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Innovations for inclusive and sustainable growth of domestic food value chains

Fruits & Vegetables Value Chains in Nigeria

Scoping Report

Hiroyuki Takeshima, Futoshi Yamauchi, Bedru Balana, Dolapo Adeyanju, Hyacinth O. Edeh (IFPRI)

Didier Kadjo, Saweda Liverpool-Tasie, Tahirou Abdoulaye (IITA)

Rosaine Nerice Yegbemey, Mathieu Ayenan, Caleb I. Olanipekun (World Vegetable Center)

Executive Summary

Fruits & vegetable value chains (F&V VC) in Nigeria hold significant potential to continue toward sustainable, inclusive food system transformation. Domestic food system growth, including that of F&V, remains crucial in achieving a healthy food environment and serving as a source of various micronutrients. There is a need for bundles of innovations to address multiple challenges along F&V VC in Nigeria, characterized by a set of challenges that are unique to developing countries and F&V.

V&F VC consists of many small actors, farmers, and traders, whereby limited vertical coordination can lead to significant efficiency loss along the value chain. Seasonal and temporal variations in supply-demand gaps for F&V commodities are substantial, and considerable scope exists for reducing losses and enhancing the overall efficiency of the domestic F&V sector. Policy environments are also favorable for such efforts, as the latest Agricultural Policy documents highlight the Nigerian government's interest in modernizing F&V VC. Given the significant involvement of women and youths in the sector, F&V VC development has substantial potential to contribute to Nigeria's inclusive development of agri-food systems.

The current domestic F&V VC in Nigeria suffers from various sets of problems. Access to quality seeds is limited due to the significant use of recycled seeds, limited supply, and high costs of certified seeds. Cooling practices are inefficient due to insufficient access to the grid and off-grid electricity, limited knowledge of intermediate cooling methods applicable at the farm gate, and constraining quality preservations at farm gate storage, during transportation, and storage at market premises. Processing is insufficient due to the high costs of processing equipment and limited knowledge of the construction and operation of simpler, less resource-dependent processing facilities, including drying of F&V commodities. Inappropriate packing, such as the use of Rafia baskets instead of Reusable Plastic Crates, which are commonly recognized, is still prevalent, potentially due to limited market coordination.

Based on the stakeholder consultations, desk reviews, validation workshops, and availability of external resources, we identified the following as critical interventions to pilot various innovation bundles. **Intervention #1** provides improved varieties and quality seeds, combined with agronomy training and certification, in northern Nigeria through the collaboration with East West Seeds and Wageningen University & Research. **Intervention #2** provides off-grid cooling and cool transportation, including forced-air evaporative cooling units at farm clusters and the combination of small and large refrigerated trucks for local and longer-distance transportation, through the collaboration with ColdHubs and MIT-Lab. **Intervention #3** introduces improved solar dryers and provides training on appropriate, hygienic processing methods, building, and utilization of these driers (possibly combined with the introduction of a business model), through the collaboration with World Vegetable Center and Nigerian Stored Products Research Institute. **Intervention #4** provides plastic crates using various rental arrangements and improves market access for farmers through collaboration with private companies, including Bunkasa. **Intervention #5** supplements interventions #1, #2, and #3 and provides improved information through certification and labeling. Lastly, **Intervention #6** strengthens linkages between existing solar powered cold storages to supplement other interventions.

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1. INTRODUCTION

Fruits & vegetable value chains (F&V VC) in Nigeria hold significant potential to continue toward sustainable, inclusive food system transformation. Domestic food system growth, including that of F&V, remains crucial in achieving a healthy food environment and serving as a source of various micronutrients (Schreinemachers et al., 2018; Fan et al., 2019). Domestic VC continues to play important roles, especially in the face of global market uncertainty due to economic (rising fuel transport costs), environmental (climate change in major exporting countries), and political risks. F&V in developing countries like Nigeria also constitute one of the commodity groups that suffer from and hold significant reduction potentials for food loss & waste (FLW) (IFPRI 2016; FAO 2019). Development of F&V VC, which tends to be land and labor-intensive, can also remain an important source of income and livelihood for smallholders who account for the bulk of the poor in Nigeria. Relative to cereals, horticulture can increase the returns on the land about 10-fold and potentially increase employment in processing, marketing, and packaging (Weinberger & Lumpkin, 2007; World Bank, 2008, p.58). Significant production/demand gap growth is also expected for F&V in West Africa, including Nigeria, in the next few decades (Zhou & Staatz 2016) as urbanization continues to intensify (AGRA 2020). Within West Africa, Nigeria holds one of the largest potentials for domestic VC development, given the dominant size of its domestic market.

There is a need for bundles of innovations to address multiple challenges along F&V VC in Nigeria, which is characterized by a set of challenges due that are unique to developing countries and F&V. Similar to non-F&V sectors, F&V VC in Nigeria consists of a large number of small, atomistic agents, ranging from upstream seed sellers, producers, marketers, and small-scale processors. Various market failures, including markets for inputs and outputs, credit and insurance, and information, can prevent optimal investments that can otherwise contribute to VC-wide efficiency improvements. These challenges are multiplied by the unique characteristics of F&V commodities, including perishability, seasonality, high seed costs, production management/care needs, and susceptibility to post-harvest handling practices.

Objectives and methods

The following objectives and methods guide this scoping report. First, it provides key context behind F&V VC in Nigeria, including market structures and relevant policy environments. The report builds on several recent studies conducted regarding Nigerian F&V VC (e.g., Plaisier et al. 2019; Dijkxhoorn et al. 2021, 2022; Rockefeller Foundation 2021; van den Broek et al. 2021; USAID 2022) by supplementing them through nationally representative information, constructed from nationwide household surveys like the LSMS-ISA data (NBS-World Bank 2019).

It then describes a key set of persistent and urgent problems in Nigeria F&V VC, background evidence for and the prevalence of these problems, and past and current support programs and policies implemented in the country. Findings through dialogues with various local stakeholders from several stakeholder consultations (SC) meetings are combined with insights from literature reviews focusing on experiences in Nigeria and other African countries where applicable.

The report will then describe the proposed pilot interventions of innovation bundles. For each intervention, it lays out expected benefits, potential complementarity with other innovation bundles, and costs of interventions while also considering inclusivity, sustainability, and scalability aspects.

2. KEY CHARACTERISTICS OF F&V VALUE CHAIN IN NIGERIA

This project focuses on a particular set of commodities within the broader class of fruits and vegetable commodities.

In particular, we **focus on tomato, mango, and orange** as priority commodities, although many of the interventions proposed can apply to a broader range of V&F commodities. Tomato and oranges are selected because, as described in later sections, these are two key F&V commodities highlighted in the Nigerian government's latest agricultural policy.

In addition to orange, we also select mango as a focus commodity. Mango is one of the key fruit commodities grown in Nigeria in terms of production quantity, and only a few commodities, like pineapple, exceed mango (FAO 2022). In addition, mango is a more smallholder-oriented commodity, with about 2/3 of producers operating as smallholders outside the orchard system, unlike pineapples, for which about half of the producers operate as orchard producers (Figure 2).

We excluded bananas and plantains because CGIAR has dedicated programs for Root, Tuber, and Banana (RTB), where bananas and plantains are covered more in-depth.

2.1. On-farm production and key inputs use of F&V commodities

In Nigeria, F&V commodities, including tomato, mango, and orange, are produced by smallholders. In 2018, the median production figures among producers during the rainy season were 140kg (₦20,000 in value) for tomato, 323kg (₦45,000) for onions, 87kg (₦22,000) for pepper, 17kg (₦2,500) for okra, 66kg (₦1,500) for mango, 220kg (₦5,000) for orange (based on LSMS-ISA data 2018). Most producers grow these commodities alongside other staples rather than specializing in them.

Seed

Figure 4 summarizes the shares of improved seeds used and the shares of seed by sources for four major vegetables (okra, onion, pepper, and tomato). The following patterns stand out:

- The use of improved seeds (based on farmers' perceptions) was still low in 2015-2018; less than 20% of growers of each vegetable used improved seeds.

- The use of recycled seeds was still common and accounted for more than half of the seeds for these commodities. The shares were especially higher for okra and pepper (more than 70%)
- About 40% of tomato and onion growers and lower shares of pepper and okra growers used seeds purchased from local markets within the town/village. About 23% and 13% of onion and tomato growers used seeds purchased from markets outside their towns.

Agrochemicals

Use of agrochemicals is somewhat common (Figure 6):

- 30 – 40% of tomato, pepper, and onion producers and about 20% of okra producers apply herbicides and/or pesticides to these crops
- On average (including non-users), the application intensity of agrochemicals for these crops is approximately 4 ~ 6 liter/ha of herbicides and 2 ~ 8 liter/ha of pesticides

Irrigation

Significant shares of vegetable production are under rainfed conditions (Figure 5), and the use of irrigation is relatively less common:

- Approximately ¼ of tomato and pepper, 10% of onion, and 2% of okra produced are from irrigated plots
- In terms of the shares of growers using irrigation, approximately 2 ~ 15% of these crops
- Use of irrigation is negligible for fruits (orange, mango, pawpaw) (not shown)

2.2. Harvesting

Production and harvesting of F&V commodities are characterized by significant variations across regions in seasons. Figure 3 shows nationally and regionally representative figures of the seasonality of harvesting. While these figures should be interpreted cautiously given the small sample sizes, key insights emerge. First, there is significant seasonality at the national level. For all regions, most harvesting of major F&V commodities is in June – December, except mango, for which the peak is mostly January - July. Therefore, the scope is enormous for smoothing the supply seasonality of F&V commodities through improved post-harvest handling and processing. Second, some variations across regions in peak season timing create scope for intra-regional commodity movements in varying directions over time. Specifically, (a) Northern zones (North-West and North-East zones) have greater harvests than the Central/South region during September – December; (b) Southern zones (South-East, South-South, and South-West) have greater harvests than North/Central during Jan - May/June (though marginal); and (c) Cen-

tral zone (North-Central zone) has greater harvests than Northern zones or Southern zones during July – September.

Harvesting practices

Horticulture products are commonly harvested manually.

Tomatoes are generally harvested through hand-picking, the most common method. Farmers selectively pluck ripe tomatoes in buckets to prevent damage.

Mangoes are harvested through several methods (Balana et al. 2022b). In some cases, a basket is attached to a long stick to which fruits are plucked manually from the tree, which is a selective harvesting method (only ripe fruits are harvested) that prevents fruit damage (no damage at all). Sometimes, suspended polythene is used, whereby someone climbs the tree to either pluck with a stick or shake the mango tree for the fruits to fall, while 4-5 people hold a polythene bag to receive the fruits. This method prevents fruit damage (little damage). However, the fruits require sorting (e.g., ripe from unripe). A more sophisticated and costly approach involves using foams (soft, light, and naked foams) which are spread under the trees while someone climbs up to pluck the fruits. Foams may not always be durable and reusable if mangoes are too heavy. Rice straws are used instead of more expensive foams as a cheaper and more viable option. However, packing straw pre- and post-harvest can be labor-intensive. Sometimes, farmers dig holes around the mango trees, which softens the soil and prevents fruit damage.

Orange fruits are allowed to fall directly on the ground, unlike mango, which is very sensitive to damage. Therefore, more oranges are harvested through the tree-shaking method or using a stick for plucking, which is more time-consuming than the tree-shaking method. Some harvesters, however, also hand-pick oranges from trees.

2.3. Postharvest handling, domestic marketing, processing and consumption

Post-harvest handling practices

Cleaning/Drying/Pest control

Cleaning of fruits is relatively rare. For mangoes, relatively few growers clean the fruits to reduce handling, prevent quick ripening, and increase shelf life. This is because, from the marketers and aggregators' point of view, cleaning/washing mangoes often hasten ripening. However, one may clean selectively with clothes/rags.

Pest control for mangoes varies depending on the varieties. For instance, while some varieties, like Broky, last longer and don't get infested, others must be treated before fruiting. However, spraying chemicals is often considered detrimental to fruit poisoning. While polythene bags are

sometimes used to cover the fruits before spraying them with chemicals, this is also considered inadvisable. Developing pest-free varieties should be considered an important alternative. Another alternative is to use an insect pest trap. The traps introduced by ECOWAS and the EU have been relatively widely adopted.

Drying mangoes is relatively rare. In some cases, cabinet dryers (a propane gas heater is attached to the sides of the dryer to generate heat) are used. However, introducing locally fabricated dryers or solar power to solve power issues is considered important.

Storage practices (On-farm storage)

Tomatoes are often stored under shady trees. Fresh tomatoes are aggregated under trees to prevent exposure to harsh sunlight. The products can often be piled under the three for up to three days. Tomatoes are sometimes stored in buckets and baskets and kept under shades. Usually, crop residues/straws are placed underneath to minimize damage due to rough ground surface.

Mangoes are typically stored under shady trees as well. This involves aggregating the fruits under a tree to prevent harsh sunlight. In some cases, mangoes are also stored in mud houses with thatched roofs built on the farm. Storage rooms are sometimes built on the farm, which contains wooden shelves with well-organized racks that house the fruits. For protection, the fruits are covered with dry grasses to reduce exposure to sunlight. This method hastens ripening, reduces spoilage, and increases the shelf life of the fruits. Processers also store mangoes in chillers, which increases the rate of ripening, reduces spoilage, and increases the shelf life of the fruits.

Transportation and packing

Tomatoes are often transported by trucks, cars, motorcycles, wheelbarrows, and donkeys. The choice of transport modes depends on the distance to the market destination and the volume of commodities. They are typically packed in Raffia baskets, traditional wooden baskets, and in some cases, reusable plastic crates (RPC).

Mangoes are transported mainly by sedans like small Toyota Corolla (most common), Hilux, and occasionally cooling vans. Fruits are packed in ventilated baskets laced and covered with dry leaves. These baskets are kept in chambers, demarcated with long planks to prevent damage. Knitted grasses are laid on the floor and sides of the transportation van to avoid fruit damage. Some use local logistics arrangements (bus drivers) to send the products to buyers in other states (Balana et al. 2022b).

Similarly, oranges are typically packed in sacks, perforated cartons, 29x4 nylon bags, and Raffia baskets during transportation.

Market storage

Market storages also remain primitive. Tomatoes and onions are often stored in sheds and kept in rice stalks, corn stalks, and open spaces (Balana et al. 2022b). Similarly, mangoes and oranges are commonly stored in open spaces, packed in baskets, or in heaps between layers of sacs or mats to prevent fruits from direct sunlight.

Marketing

Horticulture commodities are typically sold through agents at farm gates, sold as fresh products in market outlets, marketed through brokers, and sold to retail agents, hotels, and restaurants. They are also often transported to other markets outside the state. For example, tomato marketers in Kano transport products to out-of-state locations such as Lagos, Ibadan, Abuja, and Port Harcourt. Some sell tomatoes to off-takers such as Dangote, and Tomato Jos. Some sellers, such as mango traders, market their products via social media (SM) platforms (Facebook and WhatsApp) and referrals (Balana et al. 2022b).

Sorting, grading, and labelling

Tomato and fruit producers and fresh tomato/ fruits marketers often sort and grade their produce based on the freshness and size of commodities. Large-scale and medium-scale processors label and brand their products. Some small-scale processors label their products using markers/pens, although they rarely brand them (Balana et al. 2022b).

Processing

Horticulture commodities are processed in various forms. Tomatoes are often dried through sun and open-air drying. They are also wet-processed into paste, puree, sauce, and juice: This is done manually or with automated machines. Mangoes, especially those with high fiber, are sometimes processed into flakes and chips. Tomato and orange are also processed into powders.

A few larger processors, like Tomato Jos and Dangote tomato paste factory, carry out more modern processing. Processing rates for these larger processors can be around a few tons/hour (Tomato Jos) and as high as 600 ~ 1200 tons/day for Dangote (Tafida et al. 2019).

Mango and orange are also processed into juice through a fabricated multi-purpose diesel blender and an electric fruit blender. However, such processing methods do not always have standard health safety protocols (Balana et al. 2022b). Juices are often packaged in used water bottles (e.g., 75cl Eva water bottles) and stored in a chiller. The fruit juice can stay for up to 5 days with constant electricity for the chiller. Otherwise, it must be consumed within 2 days. Some processors prepare fresh juice for immediate consumption (wait and get) or distribute it door-to-door.

Consumption

Nigeria is one of the largest consumers of fruits and vegetables in Africa South of Sahara (SSA), not only in terms of aggregate but also in terms of per capita and calorie equivalent (Figure 9). According to FAOSTAT (FAO 2022), per capita calorie consumption of tomatoes, vegetables, and fruits (excluding bananas and plantains) in 2019 was 10, 49, and 34, respectively, in Nigeria, which was generally higher than figures for other parts of SSA.

Consumptions of F&V also vary considerably across regions and seasons, based on more disaggregated figures from LSMS-ISA data (Figure 10). Average per capita consumption per week is around 200g for tomato, onion, 100g for okra (fresh), pepper (fresh), orange, 50g for watermelon, and a lower amount for other primary vegetables and fruits. Consumption is significantly greater in the South for tomato, pepper (fresh), orange, mango, and pawpaw, while greater in the North for onion, okra (fresh and dried), and watermelon. Consumption also varies between August – October and February – March. Generally, consumption is greater in February-March for tomato (except South-South), okra (dried), orange, mango, pawpaw, and August-October for onion, fresh okra (except South-East), pepper (dried).

Characteristics of service providers

Various entities, including private companies, associations, and household enterprises, engage in service provisions along the F&V VC in Nigeria.

