90.3	29.8	
Millet price benchmarking													
Purchase price in abundant season	Naira/Kg	403.9	144.0	438.6	148.0	344.3	115.6	***	366.5	113.1	426.8	156.2	**
Purchase price in scarce season	Naira/Kg	551.1	171.5	553.1	183.4	547.7	150.1		514.4	155.5	573.6	177.6	*
Selling price in abundant season	Naira/Kg	472.7	190.4	525.1	192.4	382.3	149.6	***	439.2	151.4	493.1	208.8	
Seling price in scarce season	Naira/Kg	596.2	183.1	616.1	200.9	562.0	142.7		568.6	145.1	613.1	201.7	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

increase. Prices in the abundant season are significantly higher in Sokoto than Zamfara, while differences in purchase prices narrow during the scarce season. Youth aggregators pay significantly lower millet purchase prices during the abundant season.

Sale prices of high-quality millet during the abundant season averaged 473 naira/kg. Abundant season sale prices are significantly higher in Sokoto than in Zamfara, consistent with the pattern observed for purchase prices. During the scarce season, aggregators sell millet at nearly 600 naira/kg across states. These figures indicate that aggregators receive about 17 percent higher prices for millet purchased and sold within the abundant season. Price markups are smaller during the scarce season, with an average difference of 8 percent between purchase and sale prices. The difference between the average purchase price in the abundant season and the average selling price in the scarce season is about 48 percent, indicating a substantial seasonal markup that may reflect storage, handling, and other interseasonal costs.

4.2.4 Millet processing

Types of processed outputs

Fermented pastes and doughs are the most important processed millet outputs in the two states, accounting for nearly 56 percent of total processing operations (Table 4.6). The share of female processors engaged in fermented paste/dough production (62 percent) is higher than the share of male processors (23 percent). This pattern is consistent with findings from other research on the millet value chain (such as Kabir et al. 2026), which suggests that grain processing is often perceived as women's work due to its relatively lower labor intensity. Together with the absence of statistically significant spatial differences, this suggests that gender (rather than geography) primarily shapes processing specialization.

More than 17 percent of processors process millet into porridges and gruels. The share that processes millet into beverages and drinks is 11 percent, as is the share engaged in fermented batter products. The proportion of processors engaged in preparing cooked whole/flaked millet is only about 5 percent.

These patterns indicate that single processed outputs dominate millet processing in Nigeria, with 93 percent of processors producing one processed output and 7 percent producing two. Mature processors are more diversified, with a statistically significantly higher share producing two processed outputs. Similarly, female processors appear more diversified, although this difference is not statistically significant.

Millet sourcing and marketing

Most millet processors source millet directly from producers and aggregators. About 38 percent of processors purchased millet directly from producers and 75 percent from aggregators, with 14 percent sourcing millet from both processors and aggregators. The share of processors in Zamfara state purchasing from producers is considerably higher at 46 percent compared to 35 percent.

Average quantities purchased from producers total 371 kg per month, with processors paying an average of 403 naira/kg when buying directly from producers. Purchases from aggregators average 455 kg, and prices average 543 naira/kg. The prices that processors in Sokoto pay to aggregators are higher than those paid in Zamfara, which may reflect differences in market structure or transaction costs across states. This may also help explain the higher quantities purchased in Zamfara, although the difference is not statistically significant.

As expected, the seasonal price fluctuations observed upstream are also reflected in the market segment supplying processors. Prices in the abundant season average 471 naira/kg, while prices in the scarce season average 602 naira/kg, representing a 28 percent seasonal premium. Abundant-season prices are relatively higher in Sokoto than in Zamfara, while scarce-season prices converge across states.

Table 4.6 Millet processing and input use, by state

Variable	Measure	Total		Sokoto		Zamfara		Sig. test
		Mean	SD	Mean	SD	Mean	SD	
Type of processing done								
Beverages/drinks	%	11.1	31.6	7.3	26.2	19.2	40.2	
Cooked whole/flaked millet	%	4.9	21.8	5.5	22.9	3.9	19.6	
Fermented batter products	%	11.1	31.6	10.9	31.5	11.5	32.6	
Fermented pastes/doughs	%	55.6	50.0	60.0	49.4	46.2	50.8	
Porridges/gruels	%	17.3	38.1	16.4	37.3	19.2	40.2	
Number of products processed								
One	%	93.0	26.0	95.0	23.0	88.0	33.0	
Two	%	7.0	26.0	5.0	23.0	12.0	33.0	
Millet purchases								
Source and volume of millet purchases								
Producers	%	38.3	48.9	34.6	48.0	46.2	50.8	
Quantity purchased from producers	kgs	370.6	226.7	328.3	269.1	437.5	117.0	
Value of millet purchased ('000)	Naira	141.3	90.4	125.8	97.2	165.8	76.1	
Prices of millet purchased	Naira/kg	403.1	135.3	420.8	137.9	375.0	131.9	
Aggregators	%	75.3	43.4	83.6	37.3	57.7	50.4	*
Quantity purchased from aggregators	kgs	454.9	470.4	395.1	429.2	638.3	555.5	
Value of millet purchased ('000)	Naira	277.5	359.0	276.7	393.0	279.7	236.3	
Prices of millet purchased	Naira/kg	543.4	199.8	576.1	218.7	443.1	54.9	*
Seasonal variation in prices								
Purchase price in abundant season	Naira/kg	471.1	193.5	503.9	190.0	401.5	185.4	*
Purchase price in scarce season	Naira/kg	601.9	207.6	603.5	225.2	598.5	168.2	
Sales destinations								
Consumers	%	98.8	11.1	100.0	0.0	96.2	19.6	
Stores	%	7.4	26.4	1.8	13.5	19.2	40.2	**
Processors	%	7.4	26.4	3.6	18.9	15.4	36.8	
Sold to other sellers	%	14.8	35.8	10.9	31.5	23.1	43.0	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Processed product destination

Direct sales to consumers represent the primary market channel, with 99 percent of processors reporting sales of processed outputs directly to consumers, indicating a strong retail orientation among millet processors. This also suggests that most processors are small-scale (rather than large plants) and operate close to consumers. The second most important channel is sales to other sellers/retailers, with about 15 percent of processors reporting such sales. The share of processors selling to stores and other processors is the same at 7.4 percent. Few spatial and demographic differences are observed in processed output destinations. Specifically, only the share of youth processors selling to other processors and the share of Zamfara-based processors selling to stores are higher than the corresponding shares among mature processors and Sokoto-based processors, respectively.

In summary, this section provides a comprehensive overview of value chain agents and their activities along Nigeria's millet value chain, using survey data collected from producers, aggregators, and processors. The results highlight strong gender and age segmentation: millet production and aggregation are dominated by older men, while processing is largely undertaken by younger women—underscoring processing as an important entry point for youth and female participation. This finding is consistent with Kabir and colleagues (2026), who examine youth and women's engagement in Nigeria's millet value chain and show that grain production is predominantly carried out by men, while processing is concentrated in small-scale, lower-value food products largely produced by women. These gendered patterns are shaped by social norms that position processing as "women's work" and by the flexibility processing offers, including the possibility of operating from the home or close to home.

Production is characterized by smallholder millet farming systems with moderate yields, widespread use of hired labor and chemical fertilizer, limited mechanization, and significant spatial variation in input use, technology adoption, and access to services. Postharvest handling remains largely manual, and storage practices are heterogeneous and largely traditional. Downstream, aggregators play a central role in linking producers to consumers and processors, exhibiting strong seasonal price arbitrage and state-level differences in scale, formalization, and market integration. Processors, in contrast, are predominantly informal, small-scale, consumer-oriented, and specialized in fermented millet products, reflecting both demand patterns and structural constraints within the millet value chain.

5. PRE- AND POSTHARVEST MILLET LOSSES IN NIGERIA

In this section, we discuss the share of millet value chain agents in Nigeria facing losses during millet production, postharvest production, and in lower streams of aggregation and processing. We also discuss the volume and value of losses sustained as a share of millet production in the same value chain nodes and then summarize the self-reported causes of losses.

5.1 FREQUENCY OF FOOD LOSSES

5.1.1 Frequency of losses among producers

As discussed in Section 3, we gathered data on whether and how much millet producers lost during production (preharvest), harvesting (due to millet left in the field), and postharvest production activities. Table 5.1 summarizes the frequency with which producers suffered losses during these activities. Nearly all producers surveyed encountered losses at one stage (at least), with 99.8 percent indicating that they encountered losses at more than one stage. Preharvest losses were reported by 89 percent of producers and postharvest losses by 99.8 percent. Only 19.5 percent of the producers reported leaving some of their millet in the field.

The share of producers experiencing losses was comparable between treatment and control villages, except for millet left in the field: in treatment villages, more producers reported such losses (11.5 percentage points [pp]). Comparing states, 7.6 pp more producers from Sokoto reported preharvest losses, and 31 pp more producers in Zamfara reported leaving their millet in the field. A higher share of male producers reported preharvest losses than did female producers.

5.1.2 Frequency of losses among aggregators and processors

All aggregators experienced some level of postharvest losses during one or more of the activities. Although only 30 percent of the aggregators engaged in millet drying, all aggregators engaged in drying reported losses. Similarly, 78.3 percent of the aggregators undertook cleaning and packaging, and nearly all who cleaned their harvest (99.2 percent) reported millet losses during this activity. Storage was the most common activity, with approximately 86 percent of aggregators participating; around 97 percent of them reported losses during this activity.

Table 5.1. Share of producers encountering losses, by type (percent)

Category	Measure	Preharvest	Harvest	Postharvest	More than one type
Total	%	89.2	19.5	99.8	99.8
	SD	0.30	0.40	0.04	0.04
Group					
Treatment	%	90.2	25.3	100.0	100.0
	SD	0.30	0.40	0.00	0.00
Control	%	88.3	13.8	99.7	99.7
	SD	0.30	0.40	0.10	0.10
Significance test		-	***	-	-
State					
Sokoto	%	91.8	8.9	99.7	99.7
	SD	0.30	0.29	0.05	0.10
Zamfara	%	84.2	39.9	100.0	100.0
	SD	0.40	0.50	0.00	0.00
Significance test		**	***	-	-
Gender					
Female	%	50.0	15.0	100.0	100.0
	SD	0.50	0.40	0.00	0.00
Male	%	90.6	19.7	99.8	99.8
	SD	0.30	0.40	0.04	0.04
Significance test		***	-	-	-
Age					
Youth	%	90.6	18.8	99.5	99.5
	SD	0.30	0.40	0.10	0.10
Mature	%	88.6	19.9	100.0	100.0
	SD	0.30	0.40	0.00	0.00
Significance test		-	-	-	-

Source: Authors' calculations using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Storage losses were widespread in Sokoto, where all aggregators reported them, compared to 87 percent of aggregators from Zamfara. Among youth and mature groups, a nearly identical proportion of aggregators reported storage losses (96.4 percent and 96.5 percent, respectively), suggesting that age does not significantly influence storage performance.

Distribution and transportation activities were performed by 57 percent of aggregators, while a much smaller share (5 percent) were engaged in grinding. Nonetheless, all aggregators participating in these activities reported experiencing some level of loss, highlighting potential inefficiencies or risks within these activities.

Among processors, losses were also widespread, with 93.8 percent reporting them. All processors from Sokoto reported losses, though only 81 percent did in Zamfara. No statistically significant differences were observed by age. The share of female (94.1 percent) and male (92.3 percent) processors who experienced losses was not significantly different.

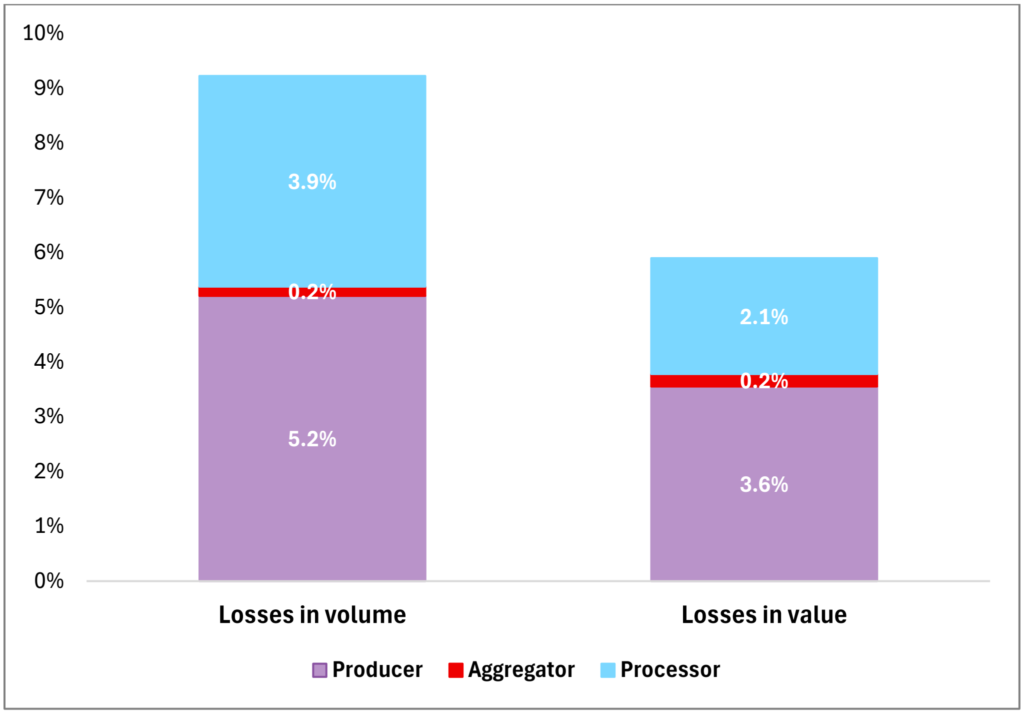
5.2 VOLUME AND VALUE OF LOSSES

Figure 5.1 provides an estimation of millet losses along the value chain from producers to aggregators and processors. These losses capture the volume and value of millet that was (1) totally lost (quantitative degradation) and (2) damaged but still potentially usable (qualitative degradation).

