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Exploring Smallholder Farmers' Awareness and Perceptions of Post-Harvest Tomato Losses, Kirinyaga County, Kenya: A Thematic Analysis

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Abstract

Tomato (*Solanum lycopersicum*) is a widely grown and consumed vegetable in Kenya, but its highly perishable nature makes it prone to post-harvest losses, which reduce marketable produce, lower farmers' income, and contribute to food insecurity and poor dietary quality. This study explored the levels of awareness and perceptions of smallholder tomato farmers regarding the causes and effects of post-harvest losses. Purposive sampling was used to select Kirinyaga East and Mwea West sub-counties, and a number of tomato farmers were interviewed. Two focus-group discussions and four key informant interviews were conducted in the study area. A total sample of 30 participants was involved in the qualitative study, comprising 26 participants in FDGs and four key informants. In each ward, participants for the FGDs were randomly selected from lists of eligible smallholder tomato farmers to minimize selection bias, while key informants were purposively selected based on their knowledge, experience, and involvement in tomato production, post-harvest handling, and agricultural extension services. Qualitative data were collected and analyzed through thematic analysis using NVivo software. The analysis identified two main themes and five subthemes that captured the key findings from participants' experiences and perceptions. The findings revealed that farmers were generally aware of post-harvest losses, identifying sorting and grading as critical stages at the farm level. Key causes identified included pest and disease infestations, poor packaging, oversupply, and price fluctuations. Participants described perceived effects such as reduced marketable produce and farm incomes, which influenced their decision-making on reinvesting into subsequent tomato production. They also reported solutions to curb post-harvest losses, which included the provision of training on post-harvest management, investment in good storage facilities, standardized packaging, and provision

of input subsidies. Therefore, minimizing these losses through improved post-harvest management, appropriate storage technologies, and encouraging farmer groups can boost farmer incomes, strengthen value chain efficiency, and enhance the sustainability of tomato production in Kirinyaga County, Kenya.

Keywords

Qualitative Study, Post-Harvest Losses, Smallholder Farmers, Tomatoes, Kenya

1. Background

Tomato (*Nyanya*) is a popular and extensively cultivated vegetable, valued for both its economic and nutritional importance compared to other vegetables. In Kenya, it is widely consumed fresh in local dishes and processed into various products such as paste, juice, soups, stews, and ketchup [1]. Tomatoes are rich in phytochemicals, such as lycopene, β-carotene, and phenolic compounds, as well as nutrients, including proteins, sugars, dietary fiber, and vitamins A, B, and C. Moreover, they provide iron and phosphorus, which promote health and aid in the prevention of chronic diseases like prostate and heart diseases, as well as lung and stomach cancers [2] [3]. In Kenya, tomatoes are among the most significant exotic vegetables, contributing approximately KES 23,485.39 million (about 29.5%) of the value of exotic vegetables, with 14% of the total vegetables grown and 7% of horticultural crops produced in the country [4]. According to AFA [4], Kirinyaga was the leading tomato producer in Kenya, with about 0.12 million tonnes in 2021, accounting for 13.4% of the total value. It was followed by Taita Taveta, which produced approximately 0.10 million tonnes (12.6%), Narok with around 0.04 million tonnes (8%), Lamu with about 0.03 million tonnes (6.7%), and Siaya, with roughly 0.26 million tonnes (5.2%).

Tomatoes are crucial for ensuring food and nutrition security within sustainable food systems, which aim to improve the living standards of Kenyans and achieve middle-income status by 2030 [5]. In Kenya, most tomatoes are intended for the local market, with a small portion exported to neighboring East African countries [6]. This sub-sector supports livelihoods and contributes to the country's economic growth by providing smallholder farmers with a steady source of income and employment [7]. In this study, a smallholder tomato farmer was defined as an individual cultivating tomatoes on less than one acre of land, either owned or rented.

Nevertheless, 74% of farmers report low profits from tomato sales, and the majority make less than KES 100,000 per season [8]. The tomato cultivation area increased from 28,263 hectares in 2018 to 31,072 hectares in 2023, reflecting a 9.9% increase. Despite this, total tomato production decreased from nearly 0.54 million tonnes to 0.52 million tonnes in the same period, reflecting a 3.7% decline [9]. This indicates persistent production constraints in Kenya, such as pest infestation,

limited access to quality high-yield planting materials, and poor post-harvest handling practices, which contribute to significant post-harvest losses [4] [6].

The Food and Agriculture Organization (FAO) defines post-harvest losses (PHL) as the measurable reduction in the quantity or nutritional value of food intended for human consumption [10]. These losses stem from various factors such as inadequate pre-harvest techniques, improper handling, transportation issues, lack of information, poor infrastructure, and limited technology, skills, and management capacity among supply chain actors [2]. Globally, tomato losses are estimated at 4.8% of total production, equivalent to approximately 0.013 million tonnes annually, primarily due to immaturity, mechanical damage, and decay [11]. Africa also faces significant challenges in post-harvest management, with fresh market tomato losses estimated at approximately 10% in Sub-Saharan Africa, including Kenya, which translates to a value of around USD 20 million [6]. Moreover, developing countries face even higher losses, with rates varying from 20% to 50%, primarily occurring between harvesting, transportation, and consumption [2] [5] [12].