Household enterprises

Many household-based enterprises engage in F&V VC activities in Nigeria, especially in F&V retail/wholesale (Figure 7). In 2012 and 2015, when information was available from LSMS-ISA data, these enterprises accounted for at least 4% of households (3% in retail/wholesale and 1% in personal service) nationally, equivalent to approximately 1.2 million households.

These household enterprises in F&V retail/wholesale have been mostly small-scale (Figure 8). Typically they employ 1 worker, as well as 1.6 unpaid workers, have business capital of $100, stock of raw commodities of $15 on an average month, and monthly sales revenue of around $1,000 / month. These enterprises typically operate for 4-6 months/year, though some operate for 12 months. These figures are comparable to other studies in other African countries, including tomato trading in Ghana (Haruna et al. 2012) and mango trading in Malawi (Nyirenda et al. 2019 Table 2).

Private companies

More specialized private companies engage in the provision of various types of services. For example, Bunkasa Agritech Limited, established in 2017 as a subsidiary of the Mile-12 International market in Lagos (the largest agricultural commodities off-taker with a supply chain to 300 smaller markets in Nigeria and West Africa sub-region states), has partnered with the West African Association of agricultural traders. It has provided actors along the tomato and other com-

modity value chains with price, market information, and rental services for their trademarked Reusable plastic crates (RPCs) (Balana et al. 2022b). The company uses PRCs to provide standardized weighting services and quality control (food safety) of products. The company also takes responsibility for crate handling, transporting, product delivery, and crate handling risks. They have market agents who take care of the crates from when they get to the market and ensure they are safely returned to the warehouse.

One tomato processing company in Kano, producing homemade condiments for personal use, received a 7 million Naira seed grant in 2014 under the Federal Government of Nigeria (FGN) You-Win program and started tomato processing in 2016 with locally fabricated machines. After facing the challenge of low processing efficiency, the company owner traveled to China in 2016 and sourced improved small processing machines manufactured based on her specifications. The company now sources fresh tomatoes from the open Yankaba Market in Kano and directly from farmers through trust-based agreements (instead of formal contractual agreements) with specific producers whose products she buys before harvest. The final products (tomato paste, sauce, and puree) are sold to supermarkets, restaurants, hotels, higher institutions of learning, wholesalers, retailers, and final consumers who buy in bulk both within and outside Kano. The products are well-packaged and labeled. Marketing materials are sourced both locally and internationally from China.

Traders

Trader associations provide various support services as well. For example, the tomato traders' association in Kano, which currently has 2500 members across the country, helps members market/sell their produce, provides both technical and financial support, and facilitates access to credit to help them trade and transport their tomatoes to markets. The associations also serve as entry points for donors to provide supporting projects. For example, the tomato traders' associations facilitated the rental of Plastic Crates distributed by the World Bank under the 'APPEALS' project in 2019 (Balana et al. 2022b).

2.4. Overall loss and waste along F&V VC in Nigeria

Food loss is an important issue in vegetable VCs. In Sub-Saharan Africa, about one-third of the food produced is lost at the production stage and between the postharvest – processing – retail stage, respectively (CBI - MOFA, 2021). Table 1 and Table 2 summarize the reported loss rates for key vegetables and fruits in Nigeria. Overall, estimated shares of losses at the post-harvest stage can be as much as 50% or more for tomato and onion and 10-20% for peppers and okra, occurring at storage, processing, and collection/transport stages. Similarly, sometimes more than 50% of mango, watermelon, and around 10% of orange can be lost during the marketing stage.

Table 1. Estimated food loss along the vegetable VCs

Crops	Production	Transportation	Marketing
Tomato	13 ~ 60%	34 ~ 50% for baskets	5 ~ 23%

		50% and 46% of the total damage occurred at the bottom and topmost layers in trucks About 5% for plastic crate	
Pepper		Bell pepper 15% and hot pepper 10%	
Okra	20%-40%	Transportation and packaging 11-20%	
Onion	About 50%		

Source: World Vegetable Center (2022).

Table 2. Estimated food loss along the fruit VCs

Crops	Production	Markets
Mango	32%	75%
Orange	6-26%	6-10% for Wholesalers and <5% for retailers
Papaya	31%	
Watermelon	40 ~ 60%	40 ~ 60%

Source: World Vegetable Center (2022).

2.5. Gender and inclusion

F&V VC in Nigeria provides significant employment and income to women and youths. This is demonstrated in Figure 12, which shows the employment in the off-farm V&F sector, excluding on-farm, by gender and age groups. These figures are based on people who explicitly mentioned the names of key vegetables/fruits in their off-farm labor activities in 2012 when data were available in LSMS. These figures might be greater in 2022, given the population growth since 2012).

According to Figure 11, at least about 900,000 workers were engaged in the off-farm V&F sector in the post-planting season (Aug-Oct) and the post-harvest season (Feb-March). Among them, women constituted about 2/3 of all workers. In the South, women account for a large share (about 80%); in the north, shares are somewhat smaller, but still, approximately 100,000 – 150,000 women work in the off-farm V&F sector. Among youths (15-34 years old), women constitute a greater share (80% or more). Youths (15-34 years old) account for 15 ~ 20% of all workers engaged.

3. POLICY ENVIRONMENT AND PROGRAMS

The development of F&V VC and its inclusivity have been highlighted as key focus areas in various policies.

Policies for developing F&V VC

National Agricultural Technology and Innovation Policy (NATIP) (FMARD 2021) is the latest agricultural policy in Nigeria and is built around 10 intervention pillars. One of the pillars includes "**vii. Strengthening Value-Chains for Priority Crops"**, which focuses on the value-chain development of maize, sorghum, rice, wheat, cassava, sesame, and tomatoes (p.4). In particular, the pillar emphasizes strengthening the processing sector, including establishing over 100 processing centers in rural communities across the country under the Green Imperatives Plan. Furthermore, the pillar promotes the development of clusters, rural nodal centers, rural cottage industries, and the establishment of at least six Special Agro-industrial Processing Zones

(SAPZs). Through these supports, the government aims to assist in linking the agricultural sector with the industrial/processing sector, thereby boosting industrialization and creating at least 1 million jobs in the country (FMARD 2021).

NATIP also emphasizes other specific areas of support related to F&V VC:

- ***Programs that promote Crop Value Chains and Food Systems***, including the support for states in promoting high-valued vegetables and tree crops
- ***Strengthening Value-Chains for Priority Crops***, through the focused deployment of knowledge, technology, and capital. In particular, NATIP develops 20 value chains, including tomatoes and oranges, together with other key staples and commercial crops.
- ***Promoting Digital and Climate SMART Agriculture***, including their applications to greenhouse crops and vegetable production

Policies for promoting gender-sensitive and inclusive F&V VC

NATIP, as well as Nigeria's Gender Policy (FMARD 2019), also highlights the Nigerian government's interest in promoting gender neutrality and inclusivity in horticulture value chains. NATIP (FMARD 2021) emphasizes that government programs focus on capacity building, acquisition of 21st-century skill-sets, gender and youth-friendly innovations and enterprises, promotion of modern agriculture, and linkages to finance. Nigeria's Gender Policy (FMARD 2019) also emphasizes that the Nigerian government will promote agri-business ventures for both people with special needs and women, ensuring that women do not lag in key sectors, especially horticulture value chains.

4. DIAGNOSIS OF PROBLEMS AFFECTING THE SUPPLY CHAIN

Key common set of problems across major horticulture commodities are

A. Upstream
    a. Insufficient access to improved seeds and varieties (supply and demand)
    b. Seasonality
B. Midstream
    a. Insufficient quality preservations using cooling technologies (insufficient access to grid electricity)
    b. Inefficient packing methods (especially, plastic crates)
    c. Insufficient value-addition through processing (capital requirements, market structure, etc)
C. Downstream
    a. Insufficient willingness to pay for domestic horticulture commodities due to information asymmetry (e.g., limited certification and labeling)
    b. Insufficient knowledge on nutrition benefits of domestic fresh horticulture commodities
    c. Significant competition with imported substitutes (such as imported tomato concentrate, tomato paste, etc.)

4.1. Problem #1: Insufficient access to suitable improved seeds and varieties

Evidence that this is a problem

The following evidence suggests that insufficient access to suitable improved varieties and seeds is a problem.

- Significant use of recycled seeds, and limited use of improved varieties, as shown in Figure 4
- The limited supply of certified seeds – few certified seeds of horticulture commodities have been produced in Nigeria in the 2010s; almost all certified seeds produced have been cereals, legumes, and cotton (NASC 2020). Some horticulture product seeds, like onion seeds, produced were 20 tons, accounting for only a fraction of 128 tons of expected seed demand (NASC & SEEDAN 2020).
- The number of vegetable varieties released in Nigeria up to 2020 has been generally small – 8 Amaranthus, 3 okras, 7 peppers, 2 cabbages, 17 tomatoes, which account for 37 out of 627 variables (NACGRAB 2020).

- Significant shares of tomato and garden egg varieties come from the public-sector bred varieties in many African countries (e.g., Afari-Sefa et al., 2012; Schreinemachers et al. (2017), suggesting that insufficient supply of seeds of these varieties can be a significant constraint.
- High costs of improved, certified seeds (Balana et al. 2022b)

Prevalence of the problem

Evidence suggests insufficient access to suitable improved varieties and seeds is a prevalent problem in Nigeria. Compared to some other countries in Africa, Nigeria has a low quantity of certified seeds for horticulture crops. For example, in Egypt, as early as 1997, certified seeds were produced for tomato (95 tons), watermelon (175 tons), cucumber (110 tons), Spinach (60 tons), okra (130 tons), lettuce (50 tons), carrot (60 tons) (FAO 2000), which is significantly higher than the quantity produced in Nigeria, where few seeds were produced in 2020 (NASC & SEEDAN 2020).

Policies or projects attempting to address the problem

Various policy and strategy documents discuss these problems, including National Seed Policy 2015 (FMARD 2015), and Plant Variety Protection Law (FMARD 2021), indicating the persistence of these problems recognized in Nigerian policies. In addition, the National Agricultural Seeds Council (NASC)'s strategies for 2020-2024 (NASC 2019) aim to achieve the following:

- Increased availability of improved seeds and adequate training led to 40% of farmers in Nigeria adopting improved seed varieties across priority value chains, including vegetables.
- An efficient and robust certification system by improving time and cost-efficient and effective seed certification system that covers additional value chains such as fruits, vegetables

4.2. Problem #2: Insufficient access to cooling technologies (cold-storage / cool transportation)

Insufficient cooling practices, cold storage, and cool transportation at various stages, whether on-farm or market level, are widely mentioned as a critical problem (e.g., Kirubi et al. 2009; Tschirley et al. 2015; Béné et al. 2019; Takeshima et al. 2021).

Evidence that this is a problem

The following evidence suggests insufficient access to cold storage and cool transportation is a significant problem.

Recent studies (e.g., Takeshima et al. 2021) suggest introducing solar-powered cold storage in major horticulture markets in Northeast Nigeria can have significant economic effects. These include a relative increase in sales volumes of horticulture commodities, reduced losses, and higher prices received by market traders and producers. The overall returns are found to be suf-

ficiently larger than the investment costs of cold storage. Such significant effects, in turn, suggest that insufficient access to cold storage in the market is limiting the potential of domestic F&V VC development.

Most of the cold storage services in Nigeria are primarily for preserving meat and fish, with comparatively few options suitable for storing fresh fruits and vegetables (FFV) (GAIN & Rockefeller Foundation 2018; USAID 2022). Poor and unstable electricity supplies, and insufficient adoption of off-grid, renewable electricity, deter the development of cold storage facilities (Plaisier et al. 2019; Dijkxhoorn et al. 2021).

Knowledge and awareness still need to be improved regarding cheaper, intermediate on-farm cold storage, such as zero-energy cooling chambers and other evaporative cooling methods (Mogaji et al., 2013; Rockefeller Foundation, 2021; Nwalieji & Ajayi, 2009). At the same time, some intermediate methods, like storing fruits in mud-houses with thatched roofs, tend to be more susceptible to external shocks like fire outbreaks and may provide only a modest degree of quality preservation, insufficient to meet consumer's preference for freshness (Balana et al. 2022b).

Generally, Nigeria's greater consumer preferences for fresh products than processed products make inappropriate storage a key constraint (Balana et al. 2022b).

In addition, insufficient cold storage / cool transportation aggravates food loss and waste due to spatial and temporal variations in supply-demand gaps. As was described earlier, production seasonality is substantial in each region, and generally, northern Nigeria faces excess supply while southern Nigeria faces excess demand.

Longer, costlier transportation challenges due to extortions on the road (illegal and informal) by unions or government agents such as police, road safety corps, inadequate road conditions, poor road linkages, and lack of aggregation centers (Balana et al. 2022b) can further lengthen the transportation time, and thus expose products longer to higher temperatures.

Prevalence of the problem

Various documents mentioned above indicate the significant prevalence of the problem anecdotally. Stakeholder consultations also revealed that mangoes in the market tend to be stored by simply covering them between layers of sacs to prevent fruits from direct sunlight (Balana et al. 2022b).

In addition, baseline surveys of horticulture traders in 14 main daily horticulture markets in Northern Nigeria conducted by Takeshima et al. (2021), which are representative of the horticulture market levels, show that very few market agents in these horticulture markets had used cold storage.

Policies or projects attempting to address the problem

Various policy and strategy documents discuss these problems. For example, National Agricultural Technology and Innovation Policy (NATIP) (FMARD 2021) aims to support cold-chain development:

- **Market Development**: A multi-stakeholder approach would be adopted to equip and upgrade major commodity markets, re-organize rural and urban market infrastructures, and establish warehouses, environmentally friendly cold chain facilities, and functional commodity exchange and warehouse receipt systems.
- **Establishment & Upgrading of Commodity Markets**: Support the establishment of cold stores, preservations, light processing in major commodity markets

4.3. Problem #3: Inefficient market structure

Evidence for and prevalence of this problem

Farmers in developing countries, particularly under-developed countries in SSA, including parts of Nigeria, continue to face high transactions costs due to inefficient market structure (Minten et al. 2012; Vandeplas & Minten 2015; Liverpool-Tasie et al. 2020), including those in tomato value-chain (e.g., Ugonna et al. 2015). Similarly, many horticulture producers consider market linkages as weak. While middle-men partly facilitate and play coordinating roles, concerns remain strong among farmers regarding the overall efficiency of the current market structure, and preferences for having more direct access to buyers like processing companies and final retailers also remain strong among producers, aggregators, and associations (Balana et al. 2022b).

Policies or projects attempting to address the problem

Various donor-initiated projects attempt to address this problem. For example, the YieldWise-TechnoServe tomato program supports strengthening the market associations and expanding the networks of the aggregators by linking them to more farmers and buyers (e.g., Rockefeller Foundation 2021). The project also developed a contract farming and aggregation model to strengthen linkages between producers and buyers, including off-takers, processors, hotels, or wholesale outlets. These buyers provide inputs to producers and purchase directly from them (e.g., Rockefeller Foundation 2021).

4.4. Problem #4: Insufficient information

Evidence for and prevalence of this problem

Market agents in developing countries, including Nigeria, also need more information about prices and demand uncertainty in staple and horticulture commodities (Minten et al. 2012; Vandeplas & Minten 2015; Liverpool-Tasie et al. 2020). More marketing information is also considered a significant challenge for the tomato value chain in Nigeria (Ugonna et al., 2015). There needs to be more quality control and standardization for processed tomatoes and mango due to

information asymmetry, have also been raised by various stakeholders in Nigeria during the stakeholder consultations (Balana et al. 2022b).

Policies or projects attempting to address the problem

As was described earlier, major agricultural policies like NATIP emphasize the importance of value-chain development, and the government contributes to building and maintaining market infrastructures through public investments. However, the investments and public expenditures still need to be increased given the sheer size of horticulture marketing activities in Nigeria (e.g., Hatzenbuehler et al. 2018; Takeshima et al. 2022).

4.5. Problem #5: Insufficient processing

The problems associated with inappropriate processing methods generally consist of the following:

- Capital requirements
- Limited technical capacity
- Insufficient training on processing
- High cost of packaging materials of processed products (Balana et al. 2022b)
- Insufficient supply of raw materials
- Low demand for processed tomatoes during the peak production season

Evidence for and prevalence of this problem

- Capital requirements – start-up costs and working capital
- Limited technical capacity
  - Limited processing capacity: locally fabricated processors are less efficient and increase processing time, leading to low production capacity (Balana et al. 2022b)
  - Inadequate infrastructure and utilities to support processing, such as power and water
- Insufficient training on processing
  - Limited training, monitoring system on personal hygiene of staff (regular washing of hands after using the toilet, handling raw food, blowing nose, handling garbage, touching body parts, handling animals, etc.) and safe handling procedure, most common infections, as well as insects (Adegbola et al. 2012; Tafida et al. 2019; Larsen et al. 2009)
  - Limited knowledge of the operational standard of the regulating body (Adegbola et al. 2012)

- Limited training programs in manufacturing (tool making, welding) for rural artisans and users (Tafida et al. 2019)
- Poor record-keeping, business management skills (Tafida et al. 2019)

- High cost of packaging materials for processed products, which forces the use of used-water-bottles or other secondary packages (Balana et al. 2022b)
- Insufficient supply of raw materials
  - Seasonality of raw materials: difficulties in accessing fresh products during the lean production season, as well as high-quality raw materials in general due to insufficient contracts (Balana et al. 2022b)
  - Similar challenges in Ghana: the lack of the right quality and quantity of fresh tomatoes that forces processing factories to go inactive or resort to importing concentrates and repackaging them for sale (Melomey et al. 2022)
- Technical requirements
  - Strict production requirements, for example, for dehydration, juice extraction, and temperature controls (contamination issues) that may prevent small actors from venturing into processing (e.g., mango chips) (Balana et al. 2022b)
- Low demand for processed tomatoes during the peak production season (Balana et al. 2022b)
  - Greater consumer preferences for fresh tomatoes during peak production seasons, when prices of fresh products are lower
- The low number of processors in other comparable countries, as well as a gap with some more advanced countries

Processing plants for tomatoes in Nigeria – 8 in 2019 (with capacity ranging between 7 – 1200 tons/day) (Plaisier et al. 2019), which is comparable to 3 in Ghana in 2009 (Robinson & Kolavalli 2010) but lower than 17 in Egypt in 2019 (with a total capacity of 6300 tons/day) (Abdelhakim 2019), about 50 in Kenya in 2009 (Larsen 2009), more than 500 in countries like Colombia (Dávila et al. 2015), and South Africa where larger companies like Giant Foods and Tiger Brands engage in significant tomato processing (Louw et al. 2007).

