INITIATIVE ON
Rethinking
Food Markets

Solar Drying Technology for Post-harvest Loss Management of Horticulture Products: Findings from Baseline Survey in Nigeria

Bedru Balana[1], Olufemi Popoola[1], Futoshi Yamauchi[1], Caleb Olanipekun[2], Edmond Totin[2], Kamaldeen Salaudeen[3], Aminu Muhammad[3], Weilun Shi[1] & Yanyan Liu[1]

[1] International Food Policy Research Institute (IFPRI)
[2] World Vegetable Center (WorldVeg)
[3] Nigerian Stored Products Research Institute (NSPRI)

December 2024

Contents

1. Background

Creating a sustainable food system requires addressing the critical challenges of food waste and loss (Kör et al., 2022). This is particularly crucial for small-scale farmers who supply local markets but lack access to modern preservation technologies, leading to significant product losses between harvesting and selling. Research indicates that in low-and middle-income countries, approximately 38 percent of harvested perishable agricultural goods are lost before consumption (Kader, 2005; Spang et al., 2019). Globally, about 22 percent of fruits and vegetables are lost in the supply chain before reaching retailers (FAO, 2019). These postharvest losses have significant impacts to low economic return and household food and nutrition security. Post-harvest losses also contribute significantly to environmental concerns, accounting for roughly 8 percent of yearly global greenhouse gas emissions (FAO, 2019). Among all food categories, fruits and vegetables experience the highest losses by weight (Lipinski et al., 2013).

Multiple challenges contribute to significant postharvest losses, including inadequate temperature control, mechanical damage, insufficient packaging materials, substandard storage facilities, poor transportation systems, unfavorable policies, and limited access to postharvest knowledge and technical solutions (Jarman et al., 2023). To combat these issues technological solutions such refrigeration systems (Behdani et al., 2019; Makule et al., 2022), solar drying equipment (Devan et al., 2020), specialized storage facilities with controlled atmospheres, enhanced packaging methods, and chemical treatments to regulate ripening processes (Jarman et al., 2023) were developed. Yet, smallholders do not have adequate access to these technologies. This undermines the potential advantages of horticultural production, often forcing small-scale farmers into disadvantageous market positions as 'price-takers' (Ambuko et al., 2018). Without adequate access to appropriate post-harvest loss management technologies, farmers are frequently compelled to sell their produce immediately after harvest, regardless of market conditions or low profit margins (Yeshiwas and Tadele, 2021; Rutta, 2022). Minimizing these postharvest losses is crucial for enhancing food availability and reducing environmental impact through decreased greenhouse gas emissions (Ortiz-Bobea et al., 2021). While international initiatives like UN SDG 12.3 and African Union commitments aim to significantly reduce supply chain losses by 2025 (Stathers et al., 2020), the agricultural sector continues to prioritize investment in staple crops (Haddad et al., 2016). The horticultural sector remains underfunded in research, for instance approximately one horticulture researcher per million people compared to 4 -5 researchers for cereal crops (Schreinemachers et al., 2018).

As part of a three-years CGIAR Rethinking Food Markets Initiative (2022 through 2024) research activities under 'Work Package 2 - Innovation for inclusive and sustainable growth of domestic food value chains' in Nigeria; solar drying units were installed at pilot level in 10 selected communities in Kano state, northern Nigeria. Baseline data was collected1 prior to the installation the technology. This report presents the synthesis of key descriptive findings from the baseline survey. The main purposes of introducing the solar drying technology were to assess: (1) effectiveness the technology in post-harvest loss management compared to the traditional open-air sun-drying practices; (2) efficiency of the technology in terms of drying time and labour use; (c) food safety and quality improvement; (d) consumers' preferences and willingness to pay premium prices for solar-dried products; and (e) adoption/acceptability of the solar-drying technology by local horticulture value chain actors. Solar dryers offer significant advantages over conventional open-air drying methods, including faster drying times and improved hygiene, while better maintaining the nutritional content of the dried products (Chua and Chou, 2003). The effectiveness of solar dryers stems from their ability to circulate heated, low-humidity air across the produce, which enhances the water evaporation process (Fuller, 2010). While open-

[1] Details of the baseline data collection, including sampling and field administration are provided in section 4.

air sun drying remains the predominant method for horticulture products in Nigeria, this traditional approach leaves produce vulnerable to various risks including pest infestation, animal consumption, theft, and contamination when dried on the ground, trays, baskets, paper, plastic sheets, or rooftops (Nagwekar et al., 2020).

2. Overview of Tomato and Pepper Value Chains in Nigeria

2.1 Production

Tomatoes and peppers are among the most widely consumed vegetable produces in Nigeria (Parkhi *et al*., 2023). Despite Nigeria's position as the second-largest tomato producer in Africa (following Egypt) and fourteenth globally, the country paradoxically ranks as the thirteenth-largest importer of tomato paste worldwide and third in Africa. The country's main tomato cultivation occurs in regions with suitable growing conditions, including Kano, Jigawa, Kaduna, Katsina, Sokoto, and Benue. However, pest and disease management remain a significant challenge in tomato production. A particularly destructive pest, the tomato leaf miner (*Tuta absoluta*), first identified in Nigeria in 2016, has caused extensive crop damage (Sanda *et al*., 2018). The crop is also vulnerable to other pests, including whiteflies, aphids, and fruit borers. Table 1 presents the production and yield figures in Nigeria using data from FAOSTAT database.

Tomato production has shown a consistent upward trend from 2019-2023, increasing from 3,103 MT in 2019 to 3,803.6 MT in 2023, representing approximately a 22.6 percent increase. However, the yield fluctuated significantly during this period. It peaked in 2020 at 3,948.3 kg/ha before declining steadily to 3,466.9 kg/ha in 2023, which is only slightly higher than the 2019 yield. This suggests that while overall production has increased, the efficiency of land use for tomato cultivation has decreased in recent years.

Globally, Nigeria ranks as the seventh-largest producer of chili peppers, with cultivation occurring across more than 80 percent of the country's states. The states of Kaduna and Kano account for most pepper production, representing 36 percent of the total output (Plaisier et al., 2019). Nigerian farmers primarily cultivate two main pepper species: Capsicum annuum, which includes varieties such as bell pepper, cayenne, and chili, and Capsicum frutescens, which encompasses elongated chili or bird chili varieties. The production of chili peppers is predominantly carried out by small-scale farmers. For green chilies and peppers, production has remained relatively stable with a slight upward trend, increasing from 765.6 MT in 2019 to 774.0 MT in 2023, showing only about a 1.1 percent increase from 2019-2023. The yield for green peppers has showed a gradual but consistent decline, dropping from 7,452.9 kg/ha in 2019 to 7,403.6 kg/ha in 2023. Despite this slight decrease in yield, green peppers maintain significantly higher yields compared to tomatoes. Dry chilies and peppers show the most stable production pattern, with slight fluctuations between 63.1 MT and 65.1 MT over the five-year period. The highest production was recorded in 2021 at 65.1 MT. The yield for dry peppers has remained relatively stable, ranging between 1,726.4 kg/ha and 1,754.1 kg/ha, with the highest yield recorded in 2021 at 1,754.1 kg/ha.

2.2 Demand

Tomatoes constitute an essential dietary component in Nigerian households, with the nation ranking among the highest consumers of this vegetable in Sub-Saharan Africa, recording approximately 22 kg per capita consumption (CBI, 2021). In Nigerian daily dietary patterns, tomatoes represent about 18 percent of total vegetable consumption (CBI, 2021). The country's tomato demand is driven by multiple factors, including demographic growth, increasing urbanization, evolving dietary preferences, and the growth of processing industries. Despite being Africa's second-largest importer of tomato paste and ranking 13th globally, Nigeria struggles to meet local demand due to inadequate post-harvest management practices. The tomato value chain faces significant challenges, including substantial post-harvest losses and insufficient processing and marketing infrastructure. Dijkxhoorn et al. (2021) reported that the tomato demand gap of 2.3 million tons in Nigeria. To bridge this gap, imports of over 300,000 metric tons of tomato paste are made annually, valued at USD 360 million. According to ITC data from 2019, the primary sources of tomato paste, ketchup, and sauces for Nigeria are Egypt, Netherlands, China, Indonesia, and Malaysia.

Regarding chili pepper, it serves multiple purposes beyond its traditional role as a flavoring and coloring agent in cuisine. The spice offers various therapeutic benefits, including its use in topical applications for muscle pain relief, inflammation reduction, and itch relief. Its cardiovascular benefits include blood flow regulation and arterial strengthening, potentially lowering the risk of heart attacks. Additional health benefits encompass digestive system support, relief from cold symptoms, sore throat, and fever, improved circulation (particularly for cold extremities), and hangover alleviation (CBI, 2021). The ITC trade map data from 2019 indicated that Nigeria's primary suppliers of fresh and dried chili peppers were France, India, China, Vietnam, and Germany.

2.3 Marketing

The distribution and sale of tomatoes and peppers in Nigeria primarily occurs through informal market channels, despite having well-organized value chains. A WUR (2019) study revealed that while these value chains are structured, they operate on informal agreements and arrangements between various stakeholders. While market intermediaries serve an important function, their involvement often results in price inefficiencies and reduced farmer profits (Balana et al., 2022). Lagos's Mile 12 Market stands as one of the country's largest foods markets and serves as a primary hub for tomato and pepper trade. Farmers and traders regularly face price volatility due to seasonal production patterns. The quality of vegetables is significantly impacted by inadequate transportation infrastructure, including poor road conditions and lack of refrigerated transport facilities, leading to substantial losses for traders. The market's logistical challenges, including rough handling during unloading and traffic congestion in and around the facility, result in considerable waste of tomatoes, onions, and chili peppers. Other significant market centers include the Sasha and Bodija markets in Ibadan, as well as various markets in Plateau State.

2.4 Processing

Despite high production volumes, Nigeria's tomato and pepper processing sector remains underdeveloped. Fresh consumption dominates the market, with minimal processing into value-added products such as paste, sauce, and ketchup (Takeshima et al., 2023). The growth of the processing industry is hampered by insufficient infrastructure and expensive processing equipment (Sibomana et al., 2016). Major processing facilities, including Tomato Jos in Kaduna and Dangote in Kano, operate below capacity due to unreliable supply of quality produce and fierce competition from imported products (Tafida et al., 2019).

Post-harvest losses are exacerbated by poor harvesting practices due to limited technical knowledge. The absence of effective drying and storage facilities throughout the value chain, from farm to market, contributes to significant product deterioration. Most farmers rely on basic storage methods, such as floor and roof drying, which are inadequate for proper preservation of tomatoes and peppers. Research has demonstrated that traditional floor drying methods for tomatoes and chilies result in inferior product quality due to contamination from dust and sand, leading to lower market prices compared to products dried using elevated solar drying platforms (Chua and Chou, 2003; Agrofair, 2018).