In Kenya, post-harvest losses in fruits and vegetables, including tomatoes, are estimated to range between 30% and 40%, significantly contributing to food insecurity and income losses for smallholder farmers [5]. A study by Gatere *et al.* [13] reported that the overall post-harvest tomato losses in Laikipia County were approximately 28.2%, with the majority occurring at the farm level during harvest. Kathimba *et al.* [14] also found that tomatoes recorded a 73.34% loss when stored at 25˚C, with more than 50.3% of produce firmness lost after three weeks of storage and more than 50% of produce weight lost after one week of storage. These losses exacerbate food insecurity, causing a decline in incomes of approximately 15% for nearly 470 million smallholder farmers across the region. Furthermore, they reduce the availability of food that can be produced locally, making Kenya more dependent on yearly food imports, which total more than 1.3 billion dollars, to meet local demands [5] [15]. However, the significant costs faced by tomato farmers hinder their ability to adopt new methods [16].

The government of Kenya, through its post-harvest management strategy for food loss and waste reduction for 2024-2028, aims to reduce post-harvest losses across various food commodities, including tomato losses at the farm level. For example, in the Central region, tomato losses have been mitigated through the provision of certified seeds, training on value addition, and appropriate storage methods, such as cold storage facilities and preservation techniques such as drying and product development (e.g., jam and sauce). Meanwhile, in the Eastern and Northern regions, the government has encouraged research on resistant varieties, as post-harvest tomato losses are mainly caused by pests and diseases [5]. Smallholder farmers also tend to sell their produce immediately after harvest (possibly at lower prices) to avoid losses, apply pesticides to avoid infestation during storage, and/or plant traditional varieties that are lower-yielding but less susceptible to PHL [17] [18].

Existing studies have primarily focused on the factors influencing post-harvest losses in fruits and vegetables, including tomatoes, using quantitative approaches,

while qualitative perspectives remain underexplored. This knowledge gap constrains the development of effective mitigation strategies and undermines the competitiveness of Kenya's tomato value chain. Therefore, this study explored the levels of awareness and perceptions of smallholder tomato farmers regarding the causes and effects of post-harvest losses at the farm level. The study defined farmers' awareness as their knowledge and understanding of tomato post-harvest quality management practices and technologies. It also identified viable interventions to reduce these losses, thus enhancing food security, improving farmer incomes, and supporting a more sustainable and efficient tomato value chain. Ultimately, this contributes to Kenya's agricultural and economic transformation.

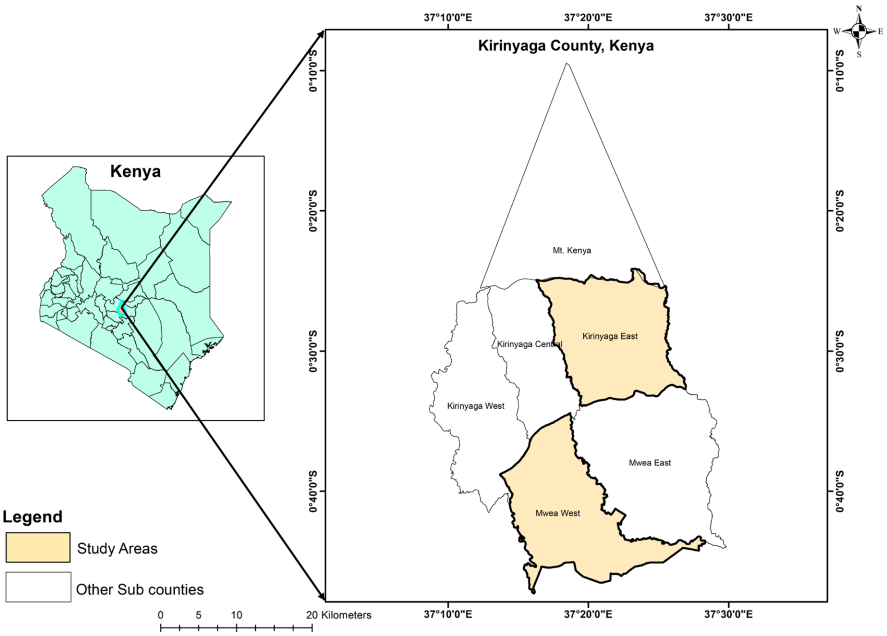
2. Materials and Methods

2.1. Study Area

The study was conducted in Kirinyaga County, Kenya, located south of Mount Kenya (as shown in **Figure 1**) and covering a total area of 1478.1 square kilometers [19]. The county's elevation ranges between 1158 meters and 5380 meters above sea level, with its highest point being the summit of Mount Kenya, greatly shaping the region's landscape [19]. Kirinyaga experiences a tropical climate, with an equatorial rainfall pattern. Temperatures range from an average of 8.1˚C in the upper zones to 30.3˚C in the lower zones during the hot season [20]. Annual rainfall varies between an average of 1212 mm and 2146 mm per month, with two distinct rainy seasons, the long rains occurring from March to May and the short rains occurring from October to November [20]. Agriculture is the primary economic activity, covering about 88,682 hectares, of which over 60% (52,890 hectares) are under subsistence production and 1791 hectares under tomato production [19] [20]. More than 80% of the population depends on agriculture for their livelihoods, with around 50,000 households earning an average income of KES 1000 per day from various value chains, including tomatoes [20].