Millet loss along the value chain averaged 9.2 percent of the total volume of producers' output. In value terms, using ideal prices, losses averaged 6.0 percent of the total production value.

Producers suffered most of these losses, accounting for an average of 56.4 percent and 60.3 percent of total volume and value of losses, respectively. Processors sustained the second-highest share of losses, with 41.7 percent and 36.0 percent of total volume and value of losses, respectively. Aggregators experienced the lowest share of losses, with an average of 1.8 percent and 3.8 percent of total volume and value of losses, respectively.

Figure 5.1 Estimated volume and value of food losses along the millet value chain in Nigeria



Source: Authors' calculations using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

5.2.1 Volume of losses among producers

Volume of losses: Overall sample

Figure 5.2 disaggregates the volume of producer losses into preharvest, left in the field, and postharvest stages for the overall sample and across spatial and demographic characteristics. Of the total volume of millet lost by producers, the highest proportion (54.2 percent) occurred at the postharvest level. Preharvest losses were comparable, at nearly 36.3 percent of volume of losses. Losses due to production left in the field accounted for less than 10 percent of the volume of output lost by producers.

Volume of losses: Across space

Producers in control areas lost more millet than those in treatment areas. Furthermore, most of the losses occurred at different nodes of production in the two areas. In treatment villages, preharvest losses accounted for approximately 48.8 percent of producer-level losses, compared to 25.8 percent in control villages. This suggests that producers in treatment villages might have been more exposed to factors adversely affecting crop growth, such as bad weather conditions or pest infestations. In contrast, postharvest losses are more substantial among producers in control areas (66 percent), indicating that improved postharvest handling practices may have contributed to reduced losses in treatment villages.

Producer losses in Zamfara are 8.0 percent of output volume—more than twice the losses in Sokoto (3.7 percent). A larger share of the volume lost (69 percent) in Sokoto occurred at the postharvest stage, while in Zamfara preharvest losses were dominant (46 percent). These differences may reflect spatial variation in climatic conditions, production practices, and access to postharvest management facilities. These results imply that interventions to reduce millet losses should be spatially targeted and address different priority nodes across locations.

Volume of losses: Across gender and age

Male producers experienced higher overall losses in volume (5.3 percent of volume) than their female counterparts (3.5 percent). Male producers experienced considerably higher postharvest losses (54.4 percent) than did female producers (42.3 percent). The case is the reverse for preharvest losses, with female producers at 44 percent compared with 36 percent for male producers. Loss comparison by gender indicates that pre- and postharvest losses were more evenly distributed among female producers, while postharvest losses were approximately 50 percent more severe than preharvest losses among male producers. These results may imply the need for gender-sensitive interventions to address food losses among producers.

Comparing food losses across producer age indicates that total losses among young producers, approximately 6.6 percent of the total production, are higher compared to losses among mature producers (4.5 percent). For both young and mature producers, postharvest losses accounted for the highest share of total production (55.2 and 53.4 percent, respectively). Interventions to reduce food losses among producers may need to focus on less experienced youth.

5.2.2 Value of losses among producers

Value of losses: Overall sample

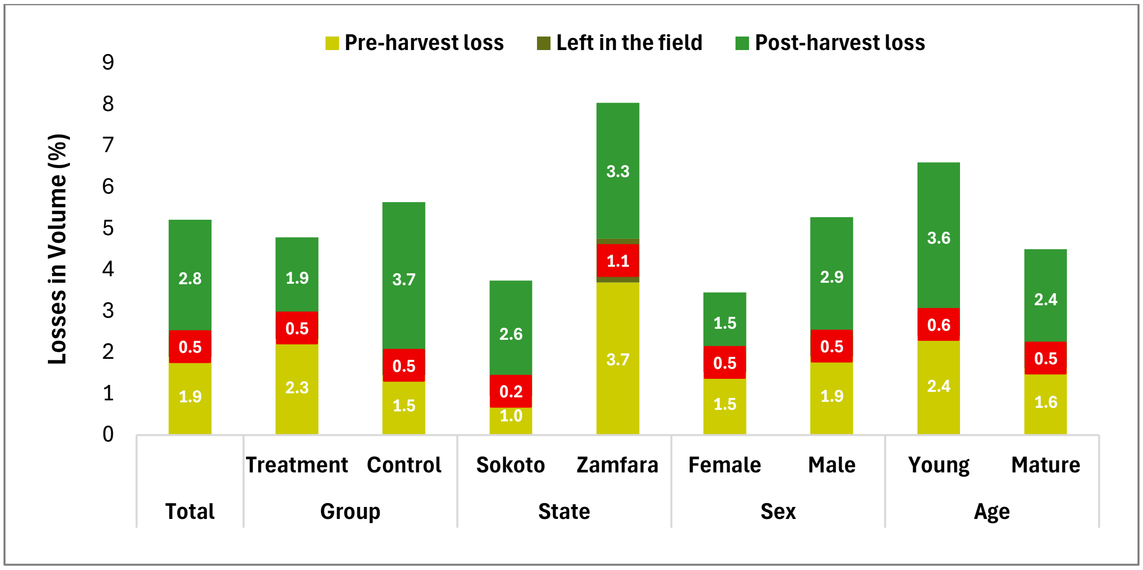
Figure 5.2 (panel b) shows the value of losses among producers, separated into pre- and postharvest losses and losses due to millet left in the field. The figure shows that 3.1 percent of the total production value is lost. This is lower than the share of losses in volume of production, reflecting the effect of prices in influencing the value-based measurement. Preharvest losses accounted for 53 percent of lost value, followed by postharvest losses at 34.5 percent.

Value of losses: Across space

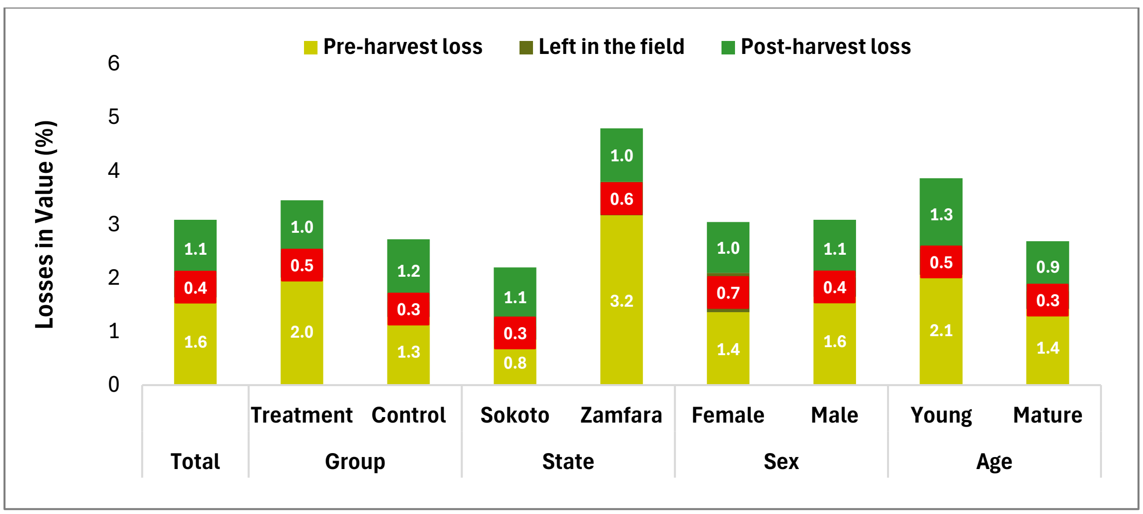
For the overall sample, the importance of production nodes in value of losses remained consistent spatially. However, producers in treatment villages reported higher losses than those in control areas (3.5 percent vs. 2.7 percent). Preharvest losses accounted for 58 percent of total lost value for treatment area producers, while this was considerably lower at 47 percent for control area producers. Losses in value due to harvest left in the field ranged from 10.8 percent in control areas to nearly 13.6 percent in treatment areas. This implies that the value of postharvest losses is more important for producers in control areas, while the value of preharvest losses is much more important in treatment areas.

Figure 5.2 Estimated food losses among producers, across spatial and demographic characteristics

a. **Food loss in the millet value chain as a percentage of total volume (kg) of production**



b. **Food loss in the millet value chain as a percentage of total value of production**



Source: Authors' calculation using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

The share of value lost by producers in Zamfara was approximately twice as high as for those in Sokoto. The share of lost value for producers in Zamfara was higher in all three stages of production. In particular, the share of total production value lost due to preharvest losses in Zamfara (3.2 percent) was four times the corresponding share in Sokoto (0.8 percent). This indicates that overall losses are considerably higher in Zamfara and preharvest losses are especially important in Zamfara, both in value and volume terms. These results suggest that producers in Zamfara may require broader loss-reduction support, with particular emphasis on preharvest risk management, while producers in Sokoto may require more support for postharvest loss reduction.

Value of losses: Across gender and age

Measured in terms of value, female producers experienced almost the same share of millet losses (3 percent) as their male counterparts (3.1 percent). This contrasts with the considerably higher volume of losses by male producers. Preharvest losses accounted for 48 percent of value of losses for women and 53.4 percent for men. Harvest left in the field accounted for more than 24 percent of lost value for women, which was considerably higher than the 12 percent experienced by men. This indicates that harvest left in the field is an important source of losses for women and is almost comparable to postharvest losses, which accounted for 31.2 percent of total lost value. This may imply that lack of labor, which is the most important source of losses due to being left in the field (Section 5.3), is an important problem among female producers.

Youth producers reported losses of 3.9 percent of the value of production. This is considerably higher than losses reported by mature producers (2.7 percent). Moreover, compared with mature producers, youth producers had higher losses across all three nodes of production. However, the relative importance of the three nodes is about the same when considering their share in total value losses for each age group. Preharvest losses accounted for 53.4 percent of total value losses among youth producers and 53.0 percent among mature producers. Similarly, postharvest losses accounted for 34.3 percent and 34.6 percent of total value losses among youth and mature producers, respectively.

5.2.3 Volume of losses among processors

Volume of losses: Overall sample

Losses incurred by processors represent a significant portion of total losses in the millet value chain, accounting for 41.7 percent of the total volume lost. As shown in Figure 5.3, processors lost approximately 4 percent of their output volume on average.

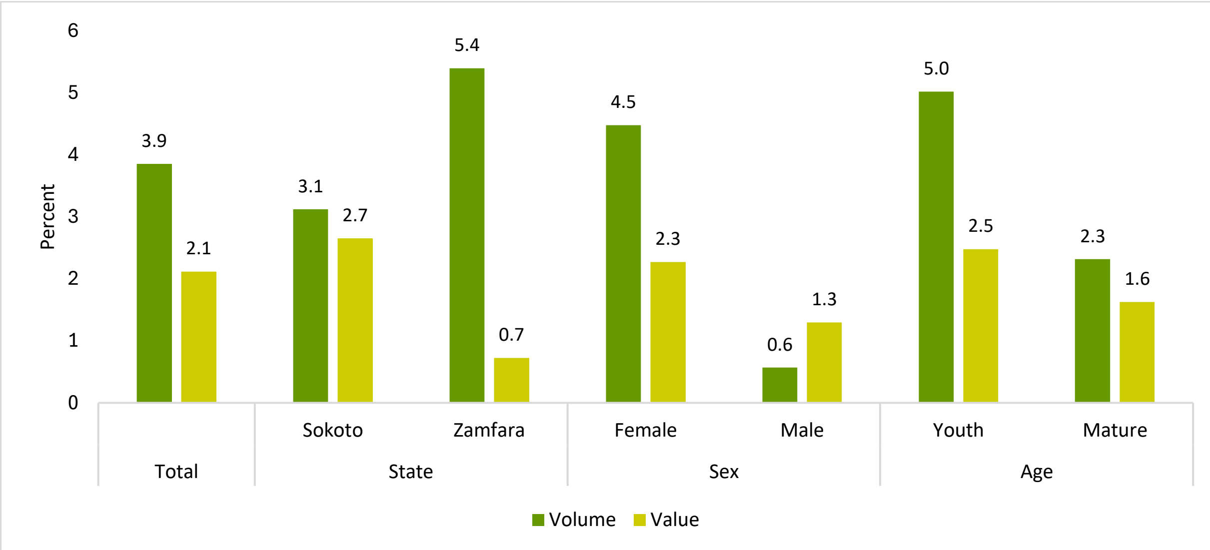
Volume of losses: Across space

Losses in volume were not evenly distributed across states, with Zamfara processors experiencing higher volume losses (5.4 percent) than those in Sokoto (3.1 percent), suggesting potential differences in handling practices and equipment quality.