Policies or projects attempting to address the problem

NATIP generally emphasizes the importance of strengthening processing capacities.

- Pillar: Strengthening Value-Chains for Priority Crops:
  - the establishment of over 100 processing centers in rural communities across the country, under the Green Imperatives Plan;

- the development of clusters, rural nodal centers, rural cottage industries and the establishment of at least six Special Agro-industrial Processing Zones (SAPZs);
- linking the agricultural sector with the industrial/processing sector, thereby boosting industrialization and creating at least 1 million jobs in the country.

- NATIP also mentions particular quantitative goals:
  - increase by 20 percent the value addition of agricultural products through processing and nutrient fortification;
  - provide 25 agro-processing facilities tied to the silos and other cottage industries for value addition by 2027

4.6. Problem #6: Inappropriate packing methods

The problems associated with inappropriate packing methods generally consist of the following:

- Low quality preservations of conventional packing materials
- High cost, variable quality of plastic crates
- Insufficient knowledge of handling of crates
- Insufficient awareness of the benefits of plastic crates

Evidence for and prevalence of this problem

The low adoption rate of crates among smallholder tomato farmers and local produce aggregators using crates (4%), with less than 100,000 crates circulated in Nigeria (Rockefeller Foundation 2021). The high and rising cost of crates in recent years (₦1,000 before 2021 (Rockefeller Foundation 2021) to ₦2,500 to 4,000 in 2022) have also induced farmers to prefer traditional wooden (Rafia) baskets despite high losses (Balana et al. 2022b).

Poor and variable quality of crates are other problems. The more recently circulated crates have become less durable and can only last for 2 years, with only one company currently producing high-quality plastic crates in Nigeria; even though plastic crates reduce postharvest losses, the texture/design of some existing crates still contributes to product damages (Balana et al. 2022b). Other problems include improper crate handling and offloading stacked tomato crates from trucks contributing to spoilage (Balana et al. 2022b) and limited farmers' understanding of the efficiency of plastic crates in transporting tomatoes (Balana et al. 2022b).

Policies or projects attempting to address the problem

NATIP emphasizes the importance of improved post-harvest handling, including that for fruits & vegetables, to which this problem falls.

In addition, various projects have provided support to address the problem. These include:

- World Bank's APPEALS (The Agro Processing, Productivity Enhancement and Livelihood Improvement Support) project provided crates through rental.
- Rockefeller Foundation (2021), through collaborations with TechnoServe and under the YieldWise project, experimented with evaluating how packaging materials contributed to the post-harvest loss. It also facilitated the formation of an RPC Association based in Danja, Katsina State, to promote the use of the crates among local produce aggregators and small-holder farmers.
- In 2019, the Nigerian Incentive-Based Risk Sharing System for Agricultural Lending financed a program for small-holder tomato farmers and aggregators in Kano State. Each farmer received 30 reusable plastic crates, crop protection, insurance services, seeds, and fertilizers.

5. INNOVATION BUNDLES TO BE PILOTED

The challenges along F&V VC, described in the previous section, can be best addressed by applying various sets of innovations in bundles.

The scoping work identified several sets of innovation bundles based on the review of challenges, lessons from recent applications, and pilot of existing innovations in some parts of the country. Three types of innovations have been considered: process, product, and information innovations. Process innovations include those in cooling and packing methods, while product innovations include improved seeds and varieties, a variety of processing methods, and so on. Information innovations include certifications and labels and better access to market information.

Table 3 summarizes the set of innovation bundles identified, and the types of F&V VC functions associated with them, while Figure 1 maps the collaborators and partners involved. The subsections below describe each intervention bundle in detail.

Table 3. Proposed innovation bundles and their expected effects

Innovations	1	2	3	4	5	6	7	8
Areas to intervene	Off-grid cooling 1	Off-grid cooling 2	Cool trans	Solar dryer	High Value added process	Improved seeds + certification	Plastic crates	Service provision
Cooling - Farm clusters	x	x	x					
Cooling - Markets		x	x					
Cool transportation			x					
Processing				x	x			
Production						x		
Production via contract					x		x	x
Seeds						x		

Varieties	x	x	x		x	x		
Certification					x	x		
Labelling	x	x	x		x	x		
Plastic crates	x	x	x			x	x	x
Market			x	x	x	x		x
Energy	x	x	x					
Coordination	x	x	x		x		x	x

Source: Authors.

	1	2	3	4	5	6	7	8
Areas to intervene	Off-grid cooling 1	Off-grid cooling 2	Cool trans	Solar dryer	High Value added process	Improved seeds + certification	Plastic crates	Service provision
Expected changes (direct impacts)								
Food loss	x	x	x	x	x		x	x
Value added				x	x			
Market coordination			x					x
Expected changes (final outcomes)								
Employment	x	x	x		x			
Technology adoption	x	x	x	x		x	x	x
Productivity						x		x
Income	x	x	x	x	x	x	x	x

Source: Authors.

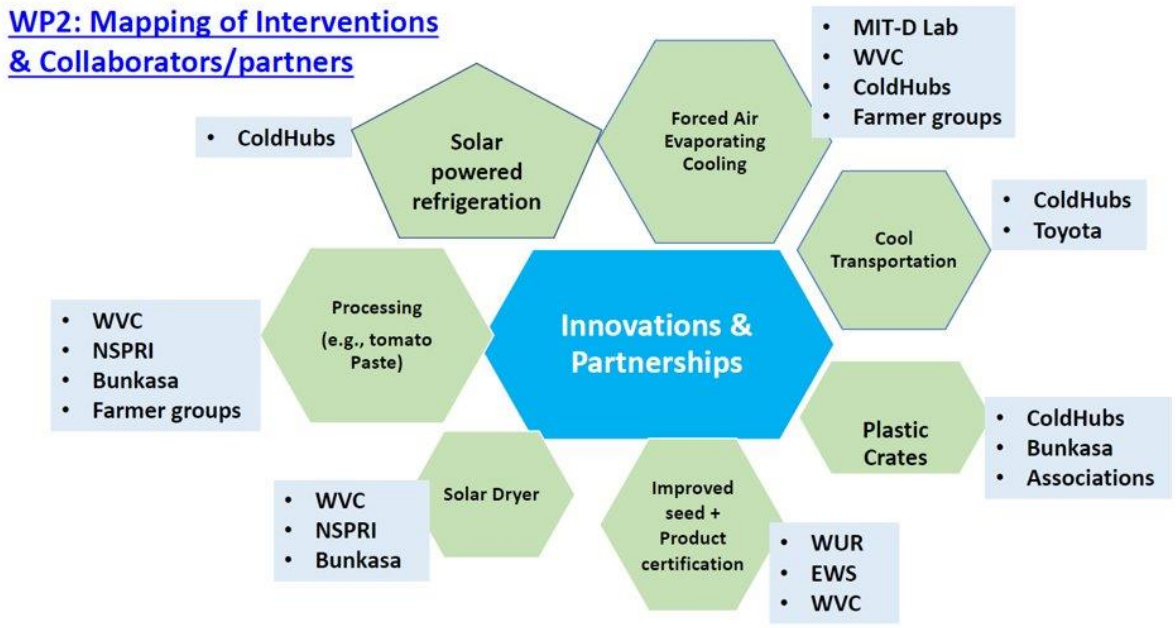


Figure 1. Mapping of collaborators and partners across innovation bundles

Source: Authors.

EWS = East-West Seed
MIT-D Lab = Massachusetts Institute of Technology D-Lab
NSPRI = Nigerian Stored Products Research Institute
WUR = Wageningen University & Research
WVS = World Vegetable Center

5.1. Seeds / varieties / on-farm production

Table 4. Pilot design

Categories	Description
Innovations	• Improved access to quality seeds (in local market) • Skill upgrading of producers through extension and training Certification of trained producers to have market premiums (plot level)
Pilot locations	Kano, Kaduna states (areas where East-West Seed Foundation operates)

Impact evaluation research design	• A factorial RCT-design, leveraging the existing diffusion/training approach of the East-West Seed foundation and its extension.
	• 150 villages (tentative)
	  ○ 50 control villages
	  ○ 50 villages receiving the existing training intervention (treatment 1)
	  ○ 50 villages receiving an augmented version of the training program (i.e. including a certification component: treatment 2).
	3000 farmers/150 villages: 400 key farmers from treatment villages, 1600 peer villagers from treatment villages, and 1000 villagers from control villages (tentative)

Source: Authors.

Benefits of the intervention

The intervention brings the benefits in three areas;

- **Improved access to quality seeds of horticulture commodities:** the quality seeds of a broad range of varieties, popular in the local area but not readily accessible in high quality, become more widely available in the local market. In addition, access will improve in local markets for more improved varieties suitable for various forms of consumption. For example, such varieties may include dual-purpose tomato varieties adapted to fresh and processing markets, solids content ideal for juice, colors, texture, and size, among others (Snels et al. 2018). More details of characteristics of improved horticulture crop varieties are provided in Appendix B.
- **Skill upgrading of producers through extension and training on improved production practices of horticulture commodities**: producers' knowledge and skills on horticulture commodity production will be enhanced both directly through training, and indirectly through exposures[i]
- **Higher market premiums for horticulture commodities sold by the producers**: providing certification to producers who received training can reduce information asymmetry from buyers' perspectives regarding the crop quality, who are willing to offer higher prices to producers

Costs of interventions

Key intervention cost components are

- Training of trainers and producers
- Costs for providing quality seeds in the local market
- Costs for certification and materials to demonstrate certification status

Inclusivity and environmental sustainability

Women and youths who engage in production, marketing (both crops and seeds), and processing broadly benefit, given their significant involvement in these activities within F&V VC.

The intervention also includes training-of-trainers (TOT), who tend to be the youths with basic agricultural backgrounds and contribute to increased youth involvement.

Training will also cover environmentally sustainable production practices, which enhance both short-term and long-term benefits for the producers.

Scalability

Certification of producers is relatively inexpensive (requiring materials to demonstrate certification status) and thus fairly easy to scale up.

5.2. Cold storage and cool transportation

Table 5. Pilot design

Innovations	Farmgate cold storage (off-grid)	Cool transportation
Technologies	3 forced-air evaporative cooling facilities (+ Zero Energy Cooling Chamber (ZECC))	2 small (short-distance) refrigerated trucks 3 large (long-distance) refrigerated trucks
Pilot locations	Selected farm clusters in Plateau, Bauchi, Jigawa (TBD)	Origins: collection centers (assembly points) in Plateau, Bauchi, Jigawa (Adamawa, Yobe optional) Destinations: Cities in southern regions
Impact evaluation research design	Food science experiment / lab-experiment	Cluster-RCT with randomly selected collection centers - Treated group collection centers and farmers – small trucks pick up products - Control group collection centers and farmers – no pickup

Source: Authors.

Benefits of the intervention

Potentials of intermediate cooling technologies have been hypothesized in past studies in Nigeria and other developing countries, including forced-air evaporative cooling (Sibanda & Workneh 2020; Kumar et al. 2022),[ii] Zero Energy Cooling Chamber (ZECC) (Odeyemi et al. 2021; RF 2021), evaporative-preservation cooling system (Mogaji et al. 2013), evaporative coolant structure (Nwalieji & Ajayi 2009), and other temporal cooling structure (Njume et al. 2020). Improved on-farm storage can also partly mitigate the challenges due to the erratic and high electricity supply cost, which discourages using modern storage facilities (Balana et al., 2022b).

Access to cold storage, among others, can help smallholders to engage in higher-value livestock and horticultural products (Hazell et al., 2019). Recent studies show the potential economic impacts of small-scale solar-powered cold storage installed in horticulture market premises in Northeast Nigeria, particularly in markets with high transactions (e.g., markets that operate every day, as opposed to markets that operate only a few times a week) (Takeshima et al. 2021). Takeshima et al. (2021) and Yamauchi & Takeshima (2022) show that, after several years, cumulative economic returns can exceed installment costs. These studies also showed that cold storage in market premises could often double the shelf-life of products, preserving

more than half of the original nutritional values after 10 days or more and reducing loss/waste of commodities.

The benefits of cool transportation, and more broadly cold-chain, have been increasingly studied as well, although the evidence base just began broadening (e.g., Mahajan & Frías 2012; Han et al. 2021; Tokala & Mohammed 2021). Generally, cool transportation can reduce the effects of ripening and spoilage, quality preservation, and increase overall economic efficiency in F&V VC.

Costs associated with the intervention

Table 6. Costs associated

Categories	Farmgate cold storage (off-grid)	Cool transportation	
	3 forced-air evaporative cooling units	2 short-distance refrigerated trucks	2 long-distance refrigerated trucks
Equipment	USD 15,000 per unit of forced-air evaporative cooling units	USD 45,000 per unit of 3.5 ton small trucks	USD 85,000 per unit of 10-ton trucks
Other costs		1 truck with solar panels and high performance batteries	
Notes			Possible: Certification on cool transported from north to south

Source: Authors.

Inclusivity and environmental sustainability

Inclusion

Access to cooling technologies can incentivize more significant investments in value-adding activities (Takeshima et al. 2021), such as grading/sorting, washing, cleaning, etc. These activities can be labor intensive and lead to increased employment in women and youths.

Environmental sustainability

While cool transportation itself could contribute to greater fossil fuel consumption and CO2 emissions (Wu et al. 2022), reduced loss and waste during transport can indirectly reduce the overall environmental footprints per value of F&V produced and consumed along the VC. Similarly, low-carbon management strategies, such as energy efficiency improvement, clean electricity grid supply, environmentally friendly refrigerants, and alternative refrigeration technologies, can mitigate adverse environmental effects (Wu et al. 2022).

Assessment of scalability

Capital-intensive technologies like forced-air evaporative cooling facilities and cool transportation technologies can be scaled up similarly to agricultural mechanization. Large farmers who purchase tractors through their private savings become a major source of mechanization services for neighboring smallholders (Takeshima et al. 2015; Diao et al. 2020). Better information

and reduced uncertainty about economic returns from cool transportation obtained from the planned pilot project can induce private investments into cool transportation technologies. Better knowledge of expected economic returns can also help potential private investors to develop business plans that the government can support through modalities like competitive grants, as found promising in an early experiment in Nigeria (e.g., McKenzie 2017).

5.3. Processing

Table 7. Pilot design

Innovations	Drying
Technologies / Knowledge	Solar dryers
Pilot locations	Kano, Plateau
Impact evaluation research design	Cluster-RCT by randomly selecting locations to set-up the solar dryer. Two potential treatments: (1) service fees to use the solar dryer and (2) the operator of the technology (solar dryer) dries and sells the processed product (dried tomato) on behalf of farmer
Collaborators	NSPRI, World Vegetable Center, Bunkasa
Notes	Women's groups Possible: -combining treatment (2) with a credit option to facilitate farmers' decision to dry, store and sell later through the operator -labelling the dried tomato as clean and hygienic to signal quality

Source: Authors.

Benefits of interventions

Solar drying is an advanced way of utilizing the usual open-air sun drying method (RF 2021; Ngasoh et al. 2018). A solar dryer is set up as a structure that is used as a collector of the ray from the sun and intensifies it to facilitate drying (Ngasoh et al. 2018). The technology is expected to enhance the speed and efficiency of drying F&V commodities at the farm gate.

The solar dryer also effectively eliminates aflatoxin contaminations in maize and ground nuts. Though these commodities are not fruits and vegetables, it is possible to use solar dryers for these commodities during the off-season for fruits and vegetables.

Training on wet processing can improve processing efficiency and adequacy, including the consistency of quality, cleanliness, and hygiene of processed products, adequate packaging materials, and adequate operation of processing equipment. In other developing countries, gaps have often been detected among processers of F&V commodities and food. The training was suggested as an effective intervention (e.g., da Cruz et al. 2006; Kussaga et al. 2014).

Improved processing skills can also mitigate losses, capturing higher value than selling raw products alone (Larsen 2009).

Costs of interventions

Potential costs of interventions are guided by field assessment and similar studies in neighboring countries.

- Tomato processing (operating costs) – Ghana (Robinson & Kolavalli 2010)
- Tomato processing (facilities and capital costs) – Nigeria (Adegbola et al. 2012; Tafida et al. 2019)
- Tomato paste plant (facilities and capital costs) – Sudan (Nasrelddin & Ahmed 2022)
- Hot pepper paste production (operating costs) – Uganda (Mayanja et al. 2013)
- Mango processing in Ethiopia (Honja et al. 2017)
- Mango processing in juice and dried mango – Kenya (Osena 2011 Appendix 18)

Inclusivity, environmental sustainability, and scalability

Solar driers (solar-dryers), more broadly solar-energy drying systems, are generally suited to women (e.g., Sharma et al. 2009) and thus gender-inclusive technologies. Solar dryers rely primarily on solar energy with little reliance on alternative electricity, negligible emission of Green House Gas, and use locally-available materials. Thus, the technology is environmentally sustainable. Solar driers are relatively simple and can be constructed mainly with locally-available materials (Ngasoh et al. 2018; Rockefeller Foundation 2021). Thus, the technology is highly scalable.