2.2. Research Design and Sampling Technique

The study used a qualitative descriptive research design to explore the level of awareness and perceptions of tomato farmers regarding post-harvest losses in Kirinyaga County. Qualitative research is an inquiry process focused on understanding and involves the researcher creating a detailed, holistic picture, analyzing spoken words, documenting the informants' perspectives, and conducting the study in a natural setting [21]. This approach enables researchers to gain a complete understanding rather than just relying on quantitative analysis. A multistage sampling procedure was used and Kirinyaga County was purposively selected because it was the top producer of tomatoes in 2021 and has a significant land area allocated to tomato cultivation. Kirinyaga East and Mwea West sub-counties were also purposively selected based on their significant tomato production and the number of tomato farmers' households. One ward was then randomly selected from each sub-county.



Source: Map created by the Author (2026).

Figure 1. Map of Kirinyaga County.

2.3. Data Collection

The study employed both focus group discussions and key informant interviews to collect qualitative data, while exploring how post-harvest losses affect the income, food security, and production decisions of individual tomato smallholder farmers in Kirinyaga County. A focus group discussion checklist was used to collect comprehensive information regarding participants' attitudes, perceptions, knowledge, experiences, and practices related to tomato post-harvest losses. These focus group discussions were conducted in Mutige and Kathiga locations. Key informant interviews were also utilized to provide in-depth qualitative discussions with individuals who possess firsthand knowledge of the community, offering insights into the nature of issues and suggesting potential solutions. The interviews were conducted with agricultural officers and extension workers from the agricultural production department of the Kirinyaga County office. Both FGDs and key informant interviews were face-to-face discussions with the researcher.

Farmers were included in the study if they were actively growing tomatoes during the study period and had at least one season of tomato production experience. A total sample of 30 participants was involved in the qualitative study, comprising 26 participants in Focus Group Discussions (FGDs) and four key informants as shown in Table 1. In each ward, participants for the FGDs were randomly selected from lists of eligible smallholder tomato farmers to minimize selection bias. In contrast, key informants were agricultural extension workers from Kirinyaga County, purposively selected based on their knowledge, experience, and involvement in tomato production, post-harvest handling, and agricultural extension ser-

vices. This sample size was considered sufficient because data collection continued until thematic saturation was reached, whereby no new information was generated from additional interviews and discussions.

Table 1. Distribution of the qualitative study sample by sub-county.

Sub-county	FGD participants	Key Informants	Total sample
Kirinyaga East	12	2	14
Mwea West	14	2	16
Total	**26**	**4**	**30**

The qualitative data were collected on factors influencing post-harvest losses, including time of planting, variety, price in the last season, access to storage facilities, transportation, handling practices, market access, and knowledge on post-harvest management, among others. The study also explored the corresponding effects, farmers' coping mechanisms, and their perceived strategies to reduce tomato post-harvest losses. Information was gathered from two focus group discussions and four key informant interviews in Kirinyaga East and Mwea West sub-counties.

2.4. Data Analysis

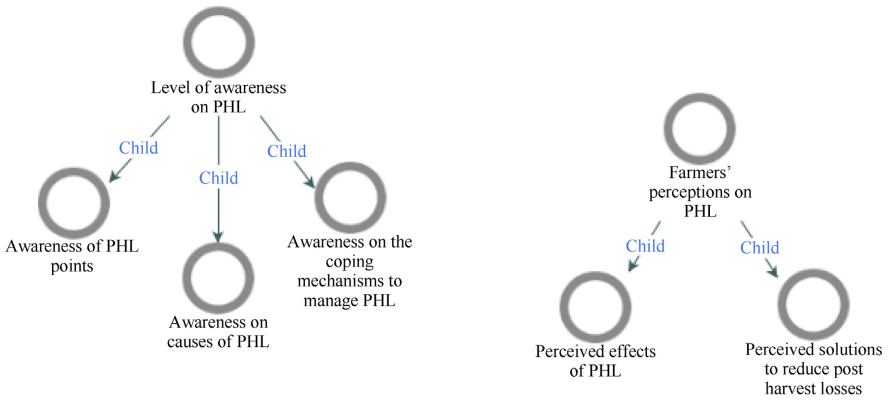
Thematic content analysis was employed based on the data collected from individual interviews with sub-county agricultural officers and focus group discussions with smallholder tomato farmers. The participants' responses provided insights into the causes, effects, and financial consequences of post-harvest losses among tomato farmers in Kirinyaga County, as well as strategies to reduce these losses. This qualitative approach systematically organized and analyzed textual data to identify recurring patterns of meaning, which were subsequently grouped into themes [21]. Specifically, a reflexive thematic analysis approach was adopted because it recognizes that themes are developed through the researcher's interpretive engagement with the data [22]. It also allowed comparison and integration of data from FGDs and KIIs [22]. Additionally, the analysis relied on NVivo software, which supported transcription, coding, and identification of recurring themes and patterns related to tomato post-harvest losses.

