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Beyond the farm and market: Food safety practices during transport in Nigerian horticulture and fish value chains

[version 1]

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Abstract

Food safety risks in low- and middle-income countries are often examined at production and retail stages, with limited attention to transport, a critical control point where contamination, exposure to extreme temperature, and product deterioration can occur. This study investigates the adoption of good food handling practices among transporters in Nigeria's horticulture and fish value chains and identifies factors associated with their uptake. Using census data from 626 transporters across three distinct states, we analyze the adoption of seven recommended practices using probit, penalized logistic, and count models. Adoption is extremely low, with transporters implementing, on average, only 10% of recommended practices, well below the rates observed among downstream actors. These findings reveal that important food safety gaps persist during transportation, highlighting the need to address risks across all value chain nodes rather than focusing primarily on production and retail. Demographic factors such as education and experience are not consistent predictors of the adoption of good food handling practices. Instead, adoption is shaped by economic incentives, exposure to spoilage risk, operational conditions, and commodity-specific factors. The results suggest that training-based interventions alone are unlikely to substantially improve food safety practices. Strengthening food safety during transportation will require stronger regulatory oversight alongside policies that reduce compliance costs and support targeted investments in aggregation systems and cold-chain infrastructure.

Keywords
Transporter, Adoption, Food handling practices, Food safety, Tomato, Fish

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1. Introduction

Food safety remains a major global public health concern, particularly in low- and middle-income countries (LMICs), where unsafe food contributes substantially to morbidity, mortality, and economic losses (Nardi et al., 2020; WHO, 2024). A defining feature of foodborne risk in these settings is that contamination can occur at multiple points along the supply chain and accumulate as products move from production to consumption. This makes it essential to identify and manage critical control points all along supply chains, including the intermediate stages where products are aggregated, handled, and transported (Kamboj et al., 2020; Nardi et al., 2020).

Despite this, both empirical evidence and food safety interventions have focused predominantly on production and retail segments of the food system (Ncama et al., 2021; Affognon et al., 2015; Stathers et al., 2020). This focus overlooks critical segments in the midstream of supply chains (wholesale, processing and transportation) where food safety risks are often introduced or intensified. Transportation, in particular, remains an under-examined but critical stage. Transporters link geographically dispersed production and consumption nodes, often moving perishable products under time and infrastructure constraints (Aung & Chang, 2014). In such conditions, inadequate handling, poor vehicle sanitation, and lack of temperature control can substantially increase contamination risks and accelerate quality deterioration (Thoden van Velzen and Lukasse, 2016). In addition, failures during transport can significantly undermine upstream food safety investments and downstream health risks.

The neglect of transporters in both research and policy limits our ability to design effective food safety control strategies. Without systematic evidence on transporter practices and their determinants, it is difficult to assess how risks are managed in practice or to identify feasible intervention points. This gap is particularly pronounced in LMIC contexts such as Nigeria, where food transport systems are often informal, cold chain infrastructure is limited, and regulatory oversight is weak (Ejairu, 2022; Yamauchi et al., 2024; Obadina, 2023; Gbadegesin et al., 2026; Lao et al., 2026; Omokpariola, 2026). In such environments, transporters' day-to-day decisions regarding hygiene, storage, and handling can play a decisive role in determining food safety outcomes.

Transporters typically operate with limited training and weak incentives to adopt improved food handling practices, even as rapid urbanization and rising demand for fresh foods increase reliance on extended and complex transport networks. Because they operate across diverse commodities and environments, both product characteristics and operating conditions are likely to shape the adoption of safe handling practices. While existing research documents gaps between knowledge and practice among producers, processors, and traders (Kamboj et al., 2020; Nardi et al., 2020; Mohamed et al., 2025), transport is rarely examined as a distinct node, and systematic evidence on transporter behavior remains limited (Ncama et al., 2021; Hossain and Kashem, 2025). Moreover, although a growing literature considers transport-related food safety risks, most studies rely on descriptive assessments, expert evaluations, policy analyses, or reviews, often in high-income settings with well-developed cold chains and regulatory systems (Ovca and Jevšnik, 2009; Ackerley et al., 2010; Aung and Chang, 2014; Grover, 2023). Empirical analyses explaining variation in the adoption of food safety practices among transport actors, particularly in developing regions, particularly the African contexts, remain scarce.

This study addresses this gap by focusing explicitly on transporters as a critical but under-examined control point for food safety in food supply chains. Using primary data from Nigeria, we assess the extent to which transporters adopt key handling practices associated with contamination risk reduction and identify the socio-demographic, operational, and contextual factors associated with adoption. The study makes three main contributions. First, it provides novel evidence on food safety practices among transporters, a group largely absent from existing food safety research. By documenting variation in the adoption of good food handling practices, the study contributes to a more complete understanding of how food safety risks are managed at the transport stage of the value chain. We are not aware of any other studies using such primary data from a large sample of transporters in a developing country. Second, by identifying the factors associated with the adoption of these practices, the study generates insights into the constraints and incentives that shape transporter behavior. This is critical for designing effective and targeted food safety interventions, particularly in settings where formal monitoring and enforcement mechanisms are limited. Third, by comparing transporters across fish and horticultural value chains within the same regional setting, the study highlights how product-specific characteristics such as perishability and handling requirements influence the adoption of safety practices. This comparative perspective helps identify where risks are likely to be most pronounced and informs the design of commodity-specific food safety strategies. Together, these contributions position transporters as key actors in food safety management and highlight the importance of incorporating midstream practices into efforts aimed at reducing foodborne risks in LMIC food systems.

The remainder of this article is organized as follows: Section 2 describes the materials and methods used in the study; Section 3 presents the descriptive and empirical results. Section 4 discusses the main findings and concludes with policy recommendations.