Volume of losses: Across gender and age

Female processors incurred 4.5 percent volume losses, markedly higher than the 0.6 percent experienced by male processors. This gap may reflect differences in processing scale, techniques, or access to resources. Age also appears to matter, with younger processors experiencing 5 percent volume losses—more than double the 2.3 percent losses among mature processors—suggesting that experience may confer advantages in mitigating losses during processing activities.

Figure 5.3 Estimated food losses of processors, across spatial and demographic characteristics



Source: Authors' calculation using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

5.2.4 Value of losses among processors

Value of losses: Overall sample

Among processors, losses accounted for 36 percent of total value lost. However, as with producers, the share of the value of output lost at the processing stage (2.1 percent) was lower than the share of total volume lost. This distinction suggests that volume losses do not always translate proportionally into monetary losses, likely reflecting differences in the market value of affected products.

Value of losses: Across space

The spatial pattern of value losses diverges from that of volume losses. While processors from Zamfara recorded higher volume losses, they had a considerably lower share of value lost (0.7 percent) than that reported by processors from Sokoto (2.7 percent). This discrepancy may reflect differences in product mix, pricing, or the timing/point at which losses occur.

Value of losses: Across gender and age

Consistent with their dominance in processing, female processors lost a larger share of value compared to male processors, though the difference is less stark than for volume losses. Notably, male processors experienced a higher share of value lost relative to volume lost, suggesting that losses for male processors may occur in higher-value products or at stages associated with higher unit values. Younger processors also experienced higher value losses than mature processors, though the disparity is smaller than the one observed for volume losses, emphasizing that experience and skills may mitigate not only the quantity but also the economic impact of losses.

5.3 CAUSES OF FOOD LOSSES AT THE PRODUCTION STAGE

This section describes reported causes of losses among producers and processors in Nigeria's millet value chain. Figure 5.4 shows the causes of preharvest losses; further details are provided in Annex

Table 6 and 7. Similarly, Figure 5.6 depicts postharvest losses, details of which are provided in Annex Table 8 and 9. Figure 5.5 shows the causes of millet harvest being left in the field, while Annex Table 10 provides the causes of losses among processors.

5.3.1 Causes of losses among producers

Causes of losses: Overall sample

Preharvest

Producers reported encountering several problems that contributed to preharvest losses: 97 percent reported problems associated with harvesting, followed by 65.5 percent reporting lack of rain. Pests and diseases infestations and weed growth were reported by 48.2 percent and 26.6 percent producers, respectively.[9] Other reported causes of losses include excessive rain, lack of chemical inputs, excess chemicals, poor seed quality, damage caused by animals and rodents, and theft.

Left in the field

Among the 19.5 percent of producers that left good harvest in the field, the majority cited labor-related constraints. Specifically, 8.1 percent reported lack of funds to hire labor, 7.7 percent cited labor shortages, and 6 percent reported high labor costs.

Postharvest

Losses were reported during all postharvest handling activities. The most frequently reported causes of were bird attacks, insect infestation, and rodent damage. More than 90 percent of the producers reported problems while transporting harvest, citing production being blown away, improperly tied sacks, and ruptured sacks. Almost all producers (99.3 percent) reported problems during threshing the harvest. Most were related to lack of proper technique and tools. Eighty four percent of the producers encountered some problems during drying and cited bird attacks, adverse weather conditions, and theft. Almost all (99 percent) encountered problems during winnowing, sifting and sorting, citing grains being blown away, spillage, and inappropriate handling of the produce. Around 90 percent experienced losses during storage. The most reported causes were rodents, insect infestations, fluctuations in moisture and temperature, and improperly tied sacks. Nearly 75 percent experienced problems while selling millet, with accidents (31.2 percent) and adverse weather (25.4 percent) representing the most frequently mentioned causes.

Causes of losses: Across space

Preharvest

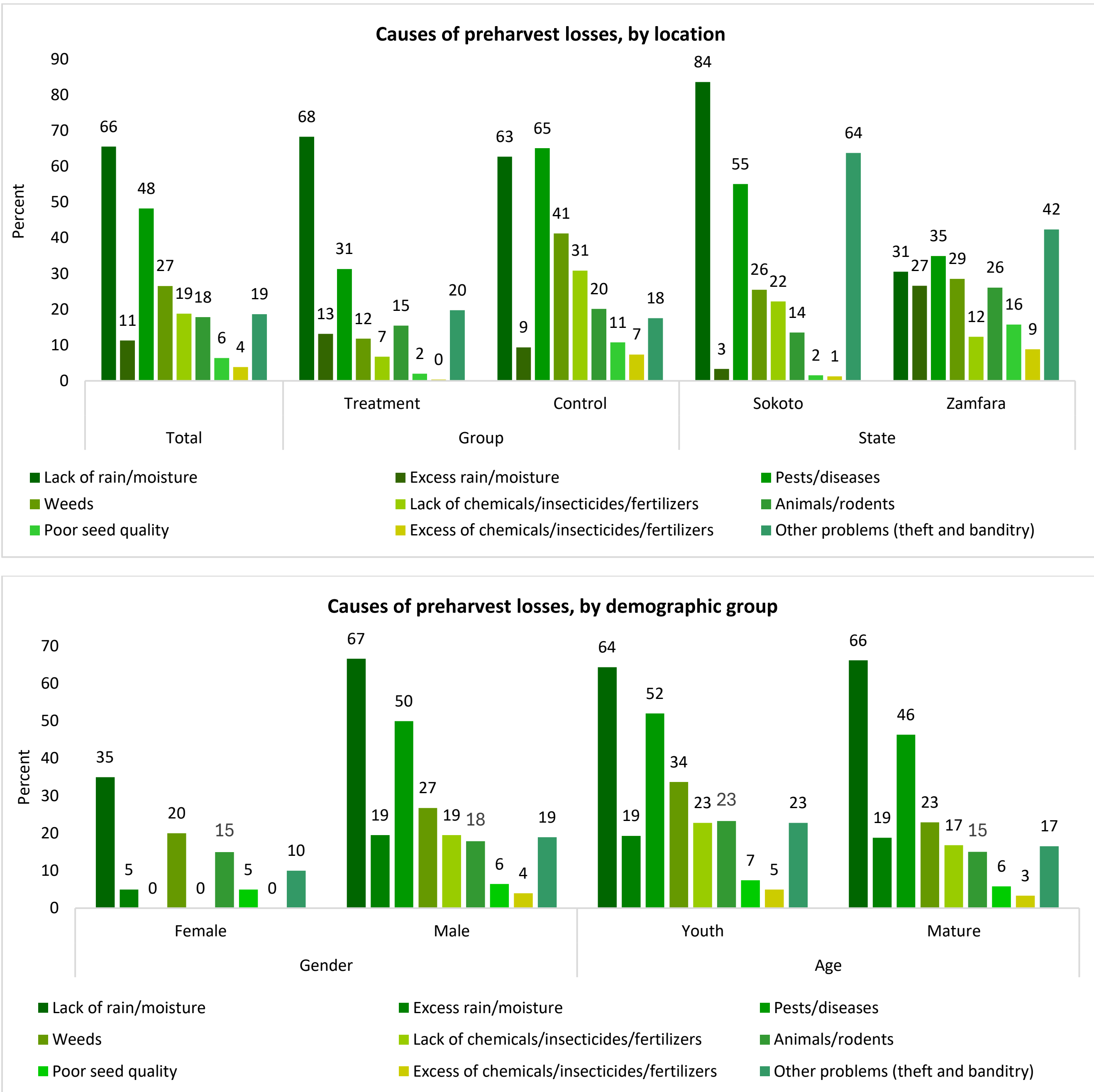
Compared to producers in control areas, a higher share of producers in treatment areas reported pests and disease infestation, weed growth, excessive use of chemicals, and lack of chemicals. There were no statistically significant differences in the two groups for the remaining causes of preharvest losses.

Fifty-five percent of producers in Sokoto and 35 percent in Zamfara reported pest problems. A much larger share of producers in Sokoto (83.7 percent) reported lack of rain as a preharvest problem than in Zamfara (30.5 percent). In contrast, excessive rain was more frequently cited in Zamfara (26.6 percent) than in Sokoto (3.3 percent), underscoring the contrasting climatic vulnerabilities that influence preharvest loss outcomes across these states. More producers in Zamfara reported that excessive use of chemicals and reduced seed quality contributed to preharvest losses, while lack of chemicals was reported

[9] Note that the sums of these percentages may be greater than 100 percent, as producers may have cited more than one problem that caused losses.

significantly more in Sokoto. Theft and damage from animals and rodents were also higher in Zamfara, highlighting state-level differences in input management, pest control, and security challenges.

Figure 5.4 Self-reported causes of preharvest losses (percent)

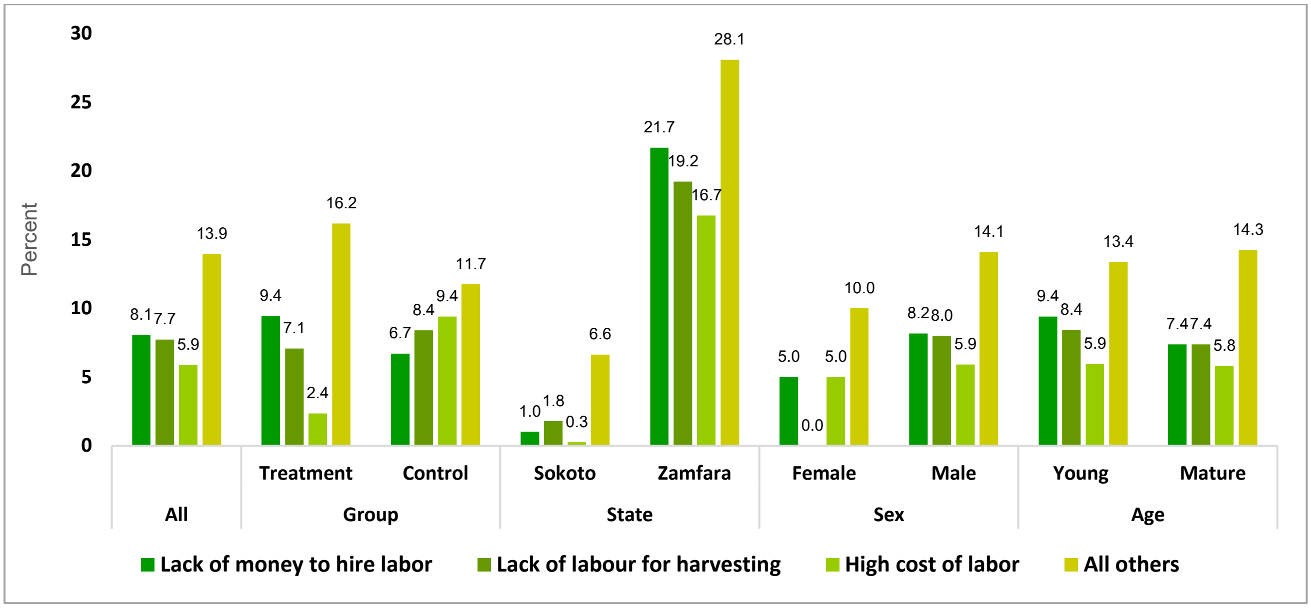


Source: Authors' calculation using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Left in the field

Despite a considerably higher share of producers in treatment areas leaving harvest in the field, the share of producers in these areas that reported facing higher labor costs, an important cause of these losses, was lower than for those in control areas. However, a larger share of producers in treatment areas cited other problems that caused them to leave harvest in the field. Consistent with the higher share of producers in Zamfara that left millet unharvested, which was four times the share in Sokoto, a higher share cited all three labor-related constraints as sources of the problem. These differences suggest that labor constraints are more prevalent in Zamfara.

Figure 5.5 Self-reported causes of harvest left in the field (percent)



Source: Authors' calculation using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Postharvest

Although the share of producers that encountered postharvest losses differed across treatment and control areas, the only cause that differed across these areas was insect-related problems, which was reported more in control villages. The causes of postharvest losses also differed by state, with producers in Sokoto reporting more bird attacks, while those in Zamfara experienced more insect and rodent infestations.

Compared to producers in control areas, a higher share of those in treatment areas reported experiencing losses during transport. A relatively higher share of producers in Zamfara reported transportation problems as a source of postharvest losses.