The analysis followed Braun and Clarke's six-step framework, which involved familiarization with the data, generating initial codes, searching for initial themes, reviewing potential themes, defining and naming themes, and writing the final report [22]. Audio recordings were transcribed verbatim and checked for accuracy. The researcher then read the transcripts repeatedly to become fully familiar with the data and to identify emerging patterns relevant to the study objectives. Initial codes were generated inductively through line-by-line reading of the transcripts using NVivo software. According to Byrne [23], a code is a label or an interpretive statement assigned to information that is significant to the research

question or objective. These codes were then grouped into categories reflecting similar patterns of meaning. The categories were further developed into initial themes, which were reviewed, refined, and combined where necessary to ensure coherence and clarity [22]. Themes are defined as "capturing something important about the data in relation to the research question, and represent some level of patterned response or meaning within the data set" [24]. During analysis, attention was given to both converging and diverging views across FGDs and KIIs to ensure a comprehensive interpretation of data. In the final step, themes were clearly defined, named, and used to present a coherent narrative of the major findings derived from the analysis [25]. Furthermore, triangulation was applied by integrating insights from existing literature on tomato post-harvest losses to contextualize the findings within broader trends and patterns observed in similar studies [2] [26]-[29]. All interview and FGD transcripts were anonymized. Respondents' identities were safeguarded through the use of pseudonyms to ensure confidentiality.

3. Results and Discussion

The qualitative findings, based on reflexive thematic analysis, were obtained from two focus group discussions and four key informant interviews conducted in the study area. The thematic analysis followed the six-step framework proposed by [24], which provided a clear and systematic process for identifying meaningful patterns within the data. Through careful reading and repeated review of the interview transcripts, codes were identified and grouped into two broader themes that reflected the farmers' level of awareness and perceptions of tomato post-harvest losses. Five sub-themes (as seen in **Figure 2**) were also derived from each main theme to prevent overloading of information regarding codes and quotations. Each sub-theme illustrated at least two examples of coded text segments, which were supported by responses from participants' interviews.



Note: Circles represent the main themes and subthemes identified during thematic analysis, while connecting arrows indicate the relationships between the themes and their corresponding subthemes. Source: Own elaboration based on data.

Figure 2. Thematic map of the awareness and perceptions of farmers regarding PHLs.

Findings from FGDs and KIIs were analyzed together and indicated strong overall agreement on the key causes, effects, and financial implications of tomato post-harvest losses. Both groups identified similar challenges related to handling, storage, and market constraints. However, FGDs mainly focused on practical, household-level challenges experienced by farmers, while KIIs emphasized broader institutional and technical constraints such as extension support and access to post-harvest technologies. These complementary views provided a more comprehensive understanding of the issue.

3.1. Theme 1: Level of Awareness of Tomato Post-Harvest Losses

One prominent theme that emerged was the farmers' level of awareness regarding post-harvest losses at the farm level, as illustrated in **Figure 2**. This theme was structured around where participants believed losses occurred and their knowledge of the causes of these losses. The theme also included what farmers viewed as coping strategies to reduce tomato post-harvest losses at the farm level. The findings indicated that farmers demonstrated practical, experience-based awareness of how and why losses occur at their farms. The data for this theme were organized into three sub-themes, which were explored in more detail.

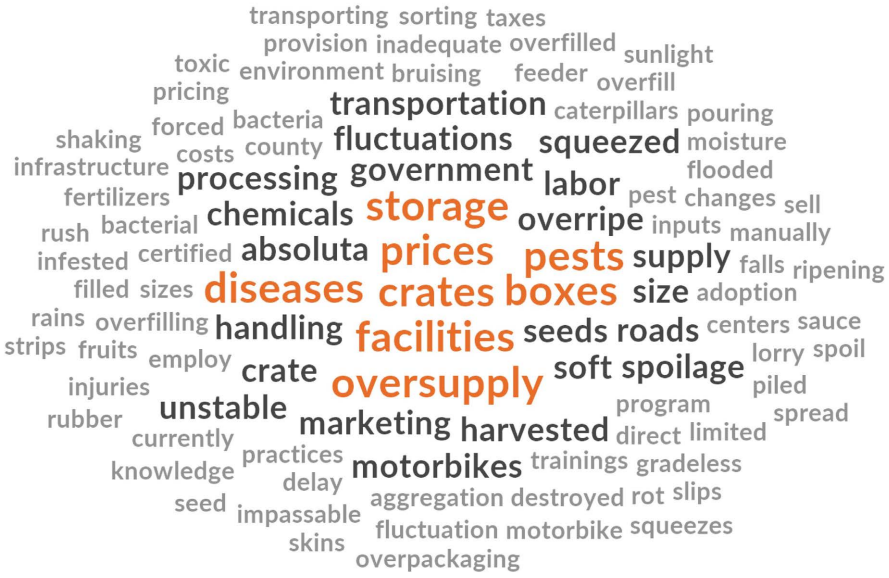
Sub-theme 1.1: Awareness of tomato post-harvest loss points

