

Leveraging the innovation potential of informal midstream actors to enhance food systems outcomes

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Abstract

Scholars and policymakers alike acknowledge that the informal midstream is an important linkage in

Africa's food system, providing a crucial connection between production and consumption of nutritious fruits and vegetables. In several instances, development practitioners have deliberately engaged informal midstream actors in interventions to enhance food systems outcomes, such as introducing plastic crates in Nigeria to reduce

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Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

postharvest losses. Using this initiative as a case study, we interview key actors to explore the relationship between challenges, motivations, innovation capacity, and conditions in the innovation and adoption of plastic crates. We conclude from our findings that successful innovation in food system depends on collaboration between informal midstream actors and formal sector service providers, and necessitates a deep understanding of socioeconomic realities and power dynamics, especially in relation to gender norms. We highlight approaches that actors in the formal sector can take to enable informal midstream actors to engage in innovation processes for positive food systems outcomes; specifically, decreased postharvest losses, improved food safety, and increased incomes for women.

Keywords

agricultural value chains, midstream actors, informal economy, innovation, food systems outcomes

Introduction

Adequate and safe consumption of fruits and vegetables has recently received considerable attention for its important role in enhancing food and nutrition security in Africa (de Steenhuijsen PETERS et al., 2021; Nyamete et al., 2024), supported by growing emphasis from national governments and food system experts on the importance of micronutrient rich diets (Herforth et al., 2019). To enhance food systems outcomes such as reduced food waste and more affordable vegetable prices for low-income consumers, innovations and interventions that effectively address challenges across horticultural value chains are crucial (Walsh et al., 2020). This recognition has led to a focused engagement with midstream actors in the value chains, who can play a pivotal role in the innovation lifecycle, from development to utilization (Kalmpourtzidou et al., 2020; Sharma & Dahlstrand, 2023).

The midstream segment of the horticultural value chain includes a wide variety of actors, encompassing the “vast network of agrifood enterprise activities between the farmer’s gate and the consumer’s plate” (International Fund for Agricultural Development, 2021, p. 14). In low- and mid-

dle-income countries, midstream actors often operate in the informal sectors of the food system, which means that both in law and practice, formal arrangements, such as official employment contracts, tax paying, and other regulatory measures, are largely absent (International Labour Organization, 2012). While some scholars assumed that with increased economic development, the informal economy would eventually disappear, informal economies worldwide are not diminishing in size; so far, many policy interventions designed to reduce informal practices, such as cutting formal registration costs and simplifying tax laws, have had very limited effects (De Andrade et al., 2016; Floridi et al., 2020; Rothenberg et al., 2016).

There is a lack of knowledge of how stakeholders can work with—rather than against—actors in informal midstream segments to address value chain challenges and inefficiencies, as they operate beyond formal market mechanisms or legal and regulatory frameworks (Dijkxhoorn et al., 2021; Vorley, 2013). The absence of comparable incentives or pressures as experienced in the formal sectors necessitates a comprehensive understanding of the mechanisms that motivate these actors to innovate and adopt, in order to contribute to enhanced food systems outcomes. Furthermore, there is a need to understand how to establish an enabling environment for innovation use and adoption, to ensure effective use and scale; this includes both formal (policy, government structures, regulations, regulated financial systems) and informal (social, cultural, and informal economic norms) support systems (Schuetz et al., 2017).

This paper utilizes a case study approach to explore and evaluate the incentives that promote innovation and its adoption by midstream actors within the informal economy through assessing a postharvest intervention, reusable plastic crates, in the tomato value chain in Nigeria. The research questions are:

1. What are the primary incentives for midstream actors in the informal tomato value chain in Nigeria to adopt the reusable plastic crate innovation?
2. What barriers do these actors face in adopt-

ing and increasing the use of reusable plastic crates?

3. What are perceived enablers of innovation and innovation adoption?
4. How should interventions be adjusted to address different food systems outcomes?

By addressing these questions, the study intends to provide a comprehensive understanding of the complex interplay between innovation, informal sector dynamics, and food systems outcomes, offering insights for policymakers, practitioners, and researchers focused on agricultural innovation and food systems.

Conceptual Framework: This research is underpinned by a conceptual framework that attempts to broadly comprehend the integration of food systems outcomes with the components of the enabling environment necessary for effective innovation adoption in informal horticultural sectors. The framework identifies three primary food systems outcomes from the crate intervention, based on the original intention of the case study intervention: Reduced postharvest losses, improved food safety, and increased income for women actors.

The analysis aims to provide a comprehensive understanding of resources, constraints, and motivations that influence behavior towards achieving diverse societal outcomes, as they relate to innovation adoption in the informal sector (Klerkx et al., 2010). The mechanisms that contributed to these outcomes, and subsequently to potential improvements to the innovating and scaling process, are assessed in the context of the survey results, culminating in a discussion on how enabling environments can support pathways that lead to these outcomes in the informal economy.

Literature Review

This literature review explores current research on innovation in informal fruit and vegetable economies, highlighting the unique drivers, constraints, and equity considerations that shape innovation processes and outcomes.

Informal Horticultural Markets

In many low- and middle-income countries, infor-

mal horticulture (or “fruit and vegetable”) supply chains represent over 90% of traded volumes (de Steenhuijsen Piters et al., 2021). The informal fruit and vegetable sector plays a key role in food and nutrition security, increasing access, availability, and consumption of nutrient-dense foods, especially for low-income households (Mekonnen et al., 2022). In Lagos, Nigeria, for example, more than 30 informal markets supply produce for 21 million, with fresh produce markets in most communities (Plaisier et al., 2019). They also substantially contribute to the livelihoods of poor women, more likely to be employed in informal settings than men (Mekonnen et al., 2022).

Informal economies are characterized by a high degree of self-organization and structure. Regulations originate from various non-state actors and informal institutions, such as powerful entrepreneurs and religious leaders, but also trade unions, associations, and other social networks (Mekonnen et al., 2022). These arrangements form an economic structure in the absence of state-led regulatory authority (Schoofs, 2015). In some cases, informal governance structures result in the formation and upholding of certain standards, such as food safety and quality (Nicolini et al., 2022). Networks of actors provide important functions, such as market regulation, service provision (water, security, electricity), finance (joint investments), and resource allocation (Kinyanjui, 2010). However, there are inefficiencies in informal vegetable value chains that can result in high food loss and price uncertainty in the market, negatively impacting the incomes of all actors involved as well as the affordability of fresh vegetables for consumers (de Steenhuijsen Piters et al. 2021).

