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Performance analysis of existing catfish and tilapia value chains and market systems in Nigeria:

A post-farmgate value chain scoping study

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Performance analysis of existing catfish and tilapia value chains and market systems in Nigeria: A post-farmgate value chain scoping study

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Front cover, Brianna Bradley/WorldFish.

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Abstract

Nigeria is the largest fish producer in Sub-Saharan Africa. Fish plays a crucial role in supporting the livelihoods of fish producers and actors along the post-farmgate value chain in the country. Despite the virtues of the aquaculture and fisheries subsectors to enhance the livelihoods of value chain actors, major gaps exist related to efficiencies of the fish value chain. These gaps include the financial performance of post-farmgate actors, gender-disaggregated data on value chain actors, the roles of women and youths in fish trade, and post-farmgate food safety practices. The aim of this study is to fill the data gap in the post-farmgate fish value chain to provide evidence-based policy suggestions to enhance the aquaculture subsector in Nigeria. Using primary data, our study provides evidence on the economic, environmental, social, nutritional and food safety performance of the post-farmgate fish value chain. Our study finds that, in general, fish value chains are economically viable (profitable) and inclusive, as women and youths own over half of post-farmgate value chain activities. These results are of interest to both private and public sector decision-makers and policymakers because they provide quantitative data on value creation (fish sales, employment, service provision), social performance (women and youth empowerment), and environmental, nutritional and food safety challenges along fish value chains.

Introduction

Nigeria is the second-largest aquaculture producer in Africa and the largest in Sub-Saharan Africa. Its fisheries and aquaculture subsectors are important for food security, employment, income, livelihoods and well-being as well as for alleviating poverty (Gona et al. 2018). Fish contributes to the livelihoods of producers (Makindie et al. 2015) and post-farmgate value chain actors (Magdugu and Edward 2011). Existing literature, such as Olasunkanmi (2012), Odebiyi et al. (2013) and Adebayo et al. (2016), in different states of Nigeria reports the profitability of fish production and value chains. Despite fish production and marketing being profitable in the country, however, its influence on the national economy is limited because of low domestic fish production relative to demand. This requires importing fish to bridge the local supply-demand gap, resulting in a significant loss of foreign exchange (Oyakhilomen and Zibah 2013).

Despite economic growth and improved nutrition policies, the prevalence of poverty and malnutrition remains high in Nigeria (USAID 2018). In this regard, fish can play a substantial role in improving livelihoods and food and nutrition security. Fish contains protein, fats, fatty acids, vitamin D, selenium, phosphorus and calcium, all of which are essential for human growth and development (Tilami and Sampels 2018). However, fish are particularly vulnerable to spoilage and can cause foodborne illnesses because of their high pH value and moisture content (Erkmen and Bozoglu 2016). Foodborne illnesses commonly lead to diarrhoeal diseases and other health problems (WHO 2019) that likely offset any nutritional benefits from fish and cause economic losses, such as absence from work due to food-related illness.

Even though Nigeria is the second-largest fish producer in Africa, there is limited knowledge available on post-farmgate value chain performance at the country level to provide policymakers with data to make better policies. Most previous studies, such as Magdugu and Edward (2011), Olasunkanmi (2012), Odebiyi et al. (2013) and Adebayo et al. (2016), focused on individual states within Nigeria. Key data gaps exist related to fish value chain efficiencies, including financial performance of post-farmgate actors, gender-disaggregated data on value chain actors, the roles of women and youths in aquaculture and fish trade, and post-farmgate food safety practices. Understanding the dynamics of both fish markets and prices and their implications on performance of value chain actors, as well as food and nutrition security, at the national level in Nigeria is critical to support national policy and decision-making to ensure economically viable fish value chains. The objective of this study is to assess the performance of current aquaculture value chains in Nigeria. This study seeks to address four key research questions to fill knowledge gaps in aquaculture value chains:

1. What are the key aquaculture value chains in Nigeria?
2. Who are the key actors of targeted aquaculture value chains?
3. What are the key leverage points along the fish value chain to enhance the contribution of the aquaculture sector to the livelihoods of smallholder producers and overall nutrition and to empower and women and youths?
4. Where are the key intervention points to better engage the private sector toward improving the contribution of fish to Nigerians?