Cottage-industry type processing, such as for simple tomato juice/sauce, is also gender-neutral because many women generally engage in post-harvest handling of fruits and vegetables. In addition, improved knowledge of processing through training can be readily disseminated locally and is scalable.

5.4. Plastic crates

Table 8. Pilot design

Innovations	**Improved packing (crosscutting innovation integrated into multiple innovation bundles)**	
Technologies / Knowledge	Reusable plastic crates	
Pilot locations	TBD	Kano, Plateau
Impact evaluation research design	RCT: Experimental rental arrangements	Cluster-RCT by randomly selecting locations for service provisions (2 treatments): Increasing returns to plastic crates as an increased incentive to use - Plastic crates provisions through rental - Market information provided to producers (price information, linkages with guaranteed market, etc.)
Collaborators	ColdHubs	Bunkasa
Notes	Plastic crates will be used in other innovation bundles (cold chain, market coordination)	

Source: Authors.

In the second sub-component, one-stop-shop type service provisions will be provided. SMEs provide multiple services ranging from providing crate rental services alongside other services to supporting client farmers and traders. A bundle of services offered includes crate rental services, farmer training on agricultural production (e.g., varieties with the high demand), packaging using

plastic crates, price information (e.g., price bands in 7 wholesale markets in southern Nigeria), advice on sales locations (e.g., supermarkets or restaurants when prices at the wholesale markets are low), establish links to agents in southern wholesale markets by guaranteeing them that farmers/northern traders will sell their produce within the band price gathered from those agents.

Benefits of the intervention

Benefits of Reusable Plastic Crates, particularly for F&V commodities, include the following:

- Improved quality preservation and reduced loss/waste
  - Transporting tomatoes in crates helps the farmers to extend the shelf life up to 10 days and allow them to access better markets outside their local production areas (Balana et al. 2022b).
- Quality control
  - RPC can also help preserve food safety quality. For example, tomatoes that are transported in crates are free from toxins, as farmers are discouraged from using ripening ingredients, and thus tomato plums tend to remain safer for eating (Balana et al. 2022b).
- Reduced per-unit transportation costs
  - A truck can load between 600-900 crates compared to 300 Rafia baskets (Balana et al. 2022b).
- Standardized weight unit
  - Each plastic crate, when fully loaded with tomato, weighs 25kg, which is half of the weight of the traditional wooden basket, commonly called the ‘Rafia’ basket, which weighs about 50kg. An RPC is generally accepted as a standard unit of measurement in tomato markets across the country (Balana et al. 2022b).
- Increased benefits in response to supplementary support like training, awareness enhancement
  - Limited awareness and insufficient knowledge in handling PRC due to little training are considered some of the barriers against using PRC (Nwabuogo et al. 2019), suggesting that supplementary support for training and awareness enhancement can raise benefits from traders’ perspectives. Training farmers on using crates to minimize post-harvest loss is also useful (Balan et al. 2022b).
  - Benefits can also be enhanced by partnering with other value chain actors across markets with the possibility of using the crates (instead of sending them back empty) to transport other commodities to where the crates originated.
- Reduced overall transactions costs for farmers by
  - Reduced transactions costs by having to deal with fewer service providers

- Better access to guaranteed and/or high-end markets like restaurants or supermarkets, where sellers can capture price premiums for high-quality produce.

Costs associated with the intervention

Key cost components of interventions utilizing Reusable Plastic Crates are the crates' costs. Prices of crates can vary depending on the quality, but typically around ₦4,000 / crate in 2022 for purchase. Crates can also be rented at a rate of ₦600 / crate per peak season. Standard crates can last for up to 2 years.

The key intervention costs for the provision of market information include the standard costs incurred by existing SMEs already providing these services.

Inclusivity and environmental sustainability

Inclusivity

Women often account for a significant share of the population engaged in trading of F&V in Nigeria. Packing techniques, including RPCs, are often suitable for women (Badu & Sahoo 2015). Furthermore, providing these bundles of services has the potential to significantly bridge gender gaps and promote inclusivity, where bridging those gaps expands the SME market access and client base. Thus, these service-provider SMEs could be incentivized to expand their operations to reach smaller and more remote farmers and traders with particular attention to youth, women, and disadvantaged castes and ethnic groups.

Environmental sustainability

Studies indicate that reusable plastic crates (RPCs) have a lower environmental impact than single-use containers (cardboard and wooden boxes) (e.g., López-Gálvez et al. 2021); a service life of only 15 rotations can be sufficient to reduce all the impacts in comparison with single-use cardboard and wooden boxes. Using plastic crates helps minimize the cost of packaging materials and makes the whole process less dependent on scarce items like wood, thereby resulting in the conservation of the environment (Badu & Sahoo 2015).

Similarly, where encouraging climate-smart practices might not currently be provided by existing SMEs, working with them (since they already have connections with farmers and are providing them with some services) could be a mechanism to promote adopting these practices. In addition, working with these SMEs could be an effective way for governments and donors to support increased farmers' knowledge and adoption of environmentally safe practices and incentivize farmers to adopt such practices.

Scalability

Given the divisibility of crates and availability of rental services, the scalability of intervention is

high once the profitability of using crates is better recognized among F&V VC actors, and the costs are directly reduced by scale economy and/or improved service provision (e.g., one-stop-shop).

Similarly, the provision of market information has already been implemented along the tomato value chain in parts of Nigeria. Thus, there are significant scalability potentials to other regions in the country with similar VC growth potentials once improved knowledge of business models is diffused to these regions.

5.5. Improved information – certification and label

Certification and labeling intervention will address information failures in the market, as discussed in the earlier section. This intervention includes labeling/certification of seeds as discussed in the other innovation bundle and labeling/certification of cool transported products.

Table 9. Pilot design

Categories	Description	
Innovations	Certification on improved seeds	Labeling on cool transported products
Pilot locations	North: local fresh markets	South: rental markets
Impact evaluation research design	RCT (plot levels)	RCT (product levels)

Source: Authors.

Benefits of the intervention

The intervention mitigates information asymmetry and reduces information costs from buyers' perspectives by improving the clarity of quality-preserving practices used for seeds and products. This can also translate into higher market premiums received by sellers.

Costs associated with the intervention

Intervention costs include labeling materials and third-party certification costs.

Impacts on inclusion and/or environment

Providing labeling and certification has the potential to significantly bridge gender gaps and promote inclusivity, especially by raising returns to quality-preserving practices often carried out by women or youths.

Similarly, if demand is high for environment-friendly practices, such as cold storage and cool chain based on renewable energy (e.g., solar power), labeling and certification of such practices can raise returns to environment-friendly practices.

Scalability

The intervention can be scalable because the costs of labeling materials can be relatively low in Nigeria, and the certification process is less capital intensive (especially if the number of certifying agents is sufficient and certification service is reasonably accessible).

6. SUMMARY AND RECOMMENDATIONS

6.1. Summary

Fruits and vegetables are critical commodities in Nigeria regarding food and nutrition security, employment, and income earning potentials of various actors along the value chain, from upstream, midstream, and downstream. Unlocking these potentials, however, requires modernizing the value chain by addressing bottlenecks at various stages across the chain. Our scoping work assessed key characteristics of relevant value chains, market structures, policy environments, potentially binding constraints, and possible sets of innovations that can address these constraints, focusing on fruits and vegetable sectors in general and key commodities like tomato, mango, and orange in particular. We built on past, and recent studies investigating F&V VC challenges in Nigeria and complemented them by providing nationally representative statistics from household data, findings from various stakeholder consultations, and co-designing possible innovative solutions with local partners.

Overall, our scoping work revealed that V&F VC consists of many small actors, farmers, and traders, whereby limited vertical coordination can lead to significant efficiency loss along the value chain. Seasonal and temporal variations in supply-demand gaps for F&V commodities exist across the country, and considerable scope exists for a more modernized value chain to reduce losses and enhance the overall efficiency of the domestic F&V sector. Policy environments are also favorable for such efforts, as the latest Agricultural Policy documents highlight the Nigerian government's interest in modernizing F&V VC. Given the significant involvement of women and youths in the sector, F&V VC development has significant potential to contribute to Nigeria's inclusive development of agrifood systems.

The current domestic F&V VC in Nigeria suffers from various sets of problems. These include insufficient access to quality seeds and farming knowledge of F&V, insufficient cooling for quality preservation, insufficient processing, inappropriate packing methods, and inefficient market linkages and coordination that can be improved. Insufficient access to quality seeds and farming knowledge is associated with significant use of recycled seeds, limited supply, and high costs of certified seeds. Deficient cooling practices are due to inadequate access to the grid and off-grid electricity, limited knowledge of intermediate cooling methods applicable at the farm gate, and constraining quality preservations at farm gate storage, during transportation, and storage at market premises. Insufficient processing results from not only high costs of processing equipment but also limited knowledge of the construction and operation of simpler, less resource-dependent processing facilities, including drying of F&V commodities. Inappropriate packing, such as using Rafia baskets instead of Reusable Plastic Crates, which are commonly recognized, is still prevalent, potentially due to limited market coordination.

6.2. Validation at the stakeholder workshop

The CGIAR Initiative on '*Rethinking Food Markets*[iii]**',** led by the International Food Policy Research Institute (IFPRI), organized a two-day (12-13 Dec. 2022) stakeholders workshop in Abuja,

Nigeria. The workshop aims to engage with key stakeholders to kick-start the co-designing of innovations and interventions in 'Food Markets and Value Chains' to enhance employment opportunities and increase income for smallholders and SMEs along the agri-food value chains in Nigeria. Specifically, the workshop's objectives are: (1) to introduce the Initiative to policymakers, implementing partners, and scaling stakeholders in Nigeria; (2) to share the findings from the Scoping Study in Nigeria with stakeholders and validate the results; (3) to co-identify and co-design innovations and interventions with partners for piloting in Nigeria; and (4) to kick-start bundling of innovations/interventions and learning between the different work packages within the Initiative.

About 50 participants were drawn from the public sector (Federal and state Ministries of Agriculture); research institutes; private sector stakeholders from food value chains and logistics service providers; cooperative societies; farmers associations; value chain aggregators; agrotechnology organizations; and financial services providers in the agri-food sectors attended the workshop. The workshop was co-facilitated by IFPRI senior researchers Dr. Bedru Balana, Research Fellow and the Initiative's Country Coordinator in Nigeria; Dr. Futoshi Yamauchi, Senior Research Fellow; Hyacinth Edeh, IFPRI-Nigeria Country Program manager and the monitoring, evaluation, learning, impact assessment and scaling preparedness and actions (MELIA&SPA) team (Dr. Minh Thai and Dr. Mijra Michalscheck) from the International Water Management Institute (IWMI).

Dr. Kwaw Andam, country program leader IFPRI-Nigeria, and Mr. Abubakar Haruna, representing the Federal Ministry of Agriculture and Rural Development (FMARD), delivered opening statements and welcome addresses. The Initiative leader and Director of the IFPRI's Markets, Trade and Institutions Division (MTID), Dr. Rob Vos, introduced the overall goals and objectives of the CGAIR 'Rethinking Food Markets' Initiative and its particular significance in the context of agri-food value chains in Nigeria. Then, leaders of the two work packages (WPs) of the Initiative being implemented in Nigeria, Dr. Futoshi Yamauchi (WP2) and Dr. Kate Ambler (WP3), introduced their respective WPs to the participants. While WP2, entitled '*Innovation for inclusive and sustainable growth of domestic food value chains',* focuses on vegetables and fruits value chains to improve participation and profitability of smallholder farmers and agri-food SMEs in domestic food value chains in Nigeria and lower their environmental footprint; WP3-*Innovations and policy design for development for cross-value chain services to leverage new employment and income opportunities'* focuses on understanding the employment and income potential of emerging innovations in cross-value chains logistics and financial services for agri-food value chain actors in the country.

Following the introduction of the Initiative and its two work packages, the research team shared the findings of the scoping studies from WP2 and WP3 with the stakeholders, followed by discussions and Q&A sessions. The second half of day one of the workshop focused on learning from the stakeholders (potential implementing partners) about their experiences, expectations, innovations, and capabilities to implement them. Accordingly, seven organizations[iv] among the stakeholders invited to the workshop each gave presentations on the following key areas: (1) their

key *activities* relevant to the Initiative's planned activities in Nigeria; (2) their key *proposed innovations/interventions* for testing/piloting in collaboration with the Initiative team; (3) *bundling potential* of their proposed innovations ; (4) their i*mplementation strategies* of the proposed innovations; (5) *income and employment opportunities* of the innovations to smallholder and SMEs; and (6) the *potential to scaling,* i.e., how scalable are their proposed innovations/interventions? The discussions and Q&A following partners' presentations were focused on the *nature of the innovations, the potential for bundling, and implementation strategies*.

Day two of the workshop was dedicated to co-designing innovation bundles and interventions in breakout parallel group sessions in four innovation areas: (1) innovations in logistics services; (2) innovations in food processing and value additions; (3) innovations in quality standards, labeling, and certification; and (4) innovations in digital financial services (DFS). The parallel group discussions were followed by a plenary session on feedback, reflections, and Q&A based on the four groups' presentations.

From the '**innovations logistic services**' discussion group, a significant challenge remains post-harvest loss because of poor/inefficient logistics services. Some proposed interventions included plastic crates transporting perishable vegetables and fruits, cool transportation services, off-grid cool storage to reduce food loss, and increased market information and coordination services.

Participants in the **'innovations in food processing and value addition'** group suggested solar dryer technology as the key innovation that can replace traditional food drying methods in the sun and the open air.

The group that discussed **'innovations in quality standards, labeling, and certification'** agreed that the barriers to quality standards include the need for more capacity for value-added services along the fruits and vegetable value chains and the lack of standardization and traceability of farm commodities. Therefore, they proposed increasing capacity building on quality standards and quality labeling from farms to aggregation centers and markets.

The group on **'innovations in digital financial services'** proposed several financial solutions to mitigate the challenges smallholders and SMEs face along the agri-food value chains. The key DFS solutions suggested: (1) digital delivery of inputs loan bundled with agronomic and weather advisory services. This could help farmers to receive payments from off-takers in a timely and efficient manner by reducing extensive paper trails and harmonizing their data; (2) an e-wallet card to drive ease of payment processes and financial inclusion; (3) digital warehousing allowing farmers to move their farm produce to designated warehouses; and (4) a centralized USSD that can give farmers access to information or link to digital financial service providers in local languages.

Participants expressed their satisfaction with the information and knowledge gained about the Initiative at the workshop and the opportunities for collaboration on innovative solutions to mitigate the challenges in the agri-food sector in Nigeria. The readiness and enthusiasm of private sector partners for collaborations are very encouraging. In addition, the reflections/feedbacks from policy stakeholders (i.e., the Ministry of Agriculture at both federal and state governments) are highly

positive. Government stakeholders expressed their willingness to engage with the Initiative team and implement local partners and contribute to the Initiative's success in producing evidence to support better and targeted policies in the agri-food sector in Nigeria.

6.3. Recommendations

Based on the scoping work, review of existing materials, and stakeholder consultations, the following interventions (innovation bundles) have been identified as promising for F&V VC in Nigeria and should be piloted.

- Intervention #1: improved varieties and quality seeds provisions, combined with agronomy training and certification
- Intervention #2: provision of off-grid cooling and cool transportation; forced-air evaporative cooling units at farm clusters and the combination of small refrigerated trucks for local transportation as well as large refrigerated trucks for longer-distance transportation; combined with labeling for cool transported products
- Intervention #3: provision of solar dryers, including training on appropriate, hygienic processing methods, building, and utilization of solar driers (possibly combined with the introduction of a business model); empowering women
- Intervention #4: plastic crates provisions incorporated into all the other innovations, in different rental arrangements, or combined with the provision of better access to markets for farmers
- Intervention #5: improved information through certification and labeling, applied to interventions #1, #2, and #3
- Intervention #6: solar powered cold storages (existing), with which to bundle other innovations such as logistical or technological ones

APPENDIX

Appendix A. Descriptive figures

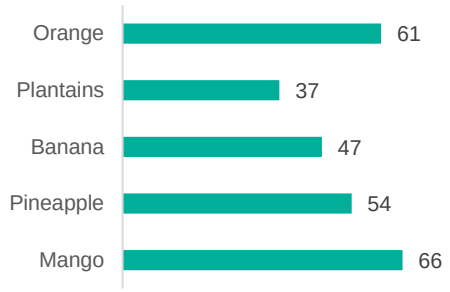
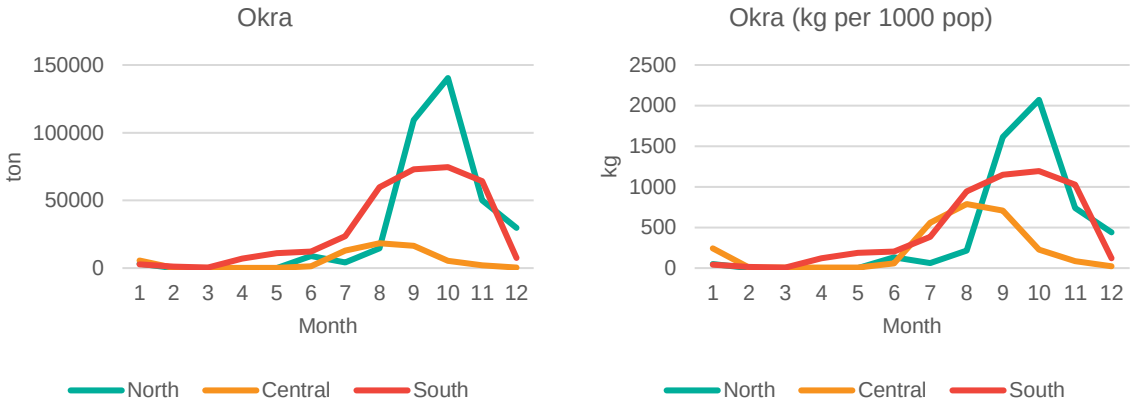
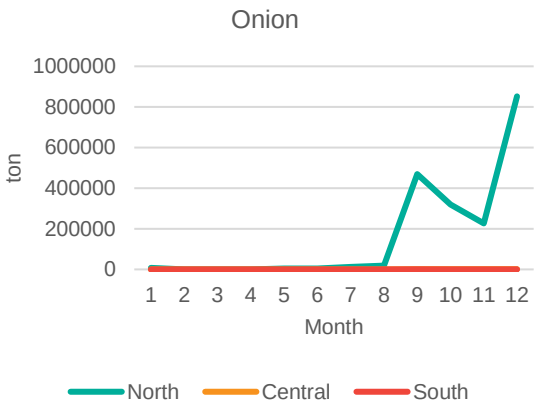


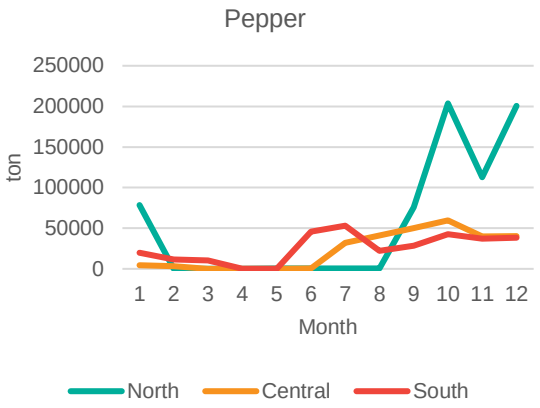
Figure 2. Share (%) of producers that are small-scale (non-orchard types) in 2018
Source: Authors' calculations based on NBS-WB (2019).