2.5 Losses in tomato and pepper value chains

Estimates of tomato losses throughout Nigeria's value chain vary among researchers, though industry experts suggest annual losses range between 45-60 percent of total production (CBI, 2021). These losses are distributed across different stages: approximately 15 precent during production, 21-30 precent during post-harvest activities including harvesting, processing, packaging, and distribution, and an additional 20 precent at market level (Agrofair, 2018).

For the pepper value chain, losses are estimated to range from 20-30 percent (Olayemi et al., 2010). The primary factors contributing to these losses include microbial contamination, natural deterioration due to ripening processes, and environmental stressors such as heat and drought. Additional waste occurs due to several factors: inadequate post-harvest sanitation, substandard storage and packaging methods, and physical damage during harvesting and transportation, particularly due to road conditions causing excessive vibration (CBI, 2021).

3. Current (existing) traditional drying practices

3.1 Temperature and relative humidity

The Kano state in northern Nigeria is a major vegetable growing area, characterized by high levels of postharvest losses of fresh vegetables. This is attributed to the lack of infrastructures like storage facilities, modern drying technologies, cold chains logistics, and preservation technologies. The commonly grown vegetables in Kano include tomatoes, peppers, onions, carrots, and leafy greens. A rapid needs assessment in several tomato growing communities in Kano show that drying of tomato and other horticulture products during the glut seasons was commonly undertaken using sun drying in open areas such as roadside, markets places, roof tops, and garden areas or farmlands exposed to sunshine (Fig. 1). Open-air sun drying that involves the use of energy from the sun to dehydrate crop products including fruits and vegetables is the traditional and widely used method of preserving agricultural products in northern Nigeria. When sun drying is undertaken in the open air and on bare ground, it exposes products to impurities and foreign particles like dust. The traditional sun drying method is labor-intensive and takes longer drying time.

Fig. 1: *Traditional sun drying practices in Northern Nigeria:*
(Photo Credit: Caleb Olanipekun @WVC)

Farmers carry out most drying activity on the farm mainly to save transport cost. Marketers and aggregators use dedicated areas around the market for drying activities (including store rooftops). Based on the needs assessment study (Olanipekun et al, 2023), a larger percentage of the actors involved in tomato dying are willing to pay for better technology indicating demand for better drying conditions.

The three crops mainly dried are tomato, pepper (habanero and chili), and okra. Some pepper farmers produce solely for drying purposes, making pepper a more preferred product for drying in some locations (Bichi, Tsanyawa, Bebeji) than tomatoes owing to its profitability. For tomatoes, however, producers prefer selling fresh rather than drying, they mainly dry to cope with glut and prevent postharvest loss especially when the market price for fresh products no longer justifies their cost of production. Additionally, unsold tomatoes at the market are dried and bagged as a means of long-term storage.

The dried product market fluctuates based on the demand for, and the availability of fresh produce. Prices for dried products depend on the drying method used and storage conditions. Dried products can be sold immediately or can be kept up to 3 – 6 months in storage before offtake to the market.

Longer-term storage results in product colour change which is the main indicator of for dried product quality and better price. Research shows that lycopene (a natural pigment) determines the colour of vegetables. Duration of exposure to light, temperature at storage, ambient relative humidity, and other chemicals can cause products to change colour during storage. Market actors adopt different storage techniques such as storing in dark rooms using sacks placed inside a dark-coloured polythene to reduce exposure to light and minimize colour changes. Dried products with the right colour command higher price (premium price).

Aggregators and marketers along the value chains make more profit from dried products by buying fresh from desperate farmers at lower prices during the glut season. Consumers of dried product either buy the dried product as whole and blend/ground to powder themselves or buy already grounded product before use (especially for chili pepper).

4. Solar drying technology intervention

4.1 Rationale

While the traditional open-air sun drying remains the predominant method for these products in the country, the approach leaves produce vulnerable to various risks including pest infestation, animal consumption, theft, color change/loss of nutrients, and impurities/contamination when dried on the ground, trays, baskets, paper, plastic sheets, or rooftops (Nagwekar et al., 2020). Solar dryers offer significant advantages over conventional open-air drying methods, including faster drying times and improved hygiene, while better maintaining the nutritional content of the dried products (Chua and Chou, 2003). The effectiveness of solar dryers stems from their ability to circulate heated, low-humidity air across the produce, which enhances the water evaporation process (Fuller, 2010).

However, there has not been a rigorous evaluation on solar dryer technology in the context of tomato and pepper processing using a randomized controlled trial (RCT) in Nigeria. The present study aims to assess the impacts of solar drying technology on food loss, income and employment in northern Nigeria using an RCT research design. The study will also conduct a laboratory experiment that assesses food safety and quality advantages of the technology relative to traditional drying methods.

4.2 Intervention design

To measure the impacts of the technology on a set of outcome areas, ten parabolic solar drying units were constructed in ten communities known for their tomato and pepper production and marketing in Kano state (Fig. 2) The Nigeria Stored Product Research Institute (NSPRI) commissioned for the construction and technical support on the usage and day-to-day management of the solar drying infrastructure. The International Food Policy Research Institute (IFPRI) leads the experimental study (randomized controlled trials) design, and the World Vegetable Center (WorldVeg) jointly (with IFPRI) implements data collection and field activities such training of field enumerators as well as field coordination of baseline survey and RCT implementation.

Nigeria Stored Product Research Institute (NSPRI) patented solar driers which has been piloted and shown to provide an improved drying condition as well as product quality. Both factors are key determinants for market acceptability and obtaining premium prices. If solar drier is combined with optimal storage conditions to maintain colour, the overall dried product quality can be improved. By improving access to market and improving dried product chain coordination, actors can maximize their profitability and outlook more market opportunities.

The baseline survey was conducted between 27 May – 7 June 2024. The target of the baseline and RCT are mainly producers who are involved in drying tomatoes and peppers. The target respondents are producers and processors of tomatoes and pepper in ten selected communities in Kano. A random sample of 100 farmers were selected based on the lists provided making the total sample size of 1,000 respondents. In cases where the selected farmers could not be reached at the time of the survey, another round of samples were randomly selected from the remaining list of farmers in the community. Of 1000 study samples, 400 households will be assigned to treatments (40 per community) and the remaining 600 households will be in the control group.

Fig. 2: Parabolic solar drying technologies constructed in selected communities in Kano

(Photo Credit: Olufemi Popoola @IFPRI)

The treatment group in each location will be trained by WVC and NSPRI in the use of solar drier and will be allowed to dry their products using the solar drier. Due to capacity limitations of the solar dryer units, the 40-treatment group in each community will use the drying units in two-drying cycle rotations as depicted in Table 2. In each Group (G1- G8), 5 users will be assigned, and each group will use the solar drying units for two drying cycles. Then, the next group of five users will take over the solar dryer for two-drying cycles. Such two-cycle drying rotations will continue until all the 40 treatment households/users use the drying facility. Specifically, one treatment group of 5-users are allowed to use the solar dryer for two-drying cycles.

To facilitate marketing and support profitability of the activities, the project links the dryers in the RCT to buyers such as retails or end users in urban centers. A random sample of the products will be labeled to show the quality advantage relative to traditional methods.

The technology can directly benefit if farmers are linked to markets and sell dried vegetables themselves rather than selling to aggregators who buy at a low price. Dried products can be packaged and sold directly to the consumers and at retail markets like the local markets in Kano, and formal market channels like supermarkets, and grocery stores.

5. Baseline Survey - Sampling

The Local Government Areas (LGAs) and communities where the study population sampled is presented in Table 1. In the first stage, based on the volume of tomatoes and pepper production and drying in Kano state, six LGAs were selected. The second stage involved selection of vegetable growing communities within the selected LGAs. The eligible population for the study is farmers who produce tomato/pepper and dry; and aggregators/marketers who buy fresh tomato and pepper to dry for sale. The third stage involved random sampling of 100 eligible respondents from the household listing. The sampling covers ten communities in six LGAs comprising of Bagwai, Tsanyawa, Makoda, and Gaya LGAs each containing two sampled communities, while Danbatta and Wudil LGAs each have one sampled community. Due to duplicate entries, we have a total sample size of 973 respondents across all communities (Tabel 3).

6. Baseline Survey - Results and Discussion

6.1 Household Characteristics

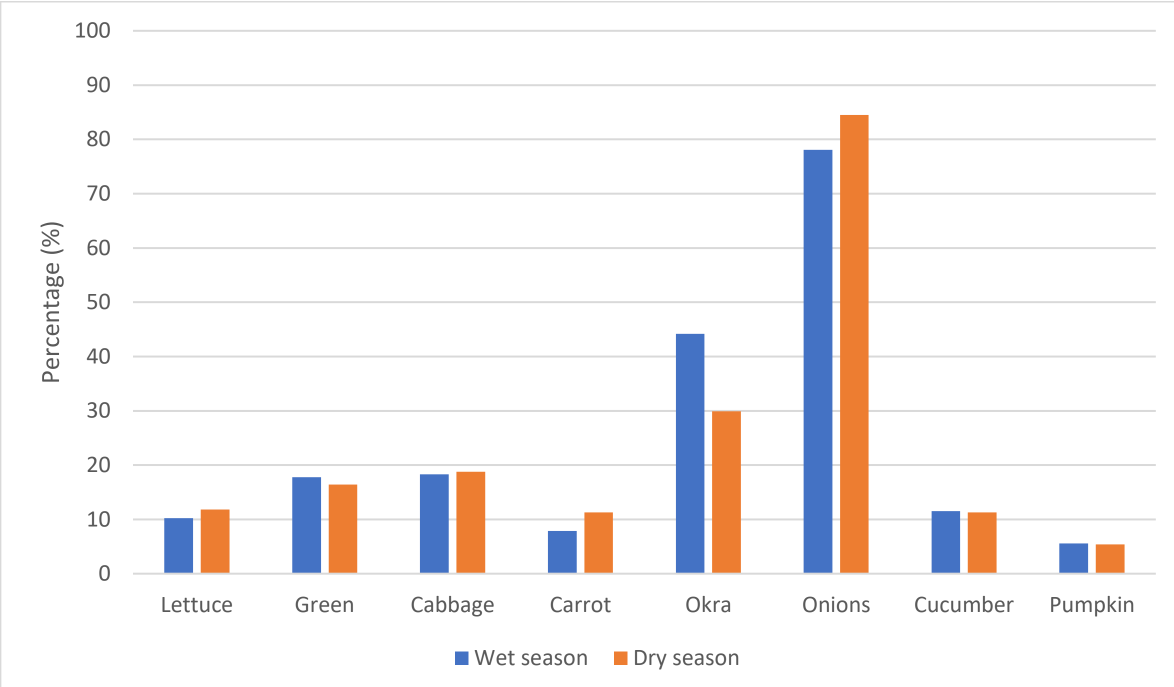
Table 4 presents the key characteristics of survey respondents. About 93.6 percent of survey households are male headed implying the dominance of patriarchal nature of households in northern Nigeria. The average age of household head was 42 years, indicating that the farmers are in their economically active years. They are mostly married (94.5 percent). An average household size of 12 persons reflects the prevalence of large households in northern Nigeria, especially with agricultural households. Similarly, around 4 household members on average are actively involved in farming and household economic activities within the household. About 26 percent of household heads do not have any formal education, while approximately 22 percent have tertiary education. About 93.5 percent of survey households reported crop farming as their primary economic activity and only less than 1 percent depend primarily on livestock, indicating the dominance of crop farming as the main means livelihood in the area. In terms of household's engagement in non-agricultural activities, about 68 percent of households reported that they engage in one or more off-farm income-generating activities, suggesting significant economic diversification despite the dominance of crop farming as the primary occupation.