Innovation for Development Outcomes

Innovation within the informal sector presents distinct characteristics compared to formal sectors (Rivera-Huerta & López-Lira, 2022). Informal sector innovation often originates from factors beyond market forces, such as individual creativity or the necessity to address local challenges. Knowledge acquisition among informal actors tends to rely more heavily on experiential learning and practical training than on formal education. Limited capital resources within the informal sector

may hinder the widespread dissemination of innovations, leading to more localized impact. Successful innovation in informal sector economies necessitates a sense of ownership among local actors and a supportive role from formal institutions (Cozzens & Sutz, 2014). Intermediaries, acting as mediators between different sources of knowledge and communities, play a crucial role in facilitating the adoption and diffusion of innovations within informal settings.

Gender Considerations in Informal Markets

The importance of focusing innovation studies on informal settings is underscored by their significant role in inclusive development, benefiting marginalized populations and improving livelihoods (Cozzens & Sutz, 2014). Women in informal markets face unique, and more severe, barriers compared to men. In informal horticulture value chains specifically, women are unequally compensated in either assets or income for their labor and time, and generally are more prone to occupational insecurity and abuse in the form of harassment (Henry & Adams, 2018; Mekonnen et al., 2022). In Nigeria, women in the informal market are left unheard and lack decision-making power, and policies to correct inequities are either absent or fail to recognize women's contribution to food security and agricultural productivity (Ajibade et al. 2021). When designing and disseminating innovations, recognizing that there are gender-specific barriers to adoption is critical (Ajibade et al., 2021). Failing to consider gender when scaling an innovation can exacerbate gender inequities (McGuire et al, 2022). Furthermore, gender considerations do not only pertain to the innovation itself, but the enabling environment, the systems surrounding the innovation, that can be determinative of whether constraints are overcome and an innovation is adopted (Petesch et al., 2018).

Methodology

To explore the complex dynamics of innovation within informal horticultural sectors, this study employs a case study methodology, focusing on the use of reusable plastic crates in Nigeria's tomato value chain. The choice of a case study approach is driven by the need to deeply under-

stand the uniquely contextual, multifaceted incentives and barriers faced by midstream actors in adopting innovations. Case studies serve to observe and contextualize actions and structures relevant to social innovation theory, providing in-depth insights from various perspectives to foster a holistic understanding and facilitate theoretical innovation and generalization (Feagin et al., 1991).

Case Study Selection

The case study of tomato crates in Nigeria presents a unique opportunity to explore several dimensions of innovation in the informal sector and provides a valuable opportunity to empirically evaluate a real-life scenario (Yin, 2009). The tomato value chain is critical to Nigeria's agriculture sector, making innovations in this space particularly impactful. Given the significant role of informal sectors in distributing tomatoes, understanding how innovations are adopted and scaled in these settings can provide insights applicable across similar market situations. It is essential to understand that the tomato value chain involves a range of stakeholders, from smallholder farmers to large aggregators, each with distinct motivations and constraints regarding innovation adoption. By analyzing this case study, we aim to uncover insights into how midstream actors respond to innovations like reusable crates and what drives their decisions to adopt such technologies. It is helpful that the research team had familiarity with this work.

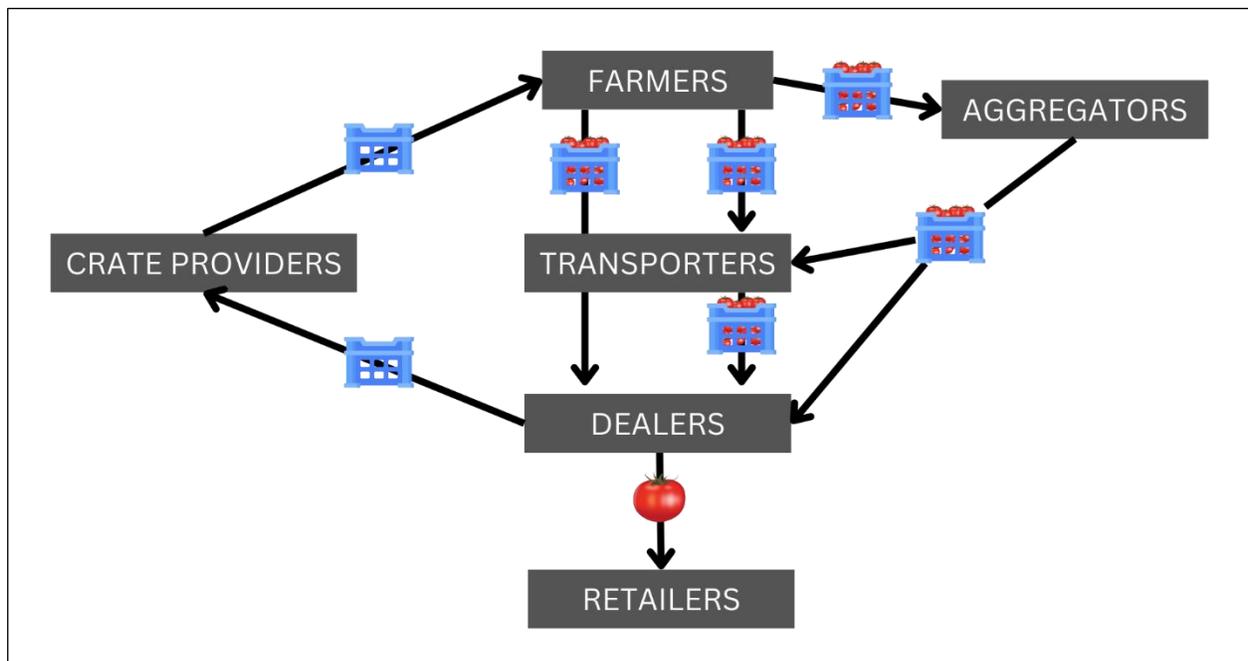
Beginning in 2016, a project funded by the Multi-Donor Trust Fund for Sustainable Logistics aimed to reduce significant tomato losses along the value chain. Following workshop-based consultations, tomato value chain actors prioritized plastic crates as a desirable intervention, resulting in pilot projects in North and Southwest regions (Kok et al., 2019; Plaisier et al., 2019). Crate use resulted in reduced losses and quality decay compared to the traditional raffia baskets (Kok et al., 2019). Thereafter, other institutions and entrepreneurs in Nigeria's tomato value chain also began piloting plastic crates, resulting in approximately ten crate renting companies becoming active in Nigeria, and subsequently becoming a new tomato value chain (Table 1; Figure 1).