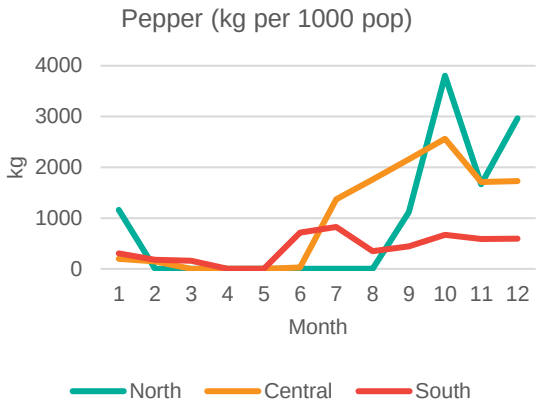


Sample size: (North = 79, Central = 49, South = 268)

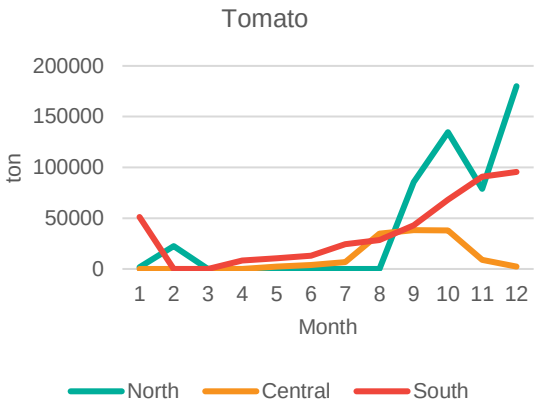


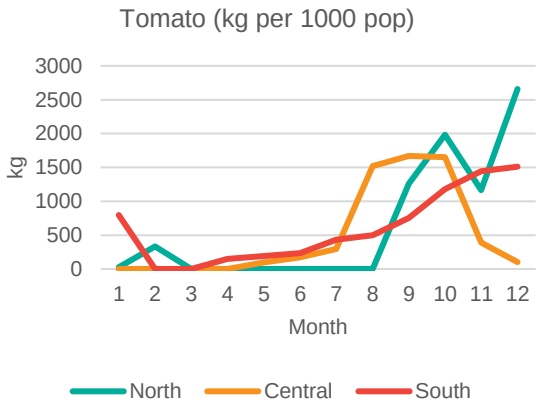
(North = 54)



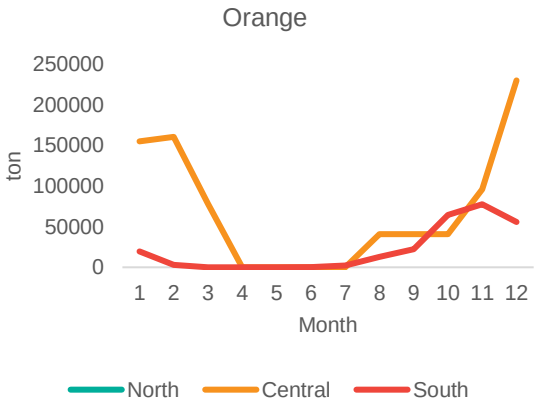


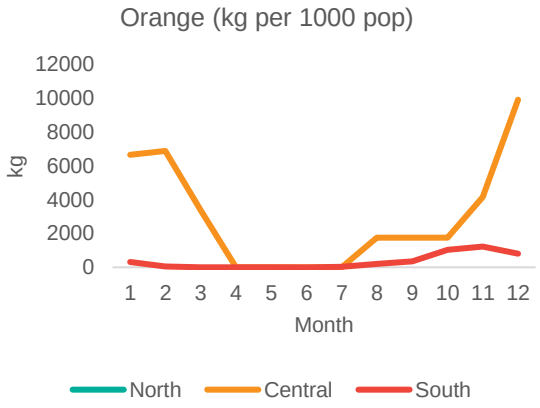
(North = 59, Central = 34, South = 94)



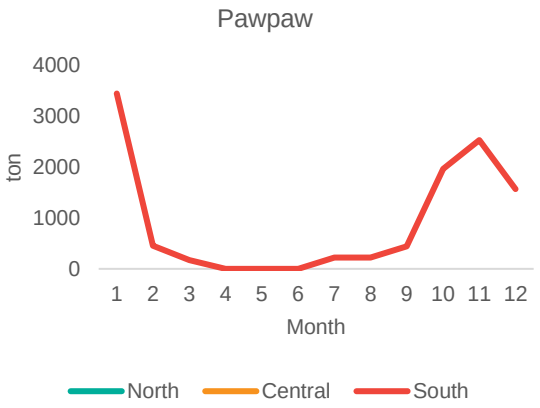


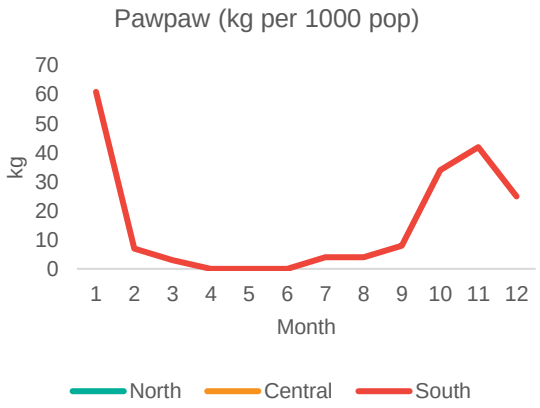
(North = 22, Central = 17, South = 53)



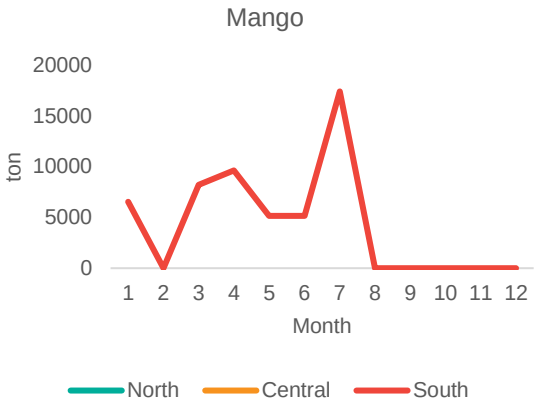


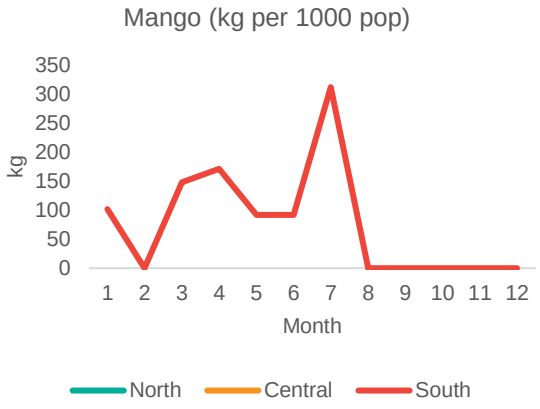
(Central = 11, South = 37)





(South = 18)





(South = 5)

Figure 3. Seasonality of harvest by regions, Nigeria (average of 2015 and 2018)
Source: Authors based on NBS-WB (2019).

Figure 4. Types and sources of seeds for major vegetables in Nigeria (average of 2015 and 2018)

Source: Authors based on NBS-WB (2019). Other purchase sources include relatives, friends/neighbors, village headman, mobile markets.

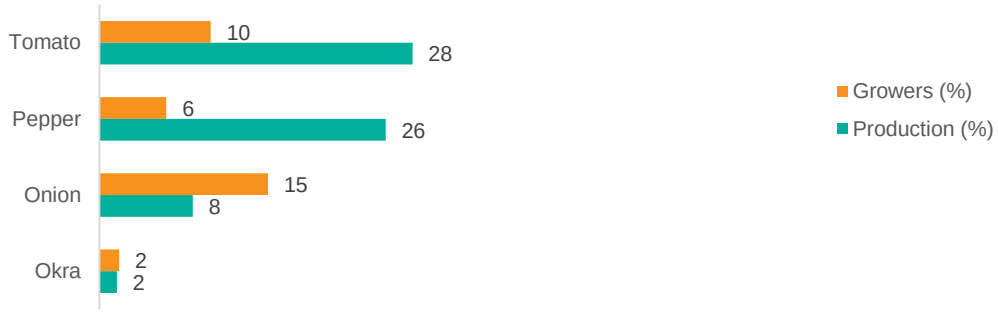


Figure 5. Irrigation shares (%) of growers and production (average of 2015 and 2018)

Source: Authors based on NBS-WB (2019). Irrigation use for fruits are minimal.

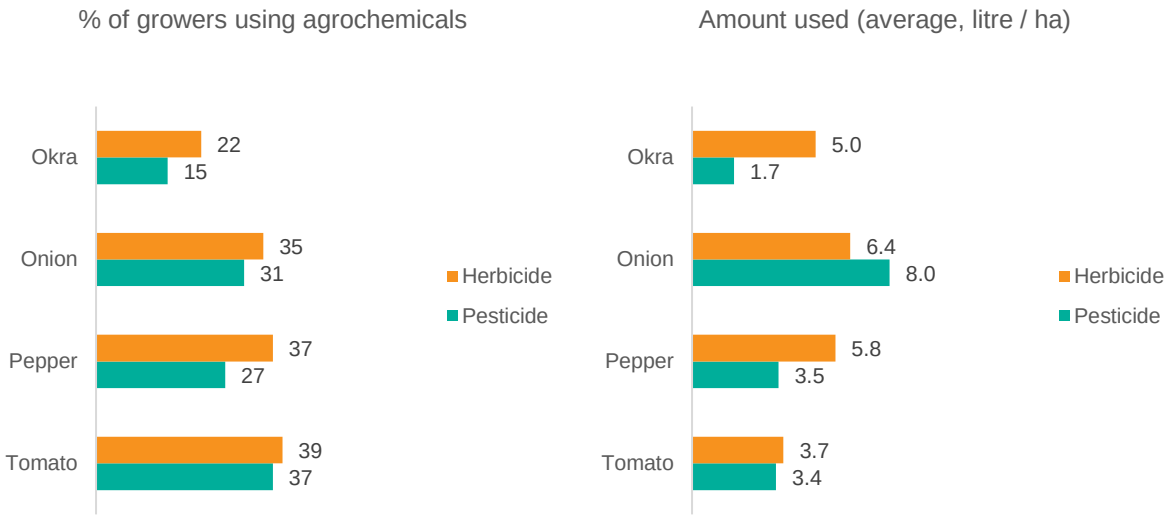


Figure 6. Agrochemical use for key vegetables in Nigeria (average of 2015 and 2018)

Source: Authors based on NBS-WB (2019).

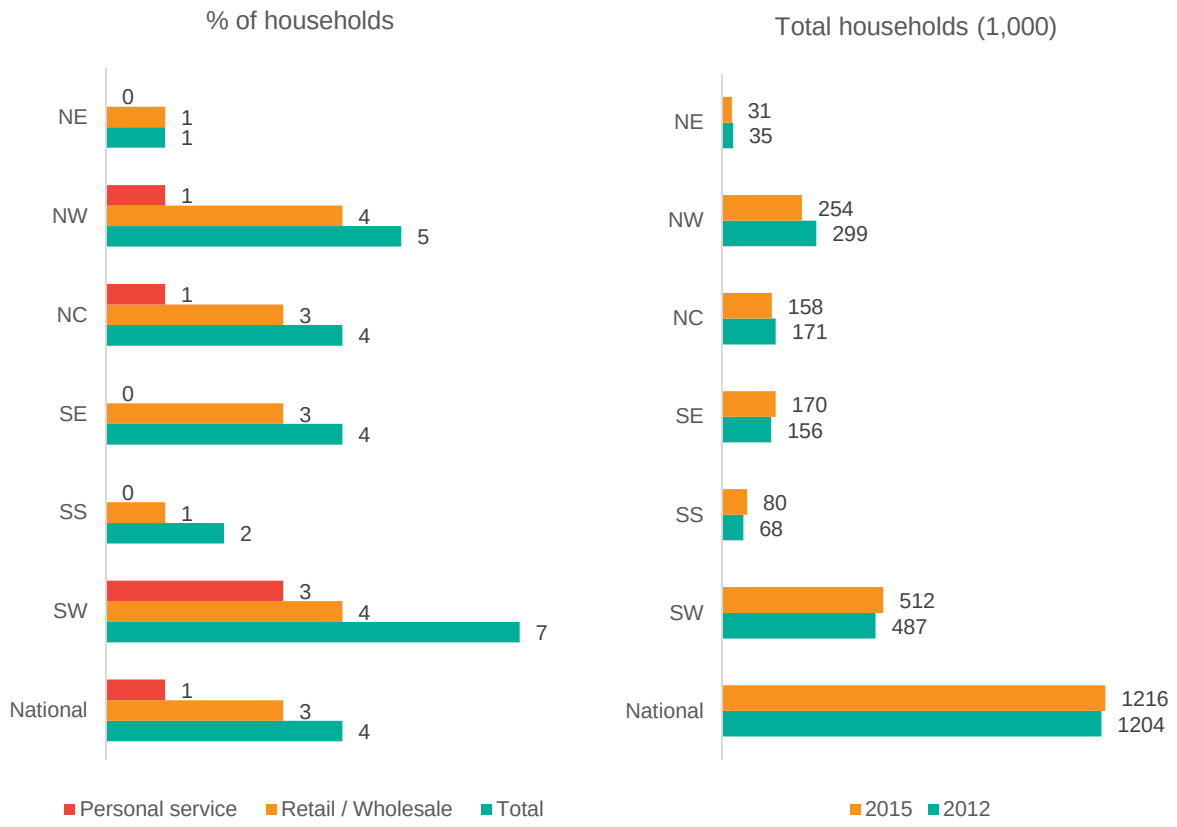


Figure 7. Number of households with off-farm enterprises related to vegetables and fruits (2012 – 2015)

Source: Authors based on NBS-WB (2019).
Note: Figures are based on LSMS-ISA data, waves 2 and 3 in which the descriptions of enterprise included the following: fruits = “banana”, “fruit”, “mango”, “melon”, “orange”, “pineapple”, “plantain”, “watermelon”; vegetables = “bitterleaf”, “egusi”, “herb”, “kuka”, “okra”, “onion”, “pepper”, “tomato”, “vegetables”. Figures above may underestimate, as they exclude other households who may handle fruits and vegetables but do not describe them explicitly.