6.2 Land

Table 5 provides land ownership and agricultural practices in the study area. Most of the respondents (92.5 percent owned land. The average farm size is approximately 3.2 hectares. Soil quality is reported to be predominantly good, with 92.3 percent reporting good soil fertility. Land tenure arrangements showed that nearly 5 percent of respondents rented land and only 2.1 percent used family land for vegetable production, being the main alternatives to ownership. Tomato is the most cultivated crop (by 88.5 percent of respondents), followed by pepper (72.5 percent). Beyond these main crops, 46 percent of farmers grow other vegetables in the wet season, while this percentage increased to 56 percent in the dry season. Among other vegetables, onions dominate both seasons but with higher prevalence in the dry season (84.5 percent) compared to the wet season (78 percent) (Fig. 3). Okra shows seasonal variation, being more common in the wet season (44 percent) than in the dry season (30 percent). Other vegetables reported in the survey include cabbage, green vegetables, and lettuce.

Figure 3: Other vegetables grown in the study area

Source: 2024 Baseline Survey, Kano/Nigeria



6.3 Tomato and Pepper Production

6.3.1 Tomato production

Table 6 presents tomato production in both wet and dry season. There is a significant difference in tomato cultivation rates, in both seasons. About 76.5 percent of respondents grow tomatoes in the dry season as compared to 33.6 percent in the wet season. This implies that tomato cultivation is higher in the dry season than in the wet season. A higher proportion of farmers use more family labor in the dry season (56 percent) relative to the wet season (26 percent). About 68 percent of the farmers practice intercropping in the wet season as compared to 76 percent in the dry season. Tomato yield was higher in the dry season than in the wet season, 13912.46 kg/ha and 10757.24 kg/ha respectively.

About 63-65 percent of tomato harvested were sold fresh; 14-16 percent processed for sale and t 9-10 percent consumed by the household. The proportion of on-farm damage before harvest is slightly higher in the dry season, which was put at about 7.6 percent as compared to 6.4 percent in wet season. Post harvest losses in both seasons were approximately 3 percent. This is shown in Figure 4.

In terms of varieties of tomato grown in both dry and wet seasons, the local UTCs emerge as the dominant variety planted by farmers. The local UTC varieties were cultivated by 75.5 percent farmers in dry season while in wet season 58 percent use UTC in the wet season (Table 7). This is followed by the local Roma variety. About 11.7 percent of dry season tomato growers use hybrid varieties from companies like East West Seeds, Syngenta, and Rijk Zwaan. Other varieties, including Open Pollinated Varieties (OPVs) whether branded or replanted and local 'Denega'.

In terms of labor input, results show that over 60 percent of tomato producers use relatively higher amount of hired labor than family in both the wet and dry seasons.

6.3.2 Cost structure of tomato production

Tomato yields in Nigeria are higher during the dry season, with distinct differences in cost structure and farming practices across seasons. Figures 4 and 5 illustrate the cost breakdowns for tomato farming in the dry and wet seasons, respectively. To understand the cost structure of tomato production in both seasons, we used a cost build-up analysis approach. This approach involves breaking down of financial cost information into key cost components to produce a given unit of produce (e.g., a metric ton of tomato) or in a unit of land (e.g., hectare of land). Such analysis can help farmers improve their financial performance and efficiency by identifying areas for improvement and making informed investment decisions.

We structured the costs into - land rental, cost of seeds, cost of hired labor, fertilizer cost (inorganic and organic) and costs on agrochemicals. Except similarity in cost of seeds, about ₦32,00/ha in both seasons; all other major costs are higher in dry season tomato production than in wet a season. For instance, land rent is higher in the dry season is about ₦61,509/ha as compared to ₦55,567/ha in the wet season. Similarly, inorganic fertilizer costs are higher in the dry season (₦130,462/ha) as compared to ₦106,979/ha in wet season. See Figures 4 and 5 for cost differences in other inputs.

Figure 4: Cost structure for tomato farmer - Wet season

Source: 2024 Baseline Survey, Kano/Nigeria

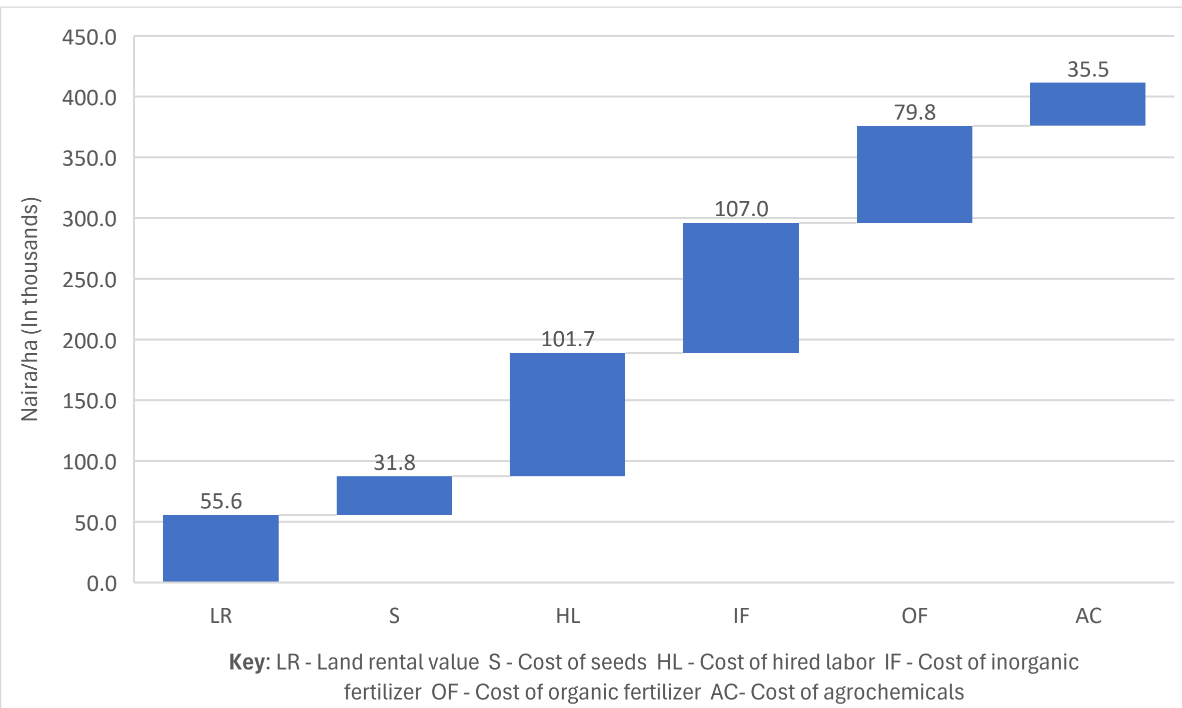
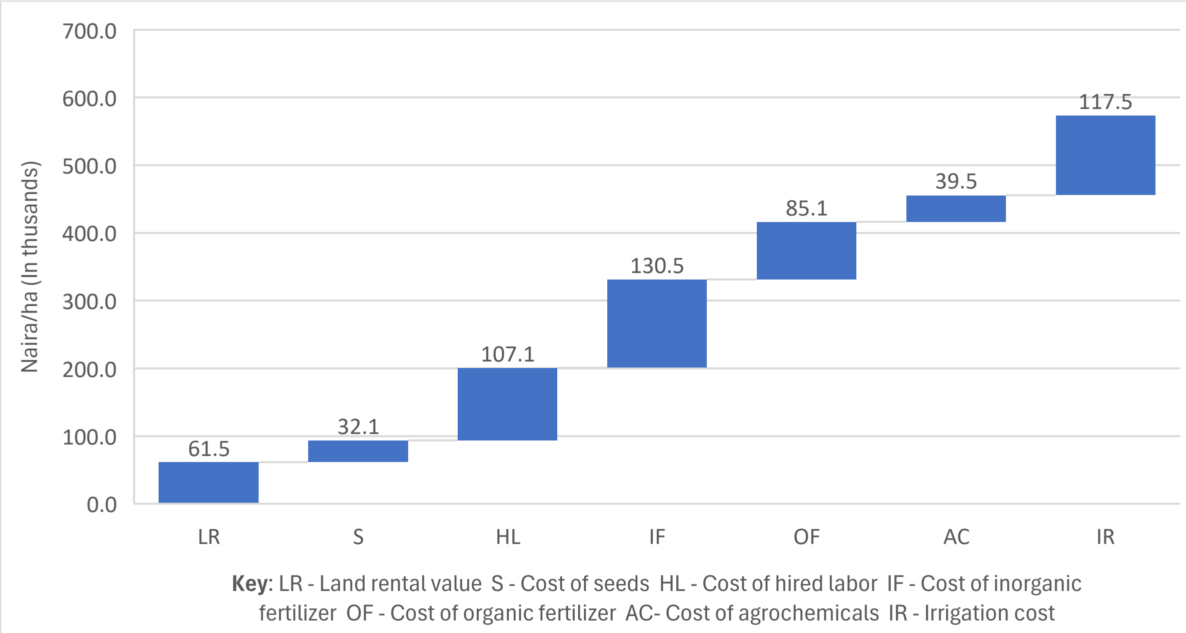


Figure 5: Cost structure for tomato farmer - Dry season

Source: 2024 Baseline Survey, Kano/Nigeria



6.3.3 Pepper production

Table 8 presents summary statistics of pepper production in Kano. About 57 percent of sampled households grow peppers in the dry season as compared with only 23 percent in the wet season. A higher proportion of farmers use more family labor in the dry season (42 percent) relative to the wet season (17 percent). About 65 percent of the farmers practice intercropping in the wet season as compared to 69.4 percent in the dry season. The quantity of harvest of pepper in the dry season was nearly double that of wet season. The quantity of harvest in dry season was 6,898 kg as against the harvest in wet season which was about 3,503 kg. Pepper yield was higher in the dry season than in the wet season. The yield was 7276.6 kg/ha in the dry season and 4048.4 kg/ha in the wet season.