Table 1. Actors in the Tomato Value Chain in Nigeria

Farmers	Cultivate tomatoes from small-scale (60%) to large-scale production (10%) (Ugonna et al., 2015). Over 50% of tomato production occurs in the north in Kano and Kaduna States under irrigated systems, but in the wet season production occurs in the south on small, rain-fed plots, with closer proximity to major markets.
Aggregators	Collect tomatoes from farmers and resell tomatoes to processors, dealers, retailers, or consumers.
Dealers	Act as intermediaries between producers and retailers, purchasing tomatoes from farmers or aggregators in larger volumes than any other marketing actors, and transporting or coordinating transport to wholesale or retail markets, primarily in the south.
Transporters	Transport tomatoes from farms to various actors (dealers, retailers, or consumers). Transportation methods vary depending on infrastructure availability and distance, which can be as far as 1,000 kilometers (620 miles) from the north to south.
Retailers	Purchase tomatoes from wholesale dealers and sell them to end consumers through informal local markets or roadside stalls. Retailers are the only value chain actors dominated by females, and notably they are no longer given access to plastic crates and continue to sell out of raffia baskets at market because of incidents of crates not being returned to the crate service providers.
Crate service providers	Rent out plastic crates to farmers, and sometimes dealers. Operations and returns of rented crates are loosely overseen and supported by the Tomato Crates Dealers Association of Nigeria, which was formed by members with sufficient financial capacity to invest.

Cited from Plaisier et al., 2019 unless otherwise noted.

Figure 1. Crate Rental Value Chain, Author's Depiction



Data Collection

A comprehensive literature review was undertaken to identify potential drivers that influence the innovation, adoption, and scalability of interventions aimed at midstream actors operating in the infor-

mal economy. Insights from the literature review informed the development of survey questions designed to gain a broad understanding of innovation and adoption motivations, challenges, and barriers for midstream actors, considering socio-

economic factors. A transdisciplinary team developed, piloted, and revised a survey during an initial field visit in August 2022 with midstream actors in the tomato value chain.

Data collection took place from 10–18 November 2022 in Kano, Ife (Osun State), Ibadan (Oyo State), and Lagos State, chosen because they cover all the significant markets where tomatoes are both sourced and sold. Crate providers and farmers were interviewed in the North (Kano), where major production occurs, while retailers and dealers were interviewed at the major markets in the south (Osun, Oyo, Lagos). This largely follows the pattern of the crate rental value chain from north to south.

Respondents were selected via snowball sampling, according to their type of value chain activity. The initial respondents were selected from the research team's previous contacts, who had been involved in the original crate intervention activities. In alignment with the scope of the study, interviews lasting 40–60 minutes were conducted with 58 value chain actors. Interviews were recorded and then transcribed.

Data Analysis

Following the interviews, data was analyzed qualitatively in Atlas.ti to gain insights into the motivations behind plastic crate adoption and into barriers to uptake, and to identify potential entry points for incentives within the informal sector during a First Cycle analysis (Saldana, 2013). Interview data were coded collaboratively, with two primary coders analyzing transcripts from each segment of the value chain to identify recurring themes and patterns and to develop a coding tree, which was discussed and approved by the transdisciplinary research team. Primary coders individually coded a subset of transcripts for comparison to ensure consistent coding, resolving discrepancies through consensus discussions. Structural coding was initially used based on survey questions, then codes were expanded (Saldana, 2013). Primary coders completed the coding and reviewed results collaboratively to verify consistency. A Second Cycle analysis was conducted, first by the primary coders then verified by a transdisciplinary team for code consolidation.

Codes were interpreted to organize emerging patterns.

Limitations

The snowball sampling approach could have led to a bias in selection of the actors we approached and invited to participate, leading to a potentially biased representation of the tomato value chain. Additionally, qualitative research is inherently subjective and open to interpretation; and the coding and analysis of data involves researcher judgment, which introduces the possibility of bias or misinterpretation. The use of multiple coders and regular discussions among researchers was intended to help mitigate this effect (Saldana, 2013). Furthermore, the sample size was not large enough to capture the full diversity of perspectives within the tomato value chain, so our findings may not be generalizable to the entire population or might overlook important potential data from non-interviewed groups.

Results

A total of 58 actors within the value chain were interviewed: 20 farmers, 20 retailers, 14 dealers, three crate service providers, and one transporter (Table 2). Discussion of results emphasizes farmers, retailers, and dealers because of their larger sample size. The sample consisted of a higher proportion of male respondents (39) than female (19), primarily attributable to gender division within value chain activities: all actors were male except among retailers, where the majority of actors are female, accounting for 19 of 20 individuals.

Group Membership and Registration: Across the value chain, groups were reported to be highly structured, including formal roles such as elected chairpersons, secretaries, treasurers, and financial secretaries. This finding aligns with current understanding of the informal sector in West Africa, in which groups and market associations play a primary role in organization and regulation, as well as coordination with local governments (Mekonnen et al., 2022). Of the 20 retailers, 17 indicated being part of a tomato seller association at the market, with a majority (11) stating that it is mandatory. Of the 20 farmers, only six are members of associations/cooperatives. All dealers indicated being part

Table 2. Descriptive Results of Respondents

Characteristic	Option	South			North	
		Retailer (n=20)	Dealer (n=14)	Farmer (n=20)	Crate Service provider (n=3)	Transporter (n=1)
Age	30–39 years	5	4	1	–	–
	40–49 years	9	8	11	2	1
	>50 years	6	2	8	1	–
Gender	Male	1	14	20	3	1
	Female	19	–	–	–	–
Years in business	1–10 years	6	1	0	3	–
	11–20 years	7	7	8	–	1
	21–29 years	5	5	8	–	–
	>30 years	2	1	4	–	–
Education	Primary	2	4	3	2	–
	Secondary	14	10	10	1	1
	Higher	1	–	3	–	–
	None	3	–	1	–	–
	Informal	–	–	3	–	–
Business Entry	Formal	–	11	1	–	–
	Informal (familial)	18	–	15	–	–
	Informal (other)	2	3	4	3	1

of dealer associations, stating that participation is mandatory after completion of an apprenticeship.