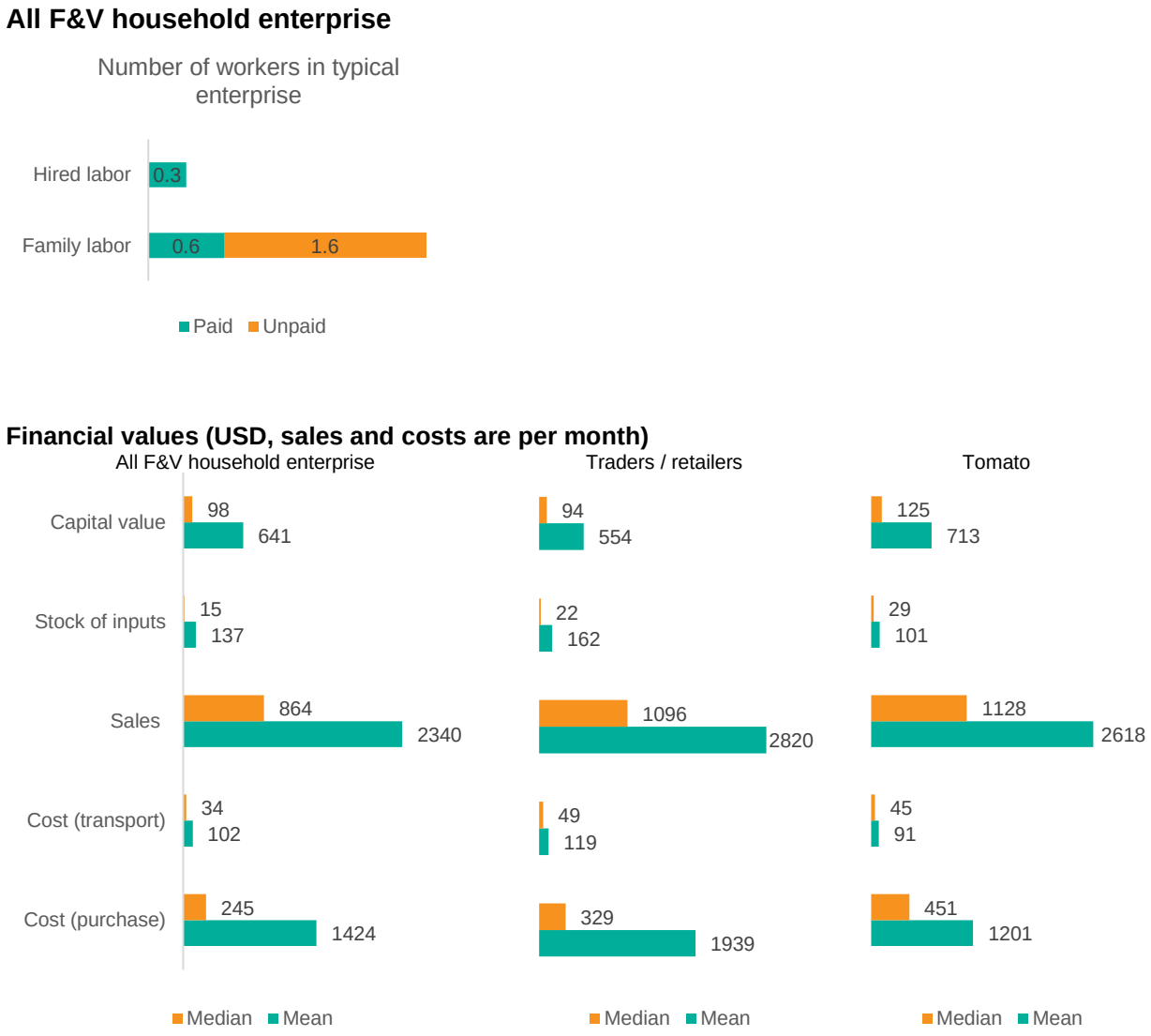


Figure 8. Business characteristics of F&V enterprises in Nigeria (average of 2012 and 2015)

Source: LSMS-ISA data.
Note: These enterprises typically operate 4-6 months / year, though some operate 12 months
Monetary figures are in 2020 USD, deflated by Naira figures with CPI, and using exchange rate in 2020

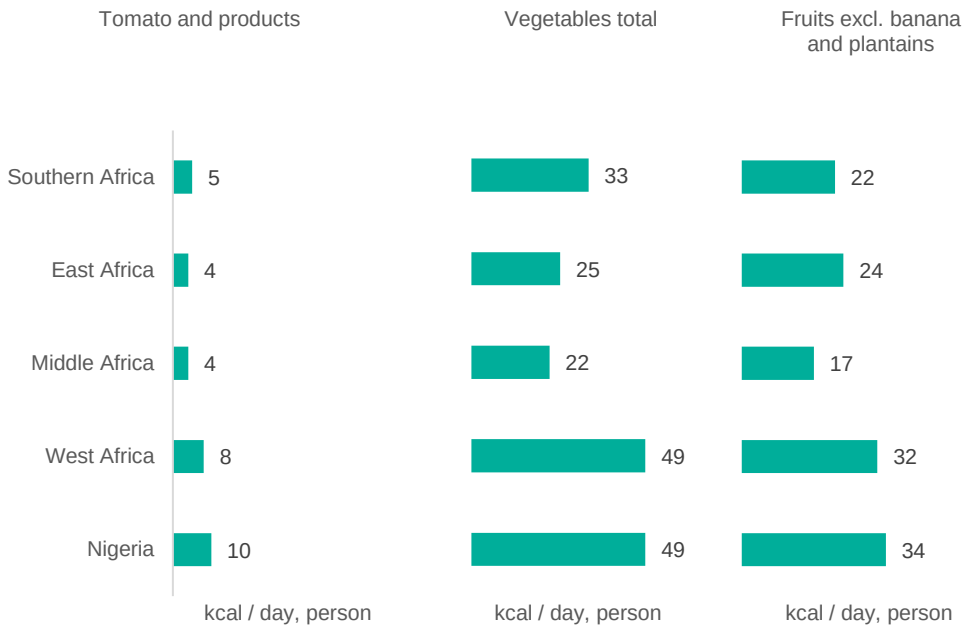
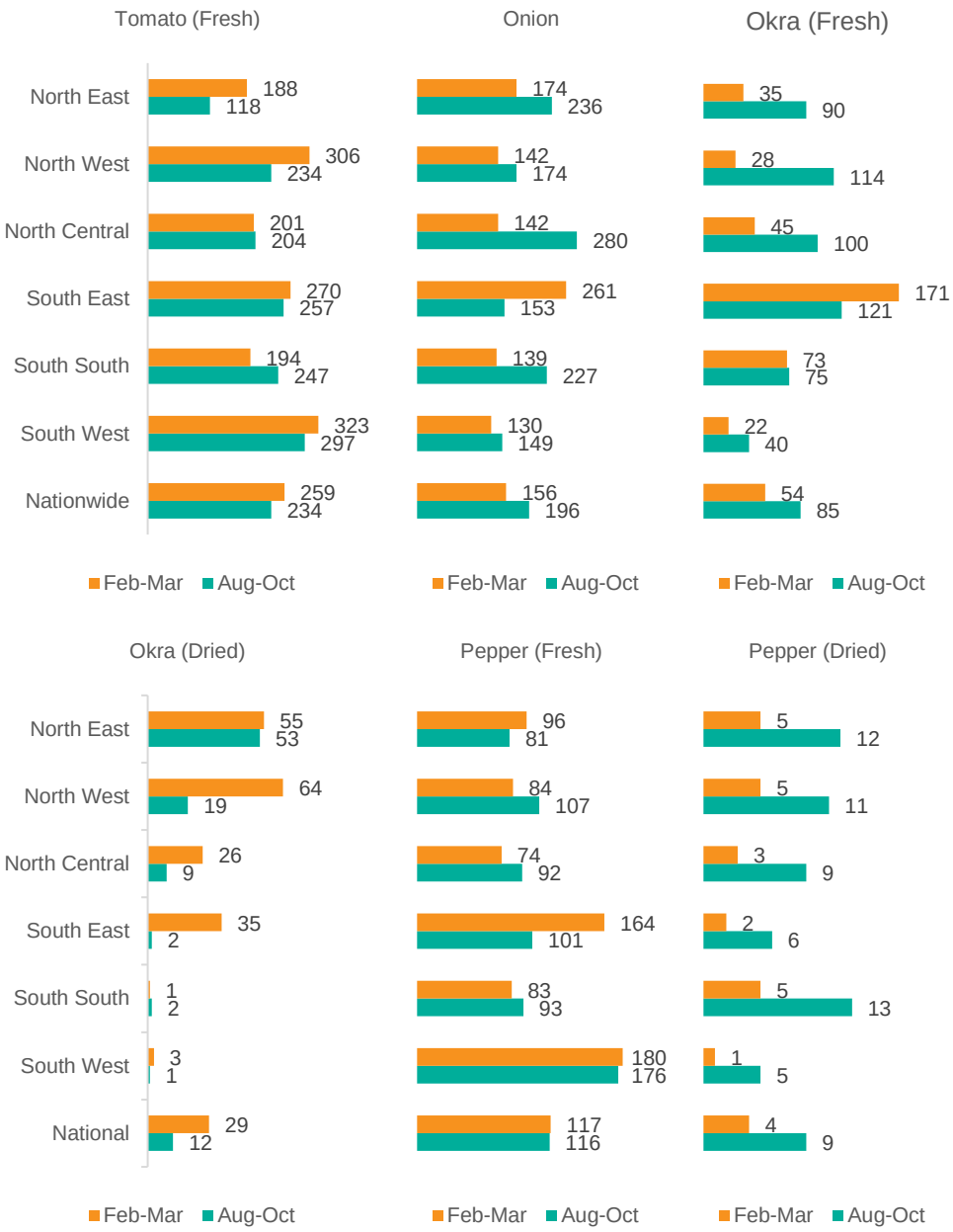


Figure 9. Consumption of fruits and vegetables in Nigeria and other African regions in 2019

Source: Food Balance Sheet (FAO 2022).


Tomato (Fresh)
North East 188 118
North West 306 234
North Central 201 204
South East 270 257
South South 194 247
South West 323 297
Nationwide 259 234
Feb-Mar Aug-Oct
Onion
North East 174 236
North West 142 174
North Central 142 280
South East 261 153
South South 139 227
South West 130 149
Nationwide 156 196
Feb-Mar Aug-Oct
Okra (Fresh)
North East 35 90
North West 28 114
North Central 45 100
South East 171 121
South South 73 75
South West 22 40
Nationwide 54 85
Feb-Mar Aug-Oct
Okra (Dried)
North East 55 53
North West 64 19
North Central 26 9
South East 35 2
South South 1 2
South West 3 1
National 29 12
Feb-Mar Aug-Oct
Pepper (Fresh)
North East 96 81
North West 84 107
North Central 74 92
South East 164 101
South South 83 93
South West 180 176
National 117 116
Feb-Mar Aug-Oct
Pepper (Dried)
North East 5 12
North West 5 11
North Central 3 9
South East 2 6
South South 5 13
South West 1 5
National 4 9
Feb-Mar Aug-Oct

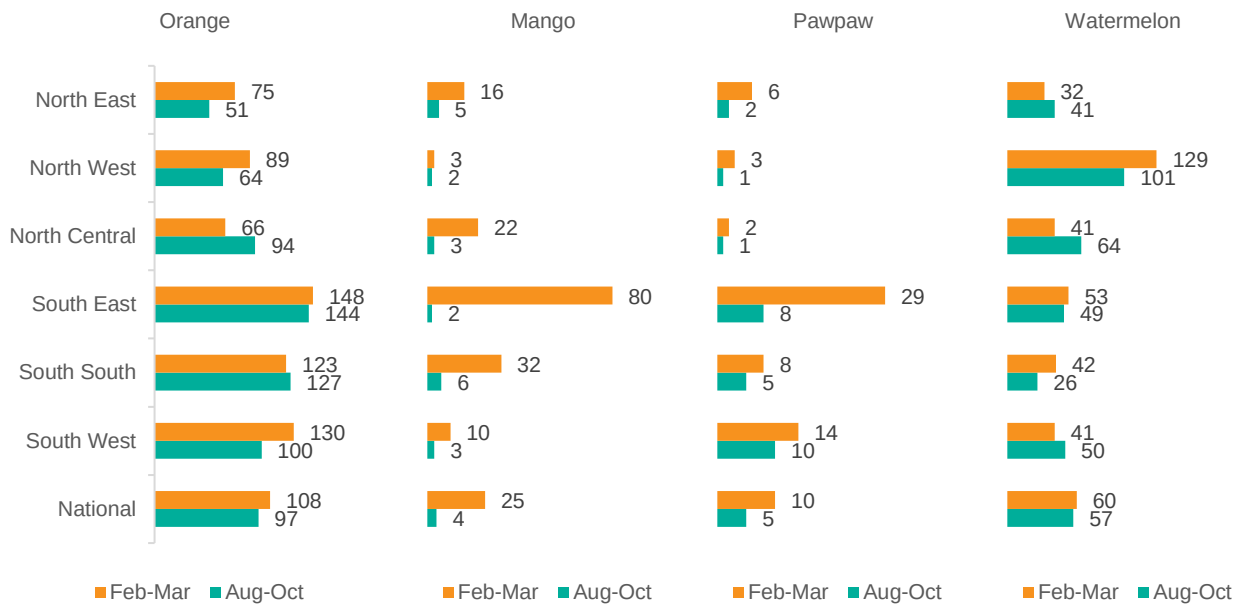
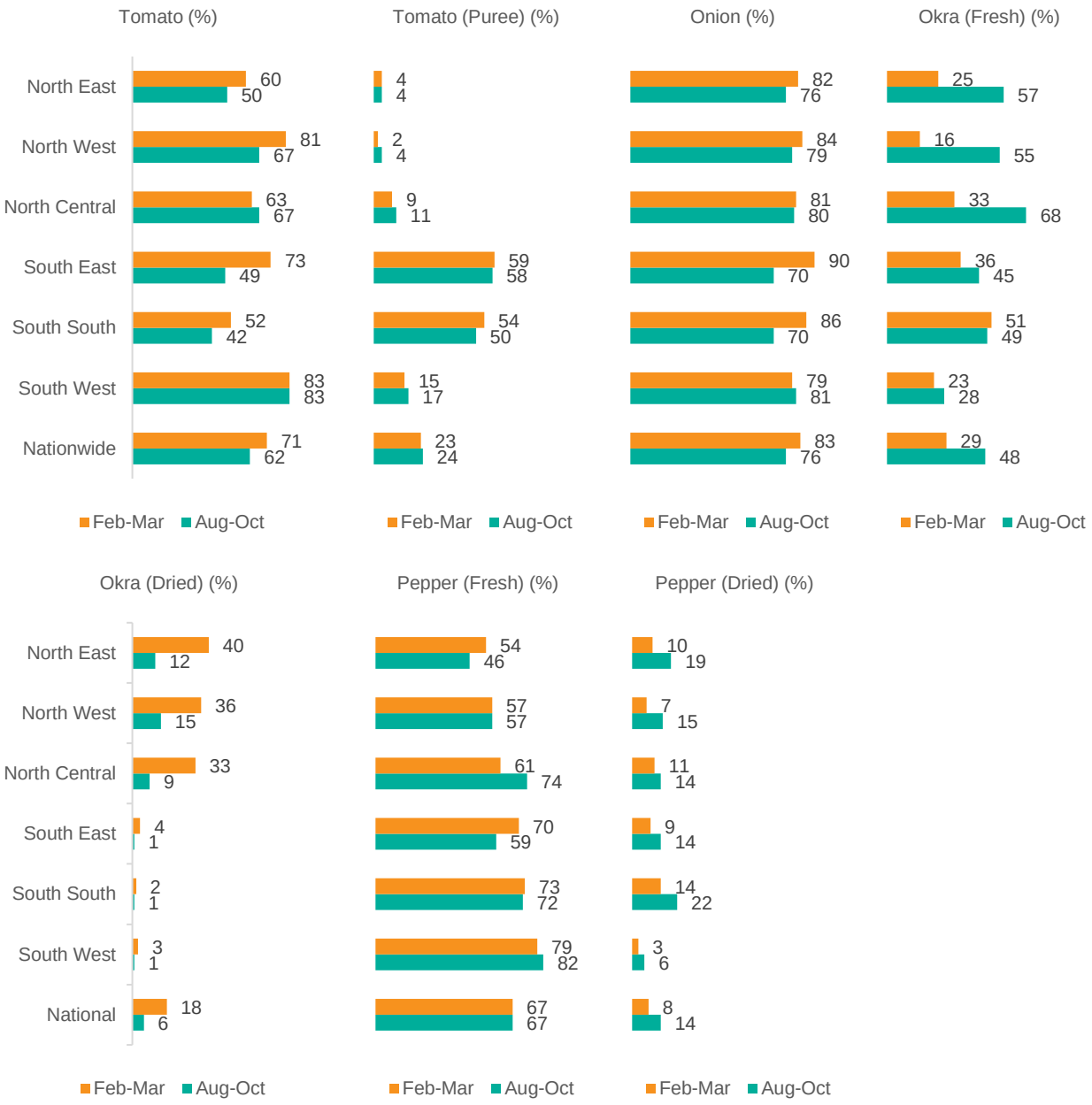


Figure 10. Consumption of horticulture commodities, excluding eating-out (gram per capita, per week)

Source: Authors based on NBS-WB (2019). Figures are averages of four-rounds of LSMS-ISA surveys.