Participants clearly identified sorting and grading as a critical stage where post-harvest losses became evident. They explained that pest-infested, undersized, damaged, and rotten tomatoes were removed or discarded at this stage, leading to the rejection of a considerable portion of the harvested produce. Findings showed that tomatoes left on the ground during sorting quickly deteriorated, further increasing spoilage, thus making them unsellable. One participant in Kirinyaga East stated, "*We experience a lot of rejected tomatoes, especially during sorting and grading of tomatoes. We lose approximately* 60 - 80 *crates* (*around* 30% *of our harvested produce*)." Similarly, a participant from Mwea West noted, "*Losses mainly occur during sorting and grading because tomatoes that are affected by Tuta absoluta or caterpillars, and those filled with too much water, are removed at this stage*." These responses indicated that pest damage and poor fruit quality often originated in the field but were fully realized as losses during sorting and grading. Thus, participants demonstrated awareness that the post-harvest losses originated on the farm and were not caused solely by transportation or marketing. This is consistent with [28], who reported that 22% of the post-harvest losses occurred at the sorting and grading stage, while losses during transportation averaged 20%.

Subtheme 1.2: Causes of post-harvest losses at the farm level

The study highlighted the most frequently cited causes of post-harvest losses at the farm level. Each of these causes was based on the codes extracted from the responses of the study participants, indicating their greater perceived significance. The primary causes identified were inappropriate packaging practices, price fluctuations, pests and diseases, oversupply of market produce, lack of storage facilities, and over-ripeness of tomatoes. The findings were presented using a word

cloud as shown in Figure 3, which visually highlights the most frequently mentioned factors based on their relative prevalence.



Note: The word cloud highlights the most frequently mentioned causes of post-harvest losses identified from the coded qualitative data. Words that appear larger reflect causes that were mentioned more often, indicating greater prominence in the participants' responses. Source: Own elaboration based on survey data.

Figure 3. Word cloud of key factors contributing to post-harvest losses.

Inappropriate packaging practices

A recurring pattern across interviews revealed that inappropriate packaging practices were one of the major factors contributing to tomato post-harvest losses. Findings indicated that farmers commonly used wooden crates and field containers like buckets and baskets during harvesting, while during handling, they mainly used wooden or plastic crates. However, these containers were often over-filled, which led to bruising and increased post-harvest losses during handling and transportation. One farmer explained, "*Brokers often reject tomatoes that are not properly packed or fully filled in wooden crates. When we overfill these crates during field harvesting, tomatoes get squeezed and develop bruises leading to losses.*" Likewise, a key informant noted, "*Farmers often overpack tomatoes in wooden crates because brokers reject crates that are not fully filled. This increases the risk of bruising and spoilage, thereby resulting in greater losses.*" These findings revealed that farmers were aware that improper packaging adversely affected the shelf life and marketability of their produce. Nevertheless, they continued using these boxes because they were readily accessible and could hold large volumes during transport. This is consistent with previous studies that associated inappropriate packaging with increased mechanical injuries and rapid deterioration of tomatoes [2] [26] [30]-[32].

Price fluctuations

Participants described that the unstable prices led to significant post-harvest

losses. They reported that a sudden drop in prices forced them to either hold harvesting while waiting for better prices, which increased the risk of spoilage, or sell at low rates. One farmer mentioned, "*Price fluctuations make marketing tomatoes a major challenge for us. When prices are low, we are forced to hold harvesting, which translates into high losses.*" A key informant further remarked, "*Prices can fall as low as KES* 3000 *or even KES* 2000 *per* 60 kg *wooden crate, which is about* 50% *of the prevailing market price. Farmers are often forced to accept these prices because tomatoes are highly perishable and cannot be stored for long.*" Unlike the packaging practices, which were linked to farm-level decisions, price instability was framed as an external and unpredictable factor beyond the farmers' control. Participants highlighted the uncertainty and lack of bargaining power, especially during the peak seasons. This aligns with Abera *et al.* [30], who reported that farmers attributed price fluctuations to market delays and intermediaries controlling communication and pricing, which exposed them to unfavorable price shifts and higher losses.