All producers from treatment villages reported losses during threshing, although the share was slightly lower in control areas (98.7 percent). Poor handling of the millet harvest by laborers and the use of inappropriate or lower-quality tools were reported by a higher share of producers from treatment villages as causes of losses during threshing. Conversely, unclean and soft floors were reported as problems during threshing by a relatively higher share of producers in control villages. Similarly, a higher share of producers in Zamfara reported soft threshing floors and poor-quality tools as causes of losses during threshing.

The share of producers that reported losses during drying was higher in treatment than in control villages. Among the commonly reported causes during drying were bird attacks and adverse weather conditions, which were both reported by more producers in treatment villages. In contrast, theft was reported by a higher share of producers in control villages. In Zamfara, a relatively higher share of producers reported losses during drying, with theft and adverse weather conditions reported by a statistically significantly higher share of producers.

All producers in treatment areas and most in control areas (98.6 percent) experienced losses during the winnowing and sorting stage. The main causes of losses during winnowing and sorting were grains being blown away and spillage, both of which were reported by a higher share of producers in control villages. Grains being blown away and inappropriate handling of the millet harvest at this stage were reported by a higher share of producers in Zamfara.

A higher share of producers from treatment villages experienced losses during the storage stage. Differences in all causes of losses during storage were statistically significant. A relatively higher share of producers in treatment areas reported sacks not being properly tied, changes in moisture and temperature, insect and mite infestations, rodent and animal attacks, and fungal or bacterial contamination as causes of losses during storage, while bird attacks were cited by a higher share of producers in control villages. Changes in moisture, insect infestations, and fungal and bacterial contamination were cited by a higher share of producers in Sokoto, while improperly tied sacks were reported by a higher share of producers in Zamfara as a cause of storage losses.

Bad weather was the only cause of losses during selling that differed between producers in control and treatment areas; this was reported by more producers in treatment villages. A relatively higher share of producers in Zamfara reported that theft, accidents, and bad weather caused losses during selling.

Causes of losses: Across gender and age

Preharvest

A considerably higher share of male producers (92 percent) reported experiencing preharvest losses than did female producers (55 percent). A relatively higher share of male producers reported lack of rain, pest and disease infestation, and lack of chemicals as causes of preharvest losses. Across age groups, a relatively higher share of young producers reported weed growth, lack of chemicals, damage by animals and rodents, and theft as important causes of preharvest losses. Despite differences in the share of producers across gender and age who reported losses during harvesting, the only cause that was statistically significantly different was the relatively higher share of male producers who reported insect infestation as a cause of harvesting losses.

Left in the field

Although a higher share of male and mature producers reported leaving part of their production in the field, none of the causes cited for such losses were statistically significantly different.

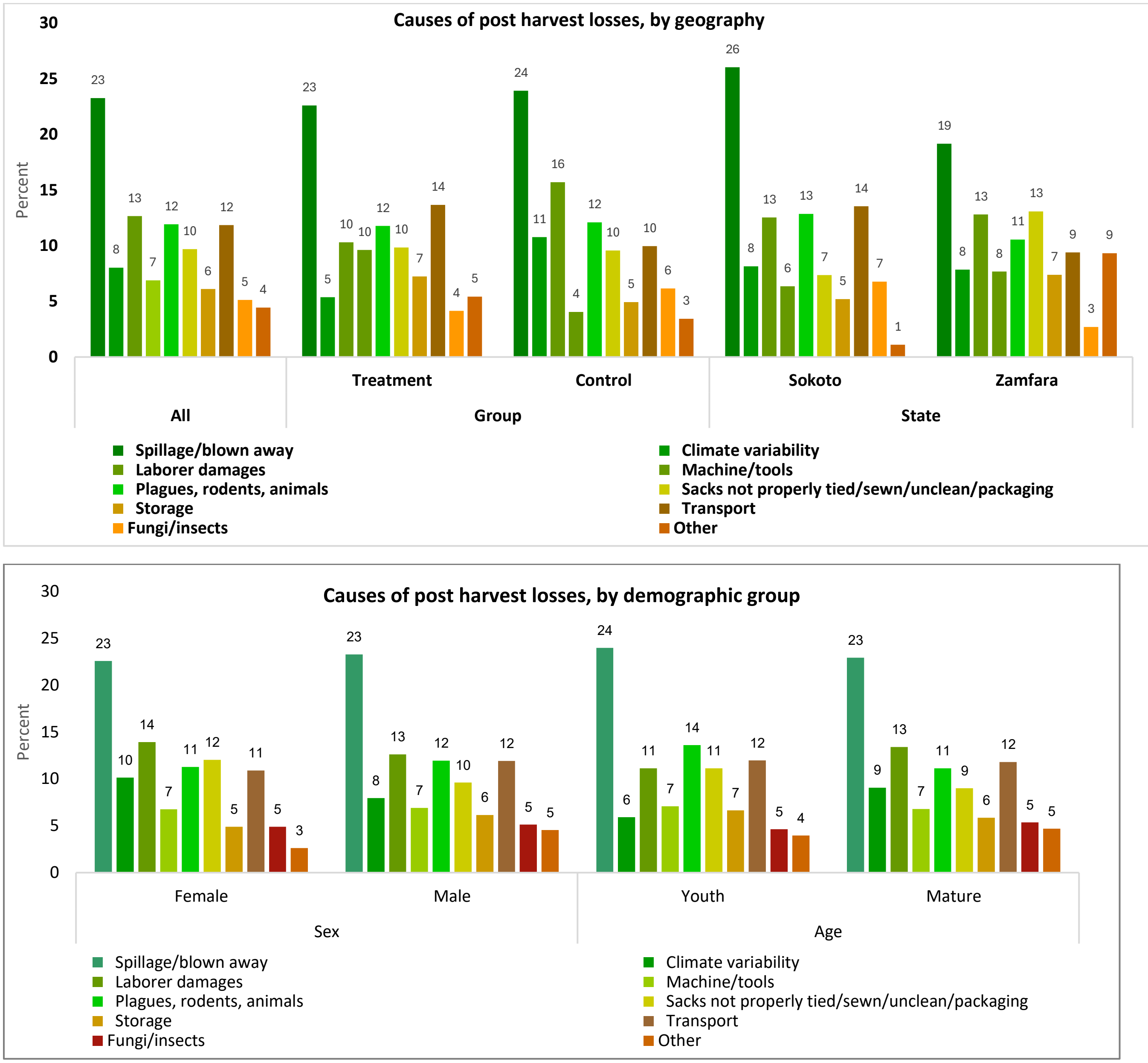
Postharvest

The difference in the shares of male and female producers that experienced problems during transportation was not statistically significant. Consistent with this finding, the only problem cited by a statistically significantly higher share of female producers was ruptured sacks. Similarly, there were no statistically significant differences in the share of young and mature producers who experienced transport-related problems, although sack rupture was cited as a cause of losses by a relatively higher share of mature producers.

There were no statistically significant differences across gender in the causes of losses during threshing. A relatively higher share of mature producers reported inappropriate handling by laborers as a cause of losses during threshing, while a higher share of young producers reported threshing floors that were not hard and clean as causes of losses.

A relatively higher share of female producers experienced drying-related problems. However, no differences in the specific causes of drying-related losses were statistically significant. In contrast, the shares of young and mature producers who encountered drying problems were not statistically different. Nonetheless, a relatively higher share of mature producers reported theft and adverse weather conditions as causes of losses during drying.

Figure 5.6 Self-reported causes of postharvest losses (percent)



Source: Authors' calculation using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

There were no statistically significant differences in the share of male and female producers that experienced winnowing-related problems, nor in the shares citing specific causes of losses during winnowing. The share of mature producers that reported inappropriate handling of the harvest as a cause of losses during winnowing was relatively higher.

A relatively higher share of male producers experienced damage caused by rodents and animals during storage, while a higher share of mature producers reported changes in moisture and temperature and insect infestations as causes of storage losses compared to young producers.

Although the share of male and female producers that encountered selling problems was not statistically significantly different, a relatively higher share of female producers reported adverse weather conditions as a cause of losses during selling. A relatively higher share of young producers encountered selling problems. A higher share of young producers indicated theft as a cause of losses during selling, while a higher share of mature producers reported bad weather as a cause.

5.3.2 Causes of losses at the aggregator and processor stages

Aggregators and processors incurred measurable losses across key postharvest activities. Aggregators were interviewed about the postharvest activities of drying, cleaning and packaging, storage, distribution and transportation, and grinding. A summary of the results is provided in Annex Table 10. While only 30 percent of aggregators indicated drying purchased harvest, all reported experiencing losses, primarily through spillage (96 percent) and weight reduction due to the drying process (76 percent).

Approximately 85.5 percent of aggregators stored millet, and most (96.5 percent) experienced losses. Spillage was reported by a majority (68 percent) as a cause of storage losses, followed by rodents (51 percent), infestations (27.7 percent), and moisture-related damage (26 percent). The predominance of spillage across stages suggests limitations in handling practices and storage infrastructure.

Cleaning and packaging were widely practiced, with more than three-quarters of aggregators engaging in these activities. Among these aggregators, 86 percent reported experiencing losses during cleaning and packaging. Spillage was the most frequently cited cause of loss at this stage (93.8 percent).

Roughly 57 percent of aggregators engaged in transportation and distribution, and all of them reported losses during this activity. The main causes of losses during transport were spillage and transport accidents (65 percent and 59 percent, respectively), indicating weaknesses in packaging integrity and transport handling practices.

For processors, the recurring causes of millet losses mirrored those of aggregators, as indicated in Annex Table 11. Different shares of processors participated across six processing steps. Spillage and accidents consistently emerged as dominant factors leading to losses at most stages, followed by using low-quality tools and inappropriate handling practices. These repeated patterns—particularly at stages close to final consumption—highlight systemic challenges related to equipment quality, technical training, and post-harvest management practices, which, if addressed, could significantly improve performance along the millet value chain.

6. CORRELATES OF PRE- AND POSTHARVEST MILLET LOSSES IN NIGERIA[10]

Tables 6.1 and 6.2 present results from the econometric analyses examining factors correlated with the occurrence and severity of pre- and postharvest millet losses, respectively. The tables report marginal effects. In the Probit models, marginal effects indicate the change in the probability (in percentage points) of experiencing pre-/postharvest damage associated with a one-unit increase in a covariate, holding other variables constant. In the Tobit models, marginal effects indicate the change in the expected observed loss intensity (in percentage points) associated with a one-unit increase in the corresponding covariate.

6.1 PREHARVEST LOSSES

The econometric analyses included several variables on demographic characteristics of producers, such as age, gender, education, experience growing millet, and other household characteristics, to investigate whether, holding other factors constant, these characteristics are correlated with the likelihood and intensity of losses. The results provide insights into some of the factors correlated with food losses. Male producers have a higher likelihood of experiencing preharvest losses than female producers, which is the omitted category in the regression (Table 6.1, first two columns). The intensity of preharvest losses is also higher among male producers (Table 6.1, last two columns). Both findings are consistent with the results of the descriptive analyses in the previous section.

Several variables capturing producers' input use and marketing behavior are also included. Both the probability and intensity of preharvest losses decline with the area cultivated under millet (log millet area). The negative association with loss intensity is consistent with the idea that, conditional on damage occurring, larger-scale producers may have stronger incentives and greater capacity to limit losses because the gains from mitigation are larger in absolute terms. The negative association with the likelihood of experiencing losses may similarly reflect scale-related advantages—such as better management, access to services, or equipment—rather than a purely mechanical relationship between farm size and exposure.

The share of output sold is positively correlated with both the likelihood and intensity of preharvest losses. This pattern may arise because market-oriented producers may delay harvest to accumulate larger marketable volumes, thereby extending field exposure to pests, diseases, and weather-related risks. In addition, commercialization may increase the salience of quality screening by buyers, which can translate into higher reported damages or losses. To capture marketing incentives, the analysis includes the producer price gap (the difference between lean- and ample-season prices). A larger price gap is associated with a lower likelihood of preharvest losses, consistent with the interpretation that stronger expected returns increase incentives to invest effort in loss-reducing practices and timely harvesting.

Input management variables also exhibit clear relationships. Applying organic fertilizer is positively correlated with both the likelihood and intensity of preharvest losses, which may reflect suboptimal handling or management conditions that elevate pest or pathogen pressure (Termorshuizen et al. 2006; Noble and Coventry 2005). By contrast, the use of insect/pest control is associated with a lower likelihood of preharvest losses, consistent with its protective role against biotic stressors.

Finally, technology and skills-related variables are associated with reduced losses. Use of mechanical equipment is negatively correlated with the likelihood of preharvest losses, potentially reflecting improved

[10] The econometric analysis identifies factors associated with preharvest and postharvest losses. As such we use the terms "correlations" and "associations" to emphasize the observational nature of the baseline data and that the reported relationships be interpreted as correlational rather than causal.

timeliness and precision in field operations (such as land preparation, planting, and input application). Similarly, receiving harvesting training is negatively correlated with the likelihood of preharvest losses, consistent with better harvest timing and handling practices that reduce shattering and other field losses.