This assessment provides evidence, based on primary data, to identify key aquaculture value chains, products and people's involvement, as well as employment and post-harvest activities up to sales at markets. The study highlights key gaps and opportunities for improving the sustainability, inclusiveness and economic viability of post-farmgate aquaculture value chains in Nigeria. Addressing such gaps will provide both the private and public sectors with investment guidance and policy direction for increasing the contribution of aquaculture and fish to rural development.

Methodology

Value chains

Value chain mapping (VCM) consists of mapping the actors who participate in the production, distribution, marketing and sales of a product. Depending on the complexity required and the objectives of the study, VCM could also include (i) information related to the flow of products and their volume, costs and margins at different stages, (ii) added value, (iii) flow of information and knowledge, (iv) types of relationships and links, (v) number of actors by gender and generation, and (vi) number of workers per actor (Dizyee et al. 2017 and 2019). The first step in value chain analysis would be mapping the actors and their associated functions to understand the structure of the chain and its strengths and weaknesses relative to infrastructural, financial, institutional and social capital endowments.

The degree to which a particular chain or chain actor is endowed with or has access to underlying factors determines its capacity to adapt (by becoming less vulnerable to shocks), move to more rewarding functions or shift to more lucrative products. The process by which chain actors change their position for higher gains and or reduced risk is known as upgrading (Bolwig et al. 2010). In this process, value chain actors can use strategic organization, such as vertical and horizontal links, to improve their competitive position by sharing knowledge and information, mitigating risk and reducing the cost of production.

Using livelihood and nutrition improvements, the targeted stakeholders in the selected value chain under our study are Nigerian fish farmers, market agents and poor consumers. The more affluent consumers can also benefit through improved safety, quality and availability of products in the marketplace. As a result, the proposed action research will articulate the link between value chain development and its potential impact on poverty through various facets, such as reduced vulnerability, better nutrition, improved livelihood or higher income.

The second step analyzes and maps as overlays a mix of products traded, volumes and marketing margins at different nodes of the chain. These two steps provide the framework to characterize the underlying patterns of comparative and competitive advantages, if any, for producers, processors and marketers, and to evaluate the existence of opportunities and potential for investment scenarios for upgrading primary product practices and value addition processes across the value chain (Dizyee et al. 2017; Ouma et al. 2018). As such, the central purpose of upgrading is to overcome the underlying constraints value chain actors face and to capture market opportunities.

The degree to which information and knowledge are shared and rewarded determines ability of participants to upgrade. There are multiple forms of upgrading, depending on the objectives sought. Kaplinsky and Morris (2000) stress the need to distinguish between several types of upgrading: (1) *process upgrading* is a strategy that seeks efficiency gain within and between individual links of the chain, (2) *product upgrading* is a product development strategy to improve competitive position relative to rivals, (3) *functional upgrading* is any strategy that seeks to increase value added by changing the mix of activities within and between individual links of the chain, and (4) *chain upgrading* is a move to new, more sophisticated and more lucrative value chains.

Survey design, study site and data sampling

We collected both quantitative and qualitative data for this study from January 2019 to December 2019. From January to May 2019, we adapted, from previous livestock value chain studies (Dizyee et al. 2017), a quantitative post-farmgate value chain survey tool for fish value chains. In June 2019, we revised the post-farmgate survey tool in consultation with stakeholders in Nigeria, including extension officers, research staff at research institutes and universities, and staff of fish society and associations. We also trained enumerators and piloted the survey and data collection tool in the field, which helped us finalize the survey tool. Collecting the quantitative survey data began in July and was completed in October 2019.