2. Materials and methods

2.1 Sampling procedure and study area

Transporters were selected using a multistage sampling procedure designed to capture horticulture and fish value chain actors in contexts where these supply chains are highly active and economically significant in Nigeria. Thus, the study covered three Nigerian states (see Figure 1) chosen for their prominence in these sectors: Oyo and Kaduna for horticulture, and Kebbi for fish (NAERLS, 2022; FMARD, 2020). Kaduna, located in the northern vegetable production belt, is a major contributor to national tomato supply and is characterized by a dynamic vegetable production and trade system supported by favorable agroecological conditions (FAO, 2025; Saras et al., 2023). Oyo serves as both a production (a leader in regional production for southwest Nigeria) and distribution hub in southern Nigeria, reflecting its central role in agricultural trade and food distribution (Subnational Climate Governance Data, 2025; Nalunga et al. 2026). Kebbi, in northwestern Nigeria, is a leading inland fisheries center, with fish production estimated at 90,000 metric tons annually and active inter-state distribution from its wholesale markets, highlighting its importance in the national fish supply chain (Olutunmogun, 2025). Together, these states provide relevant and contrasting contexts for examining transport food handling practices across major horticulture and fish subsectors.

In each state, we began by compiling a comprehensive listing of transporters operating in and around wholesale markets in each state. Wholesale markets were defined as locations with at least two active wholesalers dealing in tomatoes, green leafy vegetables, or fish, reflecting their role as key aggregation and distribution points within the value chain. However,

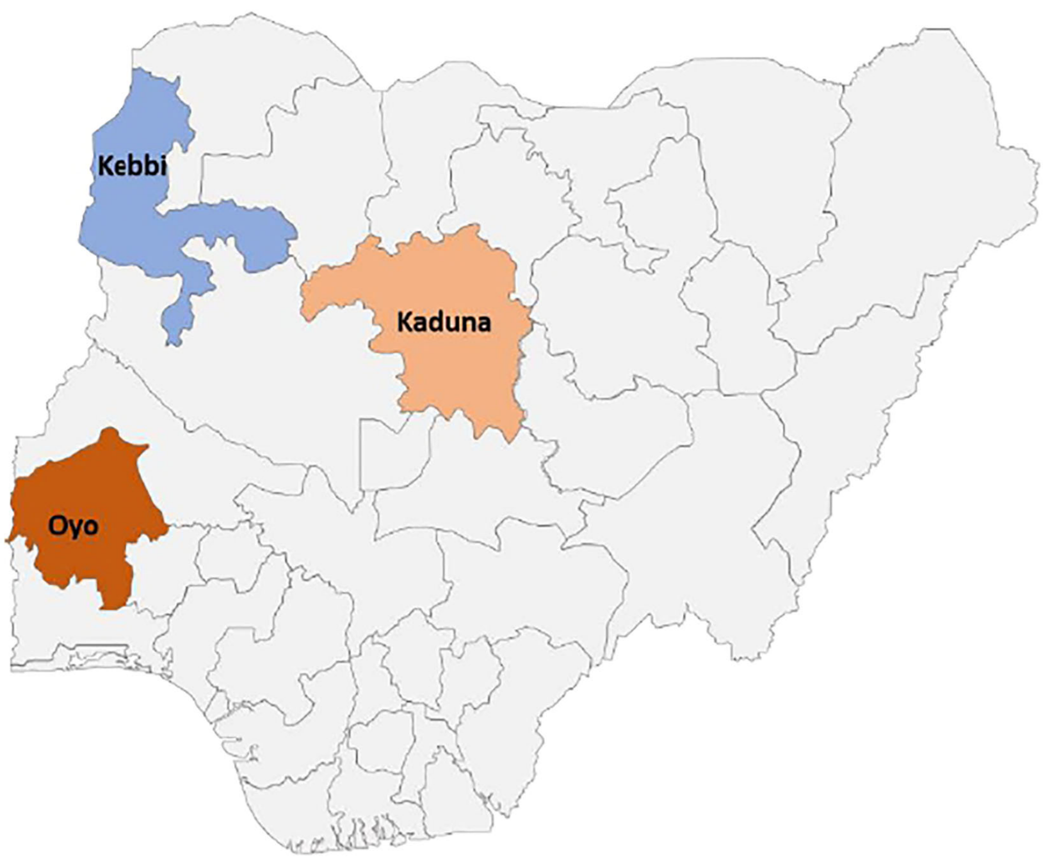

Figure 1. Map of study site.

because a substantial share of transport activity occurs outside formal market spaces, particularly in linking production zones to markets, the market-based listing was complemented with a second exercise based on referrals. Horticulture producers, wholesalers, and retailers identified during parallel listing exercises in the state were asked to name transporters they regularly engaged. This combined approach enabled the inclusion of transporters operating across both centralized and decentralized segments of the value chain, including those serving dispersed farming communities and those linking multiple market nodes. Capturing this heterogeneity is important given that food safety risks during transport, including contamination, spoilage, and temperature abuse, may differ substantially across routes and operational contexts.

The final listing identified 626 transporters; 530 moving tomatoes, and 96 transporters moving fish. All identified transporters were included in the survey, yielding a census of transport actors within the defined sampling frame rather than a subsample. Although some transporters, especially those weakly connected to markets or operating on highly irregular routes, may not have been captured in our sample, the use of both market-based listings and value chain referrals ensures broad coverage of active actors. As a result, the sample remains well-suited to capture the dominant transport practices shaping food safety outcomes in these value chains.

Transporters were interviewed directly, regardless of whether they owned the transport business, ensuring that the data reflect the practices of those directly responsible for handling and moving food products. The survey collected detailed information on transporters' socio-demographic characteristics, including age, gender, education, and household structure, alongside operational characteristics such as distance travelled, product type, vehicle type, and quantities transported. Critically, it also documented food hygiene and handling practices employed during the most recent completed transport trip. Focusing on the last trip provides a consistent reference point and reduces recall bias, while capturing practices at a critical control point in the food chain where risks of microbial growth, contamination, and product degradation are elevated.

Ethical approval

This study (MSU Study ID: STUDY00007403) received ethical approval from the Institutional Review Board of Michigan State University, on March 1, 2022, and all interviews were conducted in accordance with the local legislation and institutional requirements.