For registration requirements, 15 retailers indicated that there was no requirement to be individually registered to sell at their market, while 12 of the 14 dealers reported being registered to either the market, local government, or as a business entity with the Nigeria Corporate Affairs Commission.

Crate Use: All farmers interviewed responded that they use crates (Figure 2). Of the 14 dealers, 13 stated that they use crates; however, five indicated that their own use “depends on what farmers supply you with” (Dealer 2). Of the 20 retailers, 11 indicated that they do not use crates; Retailer 11 stated “I use more of [the] baskets. I take my baskets to market and pour the content of the crates into my basket. Sometimes, the dealers give us crates too but we must return it so that they can return it to the northern part of the country.” Seven of the 11 retailers that do not use crates stated similar indications that dealers control their access to crates. Overall, many respondents reported observing high adoption throughout the value chain: “stakeholders embraced the use of

crate almost more than the baskets for people trading the North and South corridor” (Dealer 5).

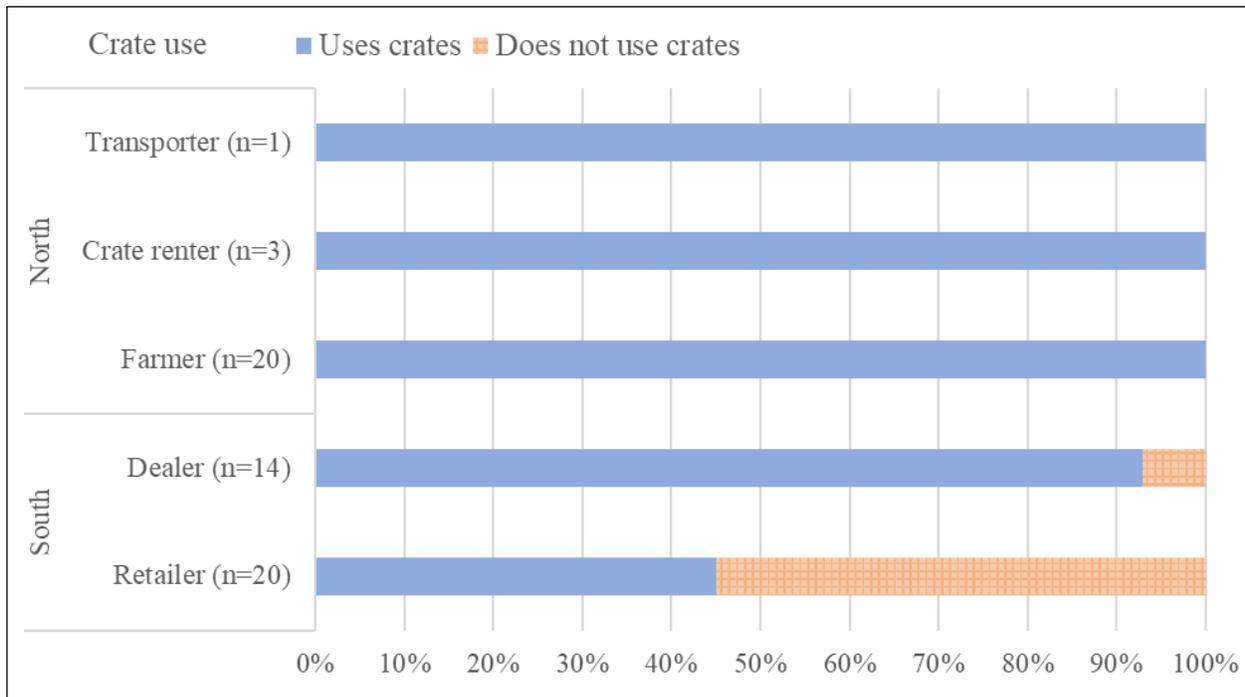
Incentives for Adoption

Several interview questions were designed to elicit responses that could provide insights into the incentives for adopting new innovations to address challenges. Overall, when asked about the main challenges in tomato trading, the four most prominent responses among the 58 participants were, overwhelmingly, postharvest losses (32), price fluctuations (30), oversupply (22), and market uncertainty (18):

Food loss is real especially in tomato production. The major cause can be seen from market price volatility. In addition, when the harvest time is due and [the] market does not want it at that time...you have two or three options, sell at lower price, cut and dry, or allow it to rot. Therefore food loss cripples capital investment. (Farmer 19)

These salient challenges are interrelated, as oversupply of highly perishable crops increases market uncertainty and price fluctuations, which in turn negatively impact the incomes of all actors

Figure 2. Crate Use of Respondents by Value Chain Segment



involved (de Steenhuijsen Piters et al., 2021). Uncertainty regarding market demand can lead to shortages, and also glut during peak seasons, which increases incidences of postharvest loss (Balana et al., 2022). Other prominent challenges include: loss of investment, poor infrastructure, low sales, capital, transportation delays, and lean periods. These challenges align closely with findings from previous literature assessing the tomato value chain in Nigeria (Norbert et al., 2023; Plaisier et al., 2019; Sibomana et al., 2019).