Oversupply of tomatoes

Several respondents emphasized that oversupply was closely linked to fluctuating prices. They explained that the large supply of tomatoes came from farmers in neighboring counties, which caused a drop in prices and a scarcity of buyers. A farmer stated, "*Farmers come from as far as Narok and Machakos, bringing tomatoes to Kirinyaga, which makes it difficult to predict the market. For example, a box may be sold at KES* 2000 *today, but two days later, if the market is flooded, the price may drop to around KES* 600, *and we end up suffering financial losses.*" Another farmer pointed out, "*When we harvest during periods of high supply, we may fail to find buyers or even brokers do not come to the shambas. Once tomatoes are not properly stored, a large portion of the produce is lost due to spoilage, resulting in greater losses.*" This suggested that oversupply accelerated quality deterioration, and this was attributed to the absence of storage facilities and limited market coordination.

Pests and diseases

Respondents frequently mentioned pests and diseases as another major cause of post-harvest losses. Several farmers identified the leaf miner, *Tuta absoluta*, as the most prevalent pest, infesting tomatoes in the field. However, the effects were also evident after harvest, where they contributed to reduced quality and shelf life of the produce, resulting in substantial losses. A farmer reported, "*Our tomatoes are highly affected by pests, especially Tuta absoluta, which is a very serious tomato pest. Infested tomatoes are not bought because their shelf life is very low, and this results in significant financial losses.*" Similarly, bacterial wilt affected farmers' yields, causing early fruit rotting and a short shelf life, which degraded the quality of tomatoes before they reached the market. This is consistent with findings reported by [26]. A key informant added, "*One of the key diseases is bacterial wilt. When it's too hot, the bacteria can spread easily, resulting in total loss.*" Participants' views indicated an awareness that production challenges in the field

extended to post-harvest stages, affecting marketability and household incomes. This finding corresponds with [28], who reported that most post-harvest pathological disorders in tomatoes originated in the field and were worsened by physical injuries, making the produce susceptible to spoilage and reducing its market value.

Lack of storage facilities

Unavailability of storage facilities emerged as a critical infrastructural constraint, leading to post-harvest losses. Participants reported that nearly half of the unsold produce was wasted due to the absence of appropriate storage facilities. One participant explained, "*We do not store because we have no storage facilities. Most of the time, the remaining produce is simply discarded due to spoilage*." This suggested that inadequate storage forced farmers to discard their unsold tomatoes, adversely affecting their income. This was consistent with [27], who found that inadequate storage led to mechanical damage, decay, and blotchiness, contributing to severe tomato post-harvest losses at the farm level.

Over-ripeness of tomatoes

Another prominent cause that emerged was over-ripeness, associated with harvesting practices influenced by broker preferences and unpredictable market conditions. The results showed that farmers harvested fully ripe (red) tomatoes to satisfy the market demand. However, this made the tomatoes vulnerable to bruising and rapid deterioration, as market pressures such as oversupply and unstable prices often lead to prolonged handling and delayed sales, which in turn accelerated post-harvest ripening and spoilage. A participant stated, "*We harvest ripe tomatoes and they tend to become overripe if brokers do not arrive on time, and we end up experiencing greater losses*." Another participant remarked, "*Tomatoes often become overripe as we hold them while searching for brokers offering better prices, especially during periods of oversupply. Once you delay selling, they translate into losses*."

The study participants stated other factors, including limited knowledge of post-harvest handling, incorrect tomato sizes (after grading), weather changes, and rough handling during harvesting, which were less frequently mentioned but still contributed to tomato losses at the farm level. The study findings corroborate previous studies identifying poor post-harvest handling practices, pests and diseases, inadequate transport infrastructure, market instability, and limited storage as major causes of post-harvest losses at the farm level [2] [26] [29] [30].

Subtheme 1.3: Farmers' coping mechanisms to reduce post-harvest losses

This subtheme reported different coping mechanisms farmers adopted and how frequently they relied on them to reduce post-harvest losses at the farm level. The most commonly reported coping strategy was selling rejected tomatoes at lower prices. Farmers described directing their rejects to local buyers, including kiosks, small hotels, and individual retailers within the sub-location, as a way of salvaging losses rather than entirely discarding the produce. For instance, one participant mentioned, "*We sell to kiosks and very small hotels within the area at a*

very low price, since they use tomatoes immediately and what remains is consumed at our homes." Also, some farmers redirected their unsold tomatoes for home consumption or fed them to livestock. Participants explained that this strategy allowed them to salvage some value from tomatoes that were not marketable. As one farmer shared, "*I use the rejects for home consumption and the rest I feed to my livestock.*" Another farmer stated, "*We sell the rejected tomatoes to small shops, while the remaining ones are consumed at home. Thus, they are not entirely wasted.*" Only a few participants reported discarding tomatoes entirely, emphasizing that this was their last strategy when the produce could neither be sold nor used for alternative purposes. As a participant highlighted, "*After small-scale buyers like mama Mboga*[1] *or local vendors come to collect the rejects, they resort and what is left is thrown away because it is the real waste.*" Overall, the findings indicated that farmers sought to minimize losses, either by accepting lower prices or finding alternative uses rather than completely wasting them.