With respect to the harvest structure, as expected, a higher proportion of harvest is sold fresh in both seasons, approximately 45- 51 percent. Only about 9-10 percent of harvest is consumed. About 38percent in dry season and 32 percent in wet season of harvest were processed for sale. This is different from the case of tomatoes, indicating that farmers process more pepper than tomatoes. The major form of processing is drying, implying that pepper drying rather than tomato is prevalent among the farmers.

In terms of varieties of pepper cultivated across season, the dominant variety cultivated is the local sweet pepper (tatase/bawa) variety. A higher proportion of farmers cultivated this variety in the dry season, 72 percent as compared to the wet season, with about 51.1 percent of farmers cultivating the variety. The local chili pepper on the other hand is more cultivated in the wet season as about 39.9 percent of sampled farmers cultivated the variety. The proportion is much lower in the dry season with about 20.9 percent of farmers cultivating the variety. Other varieties are the local Habanero/Atarudu, and the hybrid varieties from commercial seed companies such as East West Seeds, Syngenta, Bakker and others.

Just like in tomato production, hired labor plays a key role in both the wet and dry season pepper production. About 66 and 63 percent dry and wet season pepper productions respectively are use hired labour.

Just we constructed cost structure for tomato production, we used a similar cost build ups approach to analyze the cost structure of pepper production in wet and dry seasons (Figures 6 and 7) All the cost components including land rental, seed costs, inorganic fertilizer, organic fertilizer, agrochemical costs, and hired labor costs higher in dry season pepper production than the wet season (Figures 6 and 7).

Figure 6: Cost structure for pepper farmer - Wet season

Source: 2024 Baseline Survey, Kano/Nigeria

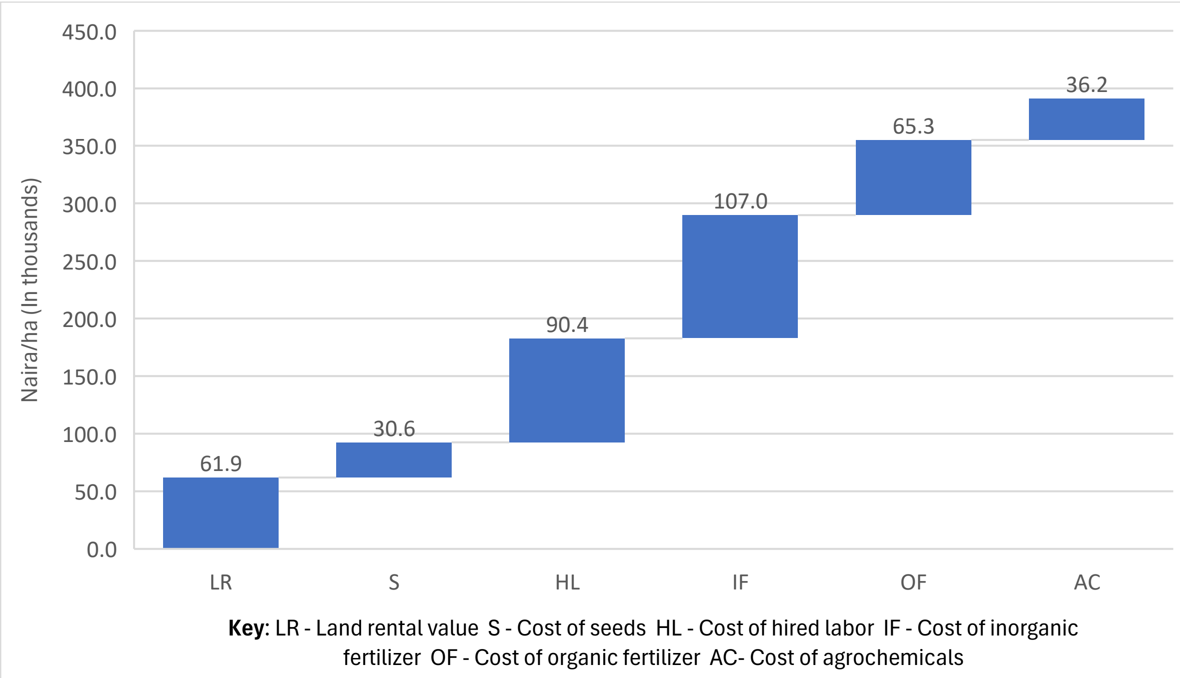
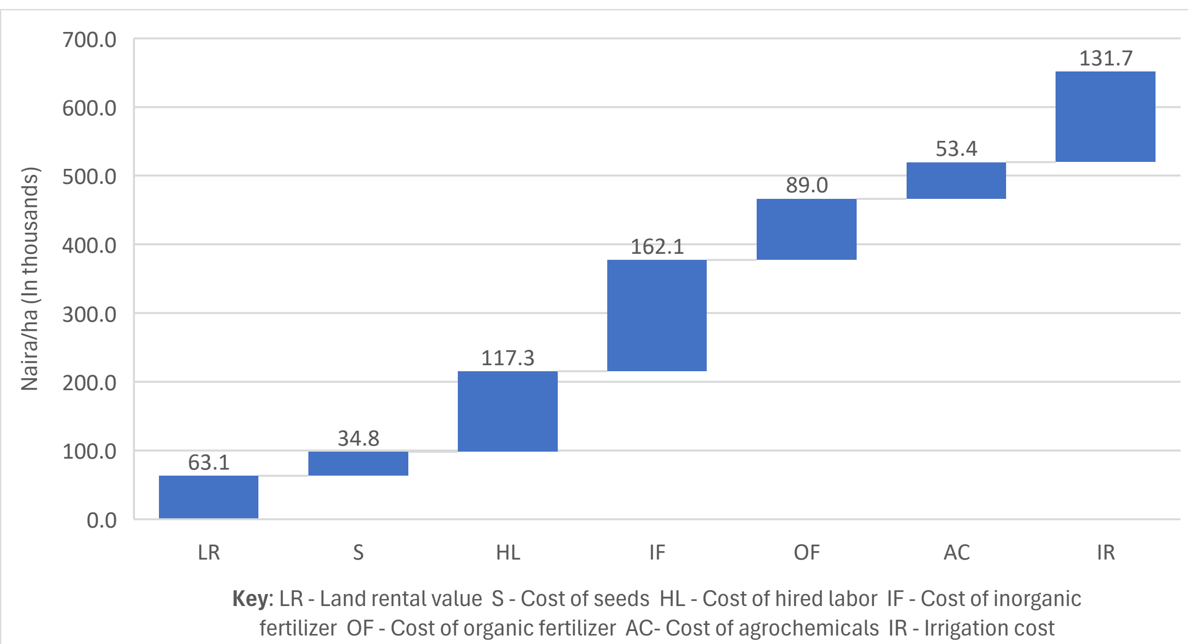


Figure 1. Cost structure for pepper farmer - Dry season

Source: 2024 Baseline Survey, Kano/Nigeria



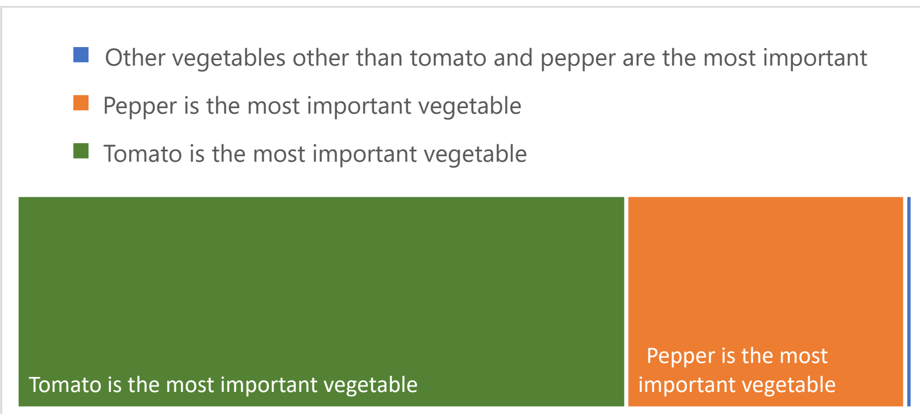
6.4 Assessment of vegetable production and drying in Kano

6.4.1 Respondents perceived importance of various vegetables

To assess the relative importance horticulture production, respondents were asked to rank their perceived economic benefits from various vegetables – "In terms of the economic benefits of vegetable production, which of the following true for your household? (1) Tomato is the most important vegetable; (2) Pepper is the most important vegetable; and (3) Other vegetables other than tomato and pepper are the most important". Figure 8 reports the results from the self-reported responses. The distribution highlights the relative importance of tomatoes, peppers, and other vegetables. Findings revealed that tomatoes are overwhelmingly considered the most important vegetable economically, as 68 percent of the farmers affirmed this position. This dominance may reflect their high market demand, and profitability. About 31 percent of farmers perceived pepper as the most important vegetable. This is still a significant proportion as it is nearly a third of respondents. Peppers often fetch high market prices, especially dried pepper and the demand for different varieties. Overall, the data underscores the centrality of tomatoes and peppers in the vegetable economy, with tomatoes being the most dominant.

Figure 8. Perceived economic importance of vegetable (based on self-reported ranking)

Source: 2024 Baseline Survey, Kano/Nigeria



6.4.2 Assessment of existing drying practices (tomatoes and pepper)

Table 10 presents summary statistics of key findings on the current drying practices for tomato and pepper across wet and dry seasons. A higher proportion of households engage in drying tomatoes during the wet season (66 percent) compared to the dry season (57 percent). This suggests increased demand for preservation during the wet season when fresh produce is more abundant. The average quantity of fresh tomatoes used for drying by a household was about 4,060 kg in the wet season as compared to 2,995 kg per household in the dry season. Similarly, the output of dried tomatoes drops from 1,365 kg in wet season to 900 kg in dry season.

The proportion of farmers who engage in drying pepper in the wet season was 47 percent, and this increased to 54 percent in the dry season. The average quantity of fresh pepper for drying is about 2,700 kg in the wet season and 4,905 kg in the dry season. Similarly, dried pepper output increased from 1,869 kg in wet season to 2,305 kg in dry season. This shows that farmers dry more pepper in the dry season expectedly as compared to the wet season.

For drying technology, ground open-air sun drying remains the dominant method of drying. This method is used by over 90 percent of households for both vegetables across all seasons, peaking at 98.5 percent for pepper in the dry season. The main dried products are dried tomato and pepper. A small proportion of farmers also produce tomato/pepper powder. It is evident that the majority of farmers grade and sort before drying as about 84 percent of tomato farmers grade and sort as compared to 76 percent for pepper.