We selected 696 actors (wholesalers, retailers and processors) to as well as complete the quantitative survey, for the post-farmgate value chain actor surveys, from eight states in Nigeria. The eight states represented different agroecological zones, fish production potential, nutritional status (stunting) and poverty indices in the country. Both the study site and sample size were selected in consultation with stakeholders in Nigeria, including extension officers, officers of agricultural development programs (ADPs), university professors and researchers, staff of fish societies and associations, aquaculture input and service providers, and government officials. For each state, the survey team consisted of a supervisor and six enumerators.

The local supervisors identified geographic clusters (fish markets) within each state considering urban, peri-urban and rural characteristics within each selected local government area, community size and population density. Individual post-farmgate value chain actors (wholesalers, processors and retailers) were surveyed using a snowball sampling method (interviews where you find value chain actors within the targeted fish market). Within each state, we selected about one-third of our sample from urban, about one-third from peri-urban and about one-third from rural markets. Table 1 shows the post-farmgate value chain survey sample size and states represented in this study.

We also conducted 24 focus group discussions (FGDs) for post-farmgate value chain actors in the eight states during November and December 2019. Three FGDs were administered per state to complement the findings of the quantitative survey. In total, 121 value chain actors participated in the FGDs (Table 2). The FGDs included a combination of four questions that were either follow-up or clarifying questions from the quantitative surveys as well as other questions to capture qualitative aspects of fish value chains such as the following: (1) aquaculture market and trading channels, (2) opportunities, constraints and value creating throughout aquaculture value chains, (3) social and cultural aspects around the consumption of fish, and (4) the role of women and youths in aquaculture businesses.

Data cleaning and analysis

Survey teams in each state consisted of a supervisor and five to six enumerators. At the inception of the project field work, we trained local enumerators to use online data collection tools, specifically Open Data Kit. We also trained smaller groups of enumerators on procedures and facilitation skills to conduct FGDs to collect qualitative data. Once the enumerators began the field work, the core post-farmgate value chain survey team put in place a monitoring and data quality control system to monitor data collection daily during the field work.

State	Agroecological zone	Traders (Wholesalers)	Retailers	Fish processors/smokers
Lagos	North-West	29	29	29
Ogun	South-East	29	29	29
Oyo	South-West	29	29	29
Delta	South-South	29	29	29
Rivers	South-West	29	29	29
Anambra	North-Central	29	29	29
Kano	South-West	29	29	29
Niger	South-South	29	29	29
Total		**232**	**232**	**232**

Table 1. Sample size and states represented for quantitative value chain assessment in Nigeria.

Communication channels through WhatsApp groups were put in place for quick communication between the core post-farmgate value chain team and enumerator groups in each state in case of any emerging issues during the survey implementation. Any abnormalities in the collected data were reported back to the local enumerators and discussed to improve data quality.

The local enumerators also reported technical issues (if any) during their field work to the core team to find technical solutions to any errors in the survey. This created multiple versions of the online database to ensure that any errors, whether technical or related to survey questions, were solved to ensure the continuity of the field work and improve the quality of data. Once the field work was completed, the core post-farmgate value chain team reconciled the online versions of the databases into one database. Inputs for each survey question were examined for abnormalities in the data, such as data entry errors, outliers and implausible values. When any data abnormalities were detected, the core team communicated and discussed the issue with the local enumerators through WhatsApp groups. The data inputs were corrected wherever enumerators provided clarity on errors or obvious spelling mistakes. Implausible values and outliers were removed from the database.

We used descriptive statistics to analyze quantitative data. Our analysis provides evidence based economic, social (gender, youth, equity), environmental, nutritional, and food safety performance indicators for fish value chains in Nigeria. The economic performance of value chain actors is measured based their financial performance, specifically profit per chain actor, profit per fish and the percentage of chain actors who made a profit. We measured social performance by separating our data based on different gender and age groups. We estimated the proportion of women and youth ownership of post-farmgate value chain activities and both their profit and roles along fish value chains.