Consent statement

Informed consent was obtained verbally from all participants after explaining and prior to survey administration. Verbal consent was chosen because many respondents had limited literacy and time constraints within the environment, making written consent impractical; however, participation was entirely voluntary.

2.2 Empirical analysis

The empirical analysis leverages both descriptive statistics and regression estimations to characterize the study sample of transporters and to explore the drivers of transporters' adoption of good food handling practices. We consider seven good food handling practices used during the transportation of tomatoes and fish, namely (1) Use of plastic crates[1] (2) covering product during transportation, (3) Use a temperature-controlled vehicle (4) Transporting product during cool hours of the day (5) Separate product (tomatoes/fish) from other goods (6) use cleaned containers, and (7) Use of protective gear (Gloves, hairnet or other protective gear).

These practices were selected based on established food safety guidance and prior literature (FAO, 2023; Obadina and Liverpool-Tasie, 2023a; Obadina and Liverpool-Tasie, 2023b), and reflect key mechanisms for reducing contamination risks, limiting microbial proliferation, and minimizing physical and quality deterioration during transport. Detailed definitions are provided in Table 1 (Panel A).

Given the binary nature of our adoption measures (equal to 1 if transporter i adopts a practice and 0 otherwise), we evaluated the factors associated with adoption using a series of probit models. The statistical model is based on a cumulative distribution function, and the probability that a transporter adopts a practice ($Y = 1$) under given conditions can be calculated as:

[1]Use of plastic crates is relevant only for tomatoes hence data on plastic crate-use was not captured for fish and use of sanitized vehicle was only recorded in the fish transport node, hence, analysed only for fish.

Table 1. Study variable descriptions.

Study variables	Definitions and units of measurement
Key Outcome variables	
Use plastic crates	Binary; 1 = Yes, 0 = No Vegetable transporter using plastics crates (Oyo and Kaduna only)
Cover product during transportation	Binary; 1 = Yes, 0 = No Transporters that cover their product during transportation (either in baskets or breathable containers)
Transport the product in the cool of the day	Binary; 1 = Yes, 0 = No Transporters move their products early in the day to maintain a low temperature
Temperature-controlled vehicle	Binary; 1 = Yes, 0 = No Transporters who move their product in temperature-controlled vehicles
Separated product (tomatoes/fish) from other goods	Binary; 1 = Yes, 0 = No Transporters who separates their vegetable/fish from other products they move before loading.
Cleaned containers	Binary; 1 = Yes, 0 = No Transporters who clean the containers for packaging their vegetables/fish before transporting
Wore protective gear (Gloves, hairnets, protective clothing)	Binary; 1 = Yes, 0 = No Transporters who wear either hairnets, gloves or clothing to prevent contamination during loading and offloading of product
Number of practices carried out by transporters	Sum of all the practices engaged by transporters of vegetables/ fish
Key explanatory variables	
Age of the Driver	Years
Years of experience	Years engaged in the transport business
Scale of enterprise	Quantity traded in a typical week in the last year in kg
The Driver has completed secondary education	Binary; 1 = Yes, 0 = No
Number of hired workers	Continuous: Number of people
Driver is also owner of the transport business	Binary; 1 = Yes, 0 = No
Coordinates the purchase or sales of tomatoes with others	Binary; 1 = Yes, 0 = No
Transporter is also engaged in other business	Binary; 1 = Yes, 0 = No
Transporter moves only vegetables/or only fish as the most important product	Binary; 1 = Yes, 0 = No
Quantity moved in the last trip (Tonne)	Continuous: Kilograms
Distance of last trip (100 KM)	Continuous: Kilometers
Road Quality is mostly good	Binary; 1 = Yes, 0 = No

Source: Authors based on field data.

$$p_i = Prob[Y = 1 \,|\, \boldsymbol{x}_i] = \boldsymbol{\phi}\left(\boldsymbol{X}_i'\beta\right) \tag{1}$$

With p_i being the probability that transporter i adopts a practice. The cumulative distribution function of a standard normal variable is represented by $\boldsymbol{\phi}$, while $\boldsymbol{X}_i'$ is a list of Z characteristics describing transporter i (e.g. enterprise activities, demographic factors, location) and β is a vector of parameter estimates associated with the Z characteristics. To determine the effect of each explanatory variable, we estimated the average marginal effects. Holding other variables constant, the marginal effect of each explanatory variable can be expressed as:

$$\Delta = \phi\left(\overline{X}\beta, d=1\right) - \phi\left(\overline{X}\beta, d=0\right), \quad (2)$$

With d as the indicator variable for binary explanatory variables in the model. In the case of continuous independent variables, it can be derived as:

$$\frac{\partial \mathrm{p}_i}{\partial \mathrm{x}_{ik}} = \phi(X_i{'}\beta)\beta_k. \quad (3)$$

Due to limited adoption of certain practices, Firth's penalized logistic regression models were estimated for all the adopted practices among fish transporters and crates usage among tomato transporters, where the probit models failed to converge. Firth's penalized logistic regression is appropriate in situations characterized by small sample size, rare events or perfect prediction, which lead to convergence issues, biased parameter estimates in conventional binary response model such as with the probit regression model (Firth, 1993; Heinze & Schemper, 2002; King & Zeng 2001).

To analyze the intensity of adoption, defined as the number of practices adopted (ranging from 0 to 7 for tomato transporters and 0–6 for fish transporters), we estimate count models. Both Poisson and zero-inflated Poisson (ZIP) specifications are used to account for the high share of transporters reporting zero adoption. As with the binary models, marginal effects are reported.

The Z explanatory variables used in this analysis are grouped into three broad empirical categories capturing key dimensions relevant to food safety behavior and technology adoption. First, transporter demographic characteristics, including gender, age, and education, proxy for human capital and risk preferences that shape awareness, knowledge, and capacity to adopt improved food handling practices. Education, in particular, is often associated with better understanding of food safety risks and the benefits of adopting improved handling practices (Su et al., 2025; Bulto et al., 2022; Young et al., 2015), while age and gender may capture differences in experience, roles within value chains, and constraints to behavior change (FAO, 2011; Doss, 2001; Abdulai & Huffman, 2014).