Nearly all respondents (97%) expressed concerns about food loss within their segment, with 82% citing economic factors, as “waste represents economic loss” (Retailer 9). This is especially severe in the farming segment, the “biggest losers” financially (Dealer 4). Many respondents stated that there is no enabling environment capable of addressing postharvest loss. A majority of respondents (40) believed that the primary benefit of crate use was to reduce postharvest losses and waste: “It has proven to be the best in controlling losses. It is better than anything used to convey tomatoes in the past” (Farmer 2). This data suggests that because the crates are perceived to directly address

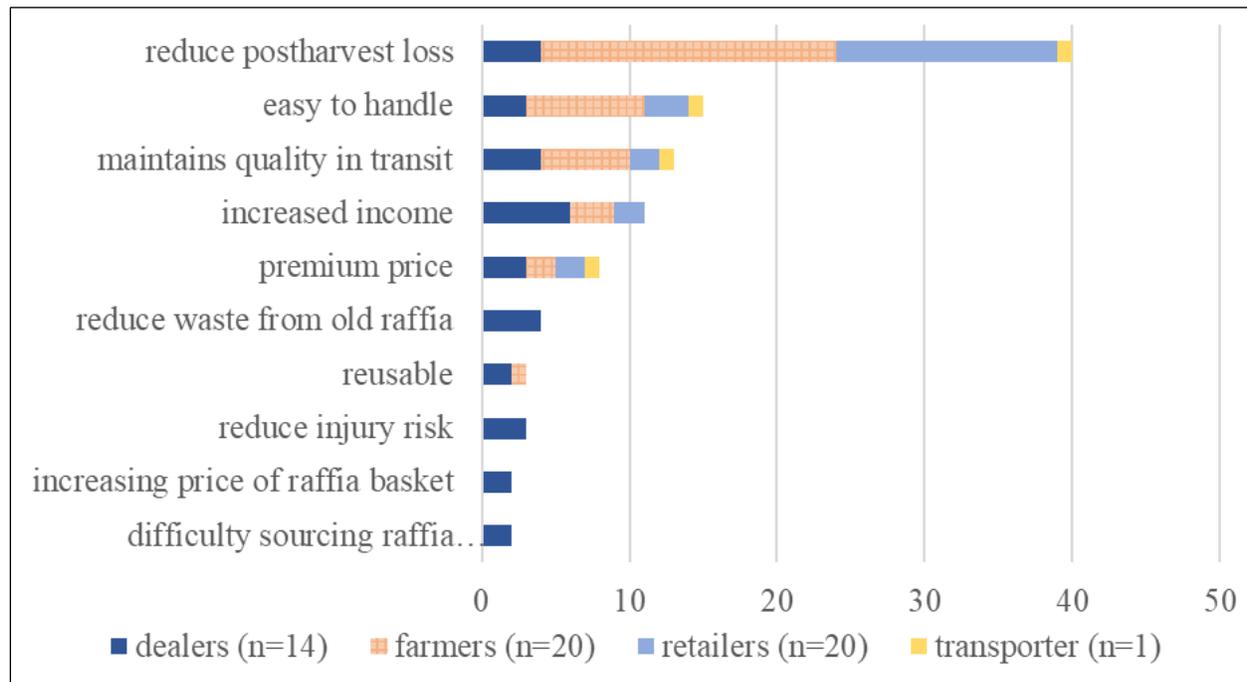
the common issue of high postharvest losses, adoption is high. Subsequent reasons for adoption described by actors include ease of handling and increased incomes (Figure 3).

While food safety was not initially listed as a challenge by any actor, when specifically asked a majority of respondents (88%) indicated that food safety is a concern for their business. While there is some inconsistency in reporting food safety practices among different actors, a majority (45) claim to apply food safety control measures. Retailers and farmers stand out as consistently reporting that they implement some level of food safety practices, particularly in sorting and grading (19 farmers, 16 retailers), and washing (20 retailers). However, five of the 14 dealers did not consider food safety a concern and 13 stated they have no food safety practices, with many associating food safety only with farmers’ use of pesticides or otherwise being out of their control, indicating gaps in food safety knowledge.

Barriers to Adoption and Use

Affordability: A significant barrier to crate adoption stated by respondents is the high cost of pur-

Figure 3. Benefits and Motivations for Crate Use



chasing crates (25), making it difficult for all value chain actors to adopt them widely. One barrier impacting the affordability of crates is limited or difficult access to finance. About 33% of respondents stated that financing is difficult to access, while 36% do not engage in borrowing funds at all, with retailers in particular avoiding borrowing completely or stating they have no need to borrow. Seventeen percent of actors borrow through informal channels, from friends, family, or group members. The barriers to finance access include collateral requirements, high interest rates, lengthy processing time, and general lack of knowledge about loan application processes and protocols.

A majority of dealers stated they have accessed finance through formal means, indicating potentially lower barriers for them to afford investing in crates. In some instances, dealers stated they support farmers and aggregators by sponsoring the upfront procurement and transportation costs of the crates, allowing farmers and aggregators without access to necessary capital the opportunity to use crates.

Availability and Awareness: Limited availability of crates (25) was stated as a challenge to crate

adoption, primarily by farmers. Barriers include a limited supply of different colored crates, which is the current system used to indicate who owns which crates, and geographical limitations in production and distribution of crates.

Lack of awareness of crate use was stated as a barrier (10), especially by farmers who viewed it as an impediment to adoption by other actors along the value chain. Only two retailers and three dealers reported participating in a training involving plastic crates, whereas 11 farmers directly participated in a crate training. While some dealers (six of 14) and farmers (11 of 20) reported involvement in some sort of formal training or project in the tomato sector (including but not limited to a training on plastic crates), a majority of retailers (19 of 20) reported that they had never been involved in a training or project.

Perceived Value and Suitability: Nine actors expressed reservations about the suitability of crates for local tomatoes, perceiving crates as being more suited for farmers and “dealers from the north,” therefore rendering their utility seasonal and less favorable for locally transported tomatoes in the south. Similarly, transportation costs are

cited as a concern, particularly among retailers (7), who note that the stackable and rigid design of crates makes them best suited for larger modes of transport, and less ideal for individual transport, thus catering more to farmers and dealers who work on larger scales. Retailer 7 states that raffia crates “contain the content of three plastic crates, so for transportation to this market, it is more expensive to use crates.” Furthermore, many retailers (8) cite the lower carrying volume of crates as undesirable, compared to raffia: “Baskets can contain more tomatoes than crates, so it might not be profitable using crates to buy” (Retailer 2). Although there is uncertainty about economic benefit, four retailers do recognize the potential for price premiums:

The cost of produce in crates is relatively more expensive than the one in the baskets. Notwithstanding, I still buy those from crates because of perceived higher quality which should give me better marginal returns than baskets. (Retailer 20)

Access and Control Imbalance: Almost all actors along the chain perceived the crates as beneficial to reduce postharvest loss in their business; however, willingness and capacity to make the required investment, including in the logistics, was varied. The value chain segment with the lowest adoption of crates in our sample are retailers, who are notably excluded from the crate renting value chain: “I regularly buy crate tomatoes but the dealers will never release their crates to us” (Retailer 1).