Table 6.1 Marginal effects of factors correlated with preharvest losses of millet in Nigeria

	Probit: Dependent variable experienced preharvest damages? (=1 if yes)		Tobit: Dependent variable preharvest losses (%)	
	Coefficient	SE	Coefficient	SE
Gender (=1 if male)	0.155*	0.095	2.019*	1.238
Youth (=1 if producer 35 or less)	-0.043	0.033	-0.288	0.350
Education level, secondary	-0.012	0.031	-0.260	0.387
Years of experience growing millet	-0.001	0.002	-0.010	0.027
Number of household members	0.001	0.003	-0.009	0.037
Wealth index	0.013	0.011	0.011	0.025
Member of agricultural cooperative (=1 if yes)	-0.019	0.056	0.927	0.743
Log millet area	-0.085***	0.028	-1.180***	0.321
Share of output sold	0.341***	0.084	3.272**	1.557
Log of producer price gap	-0.065***	0.016	-0.201	0.275
Seed type (=1 if improved)	0.059	0.062	1.094	1.027
Applied inorganic fertilizer (=1 if yes)	-0.019	0.044	-1.450	1.095
Applied organic fertilizer (=1 if yes)	0.256***	0.050	1.936**	0.983
Producer irrigated land (=1 if yes)	0.080	0.088	0.536	1.008
Applied insect or pest/insect control	-0.104*	0.059	-1.469	0.941
Used manual tilling	0.089	0.062	1.340	1.080
Used mechanical equipment	-0.163**	0.068	-1.665	1.049
Received training in harvesting	-0.110**	0.053	-1.158	0.781
Used hired labor	-0.075	0.052	-1.178	0.964
Barriers accessing input/service markets	0.095	0.061	1.218**	0.478
Access to credit	-0.158***	0.033	-1.929**	0.791
Causes of damage index	-0.007	0.009	-0.204	0.203
Average preharvest rainfall	-0.009***	0.003	-0.107**	0.044
Average preharvest temperature	-0.058	0.122	-1.602	1.394
State (=1 if Zamfara)	0.489***	0.189	6.313***	2.207
Treatment areas (=1 if yes)	0.102*	0.058	0.896	0.716
Log-likelihood	-188		-1,037	
Number of observations	595			

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).
Note: Estimates with ***, **, and * are significant at 1%, 5%, and 10%, respectively.

Farmers' access to credit is negatively correlated with both the likelihood and intensity of preharvest losses. Access to agricultural credit can indirectly contribute to loss reduction, as producers invest in preharvest management measures that they otherwise could not afford. The results indicate that the amount of precipitation received has a negative effect on the likelihood and intensity of preharvest losses. Sufficient rainfall enables timely maturation that allows harvest before prolonged field exposure to birds and weather damage during the dry season. The likelihood and intensity of preharvest losses are higher in Zamfara than in Sokoto, corroborating the results in the descriptive analyses, and preharvest losses are more likely to occur in treatment than control areas.

In summary, the econometric results show that preharvest millet losses are significantly correlated with producer characteristics, production practices, and market conditions. Male producers experience both a higher likelihood and greater intensity of losses than female producers. Loss intensity declines with cultivated area, suggesting stronger mitigation capacity among larger farms. Greater market orientation, measured by the share of output sold, is correlated with higher losses, while larger seasonal price gaps reduce loss likelihood, indicating stronger incentives for loss reduction. Organic fertilizer use is positively correlated with losses, whereas agro-chemical use, mechanization, farmers' training, credit access, and higher rainfall are correlated with reduced losses.

6.2 POSTHARVEST LOSSES

Results from the econometric analyses of postharvest losses among producers are presented in Table 6.2. The findings indicate that youth producers are less likely to experience postharvest losses, which is consistent with the descriptive evidence in Section 5. The household wealth index—a proxy for productive and durable assets—is negatively correlated with both the likelihood and intensity of postharvest losses. This result aligns with findings by Bachewe and colleagues (2020) and Kaminski and Christiaensen (2014), suggesting that greater asset ownership enhances producers' ability to invest in improved storage and handling practices.

The area cultivated under millet is negatively correlated with both the likelihood and intensity of postharvest losses. The negative association with loss intensity is consistent with the idea that larger producers may have stronger incentives and greater capacity to manage and mitigate losses once they occur. However, from a purely exposure-based perspective, larger harvest volumes could increase the probability of encountering postharvest problems. The observed negative correlation may therefore reflect scale-related advantages—such as better management, infrastructure, or access to services—rather than a mechanical scale effect.

The share of output sold is positively correlated with the likelihood of postharvest losses. Market-oriented producers handle larger volumes and often store harvest longer while awaiting favorable prices, which increases exposure to storage pests, moisture damage, and handling-related losses. In addition, greater commercialization may involve stricter quality screening by buyers, leading to higher reported losses. Producers facing barriers in reaching markets or finding buyers experience significantly higher loss intensity, suggesting that delayed sales and prolonged storage may exacerbate postharvest deterioration.

Technology and management practices also play an important role. Use of improved seed varieties is associated with lower intensity of postharvest losses, possibly reflecting greater resilience to biotic and abiotic stressors. Adoption of modern transportation methods is strongly correlated with lower postharvest loss intensity, highlighting the importance of reducing spillage and handling damage during movement from field to storage and market. Similarly, the use of modern storage facilities significantly reduces both the likelihood and intensity of postharvest losses.

Some estimates display unexpected signs. For example, the coefficient on modern winnowing methods is positive in the intensity model. This may reflect selection effects, where producers adopt modern winnowing technologies in response to already higher loss risks. Likewise, while hiring labor is negatively correlated with the likelihood of postharvest losses, it is positively correlated with loss intensity. This may indicate that hired labor reduces the probability of minor losses occurring but is associated with larger-scale operations where, conditional on losses occurring, the magnitude may be higher. These results should therefore be interpreted cautiously.

Table 6.2 Marginal effects of factors correlated with postharvest losses of millet in Nigeria

	Probit: Dependent variable experienced postharvest damages? (=1 if yes)		Tobit: Dependent variable postharvest losses (%)	
	Coefficient	SE	Coefficient	SE
Gender (=1 if male)	0.044	0.114	1.623	2.573
Youth (=1 if producer 35 or less)	-0.073**	0.033	-0.354	0.445
Education level, secondary	-0.005	0.026	-0.161	0.524
Years of experience growing millet	-0.000	0.001	-0.004	0.027
Number of household members	-0.002	0.002	-0.028	0.040
Wealth index	-0.006***	0.001	-0.053*	0.030
Member of agricultural cooperative (=1 if yes)	-0.055	0.058	-0.677	0.574
Log millet area	-0.127***	0.025	-2.476***	0.848
Share of output sold	0.255***	0.052	-0.460	1.244
Log of producer price gap	0.036	0.023	0.970**	0.460
Seed type (=1 if improved)	0.019	0.029	-1.452*	0.838
Applied inorganic fertilizer (=1 if yes)	-0.018	0.051	0.430	0.873
Applied organic fertilizer (=1 if yes)	-0.004	0.087	0.630	1.843
Applied insect or pest/insect control	-0.004	0.032	0.161	0.929
Used third party agricultural services	-0.068	0.054	-1.499	0.959
Used modern transportation	-0.143	0.125	-4.016***	1.015
Applied modern winnowing methods (=1 if yes)	-0.063	0.096	3.747**	1.719
Used modern storage (=1 if yes)	-0.101**	0.048	-1.809**	0.912
Storage fumigated before storing (=1 if yes)	0.021	0.042	-0.667	0.664
Sorted production before selling (=1 if yes)	-0.021	0.064	-0.210	0.995
Conducted quality test on production (=1 if yes)	-0.065	0.049	-1.682	1.248
Used hired labor	-0.107*	0.060	3.691*	2.204
Causes of damage index	0.053***	0.017	0.777	0.494
Share of preharvest millet losses (%)	0.031**	0.014	0.189**	0.079
Barriers reaching markets	-0.026	0.056	2.175*	1.253
Average postharvest rainfall	0.040***	0.009	0.700**	0.294
Average postharvest temperature	0.336***	0.116	6.369*	3.460
State (=1 if Zamfara)	0.147	0.126	3.600	2.473
Treatment areas (=1 if yes)	0.091	0.073	1.183	0.835
Log-likelihood	-162		-1,649	
Number of observations	595			

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).
Note: Estimates with ***, **, and * are significant at 1%, 5%, and 10%, respectively.

We construct a biotic and abiotic stress index using principal components analysis based on 10 variables capturing whether producers experienced stressors related to insects, plant diseases, weeds, and others. These factors represent production shocks that could potentially contribute to both pre- and postharvest losses. The estimate of this index is not statistically significant in the preharvest model (Table 6.1). However, in the postharvest model (Table 6.2), the index is positively and significantly correlated with the likelihood of experiencing postharvest losses, suggesting that exposure to production stress may carry into the postharvest stage.

We also include the share of preharvest losses as an explanatory variable in both postharvest loss equations. This variable is positive and statistically significant in both the likelihood and intensity models, indicating that higher preharvest losses are associated with both a greater probability and higher severity of postharvest losses. This finding underscores the propagation of losses along the value chain. Qualitative damage occurring at preharvest may intensify during storage and handling, and damage that is not immediately visible in the field may manifest later during postharvest stages.

Climatic conditions during the postharvest period also play a significant role. In contrast to the preharvest stage, increases in rainfall and temperature during postharvest months are positively correlated with both the likelihood and intensity of postharvest losses. Higher rainfall and temperature are generally associated with increased absolute humidity, which accelerates fungal growth, pest infestation, and grain deterioration. These findings are consistent with earlier evidence from Bachewe et al. (2020) and Kaminski and Christiaensen (2014).

In summary, the econometric results indicate that demographic, asset, production, and climatic factors significantly shape postharvest loss outcomes. Youth producers are less likely to experience postharvest losses, while greater asset ownership is associated with both lower likelihood and lower intensity of losses. Larger millet areas are negatively correlated with postharvest loss intensity, although greater commercialization and market access constraints increase vulnerability. Preharvest losses significantly raise both the probability and severity of postharvest losses, highlighting loss propagation along the value chain. Adoption of improved seeds, modern transport, and improved storage technologies reduce postharvest losses, whereas higher rainfall and temperatures during the postharvest period exacerbate them.

7. SUMMARY AND POLICY RECOMMENDATIONS

This study provides a comprehensive assessment of pre- and postharvest losses along the millet value chain in Nigeria, using purposively collected micro-level data from producers, aggregators, and processors in Sokoto and Zamfara states. By applying a consistent and multidimensional loss measurement methodology across multiple value chain nodes, the study contributes to the growing—but still limited—evidence base that moves beyond producer-centered analyses to capture losses throughout agrifood systems in SSA.

The results show that food losses in Nigeria's millet value chain are widespread, substantial, and systemic. Nearly all producers experience losses at one or more stages of production, particularly during preharvest and postharvest activities, which account for the bulk of total losses, while relatively little output is left in the field. On average, total losses along the value chain amount to approximately 9 percent of production volume and 6 percent of production value, with producer-level losses representing the largest share. Downstream actors—aggregators and processors—also incur pervasive losses, particularly during storage, handling, and transportation, highlighting inefficiencies that extend well beyond the farm gate.

Losses are not evenly distributed across geographic areas or demographic groups. Producers in Zamfara experience significantly higher losses than those in Sokoto, with preharvest losses playing a dominant role in Zamfara, while postharvest losses are relatively more important in Sokoto. Youth producers incur higher overall losses than mature producers, reflecting differences in experience, asset ownership, and access to technologies. Gender differences emerge in both the composition and timing of losses, underscoring the need for loss-reduction strategies that account for spatial and demographic heterogeneity rather than relying on one-size-fits-all approaches.

The econometric analyses further demonstrate that food losses are closely linked to producer characteristics, management practices, and agroecological conditions. Greater asset endowments and larger farm sizes are associated with lower loss incidence and intensity, while exposure to preharvest shocks amplifies postharvest losses. Importantly, adoption of modern pre- and postharvest technologies—including improved seeds, insect and pest control, mechanization, modern transportation and storage technologies, and training in improved harvesting practices—significantly reduces the likelihood and/or severity of losses. In contrast, biotic and abiotic stressors, as well as higher rainfall and temperatures during the postharvest period, exacerbate losses. These findings underscore that food losses in the millet value chain are not merely technical failures, but the result of interacting constraints related to climate exposure, technology access, infrastructure gaps, and human capital limitations.

Overall, the study highlights that reducing millet losses in Nigeria will require an integrated value chain approach that addresses both preharvest and postharvest stages, accounts for spatial and demographic differences, and aligns technological interventions with broader institutional and market conditions. Based on the descriptive and econometric analyses conducted in this study, the following policy implications emerge.

First, the evidence presented implies the need for strengthening preharvest loss mitigation strategies through climate-resilient and input-responsive interventions. Given the substantial contribution of preharvest losses—particularly in Zamfara—policies should prioritize improved agricultural practices that reduce exposure to weather shocks, pests, and diseases. This includes expanding access to improved seed varieties, timely and appropriate use of fertilizers and crop protection inputs, and enhanced extension services focused on crop management under variable climatic conditions. Climate-smart agriculture practices, such as integrated pest management and improved soil and water management, are especially critical in mitigating losses before harvest and preventing the amplification of losses downstream.