Second, business and operational characteristics capture the scale, scope, and intensity of transport activities. These include enterprise scale (measured by number of hired employees), transporter engagement in other businesses, the main product transported, quantity moved, and distance of the last trip. These variables reflect both incentives and constraints to adoption. Larger or more specialized operators may face stronger incentives to maintain product quality and reputation (Reardon et al., 2003; Birthal et al., 2005; Barrett et al., 2012), while longer distances and higher volumes increase exposure to spoilage risks and may necessitate better handling practices. Engagement in multiple businesses may also affect attention, investment capacity, or prioritization of food safety (Shobo et al., 2026).

Third, infrastructure and asset-related variables, including road quality and vehicle type, capture the structural and technological environment within which transporters operate. Poor road conditions can increase transit time, handling stress, and contamination risks, thereby shaping both the need for and difficulty of adopting hygienic practices. Similarly, vehicle type reflects the level of technology and capital available, influencing the feasibility of implementing safer transport practices such as improved storage, coverage, or separation of products. Together, these categories allow us to examine how individual capacity, economic incentives, and operational environments jointly influence the adoption of food safety practices. They also capture factors that are both analytically relevant and potentially amenable to policy intervention, enabling the derivation of actionable recommendations. Table 1 (panel B) provides the definitions of each explanatory variable.

The analysis is based on cross-sectional data. Key transporter characteristics such as gender, age, education, and location are treated as exogenous. Some operational choices such as shipment size and engagement in multiple businesses may be endogenous to adoption due to unobserved factors such as ability or time constraints. While we control for a rich set of variables capturing incentives, managerial capacity and constraints, the empirical estimates are interpreted as conditional associations rather than causal effects. Nonetheless, the analysis provides important insights into behavioral and structural drivers of food safety practices at a critical, yet understudied, stage of the value chain, with direct relevance for policy and intervention design.

Another challenge in our data is that driver-specific variables (age, education, and driving experience) are not consistently measured for the same decision-maker. For transporters who are owners but do not drive, these variables refer to the owner rather than the driver, even though handling practices are implemented by the driver. This introduces a systematic mismatch whereby the same covariate reflects different actors across observations, undermining interpretability and introducing measurement error. To address this, we rely on a restricted sample of drivers, where all individual characteristics correspond to the agent directly responsible for handling practices. Within this sample, we capture ownership incentives through an indicator for whether the driver is also the owner, allowing for a clearer separation between behavioral capacity and incentive effects. We conduct some robustness checks to confirm that this restriction does not affect the main study findings.

3. Results

3.1 Socioeconomic and operational characteristics of transporters

Table 2 presents the descriptive statistics of tomato transporters in Kaduna and Oyo states, as well as fish transporters in Kebbi state. All transporters across the three states were male, with an overall average age of 43 years and an average of 13 years of driving experience. Educational level varied across states, with a higher proportion of transporters having at least a secondary education in Kebbi and Oyo (~62% and 58% respectively) compared to about 47% in Kaduna.

Business structure and activity profiles indicate a sector dominated by small, owner-operated enterprises with diversified livelihoods. About 72 percent of drivers also own their transport businesses, and most transporters operate at a very small scale, with an average staff strength of about one. A majority of transporters (59 percent) are engaged in other economic activities outside transport, reflecting income diversification strategies. However, within transportation, some specialization in product movement is evident, as 92 percent identify tomato/fish as the most important commodity transported. This is particularly pronounced among tomato transporters, with 92 percent in Kaduna and 95 percent in Oyo reporting tomatoes as their primary cargo, consistent with commodity-specific specialization documented in related value chain studies (Abatan et al., 2025b).

Table 2. Socio-demographic characteristics of respondents (transporters).

	Kaduna	Oyo	Kebbi	Overall
Transporter characteristics				
Male (%)	100	100	100	100
Age (in years)	43	44	43	43
Years of experience driving	14	15	11	13
Driver has at least secondary education (%)	47	58	62	56
Business Characteristics				
Number of hired staff	1	2	1	1
Driver is also the owner of the business (%)	64	78	73	72
Transporter is engaged in another business (%)	73	60	44	59
Transporter moves other food products (%)	2	3	3	3
Transporter moves non- food products (%)	0	1	2	1
Transporter moves Tomato/fish as major cargo (%)	92	95	89	92
Trip characteristics				
Number of trips made in a typical week	8	4	6	6
Quantity (tonne) moved in a typical trip	6	1.9	0.5	2.8
Distance of last trip (100 km)	3.2	0.9	1.6	1.9
Good quality road (%)	47	39	81	56
Vehicle Type				
Sedan car (e.g. golf)	15	46	80	47
Small vehicles (motorcycle, tricycle, bicycle)	28	13	15	19
Large vehicles (Buses and trucks)	57	41	5	34
Number of observations	**251**	**279**	**96**	**626**

Source: Authors' calculation based on field data.

Table 3. Adoption of good handling practices.

	Kaduna	Oyo	Kebbi	Overall
Packaging material used				
Use plastic crates (1/0)	0.04	-	-	0.01
Condition of packaging during transportation				
Cover product during transportation	0.61	0.17	0.47	0.42
Temperature control during transportation				
Transport the product in the cool of the day(1/0)	0.05	0.22	0.06	0.11
Transport the product in a temperature-controlled vehicle (1/0)	0.10	0.004	0.01	0.04
Prevent contamination				
Separated product (tomatoes/fish) from other goods (1/0)	0.15	0.06	0.05	0.10
Cleaned containers (1/0)	0.05	0.01	0.07	0.04
Practices of Loading and Offloading Personnel				
Wore protective gear (Gloves, hairnets, protective clothing) (1/0)	0.02	0.05	0.02	0.04
Number of practices carried out by transporters	1.0	0.52	0.70	0.70
Number of observations	**251**	**279**	**96**	**626**

Source: Authors' calculation from field data.