It is notable that Retailer 14, one of the retailers involved in a plastic crate training and who was given her own crate stated that the “plastic crate I got from the intervention project is still with me. ... It makes people buy my products too. I always put my tomatoes inside the crate and it has helped me a lot,” indicating that retailers with direct access to the crates may stand to use and benefit from them. Of the retailers, nine state that they do not use crates because “dealers will not give us the crates,” with many sharing sentiments that “if the dealers are ready to give us crates, I’m ready to use it” (Retailer 15, 18). This data suggests that dealers, and crate service providers indirectly,

control adoption of crates by retailers. Because of the dealers’ highly formalized structure and greater ability to access finances, as discussed previously, they are powerful actors in terms of influence and control. They are also often the main link between farmers and retailers. Although six of the 14 dealers state that their own use of crates is dependent on the farmer, their acceptance of crate use determines whether or not a farmer can adopt the crates to begin with, since farmers rely on dealers to link them to the market.

Social Considerations: When directly asked, 78% of participants stated they believe men and women have equal opportunities within their segment of the tomato value chain. However, upon further reflection many described significant sociocultural factors indicating underlying barriers for women actors to value chain mobility and adoption:

It is free for all but the rigor of the business makes it more favorable to men than women. For example, we dealers sleep in the markets here because produce from the farm mostly arrive in the middle of the night. For married women, how many of their husband will allow that? I have not gone home for the past 3 weeks now. If I am a woman with children to take care of, will that be possible? There are few women who are divorced and or allowed by the husband to do. (Dealer 4)

Aside from not aligning with accepted gender norms, market structural obstacles, such as mandatory registration, necessary education and apprenticeship, and the significant financial investment required may further dissuade women from pursuing dealing opportunities:

The opportunities are the same for both men and women but what I notice is that men usually have more money to invest in this business than women. (Retailer 4)

This dynamic is supported in the literature, as men can be better positioned to adopt new innovations due to social imbalances, as women are discouraged from breaking gender norms (Badstue et

al., 2018). On the other hand, multiple respondents said that they perceived retailing to be “unsuitable” or “insulting” to men, which discourages men from taking part in this segment.

Furthermore, a majority of farmers noted that crate renting was a lucrative business opportunity, but only available to those who already had capital—which excludes poorer actors, as well as retailers who are both less likely to have capital and less encouraged to take business risks because of social expectations. While the adoption of crates and the emergence of the crate renting companies indicate compelling evidence for ground-up innovation approaches, the data suggest that it can also reinforce persisting social gaps.

Perceived Enablers of Innovation Use

Eighty-four percent of respondents identified capital as a critical factor in growing their business, which indicates access to capital as a barrier to adoption and innovation, a finding that aligns with other studies in the Nigerian tomato value chain (Amurtiya & Adewuyi, 2021). Respondents highlighted the significance of making the crates “cheap and available, then [increasing] awareness” (Farmer 11). Information exchange within networks about an innovation can be determinative for adoption and use. The current internalized networks were reported to be beneficial for information exchange, as 47% of respondents described it as their group’s primary benefit; however, they have not consistently formalized opportunities for co-investment to enable the adoption of an innovation. A slight majority of retailers are willing to collaborate or co-invest with each other (although some expressed a lack of trust) while, alternatively, a majority of dealers stated that co-investing is “not possible” in their segment and many concluded that “if there is an innovation from external sources, we can embrace it,” but they are unlikely to address postharvest issues jointly because of a sense of competition (Dealer 9). All farmers stated they were willing to invest with other value chain actors to pursue joint objectives, especially with crate renters who are seen to “have common goals and benefits” (Farmer 1). There is little mention of collaborating across the value chain by the retailers or dealers, with some agreement that co-investment would

not occur “across the whole value chain” (Dealer 6, Retailer 20).

Discussion

To identify optimal entry points in the value chain, we assess the innovative agency of each actor based on our results, assessing resources, constraints and motivations that influence behavior towards achieving diverse societal outcomes (Table 3).

We have developed three possible scenarios for pathways that address different desired food systems outcomes: community food safety, reduced postharvest losses and waste, and increasing income for women. Each scenario describes both the desired and observed outcomes, followed by examining the mechanisms that contributed to these outcomes. Subsequently, we explore potential improvements to the value chain process and discuss how the enabling environment can support these outcomes by identifying various pathways, policy recommendations, broader implications for agricultural development and informal economies, improved interventions and possible tradeoffs.

Outcome 1: Reduction of Postharvest Losses and Waste

Desired Outcome: Minimizing postharvest losses and waste in the horticulture supply chain through improved handling and storage practices facilitated by the crate system.

Observed Outcome: Crates were used by a majority of actors in this study along the tomato value chain due to their perceived ability to reduce postharvest losses. However, food loss remains one of the biggest issues facing all actors, indicating that adoption of crates, while effective in reducing losses, requires complementary initiatives to address losses and complementary interventions addressing systemic inefficiencies, such as improved storage facilities, better road infrastructure, and enhanced coordination across the supply chain.

Process (Mechanisms that Led to Outcome): Crate service providers’ investment in the renting plan allowed for adoption of crates by lowering the

barrier to entry among farmers who were generally constrained by capital, which was further facilitated by dealers accepting the innovation and adapting to the new operational logistics. While retailers were initially engaged in crate renting, they were eventually excluded because crates were not effectively returned, despite many retailers stating they would like to use crates. Furthermore, infrastructural (roads, storage) and logistic (market uncertainties) limitations along the value chain hinders the ability of actors to use crates to reduce losses further.