Tomato (%)
North East 60 50
North West 81 67
North Central 63 67
South East 73 49
South South 52 42
South West 83 83
Nationwide 71 62
Feb-Mar Aug-Oct
Tomato (Puree) (%)
4 4
2 4
9 11
59 58
54 50
15 17
23 24
Feb-Mar Aug-Oct
Onion (%)
82 76
84 79
81 80
90 70
86 70
79 81
83 76
Feb-Mar Aug-Oct
Okra (Fresh) (%)
25 57
16 55
33 68
36 45
51 49
23 28
29 48
Feb-Mar Aug-Oct
Okra (Dried) (%)
North East 40 12
North West 36 15
North Central 33 9
South East 4 1
South South 2 1
South West 3 1
National 18 6
Feb-Mar Aug-Oct
Pepper (Fresh) (%)
54 46
57 57
61 74
70 59
73 72
79 82
67 67
Feb-Mar Aug-Oct
Pepper (Dried) (%)
10 19
7 15
11 14
9 14
14 22
3 6
8 14
Feb-Mar Aug-Oct

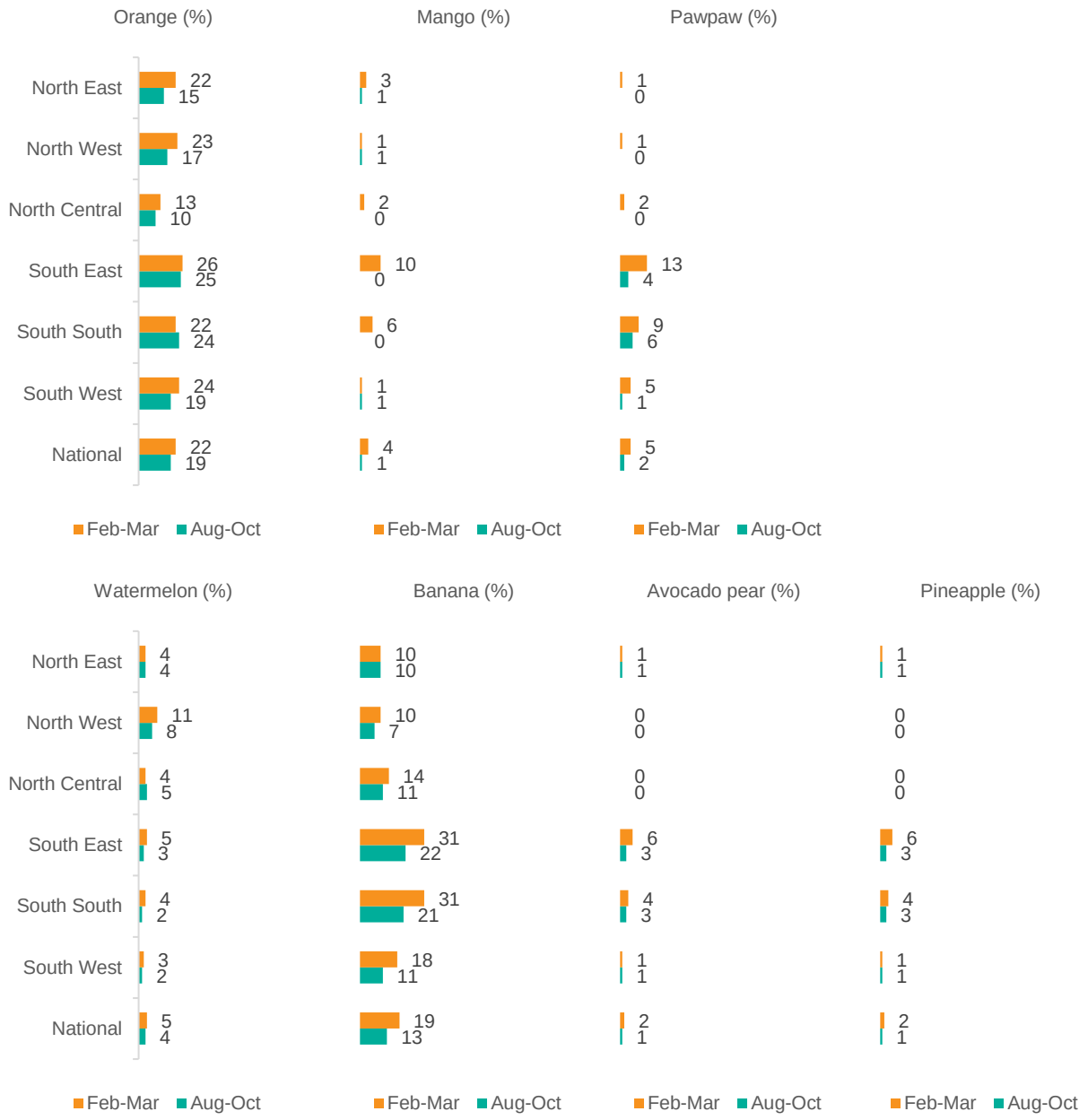


Figure 11. Consumption of horticulture commodities, excluding eating-out (% of households consuming in the past week)

Source: Authors based on NBS-WB (2019). Figures are averages of four-rounds of LSMS-ISA surveys.

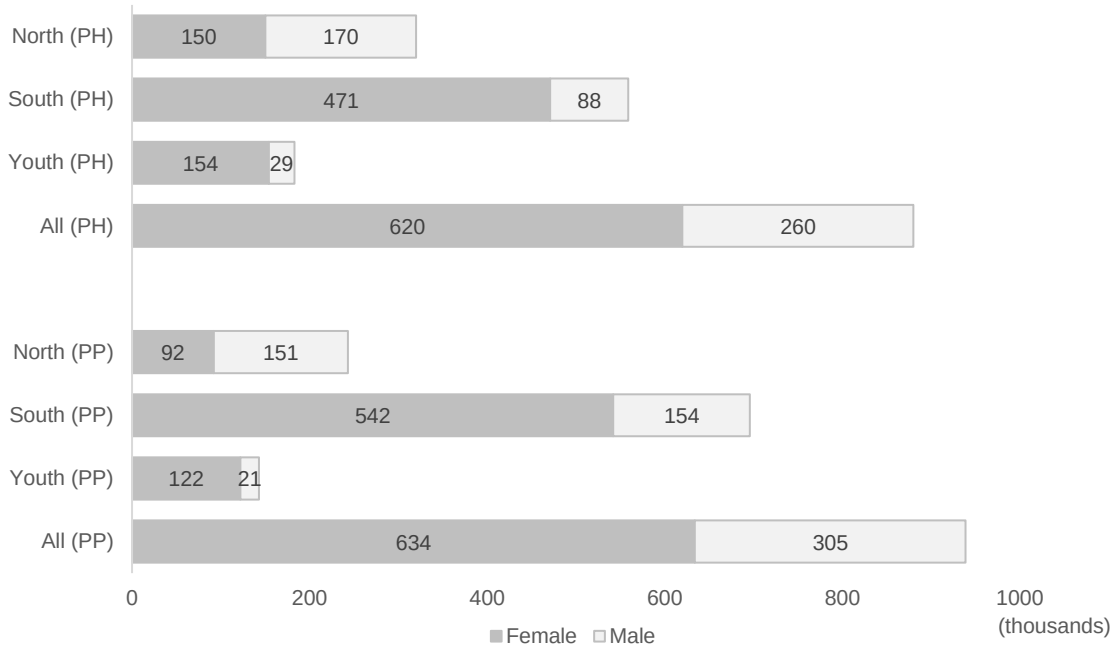


Figure 12. Number of workers in off-farm vegetables and fruits sector, excluding household enterprises (2012) (in thousands)

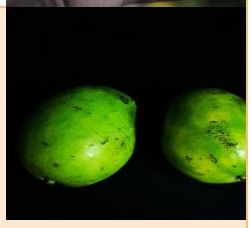
Source: Authors based on NBS-WB (2019).
Note: Figures are based on LSMS-ISA data, where the descriptions of employment included the following: fruits = “banana”, “fruit”, “mango”, “melon”, “orange”, “pineapple”, “plantain”, “watermelon”; vegetables = “bitterleaf”, “egusi”, “herb”, “kuka”, “okra”, “onion”, “pepper”, “tomato”, “vegetables”. Figures above may underestimate, as they exclude other households who may handle fruits and vegetables but do not describe them explicitly.
PH = Post harvesting season; PP = post-planting season
Youth = 15~34 years old
North = NW, NE, NC; South = SE, SS, SW

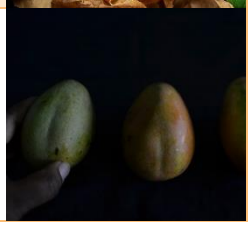
Appendix B. List of promising horticulture varieties for mango, orange and tomato in Nigeria

Selected mango varieties

Table 10 presents some selected mango varieties:

Table 10. Traits of selected mango varieties in Nigeria

Common Name	Characteristics	
Cotonou Mango	Skin Colour: Green, with a little red blush Flesh Colour: Pale lemon Yellow Shape & Size: Large, ellipse-shaped Flavor: Fresh and sour. Tastes like pineapple when ripe Texture: firm, not fibrous Ripening Cues: Softens with pressure, no visible colour change Peak Availability: March – April	
Opioro	Skin Colour: Green Flesh Colour: Yellow Shape & Size: Long & large Flavor: Fresh and sour Texture: firm, not fibrous Ripening Cues: Softens with pressure, no visible colour change Peak Availability: February/ March	
Benue Mangoes	Skin Colour: Green, with a little yellow; Red with yellow – a few varieties characterised by their size Flesh Colour: Pale yellow – light orange Shape & Size: Large – some are as big as melons Flavor: Fresh and sour Texture: Firm, not fibrous Ripening Cues: Softens with pressure, skin colour lightens with a touch of yellow Peak Availability: April***	
Normal (Ogbomosho/ Enugu (Eastern)/ Calabar/ Abuja/ Yellow) Mangoes	Skin Colour: Bright yellow skin with orange and red blush Flesh Colour: Yellow Shape: Oblong Flavor: Sweet with a hint of spice Texture: Varies from firm to soft and juicy; fibrous flesh Ripening Cues: Green overtones diminish and the yellow becomes more golden as it ripens. Squeeze gently to judge ripeness. Peak Availability: February to – ***	
Sheri Mango **May be same as Alphonso mango of India.**	Skin Colour: Green Flesh Colour: dark yellow – orange; Shape: ellipse-shaped Flavor: Sweet, rich and spicy, with aftertaste of 'turpentine/kerosene' Texture: Firm flesh, holds shape when cut Ripening Cues: Green overtones diminish and yellow becomes dominant Peak Availability: February to – ***	
Julie Mango	Skin Colour: Green Flesh Colour: dark yellow – orange Shape: Ovate and flat Flavor: Rich Texture: Juicy flesh Ripening Cues: Touch of yellow at the base Peak Availability: February to	

Common Name	Characteristics	
Peter / Jane/ Binta Sugar	Skin Colour: Green Flesh Colour: Orange Shape & Size: Large Flavor: Sour unripe, Sweet Texture: Firm Ripening Cues: Yellow/ Red blush Peak Availability: March – April	
Kerosene	Skin Colour: Pale peach Flesh Colour: Yellow – Orange Shape: ellipse-shaped Flavor: Aftertaste of turpentine/ kerosene Texture: firm to soft and juicy; fibrous flesh Ripening Cues: Green overtones diminish and peachy-tan colour prevails Peak Availability: February to ***	

*** unknown
Source: https://www.kitchenbutterfly.com/2015/varieties-of-nigerian-mangoes/

Processing mango fruit into various shelf-stable products makes the seasonal fruit conveniently available to consumers all year round. Some common processed products from mango fruit are derived from pulp. Apart from the primary products from mango pulp, mango pulp derivatives can enrich or flavor secondary products such as yogurt, ice cream, beverages, and soft drinks.

Byproducts of mango processing, such as the peel and kernel, are rich in bioactive compounds, including carotenoids, polyphenols, and dietary fibers. The byproducts of mango processing can be used in food fortification and the manufacture of feeds, thereby gaining more excellent value from the fruit while reducing wastage. Although mango can be processed into all these products, smallholder farmers and processors in developing countries have yet to exploit this potential fully.

Selected orange varieties

Only citrus varieties, of which 11 varieties of sweet orange (*Citrus sinensis*) and 1 variety of Tangelo *(Citrus tangelo*), are registered in the national variety catalog. The varieties were released in 1986 (Sweet Orange (Citrus cinensis) - Nigerian Seed Portal Initiative). Similar to vegetables, there are varieties of fruit species grown but not registered in the country.

Table 11 presents some promising orange varieties.

Table 11. Traits of selected orange varieties in Nigeria

Common Name	Characteristics	Photo
Valencia (CIT/NH 11)	Sweet Orange type, High yielding, top fruit quality, late maturity. Best for forest transition/derived savanna, southern and guinea savanna agroecological zones. Valencia is one of the best oranges to make juice. Origin: Florida, U.S.A, developed by Florida Experimental station.	
Bende (CIT/NH 10)	Sweet Orange type, High yielding, top fruit quality. does well in forest transition/derived savanna, southern and guinea savanna agroecological zones.	Not available

Common Name	Characteristics	Photo
	Origin/Source: South-east, Nigeria, developed in Nigeria by NIHORT	
Meran (CIT/NH 9)	Sweet Orange type, High yielding, top fruit quality with mid season fruiting. Best for forest transition/derived savanna, southern and guinea savanna agroecological zones. Origin/Source: South-east, Nigeria, developed and bred by NIHORT	Not available
Lue-gim-gong (CIT/NH 8)	Sweet Orange type, High yielding, top fruit quality, late maturity. Best fit for forest transition/derived savanna, southern and guinea savanna zones. Origin/Source: Florida, U.S.A, developed by the Florida Experimental station.	
Pine apple (CIT/NH 7)	Pineapple orange got its name from the yellow rind, which resembles the color of pineapple. It is a sweet orange type, outstanding characteristics includes: high yielding, top fruit quality. Agroecological zones best for production includes: forest transition/derived savanna, southern and guinea savanna. The flavor is sweet and subtle, with an amazing fragrance. Now available as seeded and seedless fruits. Origin/Source: Florida, U.S.A, developed by Florida Experimental station	
Hamlin (CIT/NH 6)	Sweet Orange variety, outstanding characteristics are high yielding, top fruit quality and early fruiting. Fruits do not have deep color, flesh is sweet and seedless. Grow abundantly during winter. Although it tastes pleasant, it is not popular for commercial uses because of the small size. Origin/Source: Florida, U.S.A Developing Institute: Florida Experimental station.	
Washington Navel (CIT/NH 5)	Sweet orange variety, it is seedless, flavor sweeter than Valencia, the name 'Navel' oranges is from the bumpy "navel" near the fruits' blossom ends. Navel oranges are more suitable for fresh consumption than juicing. High yielding, top fruit quality, best fit for forest transition/derived savanna, southern and guinea savanna agroecological zones Origin/Source: Florida, U.S.A Developing Institute: Florida Experimental station	
Parson Brown (CIT/NH 4)	Sweet orange type, popular juice variety in Florida. Parson Brown has thick skin with moderate seeds. The color is a bit dull, and the flesh is firm. High yielding, top fruit quality. Agroecological Zones: Forest Transition/Derived Savanna, Southern and Guinea Savanna Origin/Source: Florida, U.S.A.	
Umudike (CIT/NH 3)	High yielding. Agroecological Zones: Forest Transition/Derived Savanna, Southern and Guinea Savanna Origin/Source: South-east, Nigeria Developing Institute: NIHORT Breeder(s)/Collaborators: NIHORT	Not available
Agege1 (CIT/NH 2)	Sweet orange variety, high yielding, top fruit quality. Agroecological Zones: Forest Transition/Derived Savanna, Southern and Guinea Savanna. Origin/Source: Agege, Nigeria Developing Institute: NIHORT Breeder(s)/Collaborators: NIHORT	Not Available

Source: World Vegetable Center.

Selected tomato varieties

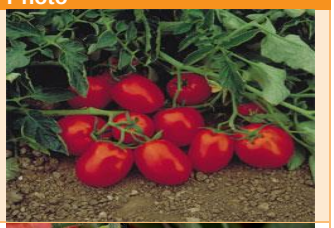
There are hundreds of tomato varieties currently being grown in Nigeria (Abdul-Rafiu et al., 2022), but only a few (17) of these varieties are registered in the national variety catalog. In 2015, Syngenta released and registered three hybrid varieties: Chibli, Kilele, and Tylka. Before the release of these three varieties, the other registered tomato varieties dated back to 1985. Varieties are being grown in the country which is not locally released and registered in the National seed catalog (Tomato (Lycopersicon esculentum) - Nigerian Seed Portal Initiative). Six WorldVeg-developed improved tomato lines, namely AVTO1464, AVTO1707, AVTO1807, AVTO1705, AVTO1706, and AVTO1427, are currently in the pipeline under the leadership of Premier Seed (Personal communication, Dr. Afolabi Samson, Research Manager at Premier Seed). Two of these lines (AVTO1707 and AVTO1706) are dual purposes.

In Nigeria, dual-purpose tomato varieties that can serve both the fresh and the processing market have higher potential for both seed producers and farmers since they can serve a larger market share. For these reasons, we proposed many dual-purpose tomato varieties already registered or with the potential to be scaled up in Nigeria (Table 6). Key post-harvest of tomato varieties that can complement value chain-wide innovations (adaptation to transport, processing) include:

- Firmness: The ability of the fruit to withstand pressure without deterioration.
- Shelf life: Period during which a fruit remains suitable for consumption without qualitative deterioration when stored at room temperature.
- Color: The external (pericarp) and internal redness is an important attribute for consumers in West Africa and especially in Nigeria.
- Brix: is the measure of the total soluble solids in tomato fruits. It is an important trait for processors. varieties with °Brix lower than 4.5 are usually not suitable for processing (Agoston et al., 2017).
- Pathogen susceptibility: There are bacterial and fungal diseases (e.g.: soft rot, gray mold, and Rhizopus rot) affecting fruits during post-harvest. The control of post-harvest pathogens requires proper handling and sanitation. Regardless of the variety, if the ripened fruits are not handled properly, they will be attacked.

Table 12 presents selected dual-purpose tomato varieties. These varieties are appropriate for processing into paste and puree. Their firmness makes them also amenable to long transportation if adequately handled.

Table 12. Traits of selected tomato varieties in Nigeria

Common Name	Characteristics	Photo
Chibli (Registered in the national seed catalog but Seeds are imported)	• Medium early determinate hybrid • Fresh market and paste-processing • High yields and nematodes resistance • Brix 5.5 to 6.0% • Fruit weight: 100-100 g • Maturity: 120 days from sowing	
Tylka (Registered in the national seed catalog but Seeds are imported)	• Indeterminate hybrid for fresh market • Very firm fruits • Suitable for greenhouse and open field • Fruit weight: 120-130 g • Maturity: 85 days after sowing Suitable for fresh market	
Kilele (Registered in the national seed catalog but Seeds are imported)	• A determinate hybrid tomato for fresh market • High yielding • Oval shape and very firm fruits • Fruit weight: 120-130 g • Maturity: 85 days after sowing Suitable for fresh market	
Diva F1 (Seeds are imported)	• Determinate variety • High yield and quality fruits • Bright red color when ripened with good firmness Suitable for fresh and processing uses	
PADMA F1 (Seeds are imported)	• Good adaptation to warm and humid growing conditions • Plant vigor is moderate to strong • Fruits are high round with good firmness Suitable for fresh market	

Source: World Vegetable Center.