3.2. Theme 2: Farmers' Perceptions of the Effects and Solutions of Post-Harvest Losses

The second theme focuses on how farmers perceived the effects of tomato post-harvest losses and the strategies that could be adopted to reduce the losses at the farm level. It captures the farmers' understanding of how post-harvest losses affected their incomes and livelihoods, as well as the practical strategies they believed to be effective in minimizing such losses. The findings for this theme were grouped into two sub-themes, each explored in detail to illustrate how farmers perceived and responded to post-harvest losses.

Sub-theme 2.1: Perceived effects of post-harvest losses

This sub-theme related to how farmers understood the impact of post-harvest losses on their income and livelihoods. The study findings indicated five perceived effects of post-harvest losses, based on the frequency of coded responses from the interview transcripts. The most frequently cited effect of post-harvest losses was reduced incomes and profits, which left many farmers struggling financially to meet their basic needs, thereby undermining their overall welfare. They explained that highly rejected tomatoes reduced their marketable volumes, which forced them to sell at lower prices, significantly reducing their incomes. As one farmer reported, "*Many tomatoes are rejected during sorting and grading because of pest damage and very small sizes. Sometimes I sell at low prices because of the quality and appearance of the produce. These losses directly reduce my income and profits.*" A key informant explained, "*When losses occur, it directly affects farmers financially. For example, if a farmer harvests* 20 *crates but loses* 10 *crates, then half of the production is lost, which directly lowers income and farm profits.*"

A recurring pattern across interviews indicated that reduced market supply emerged as the second most mentioned effect. Farmers noted that a higher pro-

[1]Mama Mboga is a Swahili term referring to small-scale, informal vendors, often women, who sell vegetables and other fresh produce in local markets.

portion of rejects decreased the quantity of tomatoes available for sale, limiting their ability to meet the brokers' demands. A farmer noted, "*Once the quantity reduces, everything is affected directly, including income and profits because the amount available for sale is lower.*" One key informant reported, "*When losses occur, the market supply is greatly affected as it declines significantly and the farmer ends up experiencing a big loss.*"

The least perceived effects of these losses were related to reduced prices and farmers' decision making. The analysis showed that farmers opted to sell their produce at reduced prices to avoid a complete waste of their harvested produce. A key informant stated, "*A Grade* 1 *tomato that is uniform, well-rounded, and fully ripe may get damaged during transport, developing blisters. This reduces its market price.*" A farmer from Kirinyaga East mentioned, "*Many tomatoes are affected by pests during production; this lowers their quality, forcing us to sell at lower prices compared to the prevailing market prices to avoid a total loss.*" Consequently, respondents perceived that severe tomato post-harvest losses influenced their willingness and ability to continue farming for the next season. Some farmers were forced to temporarily discontinue farming, while others indicated that reduced incomes left them with insufficient capital needed to reinvest in the same plot of land for the next season. As a farmer from Mwea West explained, "*When losses occur, you may not make enough money to cover your expenses for that next season. As a result, you may not have enough capital to plant again for the next season. For example, if you had one acre and incurred heavy losses, you may reduce the area to half an acre or a quarter acre in the next season.*" Another farmer from Kirinyaga East stated, "*At times we neglect farming for the next season if the losses are too high.*"

These findings demonstrate that post-harvest losses are not only perceived as immediate economic impacts but also influence the farmers' ability to sustain future production, affecting food security and farmers' livelihood. This corroborates [27], who found that losses directly reduced farmers' profits and hindered the continuation of tomato cultivation, negatively affecting food security. Wakene and Sharew [2] observed that inadequate storage and post-harvest handling led to wilting, shriveling, and moisture loss in fruits and vegetables, reducing the marketability, income, and economic value of the produce.

Sub-theme 2.2: Perceived solutions to manage post-harvest losses at the farm level

The study findings explored participants' perceived strategies for managing post-harvest losses at the farm level. These were based on the frequency of different solutions reported in the study transcriptions, as shown in **Figure 4**. The results revealed both farmer-led actions and strategies that required government support. Among these, government interventions were most frequently cited and were viewed as a key starting point for reducing losses. Provision of training and extension services emerged as a leading strategy that farmers believed could help them to reduce losses. As one participant suggested, "*We need training on post-*

harvest management to minimize losses. Most trainings provided by private companies mainly focus on pre-harvest stages of production, including soil testing, what fertilizer or chemicals to use, and how to apply them." A key informant added, "*The government should employ more extension agents because there are currently very few, and yet farmers need post-harvest trainings.*" These findings indicated that training farmers on appropriate post-harvest handling practices, coupled with the adoption of improved technologies, can reduce losses, enhance marketability, and improve farmers' incomes [30] [33]. Farmers also suggested the provision of subsidies or low taxes on agricultural inputs. One participant explained, "*The government should reduce taxes on inputs or provide subsidies. Specifically, subsidizing these chemicals or zero-rating taxes on them would help farmers manage losses.*"

Note: This hierarchy chart illustrates the relative importance of coded solutions to manage post-harvest losses. The size of each block is proportional to the number of references associated with each strategy, with larger blocks reflecting higher frequency and greater significance in the participants' responses. Source: Own elaboration based on survey data.