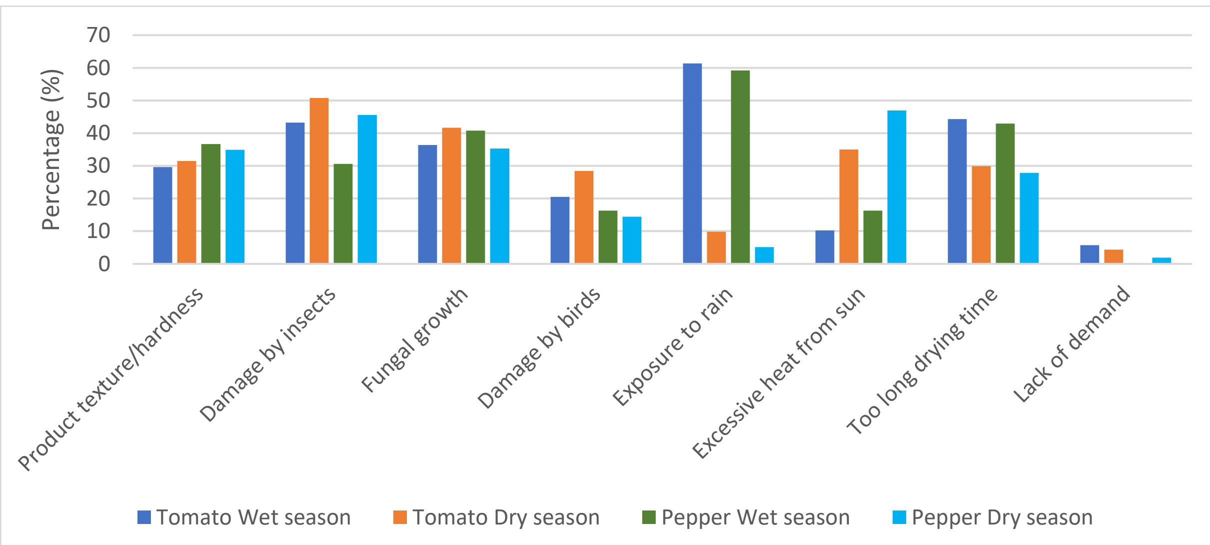
The length of drying for tomato is approximately 10 days. For pepper, it is about 9-10 days. Drying activities are predominantly carried out by adult men (46–50 percent) and hired labor (30–33 percent). Women and children contribute less, with their involvement slightly higher in the wet season for tomatoes and the dry season for peppers.

6.4.3 Challenges with current drying practices

Figure 9 presents the challenges farmers/dryers facing in the current drying practices. Exposure to rain emerges as the most significant challenge during the wet season, with about 60 percent of respondents reported this as the major challenge for drying both tomato and peppers. For tomatoes, farmers reported that 43 and 51 were damaged by pests/insects in wet and dry season, respectively. Similarly, in pepper drying, the proportion increased from 30.6 percent in the wet season to 45.6 percent in the dry season. This highlights a higher susceptibility of vegetables to insect attacks, especially in the dry season. Fungal growth is predominantly a wet-season issue for both crops due to the high moisture levels. Tomatoes are more affected, with 36.4% of respondents reporting fungal growth in the wet season, increasing to 41.7 percent in the dry season. For pepper, about 40.8 percent of the farmers reported fungal growth in the wet season as compared to 35.3 percent in the dry season. Other challenges are product texture/hardness and damage by birds.

Figure 2. Figure 13. Key challenges in drying (tomato and pepper, by season)

Source: 2024 Baseline Survey, Kano/Nigeria



6.5 Cost structure of traditional drying practices (wet and dry season)

Figures 10 and 11 present the cost structure of traditional drying activity for tomato in wet and dry seasons. The cost components considered includes transporting fresh inputs, cost of hired labor for drying, cost of storage and cost of energy. Using a similar cost build-ups approach, figures 12 and 13 show the cost-structure of drying pepper in wet and dry seasons.

In tomato drying, the cost of hired labor was the highest expense in both seasons (₦33,500 per ton in wet season and ₦31,900 per ton in the dry season), followed by the cost of transporting fresh tomatoes. A similar cost structure is observed in the dry season tomato drying activity. In both seasons, the cost of hired labor and transport remains the dominant costs incurred by tomato dryers in the study area.

Figure 3. Cost structure for a tomato drying using the current traditional method (wet season)

Source: 2024 Baseline Survey, Kano/Nigeria

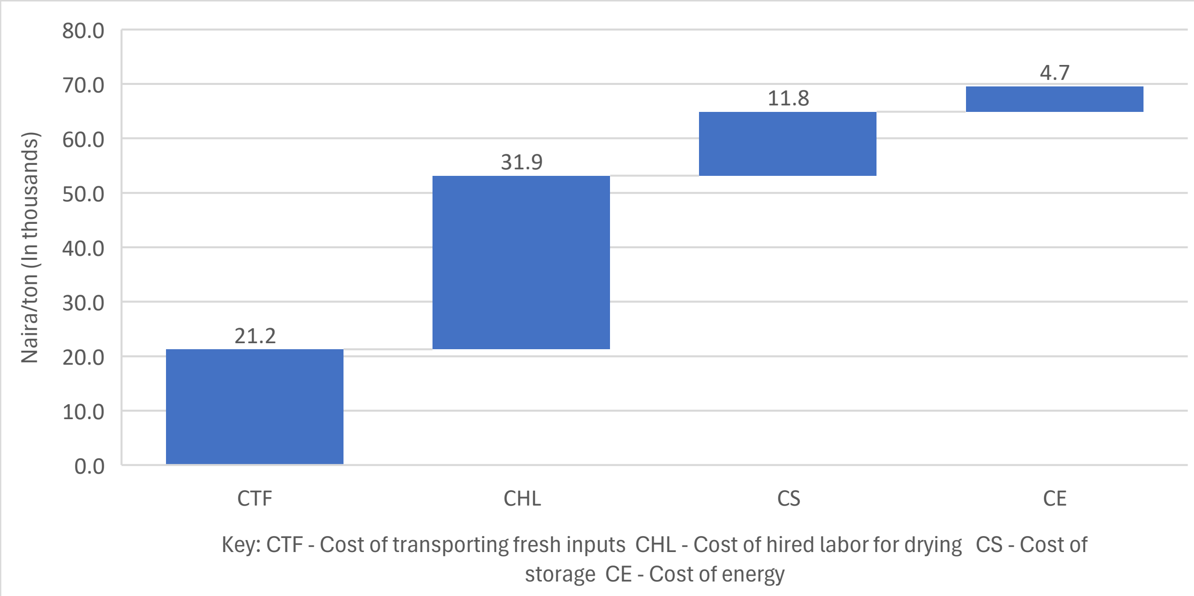
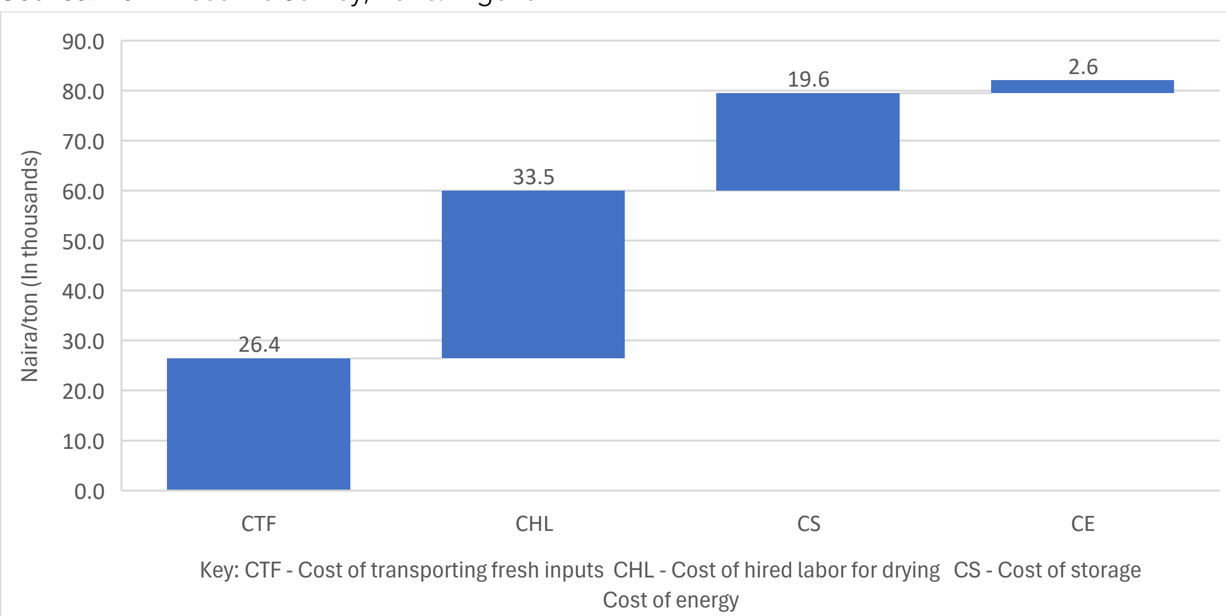


Figure 4. Cost structure for a tomato drying using the current traditional method (Dry season)
Source: 2024 Baseline Survey, Kano/Nigeria



Like that of tomato, drying, labor costs dominate the cost structure of drying pepper, amounting ₦20800 per ton in wet season and ₦19,200 in dry season. This indicates that the drying process is still labor-intensive, which may be due to limited mechanization or reliance on manual labor. Other cost items in figures 12 and 13 can be interpreted in a similar manner. In terms economic returns, the dry season pepper drying business proved more lucrative, with higher revenue and profit margins. This may be attributed to improved drying conditions or greater availability of fresh pepper during the dry season.