Improved Process: The crate system can be optimized to reduce postharvest losses more effectively by addressing the interconnected challenges within the value chain. An improved process would involve a more inclusive and coordinated approach to crate system implementation, ensuring participation from all value chain actors, including retailers. This can be achieved through:

Enhanced Communication Networks: Despite the formal organization of groups along the value

Table 3. Resources, Constraints and Motivations of Value Chain Actors

	Resources and Competencies	Constraints and Barriers	Motivations
Farmers	<ul style="list-style-type: none"> • Willing to share information and collaborate across segments for mutual benefit. • Willing to engage in collective decision-making, especially as part of an association. 	<ul style="list-style-type: none"> • Financial constraints and limited access to capital for investment in technology adoption. 	<ul style="list-style-type: none"> • Reducing postharvest losses and improving food safety standards to enhance product quality. • Reduce economic risks, improve income. • Find alternative markets during oversupply.
Retailers	<ul style="list-style-type: none"> • Strong networks within retailer groups, enabling collaboration, information sharing, and potential co-investment. 	<ul style="list-style-type: none"> • Limited formal business training or access to technology education. • Reliance on dealers for access to technologies like reusable plastic crates. • Gender-related social norms impacting participation and access to resources. 	<ul style="list-style-type: none"> • Reducing postharvest losses and improving food safety standards to enhance product quality. • Increase profitability and competitiveness and reduce uncertainty in the market.
Dealers	<ul style="list-style-type: none"> • Formal business entry through apprenticeships, indicating structured knowledge acquisition. • Participation in dealer associations, facilitating information exchange and coordination. • Better access to capital and financial resources compared to other actors in the value chain. • Ability to support and sponsor farmers and aggregators. 	<ul style="list-style-type: none"> • Reluctance to co-invest within their value chain. • Gendered norms impacting participation. • Can constrain crate access for other actors. 	<ul style="list-style-type: none"> • Optimize logistics and transportation to improve efficiency. • Maintain good relations with their farmers.
Crate service providers	<ul style="list-style-type: none"> • Control over logistical availability of reusable plastic crates. • Potential to facilitate wider adoption through rental programs, reduced upfront costs for other actors. • Risk takers, entrepreneurial, have capital. 	<ul style="list-style-type: none"> • Logistical challenges of crate losses, transport distances. • Manufacturing and geographic limitations. 	<ul style="list-style-type: none"> • Crate renting is a profitable new business opportunity.
Transporters	<ul style="list-style-type: none"> • Willingness to share information about markets, harvests, and transportation logistics. 	<ul style="list-style-type: none"> • Prioritize logistical efficiency over postharvest loss. 	<ul style="list-style-type: none"> • Optimize route planning and vehicle loading space to minimize costs.

chain, this study suggests there is limited collaboration across different segments and actors within the value chain. Improving communication and cooperation among these groups could enhance overall efficiency to further address postharvest losses, and mitigate market fluctuations. Improvement might involve initiatives aimed at fostering trust and, particularly for women farmers and retailers, addressing social norms that hinder their integration and credibility within the industry. In addition, promoting innovation and use of appropriate information and communications technologies (ICT) can enhance market efficiency by optimizing crate rentals and returns, reducing delays, and improving communication and coordination between actors to align supply with demand.

Capital Investment: With an understanding that many actors, especially farmers and retailers, do not trust or wish to seek out finance options, private sector actors and crate service providers can be leveraged to front the capital and bear investment risk to address postharvest losses and potential oversupply issues. Private sector entities can work closely with farmer cooperatives to facilitate adopting postharvest innovations, and can even facilitate forming cooperatives, as was done with a former tomato processing factory. Private entities with sufficient capital may also allow for the integration of research and development efforts aimed at improving seed quality, conducting varietal trials, and optimizing nursery production. Crate service providers, who are more willing and able to take some investment risk, can be encouraged to branch out into other areas of concern to address postharvest losses, such as lack of cold storage and lack of crates available to retailers.

Capacity Strengthening: The organized groups within each segment present an opportunity for effective dissemination of best practices and innovation within segments. Farmer groups can benefit from collective training in production and market planning to align their output with market demand, thereby minimizing oversupply. Similarly, leveraging groups to advocate to the government for rural road repairs and reducing checkpoints along transportation routes could lead to lower transportation

costs for all, enabling actors to gain better prices from informal market channels (Liverpool-Tasie et al., 2020). Due to farmers' apparent willingness to share information and collaborate across segments for mutual benefit, as seen with their eagerness to form better connections with crate service providers and sealers, and compounded with their perceived economic benefit of reducing losses, they may be a key entry point for introducing complementary postharvest loss reduction opportunities.

Outcome 2: Community-Wide Food Safety

Desired Outcome: Enhancing the safety of food products throughout the value chain by reducing contamination risks during transportation and sale.

Observed Outcome: While crates can minimize spoilage and reduce contamination to address food safety concerns, actors do not currently perceive them as food safety innovations, limiting their potential impact. Additionally, the absence of formal food safety standards reduces the incentive for value chain actors to prioritize hygiene and quality control.

Process (Mechanisms that Led to Outcome): There is limited formal regulation for food safety along the value chain, contributing to lack of knowledge among some actors in this sample and limited capacity to act on best practices. As is common in informal sectors, the current marketing is based on grades, leading to some good practices on food safety because of the economic incentive. There is also limited infrastructure for food safety, and associations often bear the cost of ensuring a clean market space, with many dealers paying a fee through their association to remove waste from the markets.

Improved Process: Because food safety is not considered a challenge by actors due to lack of standards and regulations, emphasizing the economic advantages of crate use (e.g., reducing postharvest loss), rather than food safety messaging, likely is a stronger motivator for adoption. But it is crucial to recognize that sensitization and training in other aspects are necessary to deter other prac-

tices from undermining the food safety benefits of crates. To effectively address food safety in the informal sector through crate use, addressing knowledge and infrastructure gaps, as well as ensuring widespread access to crates throughout the value chain, is crucial. A process that complements the use of crates may include:

Capacity Strengthening: Education programming or training for actors across the value chain on food safety practices, both in general practice and focused on crate benefits, can help close knowledge gaps, specifically among groups like dealers who, in this sample, did not know how they could contribute to maintaining food safety within their role. Retailers need to be more included in capacity-strengthening initiatives, considering their significant role in ensuring the safety of food for consumers.