Second, accelerated adoption of modern postharvest equipment and methods among producers is needed. The strong loss-reducing effects of improved transportation, winnowing, and storage methods observed in the econometric analysis underscore the importance of scaling up access to affordable and appropriate modern postharvest technologies, which are currently accessed by a relatively lower proportion of the producers. Public policy and investments should focus on lowering entry barriers observed in Nigeria for smallholders—particularly youth and resource-constrained farmers—through targeted subsidies, credit facilities, equipment leasing models, and collective infrastructure such as shared storage facilities. Extension systems should also place greater emphasis on postharvest management, which remains underrepresented relative to production-focused advisory services.

Third, the results imply that addressing systemic inefficiencies among aggregators and processors through infrastructure and skills development is an important step to reduce downstream losses. The prevalence of losses due to spillage, poor handling, and inadequate equipment among aggregators and processors points to critical gaps in infrastructure quality and technical capacity. Increasing accessibility and investments in improved packaging materials, handling tools, storage facilities, and transport infrastructure can substantially reduce downstream losses. Complementary training programs focused on handling practices, quality control, and basic processing technologies are essential, especially given the predominantly informal and small-scale nature of these actors.

Fourth, the nature of food losses observed in Nigeria points to the need for designing youth- and gender-responsive loss reduction strategies. Youth and women play distinct roles along the millet value chain, with processing emerging as an important entry point for young women and youth, who overall experience higher loss levels at the production stage. Policy interventions should explicitly target these groups by improving access to finance, skills training, and technologies tailored to their positions within the value chain. Supporting youth-led service provision in areas such as mechanized harvesting, transport, storage, and processing can simultaneously reduce losses and create employment opportunities.

Finally, strengthening institutional coordination and data-driven policy implementation in Nigeria will be a step in the right direction. Nigeria's evolving policy landscape—marked by initiatives such as the Presidential Food Systems Coordinating Unit and the Nigeria Postharvest Systems Transformation Programme—provides a strong foundation for integrated loss reduction strategies. To be effective, these initiatives must be informed by micro-level evidence and coordinated across ministries, value chain actors, and states/geographic regions. Continued investment in systematic data collection and monitoring of food losses will be critical for targeting interventions, evaluating impact, and ensuring that loss reduction contributes meaningfully to food security, income growth, and sustainable agrifood system transformation.

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ANNEXES

Annex Table 1. Millet value chain agents in Nigeria, by demographic characteristics

Variable	Measure	Female		Male		Sig. test	Youth		Mature		Sig. test
		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Producers											
Observations	**Number**	**20**		**575**			**202**		**393**		
Gender of head (=1 if male)	%	0.0	0.0	100.0	0.0		95.1	21.8	97.5	15.8	
Age	Years	35.8	7.1	42.3	11.2	**	30.4	4.4	48.1	8.4	***
Education in years	Years	9.1	3.6	9.9	3.9		10.0	3.8	9.7	3.9	
Experience in years	Years										
Main occupation is farming	%	95.0	22.4	94.1	23.6		93.1	25.5	94.7	22.5	
Main occupation is not farming	%	5.0		5.9			6.9		5.3		
Household size	Number	8.4	3.3	9.9	4.9		6.2	3.0	11.7	4.5	***
Household assets	Naira	1397.4	2735.9	2747.3	4451.0		2094.0	3505.2	3014.4	4782.7	*
Aggregators											
Observations	**Number**	**4.0**		**162.0**			**63.0**		**103.0**		
Gender of head (=1 if male)	%	0.0	0.0	100.0	0.0		100.0	0.0	96.1	19.4	
Age	Years	45.0	7.7	40.9	10.2		30.8	3.8	47.2	7.4	***
Experience in years	Years	20.0	8.3	15.5	9.8		10.7	6.3	18.6	10.4	***
Share of formal business	%	0.0	0.0	11.1	31.5		9.5	29.6	11.7	32.2	
Business type											
Has no store	%	50.0	57.7	31.5	46.6		23.8	42.9	36.9	48.5	
Has store	%	50.0	57.7	68.5	46.6		76.2	42.9	63.1	48.5	
Role in Business											
Owner	%	100.0	0.0	83.3	37.4		87.3	33.6	81.6	39.0	
Boss/Manager	%	0.0	0.0	2.5	15.6		0.0	0.0	3.9	19.4	
Employee/Assistant	%	0.0	0.0	4.3	20.4		6.4	24.6	2.9	16.9	
Member of cooperative	%	0.0	0.0	9.9	29.9		6.4	24.6	11.7	32.2	
Processors											
Observations	**Number**	**68.0**		**13.0**			**46.0**		**35.0**		
Gender of head (=1 if male)	%	0.0	0.0	100.0	0.0		15.2	36.3	17.1	38.2	
Age	Years	35.0	12.6	37.2	12.5		26.0	5.4	47.7	7.5	***
Experience in years	Years	12.3	8.0	11.0	6.4		8.0	4.2	17.3	8.2	***
Business type											
Formal	%	5.9	23.7	15.4	37.6		8.7	28.5	5.7	23.6	
Informal	%	94.1	23.7	84.6	37.6		91.3	28.5	94.3	23.6	
Role in Business											
Head	%	95.6	20.7	100.0	0.0		95.7	20.6	97.1	16.9	
Employee	%	1.5	12.1	0.0	0.0		2.2	14.7	0.0	0.0	
Boss	%	2.9	17.0	0.0	0.0		2.2	14.7	2.9	16.9	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 2. Millet preharvest production and input use, by demographic characteristics

Variable	Meas-ure	Female		Male		Sig. test	Youth (15-35 years)		Mature (>35 years)		Sig. test
		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Observations	Number	297		298			392		203		
Outputs											
Total output harvested ('000)	kgs	3338.6	1578.6	2765.3	2297.5		2043.5	1914.0	3165.4	2357.9	***
Yield ('000)	kgs/ha	2026.5	832.8	1314.2	816.1	***	1193.5	787.6	1412.5	836.4	**
Land											
Total area operated	Ha	2.5	1.5	2.8	1.9		2.3	1.7	3.1	1.9	***
Area rented, sharecropped, etc.	Ha	1.0	1.3	0.4	0.9	**	0.4	0.8	0.5	0.9	
Total millet area	Ha	1.7	0.8	2.3	1.4		1.8	1.3	2.4	1.4	***
Used mechanical equipment	%	35.0	48.9	40.7	49.2		37.1	48.4	42.2	49.5	
Tilling type used											
Manual	%	60.0	50.3	61.9	48.6		56.4	49.7	64.6	47.9	
Animal	%	0.0	0.0	4.9	21.5		4.0	19.6	5.1	22.0	
Mechanized	%	5.0	22.4	2.4	15.4		1.5	12.1	3.1	17.2	
More than one method	%	35.0	48.9	30.8	46.2		38.1	48.7	27.2	44.6	**
Variable inputs											
Seed use	kgs/ha	15.3	7.9	12.2	5.5	*	11.7	5.2	12.7	5.8	*
Improved seed used	%	45.0	51.0	42.6	49.5		43.6	49.7	42.2	49.5	
Applied organic fertilizer	%	90.0	30.8	66.3	47.3	*	62.4	48.6	69.5	46.1	
Applied chemical fertilizer	%	95.0	22.4	89.4	30.8		85.2	35.7	91.9	27.4	*
No. of times chemical fertilizer applied	Number	2.3	0.6	2.0	0.5	*	2.0	0.6	2.0	0.5	
Rate of fertilizer application	kgs/ha	420.2	614.8	455.3	894.0		435.6	829.0	463.6	914.3	
Crop protection	%	40.0	50.3	35.3	47.8		35.2	47.9	35.6	48.0	
Chemical insecticide	%	35.0	48.9	19.1	39.4		20.8	40.7	19.1	39.4	
Biological insecticides	%	0.0	0.0	3.1	17.4		2.0	14.0	3.6	18.6	
Herbicides	%	30.0	47.0	23.0	42.1		19.3	39.6	25.2	43.5	
Fungicides	%	0.0	0.0	5.7	23.3		5.0	21.8	5.9	23.5	
Biological pest control	%	15.0	36.6	3.8	19.2	*	3.5	18.3	4.6	20.9	
Integrated pest management	%	0.0	0.0	2.6	16.0		2.5	15.6	2.5	15.8	
Value of modern inputs applied ('000)	Naira/Ha	81.8	40.3	67.9	37.2		69.4	39.0	67.8	36.5	
Harvesting	%	100.0	0.0	100.0	0.0		100.0	0.0	100.0	0.0	
Harvesting Method											
Manual	%	95.0	22.4	93.0	25.5		95.5	20.7	91.9	27.4	
Mechanical	%	0.0	0.0	1.0	10.2	*	0.5	7.0	1.3	11.2	
Both	%	0.0	0.0	5.9	23.6	***	3.5	18.3	6.9	25.3	
Other inputs											
Used hired labor	%	90.0	30.8	93.6	24.6		91.6	27.8	94.4	23.0	
Used irrigation	%	0.0	0.0	2.6	16.0		2.5	15.6	2.5	15.8	
Used formal credit	%	40.0	50.3	43.3	49.6		39.6	49.0	45.0	49.8	
Used informal credit	%	10.0	30.8	2.1	14.3	*	3.0	17.0	2.0	14.1	
Member of agricultural cooperative	%	15.0	36.6	6.4	24.6		4.0	19.6	8.1	27.4	
Used agricultural services	%	30.0	47.0	15.5	36.2		15.4	36.1	16.3	37.0	
Barriers towards											
Accessing input/service markets	%	25.0	44.4	9.7	29.7	*	18.8	39.2	5.9	23.5	***
Reaching markets/buyers	%	25.0	44.4	8.5	27.9	*	18.3	38.8	4.3	20.4	***

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 3. Postharvest activities of millet producers, by gender and age distribution

Variable	Measure	Female		Male		Sig. test	Youth (15-35 years)		Mature (>35 years)		Sig. test
		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Observations	Number	20		575			202		393		
Harvesting	%	100.0	0.0	100.0	0.0		100.0	0.0	100.0	0.0	
Harvesting Method											
Manual	%	95.0	22.4	93.0	25.5		95.5	20.7	91.9	27.4	
Mechanical	%	0.0	0.0	1.0	10.2	*	0.5	7.0	1.3	11.2	
Both	%	0.0	0.0	5.9	23.6	***	3.5	18.3	6.9	25.3	
Received training to enhance skills	%	15.0	36.6	25.6	43.7		30.2	46.0	22.7	41.9	
Transportation	%	100.0	0.0	99.3	8.3	*	99.5	7.0	99.2	8.7	
Manual	%	70.0	47.0	73.7	44.0		72.3	44.9	74.3	43.8	
Mechanical	%	0.0	0.0	2.6	16.0	***	4.0	19.6	1.8	13.2	
Both	%	30.0	47.0	23.0	42.1		23.3	42.4	23.2	42.2	
Threshing	%	100.0	0.0	99.5	7.2		99.5	7.0	99.5	7.1	
Manual	%	100.0	0.0	92.5	26.3	***	95.1	21.8	91.6	27.8	
Mechanical	%	0.0	0.0	0.4	5.9		0.0	0.0	0.5	7.1	
Both	%	0.0	0.0	6.6	24.9	***	4.5	20.7	7.4	26.2	
Drying	%	90.0	30.8	95.5	20.8		94.6	22.8	95.7	20.4	
Manual	%	90.0	30.8	93.2	25.2		93.1	25.5	93.1	25.3	
Both	%	0.0	0.0	2.3	14.9	***	1.5	12.1	2.5	15.8	
Winnowing, sifting and sorting	%	75.0	44.4	85.2	35.5		86.1	34.6	84.2	36.5	
Manual	%	75.0	44.4	78.1	41.4		81.7	38.8	76.1	42.7	
Mechanical	%	0.0	0.0	0.4	5.9		0.0	0.0	0.5	7.1	
Both	%	0.0	0.0	6.8	25.2	***	4.5	20.7	7.6	26.6	
Storage	%	100.0	0.0	98.1	13.7	***	98.5	12.1	98.0	14.1	
Average storage period	Days	102.3	61.8	92.2	53.3		81.2	52.1	98.5	53.5	***
Maximum quantity stored (000)	kgs	3039.0	1642.1	2377.1	2081.5		1781.6	1787.6	2719.2	2135.3	***
Storage location											
Home	%	100.0	0.0	97.0	17.0	***	97.5	15.6	97.0	17.2	
Farm	%	0.0	0.0	0.7	8.3	*	0.5	7.0	0.8	8.7	
Storage method											
Rhombus	%	35.0	48.9	31.1	46.3		26.7	44.4	33.6	47.3	
Barns at home	%	5.0	22.4	21.0	40.8	**	22.8	42.0	19.3	39.6	
On bare floor uncovered	%	35.0	48.9	19.0	39.2		21.3	41.0	18.6	38.9	
All other storage methods	%	25.0	44.4	27.0	44.4		27.7	44.9	26.5	44.2	
Pre-storage activities											
Cleaning storage site	%	100.0	0.0	96.4	18.8	***	97.0	17.0	96.2	19.2	
Cleaning storage sacks/bags	%	50.0	51.3	42.8	49.5		48.5	50.1	40.2	49.1	
Preparing site (ventilation)	%	50.0	51.3	51.0	50.0		57.9	49.5	47.3	50.0	*
Curing	%	10.0	30.8	36.2	48.1	**	39.6	49.0	33.1	47.1	
Fumigation of storage site	%	102.3	61.8	92.2	53.3		81.2	52.1	98.5	53.5	***