Environmental performance is measured based on the mode and duration of transportation along the value chains. Nutritional and food safety performance is measured based on several factors: the type of fish processing, processing ingredients, removing parts of fish during processing, fish storage and duration of transportation, and fish handling practice. Data analysis for FGDs of the post-farmgate value chains involved coding participants' responses, whenever possible, to each question by grouping responses under headings in a way that the most common responses could be identified.

State	Agroecological zone	Traders (Wholesalers)	Retailers	Fish processors/smokers
Lagos	North-West	5	5	5
Ogun	South-East	5	5	5
Oyo	South-West	5	5	5
Delta	South-South	7	5	4
Rivers	South-West	5	5	5
Anambra	North-Central	5	5	5
Kano	South-West	5	5	5
Niger	South-South	5	5	5
Total		**42**	**40**	**39**

Table 2. Sample size and states represented in the FGDs.

Post-farmgate value chains

Key value chain products, and characteristics of value chain actors

This study identified five key aquaculture value chains in Nigeria. Of these, the fresh catfish value chain is the most dominant, followed by smoked catfish, dried catfish, fresh tilapia and smoked tilapia (Figure 1). In general, fish is preferably sold fresh. Value chain actors process (such as smoking and/or drying) fresh fish that they are not able to sell fresh, both small (less than 300 g) and large (greater than 300 g). Access to cold chains is limited, which forces value chain actors to smoke or dry unsold fresh fish to prevent fish loss.

Fish wholesalers, retailers and processors are key post-farmgate value chain actors in Nigerian fish value chains. Based on our survey sample, Figure 1 shows the number of value chain actors engaged at each segment of the value chain per fish product, while Figures 2 and 3 show ownership of post-farmgate aquaculture businesses by gender and age groups. Nigerian fish value chains are diverse with respect to gender and age. Women own about 50% of post-farmgate value chain activities, while youths (less than 35 years old) own 35%. This suggests that any investment in Nigerian fish value chains is likely to benefit a wide range of actors of different gender and age groups.