To address infrastructure limitations, coordination between actors in advocating for improved infrastructure storage facilities, market shade structures, and access to clean wash water may encourage faster response from government entities, who are eager to help build the tomato industry because of its importance to the Nigerian economy. Collaborative efforts to tackle common challenges like these may necessitate trust-building interventions to overcome social barriers, particularly related to gender dynamics.

Crate Access for Retailers: Restructuring of the crate renting plan to integrate retailers may be challenging at this stage, but could be feasible in certain areas where past issues can be resolved. A tailored approach could involve leveraging crate service providers and market associations to offer market-specific crate rentals specifically for retailers. External organizations could play a role in subsidizing initial crate purchasing, while association fees could contribute to some form of security or safekeeping, enhancing accountability and accessibility for retailers without penalizing them.

Consumer Awareness: Given the characteristics of the informal sector, strengthening the capacity of regulatory bodies to monitor food safety compliance and enforce regulations across the entire

value chain is not necessarily an appropriate intervention, especially when taking into account differential effects on poorer actors (Roseboom, 2012). Instead, leveraging existing economic food safety incentives indirectly through consumer awareness campaigns can teach consumers more about relevant topics, increasing demand for high quality and food-safe products. This is a promising route because actors in this sample stated that in many cases consumers already associate tomatoes from crates with higher quality products.

Outcome 3: Increased Income for Women

Desired Outcome: Elevating the economic status of women involved in the market by improving tomato quality through crate use, providing women retailers with more quality tomatoes that can be sold at higher prices.

Observed Outcome: Women interviewed along the value chain, all retailers due to gendered divisions of labor, had varying levels of belief in the capacity of crates to improve their incomes, especially because they are not directly given access to the innovation.

Process (Mechanisms that Led to Outcome): While the crate renting plan created a pathway for adoption for many, retailers encountered logistical barriers in adopting crates, including capital constraints, operational scales incompatible with crate designs, and transportation limitations exacerbated by crate design. Additionally, power dynamics and social barriers contributed to the exclusion of women retailers from crate rental when they failed to meet return standards set by more influential actors. Instead of implementing corrective measures, exclusion became the default solution.

Improved Process: Innovating and scaling to elevate women's income involves designing inclusive innovation and outcome-based strategies that address the specific social constraints faced by women, as well as logistical constraints faced by retailers in the value chain, recognizing that gender dynamics are deeply embedded in the retailing segment. Scaling efforts and enabling environments

for crate adoption that increases income for women must be tailored to address these gender-specific considerations, while also taking into account alternative pathways for generating income in some cases. These may include:

Optimizing Suitability: Adapting crates to address the needs and constraints of retailers can facilitate their adoption and integration into daily activities. For instance, introducing in-market crate rentals that address the scale and transportation challenges faced by retailers could include encouraging crate service providers to offer a range of crate sizes to accommodate varying volume needs throughout the supply chain (Sibomana et al., 2019). This tailored approach addresses the gendered roles along the value chain, improving the suitability of crates for women retailers to encourage adoption, decrease losses, and increase incomes. Given the current power dynamics along the value chain, this approach may involve providing a solution that allows for greater autonomy and control over innovation use.

Diversification Opportunities: Diversification opportunities present a promising avenue for increasing women incomes, such as engaging them in value-added processing activities like solar drying that address oversupply challenges. Diversification can also be accomplished through leveraging social enterprises that already operate in this space, like Cold Hubs, which employs women in mobile cold storage operations.

Furthermore, a new innovation always takes the place of an old one—in this case, the woven raffia basket which has traditionally provided income for many in the southeast of Nigeria, especially poor women (Babarinsa et al., 2022). As with retailing, basket making is the chosen profession by many because of the low barriers to entry, in terms of capital and skills required. Some basket makers are willing to diversify into other sectors, like trading, but lack the necessary capital and skills (Babarinsa et al., 2022). This approach could hold particular significance for basket makers, who could benefit from alternative income streams and opportunities for diversification.

Further Research

These findings have broader implications for agricultural innovation adoption, informal market dynamics, and gender-inclusive economic strategies across Africa. Nigeria is the frontrunner, leading in this particular innovation with a business model that effectively connects informal value chain actors with formal service providers. This approach offers a replicable model for other countries to adopt and tailor to their own conditions. However, further research is needed to understand what enables successful and inclusive adoption, as well as the potential challenges and trade-offs involved in scaling this model across different food systems. Key areas for further research include:

- **Enhancing food safety in informal markets:** What hybrid regulatory models (formal and informal) can be developed to improve food safety compliance without disproportionately disadvantaging smaller market actors? Can consumer demand play a stronger role in driving food safety improvements in the absence of stringent regulatory enforcement?
- **Gender-inclusive innovation adoption:** Research should explore how women can maximize economic gains from crate use and what interventions are necessary to ensure their economic empowerment, while taking into account that in most cases they do not have direct access to crate use. This may include greater efforts to facilitate access to crates by women, through adapting the current innovation to better suit their needs or agribusiness trainings to equip women with essential skills to effectively manage their businesses and maximize profits.
- **Mitigating unwanted trade-offs:** As new innovations replace traditional practices, such as crates replacing woven raffia baskets, how can policymakers and development programs support affected groups, such as basket makers, in transitioning to alternative livelihoods if necessary?
- **Private sector engagement:** How can financial mechanisms and investment strategies

be tailored to support micro-scale and small-scale actors in informal food systems while minimizing risk in participation for private sector actors?

Conclusions

A critical factor in success for uptake of innovations for actors in the informal midstream segment is collaboration with other service providers and investors from the formal sector. As this case study highlights, it is possible for formal providers to offer services that enable midstream actors operating in an informal environment to adopt innovations. Understanding the relationships between actors and value chain segments is critical to deter-

mining the incentive and disincentive structures for innovation adoption. When understanding the actor-based levers and relationship-based incentive structures, participatory innovation processes can be effectively designed. At the same time, this analysis also shows that not all actor interests can be met by a single innovation. Investigating the trade-offs and power dynamics that may resist innovations must be incorporated into feasibility studies or other preliminary research. Successful innovation in food systems requires collaboration between informal midstream actors and formal sector service providers, understanding the socio-economic realities of all stakeholders, and addressing trade-offs and power dynamics. 

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