Figure 12. Cost structure for pepper drying using the current traditional method (wet season)
Source: 2024 Baseline Survey, Kano/Nigeria

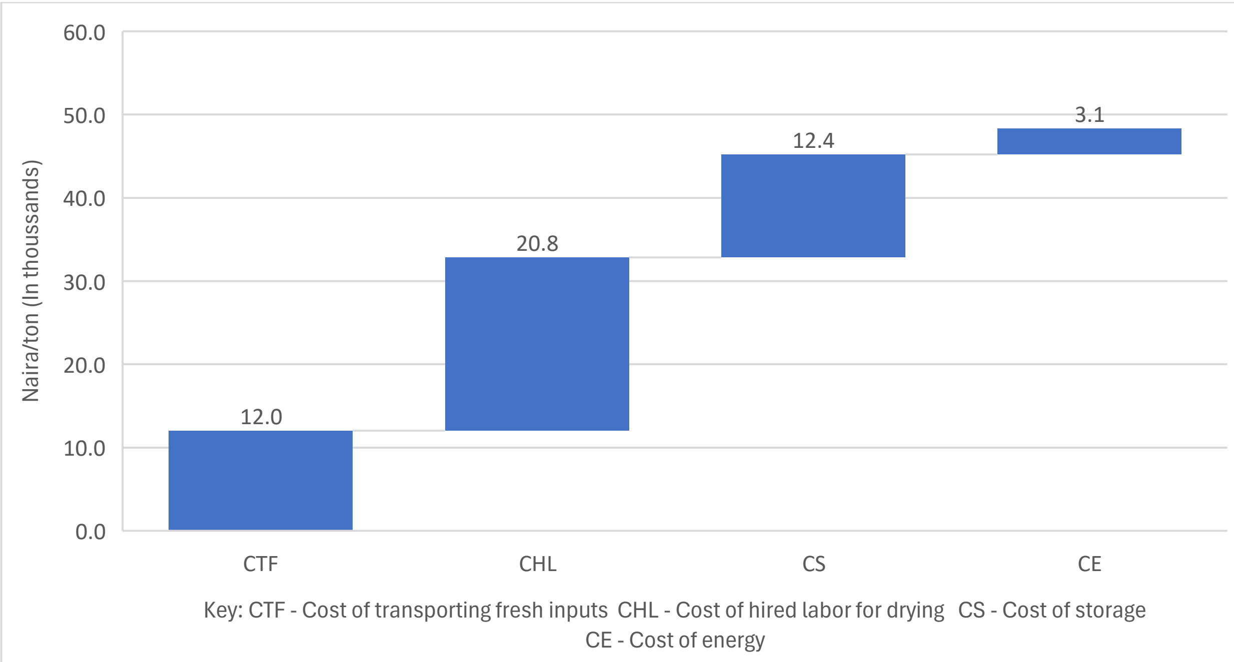
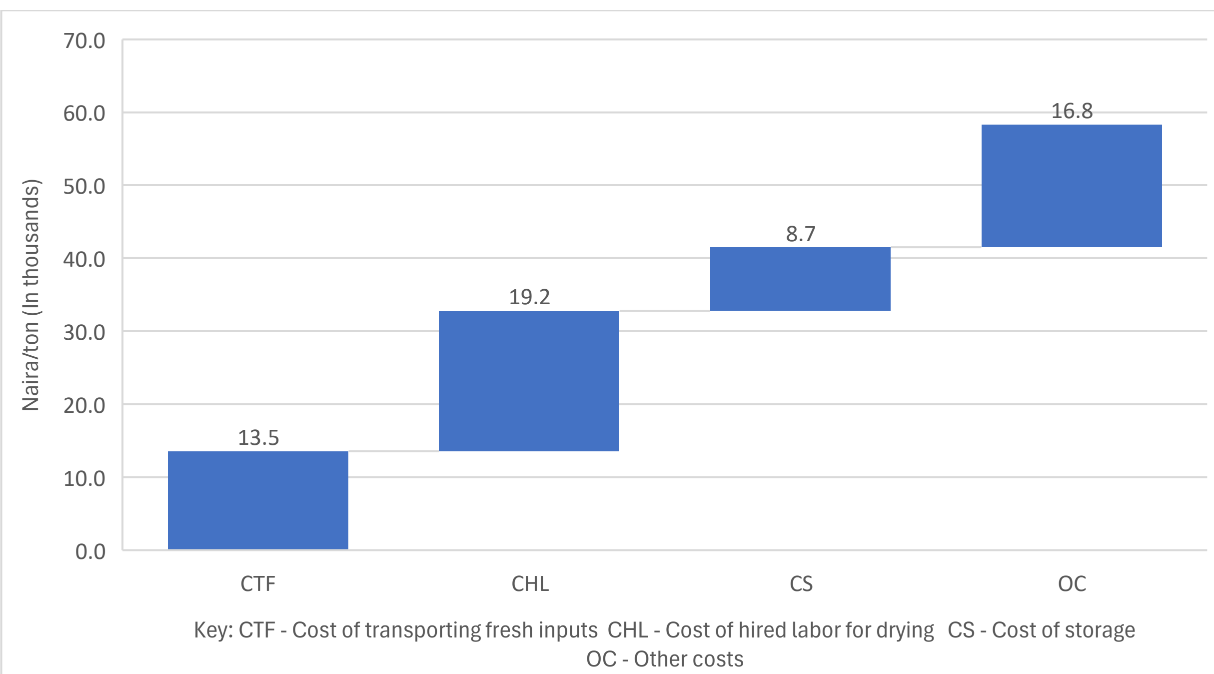


Figure 13. Cost structure for pepper drying using the current traditional method (wet season)
Source: 2024 Baseline Survey, Kano/Nigeria



6.6 Marketing of tomato and pepper in Kano

Table 11 provides insights into the distribution of main buyers of dried tomato and pepper products during both wet and dry seasons. The dominant buyers of dried products were local off takers/traders and aggregators. For instance, about 87 percent of purchasers of dried tomato in the wet season and 92 percent in the dry season were by off-takers/traders/aggregators. Similarly, for peppers, the proportion was higher, at 92 percent in the wet season and 94 percent in the dry season. This emphasizes the role of intermediaries in marketing dried vegetable products in the study area, particularly during the dry season when aggregation for larger markets intensifies. This is followed by local consumers that offer a source of consistent market for dried products. Others such hotels/restaurants, processing firms and supermarkets are not that significant. In terms of the major selling/marketplaces for dried products, wholesale market and open local retail markets are the dominant marketplace.

6.10 Awareness and knowledge of solar dryer technology

Table 12 presents a summary of responses by respondents on their current knowledge about solar drying technologies for horticulture products. About 74 percent of the respondents have heard about solar dryers, indicating substantial awareness of the technology. The willingness/interest for the usage of solar dryer technology is very high, with 98 percent of respondents expressing interest. This suggests that a significant majority sees the potential value in adopting solar dryers.

With respect to respondents' perception on the dried product quality using solar dryer, about 57 percent affirmed that solar dried vegetables would have better taste and better 51 percent indicated better product texture/hardness, 45 percent believed on prolonged shelf life and 43 percent on increased consumer acceptability. These perceptions indicate that while solar-dried vegetables are positively associated with improved taste, color, and texture, fewer respondents view the technology as significantly enhancing aroma, shelf life, or consumer acceptability. With regard to the key adoption barriers to adoption to solar drying technology, respondents reported lack of knowledge on use (67 percent), high cost of technology (59 percent), and lack of knowledge on maintenance (43.5 percent).

The perceived benefits of adopting solar dryer technology are positive, reflecting its potential to revolutionize vegetable processing and storage. Nearly nine out of ten respondents agree that solar dryers significantly reduce postharvest losses (88.3 percent). Most respondents recognize the cost-effectiveness of solar drying compared to traditional methods (84.5 percent). The majority also believe that use of solar dryers to dry vegetables increase profit margins (89.6 percent).

7. Conclusion

Tomato and pepper are among the most widely produced and consumed vegetable products in Nigeria. The major production hub of these commodities in northern Nigeria includes Kano, Jigawa, Kaduna, Katsina, Sokoto, and Benue. However, these commodities suffer significant post-harvest losses. Based on the existing estimates, post-harvest losses of tomato throughout its value chain range between 45-60 percent of total production per annum. Similarly, losses of pepper along its value chain are estimated to range from 20-30 percent. These food losses are attributed to several factors including lack of infrastructures like storage facilities, modern drying technologies, cold chains logistics, and preservation technologies. A rapid needs assessment in several tomato growing communities in Kano show that drying of tomato and other horticulture products during the glut seasons was commonly undertaken using sun drying in open areas such as roadside, markets places, roof tops, and garden areas or farmlands exposed to sunshine. This open-air sun drying involves the use of energy from the sun to dehydrate crop products including fruits and vegetables widely used as a method of minimizing food losses. However, such a traditional open-air sun drying method is inefficient and exposes the products to impurities and foreign particles like dust. This traditional sun drying method is labor-intensive and takes longer drying time.

Solar drying technology offers significant advantages over conventional open-air drying methods, including faster drying times and improved hygiene, while better maintaining the nutritional content of the dried products. The effectiveness of solar dryers stems from their ability to circulate heated, low-humidity air across the produce, which enhances the water evaporation process. However, there has not been a rigorous evaluation on solar dryer technology in the context of tomato and pepper processing using a randomized controlled trial (RCT) in Nigeria. To evaluate the impacts of the solar drying technology, ten parabolic solar drying units were constructed in ten communities known for their tomato and pepper production and marketing in Kano state. Baseline data was collected prior to the installation of the technology. This report presents the synthesis of key descriptive findings from the baseline survey.
The key concluding findings from the baseline survey include:

(a) Value chain actors

About 92.5 percent of survey households reported they owned land, implying access to land may not be a major constraint to production in the study area. The production and drying of tomatoes and pepper are dominated by males. About 93 percent of survey households are male headed indicating the patriarchal nature of these value chains.

b) Production (Seasonality)

Tomato and pepper are two of the most widely cultivated vegetables in northern Nigeria. Overall, about 89 percent of survey respondents reported they cultivate tomatoes. Though these commodities are cultivated in both wet and dry seasons, most of their production (about 76 percent tomato and 57 percent pepper) takes place in the dry season. In terms of yield too, higher yield is obtained in dry season – tomato about 14 tons/ha in dry season compared to the 10.8 tons/ha in wet season.

(c) Cost structure of tomato and pepper production

Dry and wet season production exhibit significant differences in production costs. The cost build-ups analysis all other major production costs (cost of seeds, cost of hired labor, fertilizer cost (inorganic and organic) and costs on agrochemicals) are higher in dry season production than in wet a season.

(d) Drying tomato and pepper

Results show that currently over 90 percent of households use ground open-air sun drying method of drying for both tomato and pepper. The main dried products are tomato and pepper. A small proportion of farmers also produce tomato/pepper powder. About 84 and 76 percent of households reported they grade and sort before drying tomato and pepper, respectively. In terms of the cost structure of drying, the cost of labor and transport appear to be the dominant costs in traditional method of drying tomato and pepper in both the wet and dry seasons.

(e) Marketing of dried products

Based on the survey results, the dominant buyers of dried products were local off takers/traders and aggregators. About 87 percent of purchasers of dried tomato in the wet season and 92 percent in the dry season were off takers/traders/aggregators. Similarly, for peppers, 92 percent in the wet season and 94 percent in the dry season are off takers/traders/aggregators. This emphasizes the role of intermediaries in marketing dried vegetable products. Local consumers also play an important role in purchasing dried products. Others such hotels/restaurants, processing firms and supermarkets are not that significant. In terms of the major selling/marketplaces for dried products, wholesale market and open local retail markets are the dominant marketplace.

(f) Profit margin (return)

Drying tomato and pepper have been motivated by different underlying factors. While tomato drying is mainly motivated as a strategy to minimize post-harvest losses during glut period (surplus production); drying of pepper is motivated by high profit margin, because there is a better market for dried pepper and long shelf lives for dried pepper compared to dried tomato. Though drying of drying activity/business both commodities have a positive profit margin, drying practices in the dry season have higher economic return than wet season drying practice.