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 4. Millet processing and input use, by demographic characteristics

Variable	Measure	Female		Male		Sig. test	Youth (15-35 years)		Mature (>35 years)		Sig. test
		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Type of processing done											
Beverages/Drinks	%	8.8	28.6	23.1	43.9		10.9	31.5	11.4	32.3	
Cooked Whole/Flaked Millet	%	4.4	20.7	7.7	27.7		4.4	20.6	5.7	23.6	
Fermented Batter Products	%	10.3	30.6	15.4	37.6		13.0	34.1	8.6	28.4	
Fermented pastes/Doughs	%	61.8	49.0	23.1	43.9	**	58.7	49.8	51.4	50.7	
Porridges/Gruels	%	14.7	35.7	30.8	48.0		13.0	34.1	22.9	42.6	
Number of products processed											
One	%	91.0	29.0	100	0.0		98.0	15.0	86.0	36.0	*
Two	%	9.0	29.0	0.0	0.0		2.0	15.0	14.0	36.0	*
Millet purchases											
Source and volume of millet purchases											
Producer	%	39.7	49.3	30.8	48.0		39.1	49.3	37.1	49.0	
Quantity purchased from producers	kgs	399.6	225.6	175.0	119.0		362.8	264.8	381.4	170.1	
Value of millet purchased ('000)	Naira	150.5	91.6	79.5	57.0		145.5	95.9	135.5	85.7	
Prices of millet purchased	Naira/kg	395.4	142.9	455.0	44.4		436.9	127.3	356.2	136.8	
Intermediaries	%	73.5	44.5	84.6	37.6		73.9	44.4	77.1	42.6	
Quantity purchased from intermediaries	kgs	467.0	475.2	400.0	466.4		355.9	392.4	579.6	535.1	
Value of millet purchased ('000)	Naira	280.5	356.6	263.6	387.1		184.9	249.1	394.0	439.7	*
Prices of millet purchased	Naira/kg	530.1	202.4	603.6	183.9		520.5	164.2	572.2	237.4	
Seasonal variations in prices											
Purchase price in abundant season	Naira/kg	462.3	197.9	516.9	167.9		467.3	169.1	476.0	224.0	
Purchase price in scarce season	Naira/kg	600.9	212.3	606.9	188.3		580.4	184.1	630.0	234.7	
Sales											
Consumers	%	98.5	12.1	100.0	0.0		100.0	0.0	97.1	16.9	
Stores	%	7.4	26.3	7.7	27.7		6.5	25.0	8.6	28.4	
Processors	%	7.4	26.3	7.7	27.7		13.0	34.1	0.0	0.0	*
Sold to other sellers	%	11.8	32.5	30.8	48.0		13.0	34.1	17.1	38.2	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 5. Frequency of losses among aggregators, by practiced activity (percent)

Category	Measure	Drying	Cleaning/ Packaging	Storage	Distribution	Grinding
Total	(%)	100	99.2	96.5	100	100
	SD	0	0.1	0.2	0	0
State						
Sokoto	(%)	100	100	100	100	100
	SD	0	0	0	0	0
Zamfara	(%)	100	97.7	87.2	100	100
	SD	0	0.2	0.3	0	0
Significance test				***		
Age						
Youth	(%)	100	100	96.4	100	100
	SD	0	0	0.2	0	0
Mature	(%)	100	98.6	96.5	100	100
	SD	0	0	0.2	0	0
Significance test						

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 6. Sources of preharvest losses, by spatial characteristics

	Measure	Total		Treatment		Control		Sig test	Sokoto		Zamfara		Sig test
		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Preharvest													
Encountered preharvest problems	%	89.2	0.3	90.2	0.3	88.3	0.3		91.8	0.3	84.2	0.4	
Preharvest loss causes													
Excess rain/moisture	%	19.0	0.4	20.2	0.4	17.8	0.4		3.3	0.2	26.6	0.4	***
Lack of rain/moisture	%	65.6	0.5	68.4	0.5	62.8	0.5		83.7	0.4	30.5	0.5	***
Pests/diseases	%	48.2	0.5	31.3	0.5	65.1	0.5	***	55.1	0.5	35.0	0.5	***
Weeds	%	26.6	0.4	11.8	0.3	41.3	0.5	***	25.5	0.4	28.6	0.5	
Excess of chemicals/insecticides/fertilizers	%	3.9	0.2	0.3	0.1	7.4	0.3	***	1.3	0.1	8.9	0.3	***
Lack of chemicals/insecticides/fertilizers	%	18.8	0.4	6.7	0.3	30.9	0.5	***	22.2	0.4	12.3	0.3	**
Animals/rodents	%	17.8	0.4	15.5	0.4	20.1	0.4		13.5	0.3	26.1	0.4	***
Theft	%	10.9	0.3	11.1	0.3	10.7	0.3	*	1.8	0.1	8.4	0.3	***
Poor seed quality	%	6.4	0.2	2.0	0.1	10.7	0.3	***	1.5	0.1	15.8	0.4	***
Banditry	%	8.6	0.3	7.4	0.3	9.7	0.3		0	0	25.1	0.4	
Left in the field													
Producers left millet unharvested	%	19.5	0.4	25.3	0.4	13.8	0.4	***	8.9	0.3	39.9	0.5	***
Reason for leaving millet in the field													
Lack of labor for harvesting	%	7.7	0.3	7.1	0.3	8.4	0.3		1.8	0.1	19.2	0.4	***
Lack of money to hire labor	%	8.1	0.3	9.4	0.3	6.7	0.3		1.0	0.1	21.7	0.4	***
High cost of labor	%	5.9	0.2	2.4	0.2	9.4	0.3	***	0.3	0.1	16.8	0.4	***
All others	%	14.0	0.4	16.2	0.4	11.7	0.3		6.6	0.3	28.1	0.5	***
Encountered harvesting problems	%	96.8	0.2	100	0	93.6	0.2	***	98.5	0.1	93.6	0.3	**
Harvesting problems that caused losses													
Birds attack	%	65.7	0.5	67.3	0.5	64.1	0.5		69.1	0.5	59.1	0.5	**
Insects	%	37.8	0.5	27.6	0.5	48.0	0.5	***	31.5	0.5	41.1	0.5	**
Rodents	%	11.8	0.3	11.5	0.3	12.1	0.3		9.2	0.3	16.8	0.4	***
All others	%	83.4	0.4	92.9	0.3	73.8	0.4		80.1	0.4	89.7	0.3	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 7. Sources of preharvest losses, by gender and age

	Measure	Male		Female		Sig test	Young		Mature		Sig test
		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Preharvest problems											
Encountered preharvest problems	%	91.8	0.3	55	0.5	***	90.6	0.3	90.6	0.3	
Preharvest problems that caused losses											
Excess rain/moisture	%	19.5	0.4	5	0.2		19.3	0.4	18.8	0.4	
Lack of rain/moisture	%	66.6	0.5	35	0.5	***	64.4	0.5	66.2	0.5	
Pests/diseases	%	49.9	0.5	0	0	***	52	0.5	46.3	0.5	
Weeds	%	26.8	0.4	20	0.4		33.7	0.3	22.9	0.2	***
Excess of chemicals/insecticides/fertilizers	%	4	0.2	0	0		5.0	0.2	3.3	0.2	
Lack of chemicals/insecticides/fertilizers	%	19.5	0.4	0	0	**	22.8	0.4	16.8	0.4	*
Animals/rodents	%	17.9	0.4	15	0.4		23.3	0.4	15	0.4	*
Theft	%	11	0.3	10	0.3		14.4	0.4	9.2	0.3	*
Poor seed quality	%	6.4	0.3	5	0.2		7.4	0.3	5.9	0.2	
Banditry	%	8.9	0.3	0	0		9.9	0.3	7.9	0.3	
Left in the field											
Producers left millet unharvested	%	20.4	0.4	15	0.4		19.3	0.4	20.6	0.4	
Reason for leaving millet in the field											
Lack of labor for harvesting	%	8	0.3	0	0		8.4	0.3	7.4	0.3	
Lack of money to hire labor	%	8.2	0.3	5	0.2		9.4	0.3	7.4	0.3	
High cost of labor	%	5.9	0.2	5	0.2		5.9	0.2	5.9	0.2	
All others	%	14.1	0.4	10	0.3		13.4	0.3	14.3	0.4	
Encountered harvesting problems	%	96.9	0.2	94.7	0.2		97	0.2	96.7	0.2	
Harvesting problems that caused losses											
Birds attack	%	65.9	0.5	60	0.5		67.3	0.5	64.9	0.5	
Insects	%	38.4	0.5	20	0.4	*	40.1	0.5	36.6	0.5	
Rodents	%	12	0.3	5	0.2		13.9	0.4	10.7	0.3	
All others	%	83.5	0.4	80	0.4		82.7	0.4	83.7	0.4	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 8. Sources of postharvest losses, by spatial characteristics

	Measure	Total		Treatment		Control		Sig test	Sokoto		Zamfara		Sig test
		Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Encountered transportation problems	%	90.2	0.3	92.6	0.3	87.8	0.3	*	88.5	0.3	93.5	0.3	*
Transportation problems													
Product blown away	%	56.8	0.5	66.7	0.5	47.0	0.5	***	53.8	0.5	62.6	0.5	**
Not tied properly	%	37.5	0.5	32.7	0.5	42.3	0.5	**	30.9	0.5	50.3	0.5	***
Sack ruptured	%	8.2	0.3	4.0	0.2	12.4	0.3	***	6.1	0.2	12.3	0.3	**
All others	%	75.5	0.4	66.3	0.5	84.6	0.4	***	69.1	0.5	87.7	0.3	***
Encountered threshing problems	%	99.3	0.1	100	0	98.7	0.1	**	99.2	0.1	99.5	0.1	
Threshing problems													
Inappropriate handling by laborers	%	78.7	0.4	88.2	0.3	69.1	0.5	***	76.8	0.4	82.3	0.4	
Threshing-floor is soft and unclean	%	28.9	0.5	19.2	0.4	38.6	0.5	***	18.4	0.4	49.3	0.5	***
Bad quality tools/ machine	%	40.7	0.5	24.9	0.4	56.4	0.5	***	33.4	0.5	54.7	0.5	***
All others	%	40.7	0.5	35.4	0.5	46.0	0.5	***	48.0	0.5	26.6	0.4	***
Encountered drying problems	%	84.1	0.4	85.4	0.4	82.9	0.4		82.0	0.4	88.1	0.3	*
Causes of losses during drying													
Theft	%	4.4	0.2	1.4	0.1	0.1	0.3	***	0.8	0.1	11.3	0.3	***
Bad weather condition	%	25.0	0.4	33.7	0.5	16.4	0.4	***	17.4	0.4	39.9	0.5	***
Bird	%	48.6	0.5	53.2	0.5	44.0	0.5	**	50.5	0.5	44.8	0.5	
All others	%	67.4	0.5	75.1	0.4	59.7	0.5	***	60.7	0.5	80.3	0.4	***
Faced winnowing, sifting, and sorting problems	%	99.2	0.1	100	0	98.6	0.1	*	98.7	0.1	100	0	
Winnowing, sifting, and sorting problems that caused losses													
Spillage	%	68.4	0.5	54.9	0.5	81.9	0.4	***	67.9	0.5	69.5	0.5	
Grains blown away	%	76.3	0.4	68.0	0.5	84.6	0.4	***	73.0	0.4	82.8	0.4	***
Inappropriate handling	%	43.4	0.5	46.5	0.5	40.3	0.5		31.6	0.5	66.0	0.5	***
Inappropriate quality tools	%	28.9	0.5	14.1	0.4	43.6	0.5	***	27.6	0.5	31.5	0.5	
Experienced storage problems	%	89.9	0.3	95.6	0.2	84.1	0.4	***	92.8	0.3	84.0	0.4	***
Causes of losses during storage													
Improperly tied/sewn/cleaned sacks	%	31.3	0.5	39.4	0.5	23.2	0.4	***	11.7	0.3	69.0	0.5	***
Changes in moisture & temperature	%	41.0	0.5	47.8	0.5	34.2	0.5	***	44.9	0.5	33.5	0.5	***
Insects/mites	%	45.0	0.5	52.2	0.5	37.9	0.5	***	51.5	0.5	32.5	0.5	***
Rodents/animals	%	48.9	0.5	63.0	0.5	34.9	0.5	***	51.0	0.5	44.8	0.5	
Birds	%	11.9	0.3	7.7	0.3	16.1	0.4	***	12.2	0.3	11.3	0.3	
Fungi/bacteria	%	15.1	0.4	18.9	0.4	11.4	0.3	**	20.2	0.4	5.4	0.2	***
All others	%	28.1	0.5	32.0	0.5	24.2	0.4	**	30.4	0.5	23.7	0.4	*
Faced problems during selling	%	74.6	0.4	72.9	0.5	76.2	0.4		70.05	0.5	83.3	0.4	***
Causes of losses during selling													
Theft	%	3.7	0.2	4.4	0.2	3.0	0.2		0.77	0.1	9.4	0.3	***
Accident	%	31.3	0.7	28.6	0.5	33.9	0.5		28.32	0.5	37.0	0.5	**
Bad weather	%	25.4	0.4	35.7	0.5	15.1	0.4	***	21.68	0.4	32.5	0.5	***
Others	%	32.9	0.5	21.6	0.4	44.3	0.5	***	28.06	0.5	42.4	0.5	***