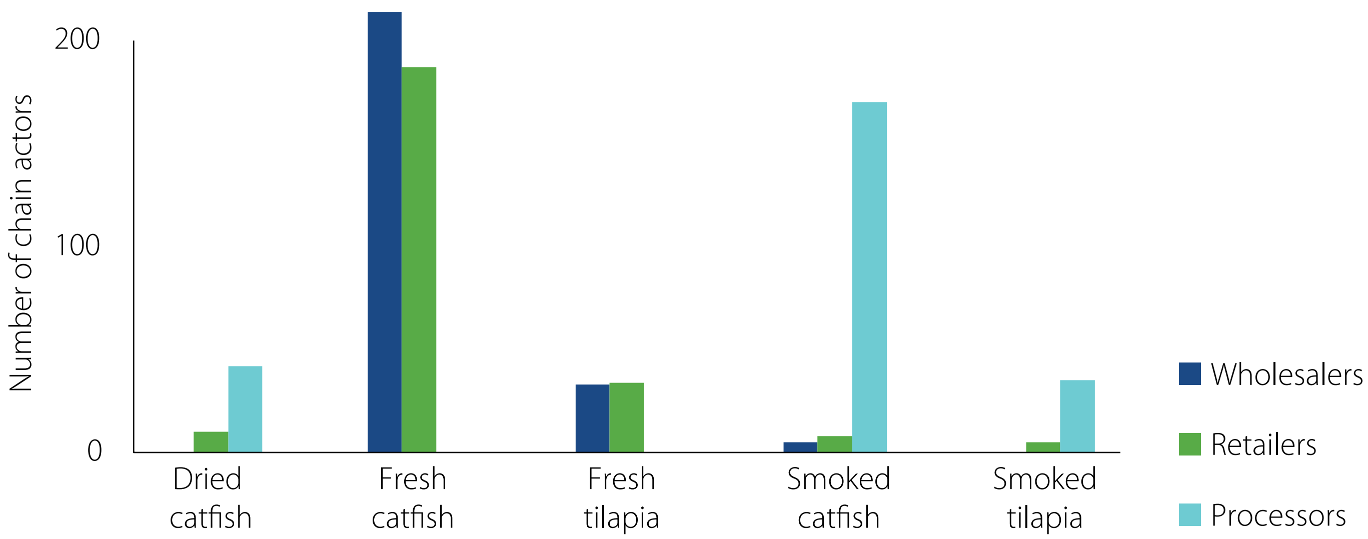

Figure 1. Types of aquaculture value chains in Nigeria.

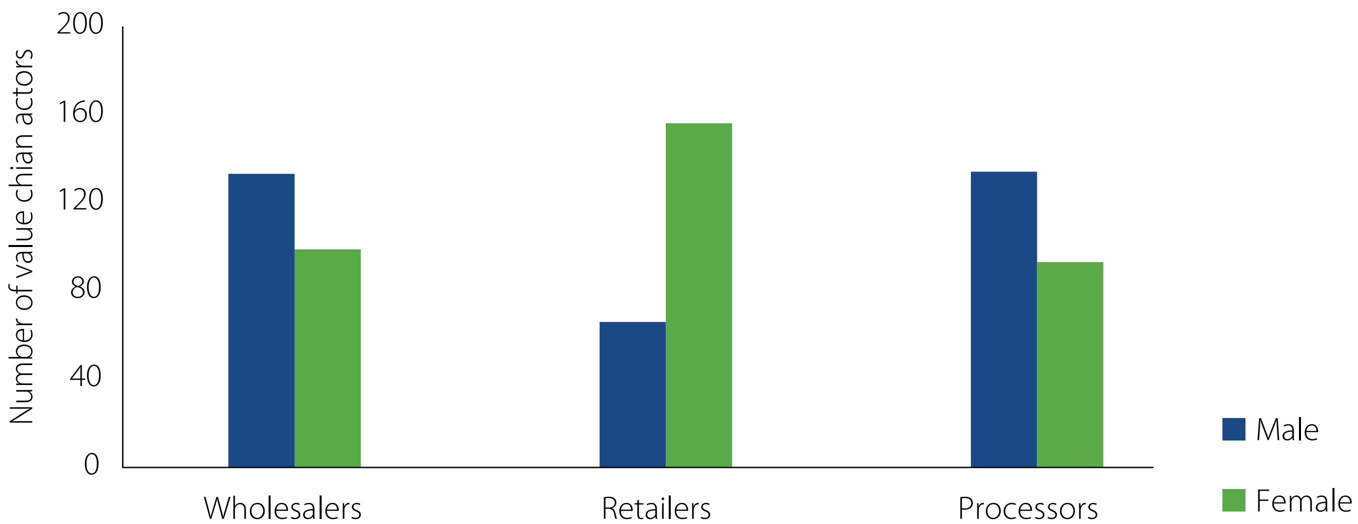

Figure 2. Gender of value chain actors.