References

Agrofair,2018. AGRILOGISTICS – Nigeria Improving Inland Transport Modalities for Vegetables and Food Crops between Production Zones, Urban Conglomerations and Export Hubs, online http://documents1.worldbank.org/curated/ar/119621553491843031/pdf/Improving-Inland-Transport-Modalitiesfor-Vegetables-and-Food-Crops-between-Production-Zones-Urban-Conglomerations-and-Export-Hubs.pdf, p.137.

Ambuko, J., Karithi, E., Hutchinson, M., Wasilwa, L., Hansen, B., Owino, W., 2018. Postharvest shelf life of mango fruits stored in a Coolbot™ cold room. Acta Hortic. 193–198. https://doi.org/10.17660/ActaHortic.2018.1225.25.

Balana, B. B., Aghadi, C. N., & Ogunniyi, A. I. (2022). Improving livelihoods through postharvest loss management: evidence from Nigeria. Food security, 14(1), 249-265.

Behdani, B., Fan, Y., Bloemhof-Ruwaard, J., 2019. Cool chain and temperature-controlled transport: an overview of concepts, challenges, and technologies. Sustainable Food Supply Chains. Academic Press, London, pp. 167–183. https://doi. org/10.1016/b978-0-12-813411-5.00012-0.

CBI (2021). Food Loss in Nigeria Value Chain Analysis (VCA) of Tomato, Onion, Chilli value chains. Commissioned by The Centre for the Promotion of Imports from developing countries (CBI). https://www.cbi.eu/sites/default/files/market_information/researches/VCA%20Food%20Loss%20in%20Nigeria%202020.pdf

Chua, K.J., Chou, S.K., 2003. Low-cost drying methods for developing countries. Trends Food Sci. Technol. 14, 519–528. https://doi.org/10.1016/j.tifs.2003.07.003.

Devan, P., Bibin, C., Shabrin, I.A., Gokulnath, R., Karthick, D., 2020. Solar drying of fruits – a comprehensive review. Mater.: Proc. 33 (Part 1), 253–260. https://doi.org/ 10.1016/j.matpr.2020.04.041.

Dijkxhoorn, Y., J. Talabi, L. Eunice, 2021. Scoping study on fruits and vegetables; Results from Nigeria. Wageningen, Wageningen Economic Research, Report 2021-110. 68 pp.; 8 fig.; 13 tab.; 68 ref.

FAO, 2019. The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. Food and Agriculture Organization, Rome. http://www.fao. org/3/ca6030en/ca6030en.pdf

Fuller, R.J., 2010. Solar drying – A technology for sustainable agriculture and food production. Solar Energy Conversion and Photoenergy Systems 3, 1–24. Retrieved from: UNESCO - Encyclopedia Life Support Systems.

Haddad, L., Hawkes, C., Webb, P., Thomas, S.M., Beddington, J., Waage, J., Flynn, D.J., 2016. A new global research agenda for food. Nature 540 (7631), 30–32. https://doi. org/10.1038/540030a.

Jarman, A., Thompson, J., McGuire, E., Reid, M., Rubsam, S., Becker, K. and Mitcham, E., (2023). Postharvest technologies for small-scale farmers in low- and middle-income countries: A call to action. Postharvest Biology and Technology, 206 (112491), ISSN 0925-5214, https://doi.org/10.1016/j.postharvbio.2023.112491.

Kader, A.A., 2005. Increasing food availability by reducing postharvest losses of fresh produce. (https://postharvest.ucdavis.edu/Library/Publications/?uid=794&ds=807). Acta Hort. 682, 2169–2176. doi: 10.17660/ ActaHortic.2005.682.296.

Kitinoja, L., Kader, A.A., 2015. Measuring postharvest losses of fresh fruits and vegetables in developing countries. Postharvest Educ. Found. White Paper 15–02, 1–26. https://doi.org/10.13140/RG.2.1.3921.6402.

KÖr, B., Krawczyk, A., Wakkee, I., 2022. Addressing food loss and waste prevention. Br. Food J. 124 (8), 2434–2460. https://doi.org/10.1108/BFJ-05-2021-0571

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., Searchinger, T., 2013. Reducing food loss and waste. Working paper, installment 2 of creating a sustainable food future. World Resour. Inst., Retrieved World Resour. Inst.

Makule, E., Dimoso, N., Tassou, S.A., 2022. Precooling and cold storage methods for fruits and vegetables in sub-Saharan Africa—a review. Horticulturae 8 (776), 1–15. https://doi.org/10.3390/horticulturae8090776.

Olayemi F. F., Adegbola J. A., Bamishaiye E. I. and Daura A. M (2010), Assessment of post-harvest challenges of small-scale farm holders of tomatoes, bell and hot pepper in some local government areas of Kano State Nigeria, p.39.

Ortiz-Bobea, A., Ault, T.R., Carrillo, C., Chambers, R., Lobell, D.B., 2021. Anthropogenic climate change has slowed global agricultural productivity growth. Nat. Clim. Change 11 (4), 306–312. https://doi.org/10.1038/s41558-021-01000-1.

Parkhi, C.M., LSO Liverpool-Tasie, T. Reardon, M. Dolislager. Heterogeneous consumption patterns of fruits and vegetables in Nigeria: A panel data analysis. Policy Research Brief 2. Feed the Future Nigeria Agricultural Policy Activity. East Lansing: Michigan State University. July. https://www.canr.msu.edu/fsg/publications/Nigeria_Policy%20Brief_Fruits_Vegetable%20Consumption%2 01.pdf

Plaisier, C., Dijkxhoorn, Y., van Rijn, F., Bonnand, J. and Talabi, O. 2019. The vegetable and potato sector Nigeria: An overview of the present status. Wageningen, Wageningen Economic Research, Report, P.7

Rutta, E.W., 2022. Understanding barriers impeding the deployment of solar cold storage technologies for post-harvest tomato losses reduction: Insights from small-scale farmers in Tanzania. Front. Sustain. Food Syst. 6, 1–15. https://doi.org/ 10.3389/fsufs.2022.990528.

Schreinemachers, P., Simmons, E.B., Wopereis, M.C.S., 2018. Tapping the economic and nutritional power of vegetables. Glob. Food Sec. 16, 36–45. https://doi.org/ 10.1016/j.gfs.2017.09.005.

Sibomana, M. S., Workneh, T. S., & Audain, K. J. F. S. (2016). A review of postharvest handling and losses in the fresh tomato supply chain: a focus on Sub-Saharan Africa. Food Security, 8, 389-404. https://doi.org/10.1007/s12571-016-0562-1

Spang, E.S., Achmon, Y., Donis-Gonz´alez, I.R., Gosliner, W.A., Jablonski-Sheffield, M.P., Momin, M.A., Moreno, L.C., Pace, S.A., Quested, T.E., Winans, K.S., Tomich, T.P., 2019. Food loss and waste: measurement, drivers, and solutions. Ann. Rev. Envir. Res. 44 (13), 117–156. https://doi.org/10.1146/annurev-environ-101718-033228.

Stathers, T., Holcroft, D.M., Kitinoja, L., Mvumi, B.M., English, A., Omotilewa, O., Kocher, M., Ault, J., Torero, M., 2020. A scoping review of interventions for crop postharvest loss reduction in sub-Saharan Africa and South Asia. Nat. Sustain. 3 10, 821–835. https://doi.org/10.1038/s41893-020-00622-1.

Tafida I, AA Idris & ZA Abdullahi. (2019). Identification of agro-processing clusters for rice, wheat and tomato for APPEALS project in Kano state, Nigeria. Report submitted to Kano state agro-processing, productivity enhancement and livelihood improvement support (APPEALS) project. Kano, Nigeria.

Takeshima, H., Yamauchi, F., Balana, B., Adeyanju, D., Edeh, H., Kadjo, D., ... & Olanipekun, C. I. (2023). Innovations for inclusive and sustainable growth of domestic food value chains: Fruits and vegetables value chains in Nigeria scoping report. Intl Food Policy Res Inst.

Wageningen (2019) A Measurement tool on Food losses and Waste, online: https://edepot.wur.nl/470201, viewed in January 2021.

Yeshiwas, Y., Tadele, E., 2021. An Investigation into major causes for postharvest losses of horticultural crops and their handling practice in Debre Markos, North-Western Ethiopia. Adv. Agric. 2021 1–10. https://doi.org/10.1155/2021/1985303

Tables

Table 1: Production of Tomato and Pepper in Nigeria

Vegetable		2019	2020	2021	2022	2023
Tomatoes	Production (metric tons)	3103.0	3390.2	3478.0	3600.8	3803.6
	Yield (kg/ha)	3436.6	3948.3	3752.7	3609.8	3466.9
Chilies and peppers, green	Production (metric tons)	765.6	770.5	769.7	771.8	774.0
	Yield (kg/ha)	7452.9	7454	7451.6	7427.6	7403.6
Chilies and peppers, dry	Production (metric tons)	63.1	64.5	65.1	64.2	64.6
	Yield (kg/ha)	1731.9	1743.4	1754.1	1726.4	1731.1

Source: FAOSTAT, 2024

Table 2: Rotation based solar dryer use design (treatment group) *

Drying Cycles	G1		G2		G3		G4		G5		G6		G7		G8	
Drying Cycle - 1	G1_C1															
Drying Cycle - 2		G1_C2														
Drying Cycle - 3			G2_C3													
Drying Cycle - 4				G2_C4												
Drying Cycle - 5					G3_C5											
Drying Cycle - 6						G3_C6										
Drying Cycle - 7							G4_C7									
Drying Cycle - 8								G4_C8								
Drying Cycle - 9									G5_C9							
Drying Cycle - 10										G5_C10						
Drying Cycle - 11											G6_C11					
Drying Cycle - 12												G6_C12				
Drying Cycle - 13													G7_C13			
Drying Cycle - 14														G7_C14		
Drying Cycle - 15															G8_C15	
Drying Cycle - 16																G8_C16

*Note: G1, …,, G8 = the eight groups (each with 5 users) for each of the solar dryer unit. A total of 40 users (treatment households) per community (i.e., per drying will use the C1,…, C16 = Drying cycles until the end of the RCT experiment (each group uses two-drying cycles).