Operational characteristics vary across states, products, and vehicle types, with notable implications for scale and efficiency. The average quantity transported per trip is about 3 tons, with substantially higher volumes in Kaduna, where tomato transporters move an average of 6 tons. Transport condition shows that 56 percent of transporters report operating on good quality roads, although this share is higher in Kebbi. Sedan cars are the most commonly used vehicles, accounting for 47 percent of transporters, followed by large vehicles at 34 percent, and vehicles make an average of six trips per week, reflecting relatively high frequency but low volume movement consistent with fragmented supply chains (Abatan et al., 2025b).

Table 3 represents a summary of good handling practices among transporters in the three study States. Overall, the adoption of good handling practices is very low with transporters implementing an average of only one of the 7 practices considered. Among tomato transporters, adoption patterns differ sharply between Oyo and Kaduna. Transporters in Kaduna consistently report higher adoption of most the good handling practices considered than their counterparts in Oyo. For instance, 61 percent of transporters in Kaduna cover products during transportation compared to only 17 percent in Oyo, and separation of goods is more than twice as common in Kaduna (15 percent) as in Oyo (6 percent). Similarly, the use of temperature-controlled vehicles, while generally low, is still higher in Kaduna (10 percent) relative to Oyo (less than 1 percent). The main exception relates to timing of transport, where Oyo transporters are more likely to move products during the cooler parts of the day (22 percent versus 5 percent in Kaduna), as well as the use of protective gear (5 percent versus 2 percent). Overall, however, the number of practices adopted is substantially lower in Oyo (0.52) than in Kaduna (1.0), indicating weaker adherence to recommended handling practices among horticultural transporters in Oyo.

Within northern Nigeria, differences between Kaduna and Kebbi suggest that variation in practice adoption is not only state-specific but also likely reflects the nature of products transported, particularly when contrasting horticulture (more perishable) with fish (less perishable but often temperature-sensitive). In Kaduna, there is a higher adoption of protective and handling practices that are especially relevant for perishable horticultural goods, such as covering products (61 percent versus 47 percent in Kebbi) and separating goods (15 percent versus 5 percent). Kaduna also shows higher use of temperature-controlled vehicles (10 percent versus 1 percent in Kebbi), which, although still limited overall, is more aligned with the needs of highly perishable products. In contrast, Kebbi transporters (for fish) show comparatively stronger adoption of basic hygiene-related food handling practices, including cleaning containers (7 percent versus 5 percent in Kaduna). These patterns suggest that while Kaduna transporters are more likely to adopt practices associated with protecting produce during transit, Kebbi transporters may be relatively more attentive to cleanliness and handling, likely reflecting the distinct spoilage and contamination risks associated with fish.

3.2 Determinant of good practices among tomato and fish transporters

Table 4 and Table 5 present the factors associated with the adoption of good food handling practices among tomato and fish transporters, respectively. Among tomato transporters, three key findings emerge. First, transporter location significantly influences the adoption of most of the food handling practices considered. Transporters in Oyo State were less likely to use plastic crates, clean containers, cover tomatoes, separate tomatoes from other products, and use temperature-controlled vehicles. This lower adoption may reflect differences in value chain roles and economic incentives across locations. As a major consumption hub, Oyo transporters may be more focused on moving already sourced tomatoes efficiently and at low cost, reducing incentives to invest in quality-preserving practices that require additional equipment, labor, or transport space. In contrast, transporters in Oyo were significantly more likely to transport tomatoes during the cooler hours of the day. Unlike the other practices considered, cool-hour transportation requires relatively limited additional capital investment and may offer an accessible means of preserving tomato quality. This higher adoption may therefore reflect stronger incentives to adopt lower-cost options to maintain product quality in consumer-oriented markets. More broadly, these location effects likely capture differences in market conditions, operational constraints, and value chain organization across locations. Among individual characteristics, years of driving experience positively influenced the use of protective gear, suggesting that more experienced transporters place more emphasis on food handling, while age had a mixed effect- older transporters were more likely to transport products in temperature-controlled vehicles but less likely to transport products during the cool hours of the day.

Second, business and operational characteristics emerge as substantively important drivers of adoption, largely in line with the study's hypotheses. Specialization in the transportation of horticultural products is one of the strong predictors, being positively and statistically significantly associated with covering products during transportation. This supports the idea that specialization increases incentives to maintain product quality. Similarly, indicators of operational scale and exposure to transport-related risk, such as quantity of products handled and number of workers, show systematic relationships with adoption. Larger quantities transported were positively associated with covering product and separating from other goods. Similarly, a larger workforce increased the likelihood of transporting in the cool hours of the day and the use of protective gear but reduced the likelihood of separating tomatoes from other goods. Transport enterprises with more employees might be more likely to transport during cooler hours and use protective gear because additional labor increases operational flexibility, allowing workers to coordinate loading and departure schedules efficiently while maintaining food safety protocols. Larger workforces may also facilitate the implementation and monitoring of good food handling practices without significantly slowing operations. Unlike cool-hour transportation or protective gear use, product separation may require dedicating valuable vehicle space to a single commodity, reducing load consolidation opportunities and transport efficiency. As a result, enterprises with larger workforces and higher throughput may prioritize maximizing vehicle utilization and shipment volume over practices that limit cargo mixing.

Transport distance and business ownership were also important determinants of adoption. Longer distances were positively associated with covering, consistent with greater spoilage risk over longer trips. However, they were associated with a lower likelihood of separating tomatoes from other goods during transportation. This may be because many transporters appear to move only tomatoes, making separation unnecessary. Alternatively, among transporters carrying multiple products, the higher costs associated with longer trips may encourage load consolidation to maximize vehicle utilization and spread transport costs across a larger volume of goods, reducing incentives to keep products separate. In addition, transporters who were also owners of the transport businesses were less likely to separate tomatoes from other products during transportation. Overall, these variables provide the clearest and most consistent support for the hypothesis that incentives and exposure to risk shape adoption behavior.