Appendix C: Generic illustration of value-chain structures of key commodities (tomato, mango)

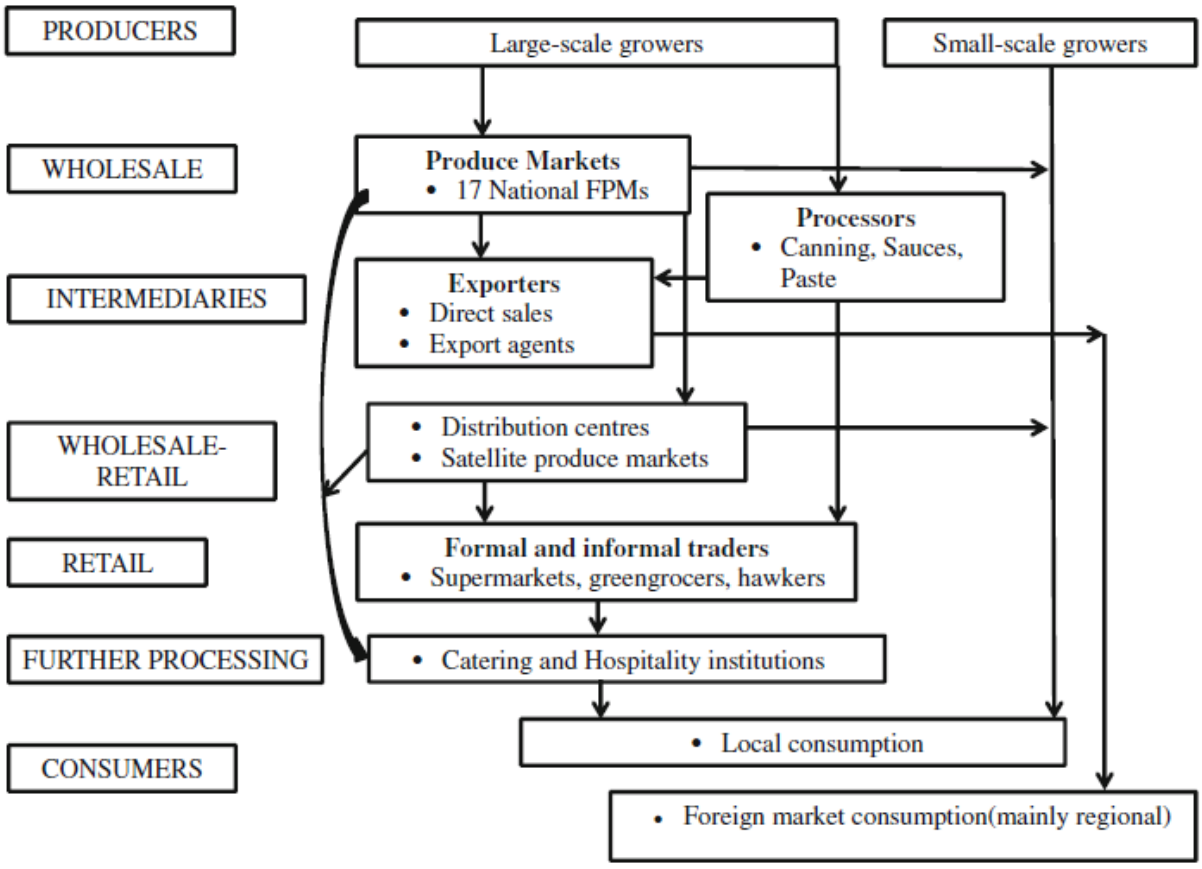


Figure 13. Illustration of the tomato value-chain (adapted from South Africa)
Source: Sibomana et al. (2016).

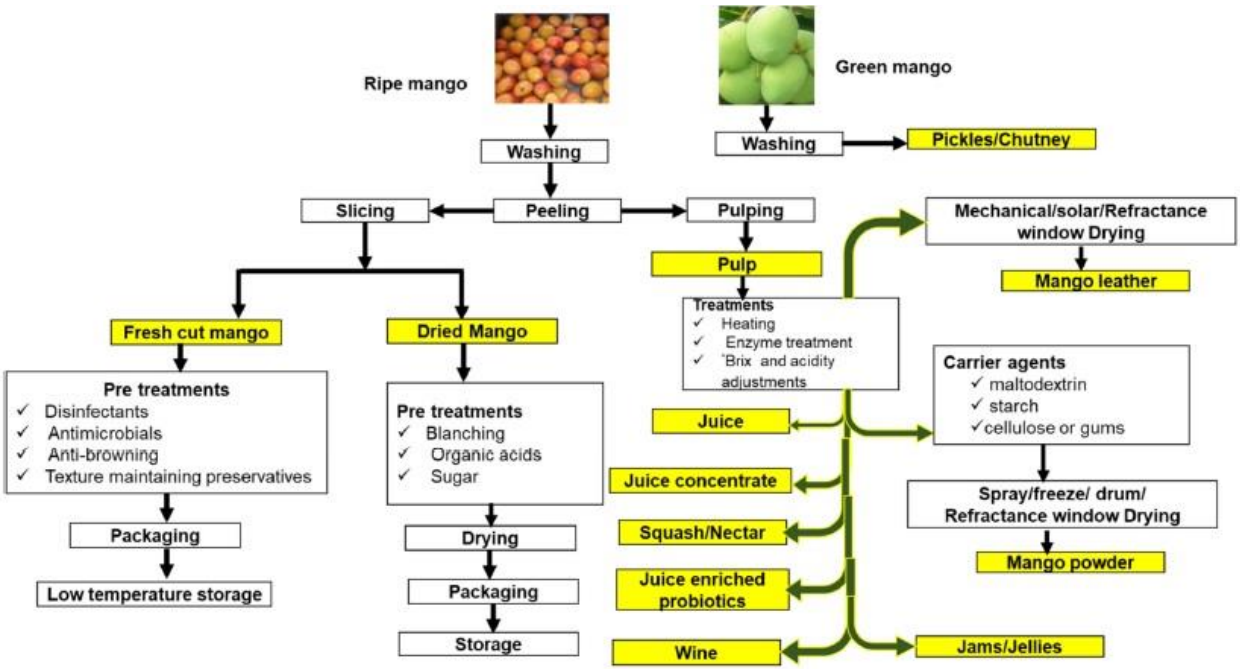


Figure 14. Processing of different products derived from mango in developing countries

Source: Owino & Ambuko (2021)

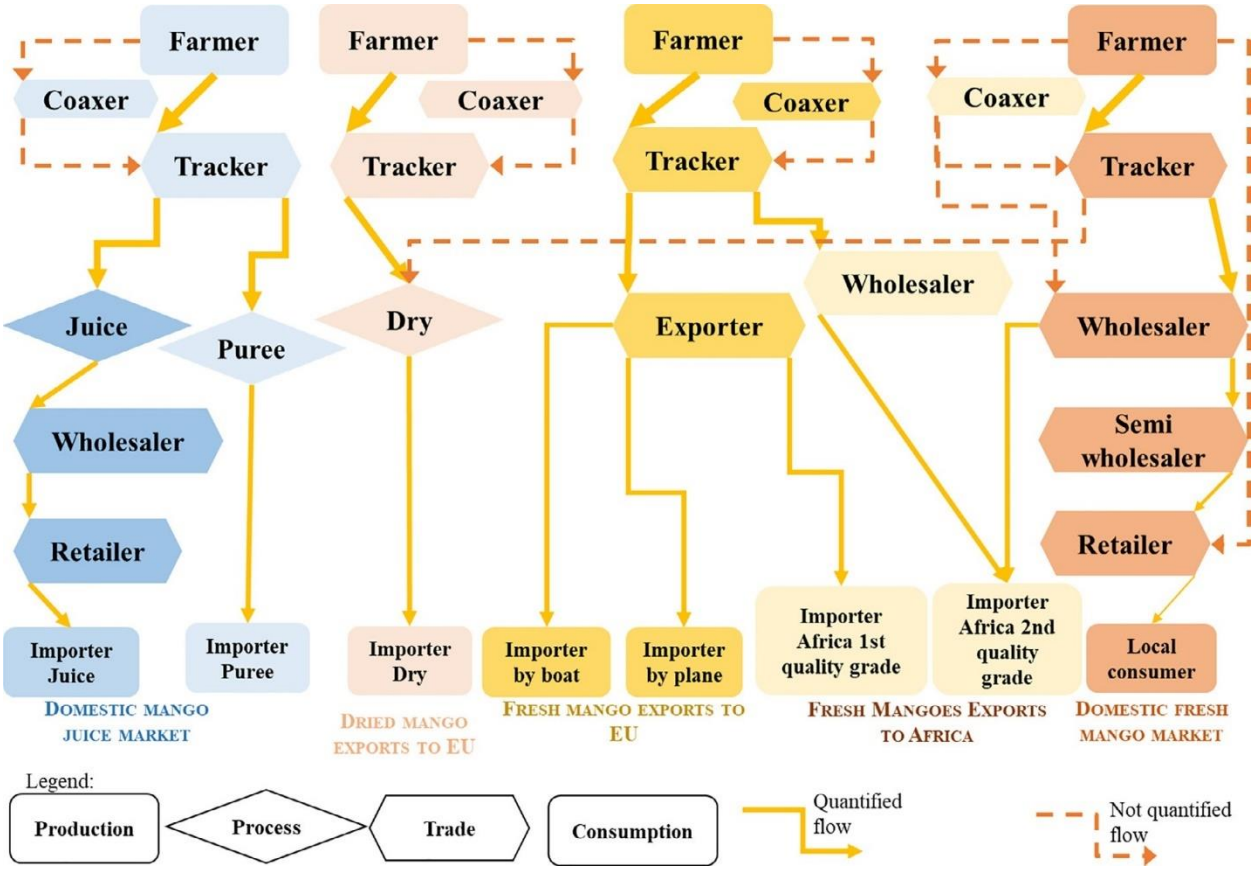


Figure 15. Mango supply chains in Burkina Faso in 2016.
Source: Parrot et al. (2022)

[i]Some improved production and harvesting methods were also clearly expressed at the stakeholder consultation meetings, including harvesting and post-harvesting handling practices (Balana et al. 2022b). For example, creating large passages/spaces between ridges will minimize trampling on tomato fruits during harvest while discouraging child and unskilled labor for harvesting raises harvesting quality. Other examples include harvesting early in the morning when the temperature is the coolest (Komolafe et al. 2015; Nwaobiala & Nwosu 2013).

[ii]Forced-air cooling is also more suitable than other methods, like hydro cooling for specific fruits and vegetables like strawberries and tomatoes that do not tolerate submersion (Kumar et al. 2022). Forced-air evaporative cooling (FAEC) uses an evaporative cooler that passes air through a water pad before contacting fruits and vegetables (Kumar et al., 2022). FAEC is considered particularly suited for produce to be kept at moderate temperatures (e.g., tomatoes) or soon to be marketed after harvest (Kumar et al. 2022). "Evaporative cooling technology, if used with forced air, requires lower energy to operate water pump and fans while it is effective in providing cold and humid air to the storage chamber" (Sibanda & Workneh 2020).

[iii]The Initiative aims to provide evidence on what types of bundled innovations, incentive structures, and policies are most effective for creating more equitable sharing of income and employment opportunities in growing food markets while reducing the food sector's environmental footprint. In collaboration with partners, the Initiative will produce a robust evidence base and rigorous impact assessments of the technological, process, and policy innovations for inducing favorable changes in food markets and value chains in five countries (Bangladesh, Ethiopia, Nigeria, Uganda, Uzbekistan, and Central America sub-region. The innovations will primarily benefit smallholder farmers and agrifood SME business owners and workers along the value chains.

[iv]These include Bunkasa AgriTech Ltd., Coldhubs Ltd., Nigerian Stored Product Research Institute (NSPRI), World Vegetable Center (WVC), East-West Seeds Ltd., Crop2Cash Ltd., and Agrorite Ltd.

Appendix D: Maps of Nigeria

Figure 16. Map of Nigeria (primary road network and cities)

Source: Authors' modification from https://www.dreamstime.com/stock-illustration-nigeria-road-map-vector-federal-republic-image74104122.

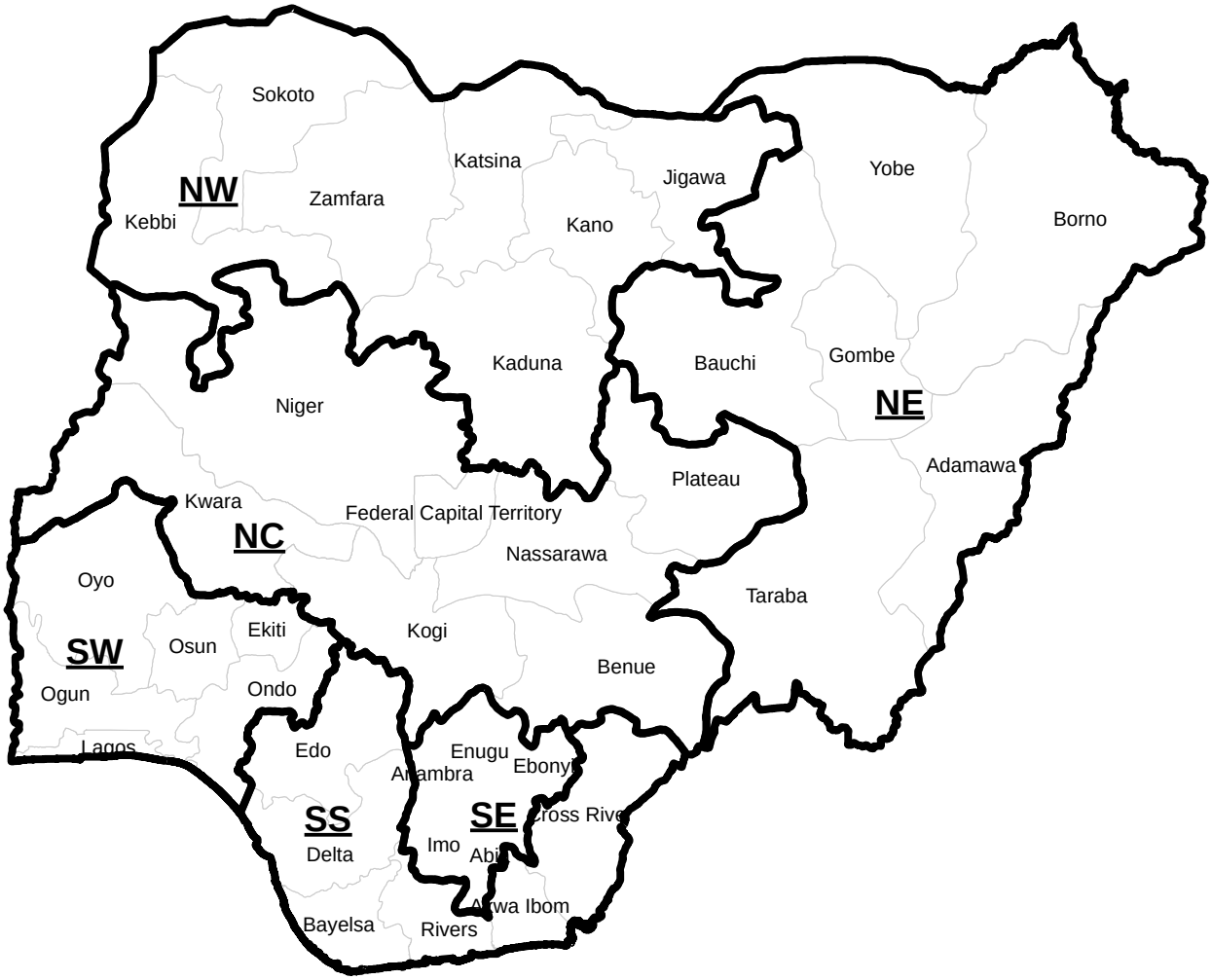


Figure 17. Geopolitical zones and states in Nigeria

Source: Authors.
NE = North East; NW = North West; NC = North Central; SE = South East; SS = South South; SW = South West

ABOUT THE AUTHORS

Hiroyuki Takeshima is a Senior Research Fellow, Bedru Balana is a Research Fellow, Opeyemi Olanrewaju is a Research Analyst, and Hyacinth O. Edeh is a Country Program Manager with IFPRI's Development Strategy and Governance Division. Futoshi Yamauchi is a Senior Research Fellow with IFPRI's Markets, Trade, and Institutions Division. Didier Kadjo is an Agricultural Market Economist at IITA, Saweda Onipede Liverpool-Tasie is a Visiting Scientist Market Economist at IITA, and Tahirou Abdoulaye is the Director of Sahel Africa Hub at IITA. Mathieu Ayenan and Caleb I. Olanipekun are research assistants, and Rosaine Nerice Yegbemey is an Agricultural Economist with the World Vegetable Center.

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A world free of hunger and malnutrition
IFPRI is a CGIAR Research Center
1201 Eye Street, NW, Washington, DC 20005 USA | T. +1-202-862-5600 | F. +1-202-862-5606 | Email: ifpri@cgiar.org | www.ifpri.org | www.ifpri.info