Table 3: Distribution of sample communities and sample size

LGAs	Communities	Number sampled
Bagwai LGA	Bagwai	100
	Kiyawa	92
Tsanyawa	Dan Isa	99
	Dumbulum	100
Makoda	Baban Ruga	93
	Laberiya	100
Danbatta	Gawon Bature	98
Wudil	Lajawa	100
Gaya	Gaya Balan	94
	Gaya Boda	96
Total		973

Source: 2024 Baseline Survey, IFPRI and WVC

Table 1. Key Characteristics of Sample Respondents (n=973)

Variable	Mean	Std. Dev.	Min	Max
Sex of household head				
Male	0.936	0.244	0	1
Female	0.063	0.243	0	1
Age of household head (years)	42.228	12.288	18	85
Marital status				
Married (0/1)	0.945	0.229	0	1
Never married (0/1)	0.035	0.184	0	1
Divorced/Separated/Widowed (0/1)	0.02	0.138	0	1
Household size (average, #)	11.725	6.715	1	27
Economic active household members (average, #)	4.059	3.099	1	30
Educational attainment				
Household members who completed at least primary school (#)	4.37	3.48	1	24
Head, No formal education (%)	0.261	0.439	0	1
Head, Incomplete primary (%)	0.051	0.221	0	1
Head, Completed primary (%)	0.189	0.392	0	1
Head, Incomplete secondary (%)	0.051	0.221	0	1
Head, Completed secondary (%)	0.217	0.412	0	1
Head, Tertiary education (%)	0.218	0.413	0	1
Occupation				
Agriculture (crop farming) (%)	0.935	0.246	0	1
Agriculture (livestock) (%)	0.006	0.078	0	1
Agriculture (processing/marketing) (%)	0.012	0.11	0	1
Casual (%)	0.007	0.085	0	1
Non- agriculture sectors (%)	0.016	0.127	0	1
Wage/salary employee (%)	0.017	0.131	0	1
Engage in off-farm activity (%)	0.679	0.467	0	1

Source: 2024 Baseline Survey, IFPRI & WVC

Table 2. Land characteristics

Variable	Obs	Mean	Std. Dev.	Min	Max
Own land *(0/1)*	973	0.925	0.264	0	1
Farm size (ha)	899	3.171	2.417	0.4	10
Soil fertility					
Good soil (0/1)	973	0.923	0.267	0	1
Fair soil (0/1	973	0.075	0.264	0	1
Poor soil (0/1)	973	0.001	0.032	0	1
Land tenure arrangement					
Rented (0/1)	973	0.049	0.217	0	1
Family (0/1)	973	0.021	0.142	0	1
Government (0/1)	973	0.002	0.045	0	1
Grow tomato *(0/1)*	973	0.885	0.319	0	1
Grow pepper *(0/1)*	973	0.725	0.447	0	1
Amount paid for rented land in wet season *(Naira)*	51	73627	61431	5000	240000
Grow vegetables other than tomato and pepper in wet season *(0/1)*	973	0.462	0.499	0	1
Grow vegetables other than tomato and pepper in dry season *(0/1)*	973	0.56	0.497	0	1
Source: 2024 Baseline Survey, IFPRI & WVC					

Table 3. Tomato production

Variable	Wet			Dry		
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Household cultivate tomato	973	0.336	0.473	973	0.765	0.424
Years of tomato production	327	12.642	8.785	743	12.051	8.757
Area of land under tomato cultivation	326	1.325	0.992	743	1.197	0.755
Use of family labor	973	0.261	0.439	973	0.563	.496
Practice intercropping	327	0.679	0.468	744	0.763	0.425
Quantity of harvest (kg)	327	10023.624	10817.541	743	11067.225	14621.089
Yield (Kg/ha)	326	10757.24	14067.16	742	13912.46	40654.9

Source: 2024 Baseline Survey, IFPRI & WVC

Table 4. Tomato varieties cultivated

Variety cultivated	Wet season		Dry season	
Tomato	Frequency	Percentage	Frequency	Percentage
Hybrids	17	5.21	87	11.71
Local (*'Denega'*)	3	0.92	9	1.21
Local (Roma)	108	33.13	35	4.71
Local (UTCs)	189	57.98	561	75.50
Others (OPVs branded or replanted)	9	2.76	51	6.86
Total	**326**	**100.0**	**743**	**100.0**

Source: 2024 Baseline Survey, Kano/Nigeria

Table 5. Summary statistics of pepper production

Variable	Wet season			Dry season		
	Obs	**Mean**	**Std. Dev.**	**Obs**	**Mean**	**Std. Dev.**
Household cultivate pepper *(0/1)*	973	0.229	0.421	973	0.567	0.496
Experience in pepper production *(years)*	223	10.242	8.021	552	11.268	8.606
Area of land under pepper cultivation *(ha)*	223	1.189	0.965	552	1.166	0.817
Use of family labor *(0/1)*	973	0.169	0.375	973	0.421	0.494
Practice intercropping *(0/1)*	223	0.646	0.479	552	0.694	0.461
Quantity of harvest *(kg)*	223	3503	4147	550	6898	8567
Yield *(Kg/ha)*	223	4048	4885	550	7277	11174

Source: 2024 Baseline Survey, IFPRI & WVC

Table 6. Pepper varieties cultivated

	Wet season		Dry season	
Variety	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Hybrid pepper	4	1.79	13	2.36
Local (Chili)	89	39.91	115	20.87
Local (Habanero/Atarudu)	16	7.17	25	4.54
Local (Sweet pepper/Tatase/Bawa	114	51.12	398	72.23
Total	**223**	**100.00**	**551**	**100**

Source: 2024 Baseline Survey, Kano/Nigeria

Table 7. Key characteristics of current drying practices

	Tomato		Pepper	
	Wet season	**Dry season**	**Wet season**	**Dry season**
Household engage in drying activity *(%)*	66.2	56.9	47.1	54.2
Quantity of fresh materials used for drying *(kg)*	4060.096	2994.94	2699.87	4904.937
Quantity of dried products per season *(kg)*	1365.049	900.2	1869.59	2304.684
Technology used for drying				
Ground sun drying (%)	92.3	97.8	82.4	98.5
Roof sun drying (%)	6.7	2.2	16.2	1.5
Main dried products				
Dried tomato/pepper (0/1	99.0	97.8	96.0	94.2
Tomato/pepper powder (0/1)	0.96	1.9	4.1	5.6
Experience in in drying vegetables *(years)*	9.5	9.3	9.27	10.3
Drying cycle: Rounds per cycle *(per season)*	6.1	5.4	5.2	5.5
Length of drying using the current mode of drying (days)	9.7	10.1	10.2	9.0
Grading and sorting before drying (0/1)	87 (83.7)		56 (75.7)	
Who does the drying activity?				
Adult men (family) (%)	46.53	46.96	50.0	47.58
Adult women (family) (%)	14.85	11.44	9.5	10.43
Children (family) (%)	5.94	10.95	6.8	8.40
Hired labor (%)	32.67	30.66	33.8	33.59

Source: 2024 Baseline Survey, Kano/Nigeria

Table 8. Main marketing channels (buyers and marketplaces) of dried products

Main buyers (%)	Wet season	Dry season	Wet season	Dry season
	(Tomato)		(Pepper)	
Local consumers	52.4	47.5	51.4	49.1
Off-takers/traders/aggregators	87.4	91.6	91.9	93.9
Hotels/restaurants	1.0	0.48	1.4	0.25
Processing firms	0	0.96	1.4	2.78
Supermarkets	1.0	-	-	-
Major marketplace (%)				
Collection/aggregators market center for processors	5.83	11.57	8.11	11.68
Farmgate	9.71	6.51	6.76	5.84
Open local retail market	33.01	33.73	39.19	31.47
Wholesaler/Wholesale market	50.49	46.99	45.95	49.75

Source: 2024 Baseline Survey, IFPRI & WVC

Table 9. Respondents' awareness and knowledge about solar drying technology

	Obs	Mean	Std. Dev.
Heard about solar dryer	965	0.741	0.438
Interested in using solar dryer technology	965	0.98	0.139
Perception on qualities of solar-dried vegetables			
Better taste	963	0.573	0.495
Better color	963	0.567	0.496
Better aroma	963	0.305	0.461
Better product texture/hardness	963	0.514	0.5
Prolonged shelf life	963	0.447	0.497
Increased consumer acceptability	963	0.431	0.495
Major barriers to adoption of solar dryer technology			
Cost of technology	929	0.592	0.492
Lack of knowledge on use	929	0.668	0.471
Lack of knowledge on maintenance	929	0.435	0.496
Perceived benefits of solar dryer			
Minimize postharvest loss	963	0.883	0.322
Solar dryer adoption reduces cost of drying	966	0.845	0.362
Solar dryer adoption technology increase profit margin	967	0.896	0.306

Source: 2024 Baseline Survey, IFPRI & WVC

Futoshi Yamauchi, International Food Policy Research Institute, f.yamauchi@cgiar.org

Yanyan Liu, International Food Policy Research Institute, y.liu@cgiar.org

Bedru Balana, International Food Policy Research Institute, b.balana@cgiar.org

Olufemi Popoola, International Food Policy Research Institute, olufemi.popoola@cgiar.org

Caleb Olanipekun, World Vegetable Center, caleb.olanipekun@worldveg.org

Edmond Totin, World Vegetable Center, edmond.totin@worldveg.org

Kamaldeen Oladimeji Salaudeen, Nigerian Stored Products Research Institute, ksk_deen@yahoo.com

Aminu Muhammad, Nigerian Stored Products Research Institute, aminumuhammad76@yahoo.com

Weilun Shi, International Food Policy Research Institute, weilun.shi@cgiar.org

CGIAR is a global research partnership for a food-secure future. CGIAR science is dedicated to transforming food, land, and water systems in a climate crisis. Its research is carried out by 13 CGIAR Centers/Alliances in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations and the private sector. www.cgiar.org

We would like to thank all funders who support this research through their contributions to the CGIAR Trust Fund: www.cgiar.org/funders.

To learn more about this Initiative, please visit this webpage.

To learn more about this and other Initiatives in the CGIAR Research Portfolio, please visit www.cgiar.org/cgiar-portfolio

INITIATIVE ON Rethinking Food Markets

Futoshi Yamauchi, International Food Policy Research Institute, f.yamauchi@cgiar.org

Yanyan Liu, International Food Policy Research Institute, y.liu@cgiar.org

Bedru Balana, International Food Policy Research Institute, b.balana@cgiar.org

Olufemi Popoola, International Food Policy Research Institute, olufemi.popoola@cgiar.org

Caleb Olanipekun, World Vegetable Center, caleb.olanipekun@worldveg.org

Edmond Totin, World Vegetable Center, edmond.totin@worldveg.org

Kamaldeen Oladimeji Salaudeen, Nigerian Stored Products Research Institute, ksk_deen@yahoo.com

Aminu Muhammad, Nigerian Stored Products Research Institute, aminumuhammad76@yahoo.com

Weilun Shi, International Food Policy Research Institute, weilun.shi@cgiar.org

We would like to thank all funders who support this research through their contributions to the CGIAR Trust Fund: www.cgiar.org/funders.

To learn more about this Initiative, please visit this webpage.

To learn more about this and other Initiatives in the CGIAR Research Portfolio, please visit www.cgiar.org/cgiar-portfolio

CGIAR

INITIATIVE ON
Rethinking
Food Markets