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 9. Sources of postharvest losses, by gender and age

	Meas-ure	Male		Female		Sig test	Young		Mature		Sig test
		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Encountered transportation problems	%	90	0.3	95	0.22		88.6	0.32	91	0.29	
Transportation problems that caused losses											
Product blown away	%	56.5	0.5	65	0.49		56.4	0.5	57	0.5	
Not tied properly	%	37	0.5	50	0.51		36.4	0.49	39.6	0.48	
Sack ruptured	%	7.48	0.3	30	0.47	***	4.95	0.22	9.92	0.3	**
All others	%	75.1	0.4	85	0.37		75.3	0.43	75.6	0.43	
Encountered threshing problems	%	99.3	0.1	100	0		99.5	0.1	99.2	0.1	
Threshing problems that caused losses											
Inappropriate handling by laborers	%	78.3	0.4	90	0.3		70.3	0.5	83	0.4	***
Threshing-floor is soft and unclean	%	28.9	0.5	30	0.5		34.2	0.5	26.2	0.4	**
Bad quality tools/machine	%	40.5	0.5	45	0.5		41.6	0.5	40.2	0.5	
All others	%	40	0.5	60	0.5		38.6	0.5	41.7	0.5	
Encountered drying problems	%	83.6	0.4	100	0	*	82.2	0.4	85.1	0.4	
Causes of losses during drying											
Theft	%	4.5	0.2	0	0		2.0	0.1	5.6	0.2	**
Bad weather condition	%	24.9	0.4	30	0.5		17.3	0.4	29	0.5	***
Bird	%	48.4	0.5	55	0.5		52	0.5	46.8	0.5	
All others	%	66.8	0.5	85	0.4		65.4	0.5	68.5	0.5	
Faced winnowing, and sorting problems	%	99.2	0.1	100	0		99.4	0.1	99.1	0.1	
Winnowing, sifting, and sorting problems											
Spillage	%	68.2	0.5	75	0.4		69.8	0.46	67.7	0.47	
Grains blown away	%	76.4	0.4	75	0.4		74.8	0.44	77.1	0.42	
Inappropriate handling	%	43.1	0.5	50	0.5		36.1	0.48	47.1	0.5	**
Inappropriate quality tools	%	26.7	0.5	30	0.5		28.9	0.44	30	0.5	
Experienced storage problems	%	99.2	0.1	100	0		99.4	0.1	99.1	0.1	
Causes of losses during storage											
Sacks are not properly tied/sewn/cleaned	%	31	0.5	40	0.5		35.2	0.5	29.3	0.5	
Changes in moisture and temperature	%	40.5	0.5	55	0.5		34.7	0.5	44.3	0.5	**
Insects/mites	%	44.9	0.5	50	0.5		38.6	0.5	48.4	0.5	**
Rodents/animals	%	49.6	0.5	30	0.5	*	50.5	0.5	48.1	0.5	
Birds	%	11.8	0.3	15	0.4		14.9	0.4	10.4	0.3	
Fungi/bacteria	%	15.1	0.4	15	0.4		13.4	0.3	16	0.4	
All others	%	28.7	0.5	10	0.3		25.7	0.4	29.3	0.5	
Faced problems during selling	%	75	0.4	63.2	0.5		78.9	0.4	72.3	0.6	*
Causes of losses during selling											
Theft	%	3.7	0.2	5	0.2		5.9	0.2	2.54	0.2	**
Accident	%	31.7	0.5	20	0.4		33.7	0.5	30	0.5	
Bad weather	%	24.7	0.4	45	0.5	**	18.8	0.4	28.8	0.5	***
Others	%	33.2	0.5	25	0.4		37.1	0.9	30.8	0.5	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 10. Causes of aggregator losses, across spatial and demographic characteristics

	Total		Male		Female		Sig test	Young		Mature		Sig test	Sokoto		Zamfara		Sig test
	%	SD	%	SD	%	SD		%	SD	%	SD		%	SD	%	SD	
Drying																	
Encountering drying problems	100.0	0.0	100.0	0.0	0.0	0.0		100.0	0.0	100	0.0		100.0	0.0	100.0	0.0	
Drying problems																	
Spillage	96.0	0.2	96.0	0.2	0.0	0.0		89.5	0.3	100	0.0	*	100.0	0.0	94.1	0.2	
Weight loss due to drying	76.0	0.4	76.0	0.4	0.0	0.0		68.4	0.5	80.7	0.4		87.5	0.3	70.6	0.5	
Cleaning and Packaging																	
Encountered cleaning/packaging pb.	99.2	0.1	99.2	0.1	100.0	0.0		100.0	0.0	98.7	0.1		100.0	0.0	97.7	0.2	
Cleaning and packaging problems																	
Spillage	93.1	0.3	92.9	0.3	100.0	0.0		91.1	0.3	94.6	0.2		1.0	0.2	0.8	0.4	***
Loss due to blowing/cleaning	79.2	0.4	80.3	0.4	33.3	0.6	**	75.0	0.4	82.4	0.4		77.0	0.4	83.7	0.4	
Storage																	
Losses during storage	96.5	0.2	96.4	0.2	100.0	0.0		96.4	0.2	96.5	0.2		100.0	0.0	87.2	0.3	***
Spillage	79.6	0.4	79.9	0.4	66.7	0.6		75.0	0.4	82.6	0.4		88.4	0.3	56.4	0.5	***
Infestation	32.4	0.5	33.1	0.5	0.0	0.0		25.0	0.4	37.2	0.5		24.3	0.4	53.9	0.5	***
Rodents	59.9	0.5	59.7	0.5	66.7	0.6		60.7	49.3	59.3	49.4		65.1	0.5	46.2	0.5	**
Moisture	30.3	0.5	30.2	0.5	33.3	0.6		14.3	0.4	40.7	0.5	***	28.2	0.5	35.9	0.5	
High temperature	25.4	0.4	25.9	0.4	0.0	0.0		30.2	0.5	17.9	0.4	*	24.3	0.4	28.2	0.5	
Theft	2.8	0.2	2.9	0.2	0.0	0.0		1.8	0.1	3.49	0.2		0.0	0.0	10.3	0.3	***
Distribution and transportation																	
Losses during distribution	100.0	0.0	100.0	0.0	100.0	0.0		100.0	0.0	100	0.0		100.0	0.0	100.0	0.0	
Reasons for losses at distribution																	
Spillage	65.3	0.5	64.5	0.5	100.0	0.0		46.0	0.5	77.6	0.4	***	66.7	0.5	64.2	0.5	
Theft	9.5	0.3	9.7	0.3	0.0	0.0		8.1	0.3	10.3	0.3	***	0.0	0.0	17.0	0.4	***
Accident	59.0	0.5	58.1	0.5	100.0	0.0		75.7	0.4	48.3	0.5	***	69.1	0.5	50.9	0.5	*
Grinding																	
Experienced losses during grinding	100.0	0.0	100.0	0.0	0.0	0.0		100.0	0.0	100	0.0		100.0	0.0	100.0	0.0	
Grinding problems that caused losses																	
Spillage	100.0	0.0	100.0	0.0	0.0	0.0		100.0	0.0	100	0.0		100.0	0.0	100.0	0.0	
Theft	25.0	0.5	25.0	0.5	0.0	0.0		0.0	0.0	0.29	0.5		0.0	0.0	0.3	0.5	
Grinding problems	87.5	0.4	87.5	0.4	0.0	0.0		100.0	0.0	0.86	0.4		100.0	0.0	0.9	0.4	
Selling																	
Encountered selling problems	100.0	0.0	100.0	0.0	0.0	0.0		100.0	0.0	100	0.0		100.0	0.0	0.0	0.0	
Reasons that caused losses at sale																	
Spillage	1.0	0.2	1.0	0.2	0.0	0.0		0.9	0.3	100	0.0		1.0	0.2	0.0	0.0	

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

Annex Table 11. Causes of processor losses, across spatial and demographic characteristics

	All		Sokoto		Zamfara		Male		Female		Youth		Mature	
	%	SD	%	SD	%	SD	%	SD	%	SD	%	SD	%	SD
Causes of losses for step 1 processing														
Spillage	80.9	0.4	94.2	0.2	37.5	0.5	90.9	0.3	79.0	0.4	82.9	0.4	77.8	0.4
Accident	4.4	0.2	5.8	0.2	0.0	0.0	9.1	0.3	3.5	0.2	4.9	0.2	3.7	0.2
Poor grain quality	1.5	0.1	0.0	0.0	6.3	0.3	0.0	0.0	1.8	0.1	0.0	0.0	3.7	0.2
Others	13.2	0.3	0.0	0.0	56.3	0.5	0.0	0.0	15.8	0.4	12.2	0.3	14.8	0.4
Causes of losses for step 2 processing														
Spillage	37.1	0.5	41.7	0.5	21.4	0.4	11.1	0.3	41.5	0.5	32.4	0.5	44.0	0.5
Accident	24.2	0.4	31.3	0.5	0.0	0.0	66.7	0.5	17.0	0.4	32.4	0.5	12.0	0.3
Poor quality tools and handling	12.9	0.3	14.6	0.4	7.1	0.3	11.1	0.3	13.2	0.3	10.8	0.3	16.0	0.4
Other	25.8	0.4	12.5	0.3	71.4	0.5	11.1	0.3	28.3	0.5	24.3	0.4	28.0	0.5
Causes of losses for step 3 processing														
Spillage	47.6	0.5	52.3	0.5	36.8	0.5	20.0	0.4	52.8	0.5	44.7	0.5	52.0	0.5
Accident	23.8	0.4	31.8	0.5	5.3	0.2	70.0	0.5	15.1	0.4	31.6	0.5	12.0	0.3
Poor quality tools and handling	6.4	0.2	9.1	0.3	0.0	0.0	10.0	0.3	5.7	0.2	5.3	0.2	8.0	0.3
Other	22.2	0.4	6.8	0.3	57.9	0.5	0.0	0.0	26.4	0.4	18.4	0.4	28.0	0.5
Causes of losses for step 4 processing														
Spillage	26.8	0.4	27.9	0.5	23.1	0.4	11.1	0.3	29.8	0.5	32.4	0.5	18.2	0.4
Accidents	35.7	0.5	44.2	0.5	7.7	0.3	77.8	0.4	27.7	0.5	47.1	0.5	18.2	0.4
Poor quality tools and handling	17.9	0.4	18.6	0.4	15.4	0.4	0.0	0.0	21.3	0.4	11.8	0.3	27.3	0.5
Other	19.6	0.4	9.3	0.3	53.9	0.5	11.1	0.3	21.3	0.4	8.8	0.3	36.4	0.5
Causes of losses for step 5 processing														
Spillage	31.1	0.5	35.3	0.5	27.3	0.5	0.0	0.0	36.8	0.5	31.0	0.5	31.3	0.5
Accident	37.8	0.5	47.1	0.5	9.1	0.3	85.7	0.4	29.0	0.5	44.8	0.5	25.0	0.4
Poor quality tools and inappropriate handling	20.0	0.4	20.6	0.4	18.2	0.4	14.3	0.4	21.1	0.4	20.7	0.4	18.8	0.4
Other	11.1	0.3	0.0	0.0	45.5	0.5	0.0	0.0	13.2	0.3	3.5	0.2	25.0	0.4
Causes of losses for step 6 processing														
Spillage	34.8	0.5	33.3	0.5	40.0	0.5	0.0	0.0	44.4	0.5	31.6	0.5	50.0	0.6
Accident	34.8	0.5	44.4	0.5	0.0	0.0	80.0	0.4	22.2	0.4	42.1	0.5	0.0	0.0
Poor quality tools and handling	17.4	0.4	16.7	0.4	20.0	0.4	20.0	0.4	16.7	0.4	21.1	0.4	0.0	0.0
Other	13.0	0.3	5.6	0.2	40.0	0.5	0.0	0.0	16.7	0.4	5.3	0.2	50.0	0.6

Source: Authors' analyses using data from the baseline survey of food losses in millet value chain of Nigeria (2024).

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