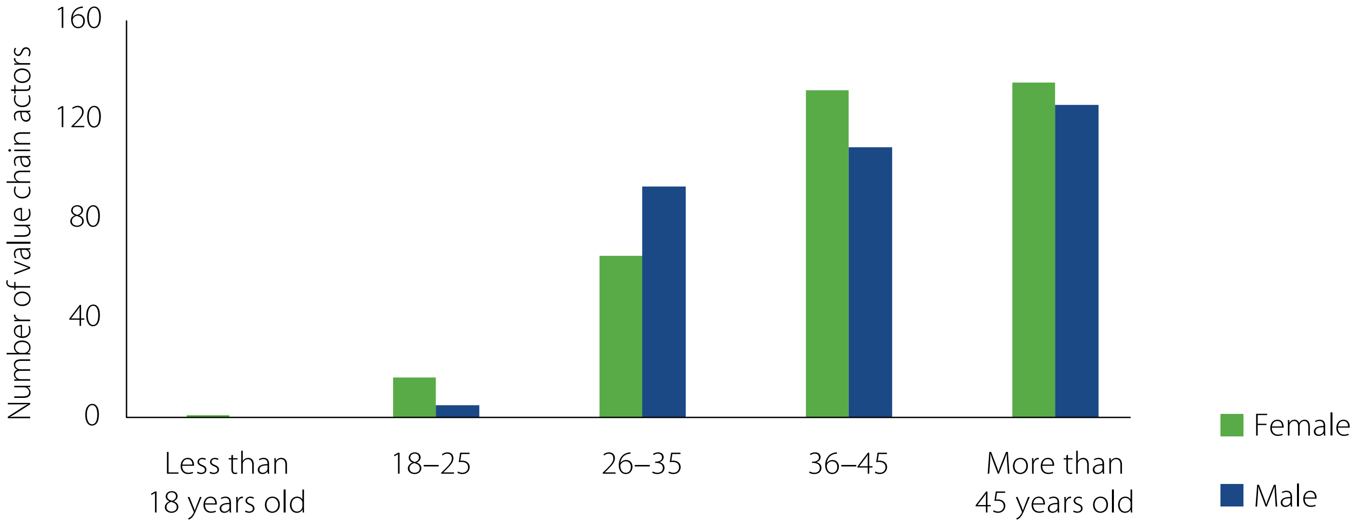

Figure 3. Age of value chain actors.

Value chain structure

Fish value chains in Nigeria consist of different actors, such as input providers, producers, capture fisheries, post-farmgate chain actors (wholesalers, processors, retailers/marketers) and consumers (Figure 4). In this study, we only report analysis done on post-farmgate value chain actors of wholesalers, processors and retailers. We also capture the various channels that these actors use to buy and sell fish, the role of gender and youths along the value chain, and the value created through input providers, such as labor and employment.