Third, infrastructure and asset-related variables also play an important but practice-specific role, broadly consistent with expectations about structural constraints. Good road quality is strongly associated with the use of temperature-controlled vehicles, suggesting complementarity between infrastructure and technology adoption, but is otherwise not a consistent predictor across practices. Vehicle type, however, shows clear and systematic effects. Compared to transporters using four-door sedan cars, tomato transporters using small vehicles are significantly less likely to adopt several practices, including using temperature control, separating tomatoes from other goods, and transporting during cooler periods, reflecting clear technological and capacity constraints. In contrast, the use of large vehicles is positively associated with separation practices, indicating that higher-capital assets facilitate certain forms of safer food handling. The Oyo state indicator is negative and highly significant across several practices, reinforcing earlier descriptive evidence of lower adoption of recommended food handling practices in that state. Taken together, these findings suggest that while human capital plays a limited role, adoption is more strongly shaped by economic incentives tied to specialization and scale, as well as by structural constraints related to infrastructure and transport technology.

Table 4. Regression -Determinants of good practices among tomato transporters.

	1	2	3	4	5	6	7
	Use of plastic crates	**Covered product**	**Temperature-controlled vehicle**	**Transport during cool hours**	**Separated tomatoes from other goods**	**Cleaned containers**	**Used any protective gear**
Age (in years)	0.000 (0.000)	0.002 (0.002)	0.002* (0.001)	−0.004** (0.002)	−0.002 (0.002)	0.000 (0.001)	−0.001 (0.001)
Years of experience driving	0.000 (0.000)	−0.003 (0.002)	0.001 (0.001)	−0.001 (0.002)	0.002 (0.002)	−0.000 (0.001)	0.003** (0.001)
Driver has at least secondary education (1/0)	0.007 (0.007)	0.003 (0.037)	0.016 (0.020)	0.029 (0.031)	0.039 (0.026)	0.004 (0.015)	0.022 (0.019)
Transporter in Oyo (1/0)	−0.029** (0.013)	−0.334*** (0.030)	−0.136*** (0.031)	0.141*** (0.034)	−0.067** (0.027)	−0.049** (0.021)	0.036 (0.023)
Number of workers	0.001 (0.001)	−0.005 (0.010)	0.002 (0.005)	0.020** (0.008)	−0.055*** (0.016)	0.005 (0.003)	0.006* (0.003)
Driver is the business owner (1/0)	−0.001 (0.006)	0.006 (0.045)	−0.006 (0.021)	−0.044 (0.037)	−0.081*** (0.028)	0.006 (0.020)	−0.002 (0.023)
Employment diversification (1/0)	−0.000 (0.000)	0.001 (0.001)	−0.000 (0.000)	−0.000 (0.001)	0.000 (0.001)	0.001** (0.000)	−0.001*** (0.000)
Product specialization (1/0)	0.006 (0.013)	0.577*** (0.136)	-	0.057 (0.075)	−0.064 (0.047)	−0.001 (0.028)	-
Distance of last trip (100 km)	0.000 (0.000)	0.028*** (0.008)	−0.001 (0.001)	−0.011 (0.008)	−0.010** (0.004)	0.000 (0.001)	0.001 (0.001)
Quantity moved in last trip (tonne)	0.000 (0.000)	0.002** (0.001)	−0.010 (0.010)	−0.000 (0.000)	0.001** (0.000)	−0.000 (0.000)	−0.000 (0.000)
Good road quality (1/0)	0.001 (0.006)	0.012 (0.038)	0.071*** (0.021)	−0.007 (0.029)	0.008 (0.026)	0.007 (0.014)	0.026 (0.017)
Small vehicles =1(motorcycle, tricycle, bicycle) base = sedan	−0.011 (0.011)	−0.064 (0.053)	−0.046** (0.021)	−0.123*** (0.036)	−0.048* (0.029)	−0.031 (0.026)	−0.016 (0.022)
Large vehicles = 1 (Buses and trucks) base = sedan	−0.001 (0.010)	−0.051 (0.045)	0.009 (0.030)	−0.035 (0.038)	0.080** (0.034)	−0.014 (0.021)	0.008 (0.019)
Number of observations	**514**	**514**	**482**	**514**	**514**	**514**	**482**

Source: Authors' calculation from field data. Robust standard errors in parentheses. This analysis is based on restricted sample of 514 tomato transport operators who handled the last trip and excludes transport operators in the sample who were not drivers. Regressions with less than 514 are because variable was omitted by STATA due to perfect prediction.

*** $p < 0.01$,
** $p < 0.05$,
* $p < 0.1$.

Table 5. Regression -Determinants of good practices among fish transporters.