Figure 4. Hierarchy chart on the perceived solutions to manage tomato post-harvest losses.

Participants emphasized the need for standardization of handling crates and sale by weight (kilograms) as opposed to volumetric measures to avoid exploitation by middlemen. A key informant mentioned, "*I would suggest the standardization of buying crates. Currently, farmers are sometimes exploited by brokers because the crates have no standard weight. For example, one farmer noted that the actual weight of tomatoes in plastic crates varies between* 35 - 40 kg, *but payment is per crate.*" A farmer added, "*If regulations required are made to sell tomatoes by weight* (*in kgs*), *we would benefit more.*" The findings highlighted other recommended government interventions, such as processing and value addition, construction of aggregation centers, provision of storage facilities, formation of farmer groups, and identification of toxic chemicals, which were mentioned less frequently by the participants.

In addition to government interventions, farmers described strategies within

their control to minimize post-harvest losses. Price negotiation was the most commonly cited approach. One participant explained, "*When brokers come, we first negotiate with them and agree on the price per crate before we harvest.*" Farmers also emphasized sharing market price information among themselves. As one respondent stated, "*If one farmer knows the price from the previous day, they share that information with others.*" Another farmer added, "*We also talk to farmers from the other sub-counties to know the prevailing price per crate. Because of this, we already have an idea of yesterday's price and use that for negotiation with the brokers.*" The analysis further showed that farmers contracted brokers directly to secure better prices for their produce and also coordinate timely harvesting, although these contracts were informal. One participant noted, "*We contract with brokers ready to buy before harvesting, though not formal contracts. This reduces the risk of unsold tomatoes which could get spoiled.*" Another prominent strategy suggested to help reduce post-harvest losses at the farm level was proper packaging. A farmer explained, "*We pack tomatoes directly into the crates by spreading them evenly, cover with cartons, tie properly and then take to the market to reduce losses.*" A key informant emphasized the significance of improved packaging, noting, "*There is need to shift from the wooden crates to the plastic ones with appropriate sizes, such as medium-sized plastic containers rather than the wooden types.*" The perceived solutions were considered essential to reduce losses, improve marketability, and increase farmers' incomes at the farm level. This aligns with Wakene & Sharew [2], who found that improving harvest practices, adopting modern storage technologies, and enhancing market information systems were crucial for reducing post-harvest losses and promoting food security as well as economic growth in Ethiopia.

3.3. Study Limitations

This study did not collect a detailed demographic profile of FDG participants and key informants, such as age, sex, and farming experience, among others, which limited a deeper understanding of how these characteristics may have influenced participants' views. Additionally, the study was conducted in only two purposively selected sub-counties and involved a relatively small qualitative sample. As a result, the findings cannot be statistically generalized to all tomato farmers. However, they offer valuable insights into post-harvest losses among smallholder tomato farmers and may be relevant to similar production settings. Future studies should consider collecting and reporting participant demographic characteristics and also include a wider geographic area to strengthen the interpretation and broader applicability of qualitative findings.

4. Conclusion and Recommendations

The study examined the level of awareness and perceptions of smallholder tomato farmers in Kirinyaga County, Kenya. The findings indicated that farmers are generally aware of post-harvest losses at the farm level, identifying sorting and grad-

ing as the critical stages where they experienced more losses. Major causes reported included pest and disease infestation, inappropriate packaging, oversupply, and price fluctuations. To cope, farmers sold the rejected tomatoes at very low prices, used them for home consumption, or fed them to livestock. Farmers also understood that losses reduced marketable output and farm incomes, limiting their ability to reinvest in subsequent planting seasons. The findings underscore the need for integrated interventions including regular training on post-harvest management, standardization of packaging and weight-based marketing systems to ensure fair pricing, and provision of storage facilities to manage oversupply. Such measures are essential for minimizing post-harvest losses, supporting sustainable agricultural production, and enhancing farmers' livelihoods.

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Ethical Approval

The survey was approved by the Institutional Scientific and Ethics Review Committee (EUISERC) of Egerton University (Approval No. EUISERC/APP/492/2025) on September 3, 2025.

Respondent Consent

The respondent's consent was obtained before the interview. The interviewer explained the purpose of the study and asked the respondents if they were willing to participate. The interviewer would proceed with the interview only if the respondent gave their consent.

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Author Contributions

Nakato Caroline Bukirwa: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, resources, visualization, writing—original draft, writing—review & editing.

Margaret Ngigi: Conceptualization, supervision, validation, verification, manuscript review, and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Abbreviations

FAO—Food and Agriculture Organization of the United Nations
FAOSTAT—Food and Agriculture Organization Corporate Statistical Database
FGDs—Focus Group Discussions
GDP—Gross Domestic Product
Govt—Government
Kg—Kilogram
KIIs—Key Informant Interviews
KNBS—Kenya National Bureau of Statistics
MoALD—Ministry of Agriculture and Livestock Development