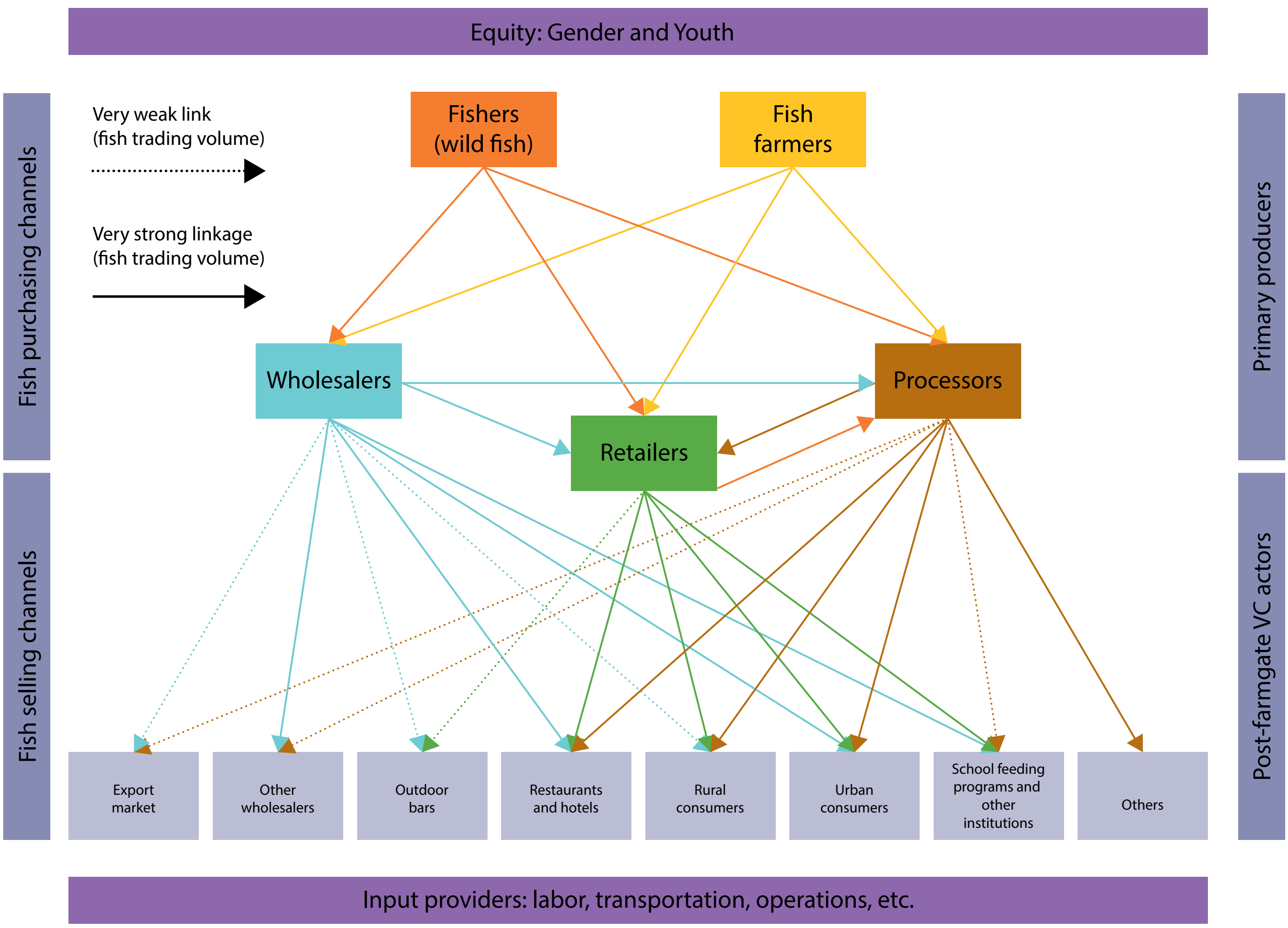

Figure 4. Post-farmgate fish (catfish and tilapia) value chains in Nigeria.

Our primary data shows that post-farmgate value chain actors source fish from both farmed and captured fisheries. The catfish value chain relies largely on farmed fish, while the tilapia value chain is more dependent on capture fisheries. In both value chains, captured and farmed fish contribute a substantial proportion of fish to the market. The catfish aquaculture sector is better established than the corresponding tilapia sector (Table 3) as it sources more fish from farms than capture fisheries. This suggests that investment in farmed catfish could generate positive livelihood impacts for a larger number of fish producers and post-farmgate value chain actors relative to farmed tilapia. However, there is investment potential in expanding capacity to supply more farmed tilapia to Nigerian fish markets. In return, this could create new opportunities to promote and expand farmed tilapia value chains to generate more value throughout the economy.

Post-farmgate value chain actors not only source fish from producers, but also from intermediaries and fishers. Both wholesalers and processors source most of their fish from farmers and fishers (capture fisheries) directly, while retailers, in addition to producers and fishers, rely also on wholesalers (Table 3). Among fish value chain actors, sales channels are more complex than purchase channels (Table 4). Wholesalers and processors sell most of their fish to retailers and urban consumers directly, while retailers sell the vast majority of their fish to urban consumers. Purchasing and sales channels show that 32%–50% of catfish and 48%–62% of tilapia go from production (farmed and captured fish) through a single intermediary (such as wholesaler, processor or retailer) before reaching consumers (urban and rural) (Table 4). The rest of the fish goes through multiple chain actors until it reaches consumers.