	1	2	3	4	5	6
	Covered product	**Transport during cool hours**	**Separated fish from other goods**	**Sanitized vehicles**	**Cleaned containers**	**Used any protective gear**
Age (in years)	0.013 (0.009)	−0.001 (0.004)	0.001 (0.004)	0.003 (0.002)	0.002 (0.002)	0.110 (0.002)
Years of experience driving	0.003 (0.013)	−0.000 (0.005)	0.005 (0.004)	−0.007 (0.005)	0.002 (0.004)	−0.005 (0.005)
Driver has at least secondary education (1/0)	−0.001 (0.002)	0.000 (0.001)	−0.001 (0.001)	−0.000 (0.000)	−0.001 (0.001)	−0.000 (0.000)
Number of workers	−0.068 (0.095)	0.006 (0.048)	0.042 (0.033)	0.003 (0.018)	−0.006 (0.044)	−0.041 (0.040)
Driver is also the owner of the business (1/0)	0.129 (0.176)	−0.015 (0.087)	−0.106* (0.063)	0.100 (0.073)	−0.051 (0.051)	−0.029 (0.055)
Employment diversification (1/0)	−0.001 (0.003)	−0.000 (0.001)	−0.001 (0.001)	0.001 (0.001)	−0.001 (0.001)	−0.000 (0.001)
Product specialization (1/0)	0.671* (0.368)	0.029 (0.135)	−0.054 (0.059)	−0.001 (0.046)	0.061 (0.092)	0.012 (0.049)
Distance of last trip (100 km)	−0.062 (0.056)	0.021 (0.025)	−0.029 (0.023)	0.038 (0.042)	−0.005 (0.016)	−0.038 (0.024)
Quantity moved in last trip (tonne)	−0.203 (0.143)	0.078 (0.048)	−0.060 (0.067)	0.033 (0.028)	−0.809 (0.101)	0.024 (0.032)
Good road quality	0.160 (0.171)	0.012 (0.082)	1.154 (1.790)	0.006 (0.042)	0.062 (0.067)	−0.027 (0.044)
Small vehicles =1 (motorcycle, tricycle, bicycle)	0.296 (0.189)	−0.009 (0.122)	−0.013 (0.054)	0.327 (0.382)	−0.038 (0.049)	−0.038 (0.034)
Large vehicles = 1 (Buses and trucks)	−0.301* (0.178)	0.121 (0.324)	−0.039 (0.039)	0.203 (0.316)	0.293 (0.465)	0.125 (0.282)
Number of observations	**89**	**89**	**89**	**89**	**89**	**89**

Source: Authors' calculation from field data. Robust standard errors in parentheses. This analysis is based on restricted sample of 89 fish transport operators who handled the last trip and excludes transport operators in the sample who were not drivers.
***$p < 0.01$,
**$p < 0.05$,
*$p < 0.1$.

Table 5 presents the drivers of adoption among fish transporters. Across the six practices considered, demographic characteristics show weak and inconsistent associations with adoption. In particular, age, secondary school attainment, and driving experience are not significantly associated with any of the practices considered.

Although limited in number, the significant business and operational characteristics provide some important insights. Business ownership is negatively associated with separating fish from other products, suggesting that transporters who own their businesses are less likely to separate fish from other goods during transportation, as was also observed among tomato transporters. As noted earlier, this may reflect the fact that most transporters appear to specialize in a single commodity. As a result, separating fish from other products may be unnecessary for many operators because they are not transporting multiple commodities simultaneously. Similar to the findings for tomatoes, product specialization is positively associated with covering fish during transportation, indicating that transporters for whom fish is the primary cargo are more likely to adopt this practice.

In contrast to the tomato results, asset-related characteristics show little association with the adoption of handling practices among fish transporters. The one exception is vehicle size: transporters using large vehicles are less likely to cover fish during transportation. While the mechanisms underlying this relationship cannot be established from the available data, covering large loads may be more costly and labor-intensive, reducing the likelihood of adoption. More

Table 6. Factors associated with the number of recommended practices adopted by transporters.

VARIABLES	Tomato transporters		Fish transporters	
	Poisson	**Zero-Inflated Poisson**	**Poisson**	**Zero-Inflated Poisson**
Transporter characteristics				
Age (in years)	−0.002	−0.002	0.010	0.010
	(0.006)	(0.006)	(0.013)	(0.013)
Years of experience driving	−0.000	−0.000	0.007	0.007
	(0.005)	(0.005)	(0.027)	(0.027)
Driver has at least secondary education (1/0)	0.173**	0.173**	−0.005	−0.005
	(0.087)	(0.087)	(0.004)	(0.004)
Transporter in Oyo (1/0)	−0.721***	−0.721***	NA	NA
	(0.097)	(0.097)		
Business characteristics				
Number of workers	0.014	0.014	−0.136	−0.136
	(0.023)	(0.023)	(0.223)	(0.223)
Driver is also owner of the business (1/0)	−0.175*	−0.175*	−0.104	−0.104
	(0.101)	(0.101)	(0.349)	(0.349)
Employment Diversification (1/0)	0.002	0.002	−0.010	−0.010
	(0.002)	(0.002)	(0.007)	(0.007)
Product Specialization (1/0)	0.996***	0.996***	1.901*	1.901*
	(0.362)	(0.362)	(1.024)	(1.024)
Distance of last trip (100 km)	−0.001	−0.001	−0.105	−0.105
	(0.005)	(0.005)	(0.126)	(0.126)
Quantity moved in last trip (tonne)	0.001	0.001	−0.126	−0.126
	(0.001)	(0.001)	(0.342)	(0.342)
Road quality for last trip				
Good road quality (1/0)	0.153*	0.153*	0.497	0.497
	(0.085)	(0.085)	(0.415)	(0.415)
Vehicle Type (1/0) (base = sedan car and golf)				
Small vehicles =1 (motorcycle, tricycle, bicycle)	−0.606***	−0.606***	−0.090	−0.090
	(0.154)	(0.154)	(0.301)	(0.301)
Large vehicles = 1 (Buses and trucks)	−0.021	−0.021	−0.472	−0.472
	(0.102)	(0.102)	(0.752)	(0.751)
Observations	**514**	**514**	**89**	**89**

Source: Authors' calculation from field data. Robust standard errors in parentheses. This analysis is based on the restricted sample of 514 and 89 transport operators who handled the last trip and excludes transport operators in the sample who were not drivers.
***p < 0.01,
**p < 0.05,
*p < 0.1.

generally, the results suggest that, as with horticultural transporters, adoption among fish transporters is driven more by operational characteristics and business incentives than by transporter demographic attributes.

Table 6 presents the determinants of adopting a higher number of recommended handling practices among transporters. Across both tomato and fish transporters, the intensity of adoption is only weakly associated with demographic characteristics but is more strongly linked to business structure, specialization, and transport conditions, although the specific drivers differ across commodities. Age and driving experience are not significantly associated with the number of practices adopted in any specification. For tomato transporters, both the Poisson and ZIP models indicate that having secondary education is associated with adopting more practices (≈ 0.17, $p < 0.05$).

Business structure and specialization play a more consistent role. Owner-drivers adopt fewer practices for tomato transport (≈ -0.18, $p < 0.10$), consistent with the possibility that they face tighter resource or time constraints. Product specialization is positively associated with the number of practices adopted among tomato transporters (≈ 0.90, $p < 0.01$), suggesting that transporters that are specialized in moving tomatoes may have stronger incentives to reduce quality losses and greater opportunities to develop product-specific handling knowledge. A similar relationship is observed among fish transporters (≈ 1.90, $p < 0.10$).

In contrast with the regressions for specific handling practices, asset and infrastructure characteristics show more limited effects on the intensity of adoption. Among tomato transporters, the use of smaller vehicles, such as motorcycles and tricycles, is associated with adopting fewer practices than the reference category of standard four-door sedans (≈ -0.61, $p < 0.01$). In contrast, vehicle size is not significantly associated with adoption intensity among fish transporters. Road quality exhibits a weak positive association with the number of practices adopted (≈ 0.15, $p < 0.10$).

Finally, substantial spatial differences emerge within tomato transport. Transporters in Oyo adopt significantly fewer practices than those in Kaduna (≈ -0.72, $p < 0.01$). While this may appear surprising given the relatively higher levels of economic development in southern Nigeria, the pattern may reflect differences in value chain organization and exposure to spoilage risk rather than differences in development levels per se. Kaduna is located within a major tomato-producing region that supplies distant markets, potentially increasing transport distances and quality risks and thereby strengthening incentives to adopt quality-preserving practices. In contrast, transporters operating in Oyo may face different market conditions that reduce the perceived benefits of adopting such practices. Overall, these findings reinforce the broader conclusion that adoption is shaped more by economic incentives, business characteristics, and operational conditions than by transporter demographic characteristics.

As a robustness check, we confirm that our main results are upheld when using the full sample of transporters versus just the sub-sample of drivers[2]. For horticulture transporters (Table 4), the set of statistically significant variables remains unchanged. For fish transporters and for the number of practices adopted (Table 6), the effects of business characteristics are largely consistent, although some driver-specific variables lose statistical significance in the full sample, likely reflecting the conflation of owner and driver characteristics.

4. Discussion and conclusion

This study contributes to a limited but growing literature on the behavior of midstream actors in informal food systems, focusing specifically on the adoption of food safety practices among transporters. The findings reveal low adoption of recommended food handling practices, consistent with evidence from retail and trading nodes (Abatan et al., 2025b; Abass et al., 2019; Boakye et al., 2023; Erinle and Ajayi, 2022; Gemeda et al., 2023; Imafidor et al., 2018).

When considering adoption as a share of recommended practices, we find that transporters in Kaduna and Oyo adopt only 14.6% and 7.4% of recommended practices, respectively, with an overall average of 10%. In comparison, adoption among retailers in the same contexts averages 34.2% (Abatan et al., 2025b). These findings underscores that gaps in food safety practices are not limited to farmers (upstream) or vendors (downstream), but are also pronounced at the transport stage, a critical control point where risks of contamination, temperature abuse, and product deterioration are high (Nordhagen et al., 2022; Abatan et al., 2025b). These findings highlight the need for food safety strategies that expand beyond upstream and downstream segments to explicitly address midstream value chain actors' food handling behaviors.

A key finding of this study is the limited explanatory power of human capital variables in transporter adoption behavior. In contrast to standard technology adoption models, education and experience do not emerge as consistent predictors of adoption across practices. This aligns with emerging evidence that, in informal and weakly regulated contexts, knowledge is often not the primary constraint; instead, economic and structural factors dominate (Abatan et al., 2025b; Nordhagen et al., 2022). This helps explain why training- and awareness-based interventions alone have yielded limited improvements in food safety practices.

[2] These results are available upon request.

Instead, adoption is more strongly shaped by incentives, exposure to spoilage risk, and operational conditions. Greater specialization and higher risk exposure increase the likelihood of adopting practices that preserve product quality and safety. However, these relationships vary by commodity. In horticulture, adoption responds more to shipment size, reflecting incentives to protect higher volumes. In contrast, fish transporters respond more to distance-related risks, consistent with the rapid perishability and higher safety risks associated with fish. These differences highlight the importance of commodity-specific approaches to improving food safety practices.

Structural constraints linked to business organization and assets also play a central role. Smaller, owner-operated transport systems are less likely to adopt recommended practices, suggesting that liquidity, labor, and time constraints limit the ability to implement even low-cost hygiene measures. Transport assets further shape feasible behavior: smaller vehicles constrain adoption, while larger assets enable some practices without ensuring comprehensive compliance. These findings are consistent with broader evidence that improvements in food safety require not only knowledge but also access to appropriate technologies and organizational capacity (Nordhagen et al., 2022).

The findings have several implications for food safety policy and control systems. First, interventions focused solely on training are unlikely to be sufficient. Effective strategies must address the economic incentives facing transporters by reducing the costs or increasing the returns to adopting safe handling practices. Second, the importance of scale and specialization suggests opportunities for interventions that strengthen coordination and aggregation within value chains, which can facilitate the adoption of improved practices. Third, the observed heterogeneity across commodities highlights the need for targeted approaches, with volume-based incentives more relevant for horticulture and investments in temperature control and cold chain infrastructure more critical for fish. Finally, spatial variation in adoption underscores the need for locally adapted interventions that reflect differences in infrastructure, market organization, and enforcement capacity.

More broadly, these findings carry implications beyond Nigeria. Improving food safety practices at the transport node is central to advancing both SDG 2 (food security and reduced losses) and SDG 3 (health and food safety) in low- and middle-income countries, where informal markets dominate and cold chain systems remain underdeveloped and under-regulated. The evidence suggests that progress toward these goals will depend less on information provision alone and more on addressing the structural and incentive constraints that shape behavior at this critical stage of the food supply chain.

Data availability Statement

Data will be made available on request.

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