The quantitative data on the purchase and sales channels of post-farmgate value chains (Tables 3 and 4) is consistent with our field and FGD notes where Nigerian fish value chains are described as short and fresh. These results are not surprising as cold chains are nonexistent in Nigeria, which forces chain actors to sell fish fresh or process unsold fish to avoid spoilage. Rather than primarily focusing on a single activity, the chain actors play multiple roles, specifically wholesaling, retailing and processing. Nigerian farmed fish value chains are market driven; no single chain actor or a small group of actors has a monopoly over post-farmgate activities. Data in Tables 3 and 4 shows that the purchase and sales channels of chain actors are diverse, with post-farmgate chain actors buying fish directly from producers or intermediaries and selling to a variety of end market actors. This suggests that investment in fish value chains in Nigeria not only serves producers, key post-farmgate value chains actors and consumers, but also a variety of other market actors, such as restaurants, hotels and school feeding programs.

Fish type	Purchase channel	Wholesalers	Processors	Retailers
Catfish	Producers	62.2	69.3	41.9
Catfish	Wholesalers	2.2	7.2	43.1
Catfish	Processors	0.4	0.1	1.4
Catfish	Other (e.g. agents, fishers)	35.3	23.4	13.6
Tilapia	Producers	15.9	6.8	6.1
Tilapia	Wholesalers	0.4	18	45.2
Tilapia	Processors	0.3	5	3.4
Tilapia	Other (e.g. agents, fishers)	83.4	70.1	45.3

Table 3. Purchase channels of post-farmgate value chain actors (% sourced from each purchase channel).

Fish type	Sales channel	Wholesalers	Processors	Retailers
Catfish	To export markets	0.1	0.3	
Catfish	To other wholesalers	8.9		
Catfish	To outdoor bars	0.2	0.1	0.9
Catfish	To processors	2.5		3.5
Catfish	To restaurants and hotels	7.7	5.3	11.8
Catfish	To retailers	44.9	41	2.2
Catfish	To rural consumers (fresh village fish market)	0.7	3	4.4
Catfish	To school feeding programs and other institutions	3.8	0.9	4.2
Catfish	To urban consumers	31.1	47.6	73.1
Catfish	To others		1.8	
Tilapia	To export markets		0.3	
Tilapia	To other wholesalers	0.9		
Tilapia	To processors	1.4		12.8
Tilapia	To outdoor bars		0.04	0.1
Tilapia	To restaurants and hotels	0.6	1.1	1.9
Tilapia	To retailers	49.7	35.4	8.3
Tilapia	To rural consumers (fresh village fish market)	0.3	11.5	16.4
Tilapia	To urban consumers	47.3	50.4	60.6
Tilapia	To others		1.3	

Table 4. Sales channels of post-farmgate value chain actors (% sold through each sales channel).

We conducted three FGDs per state across all eight states covered in this study, with a total of 121 participants. Of the participants, 66 said that a larger portion of their customers prefer captured fish, while 36 said farmed fish is preferred. The key reason customers prefer captured fish is because it tastes better and the fish are bigger, while farmed fish is preferred because it is available year-round. Of the 121 participants, 91 said that catfish is the most popular fish in Nigeria, because it is affordable, nutritious, available and sold fresh (alive), while 41 participants said a range of "other" fish were popular, including local delicacies. Only seven participants said tilapia is popular. Tilapia is considered one of least popular fish among chain actors and their customers because it is expensive, hard to grow and has a high degree of perishability.

Financial performance

According to our data, which represents a snapshot of the previous 7 days before the survey date, over 80% of value chain actors who were engaged in post-farmgate fish value chain activities reported earning a profit (Figure 5). However, profit generated per fish per value chain actor varies based on the type of value chain (fresh catfish, smoked catfish, fresh tilapia, etc.) and different segments (retailers, wholesalers, processors). Trading both fresh and processed catfish and tilapia is profitable, except for smoked tilapia at the processor level, which generated a loss of about NGN 9 per fish. This loss might be linked to the lack of a cold chain to preserve freshness. For the rest of the fish products, the profit of value chain actors per fish varied from NGN 40 for fresh tilapia at the wholesaler level to NGN 506 for smoked catfish at the retailer level (Figure 6).

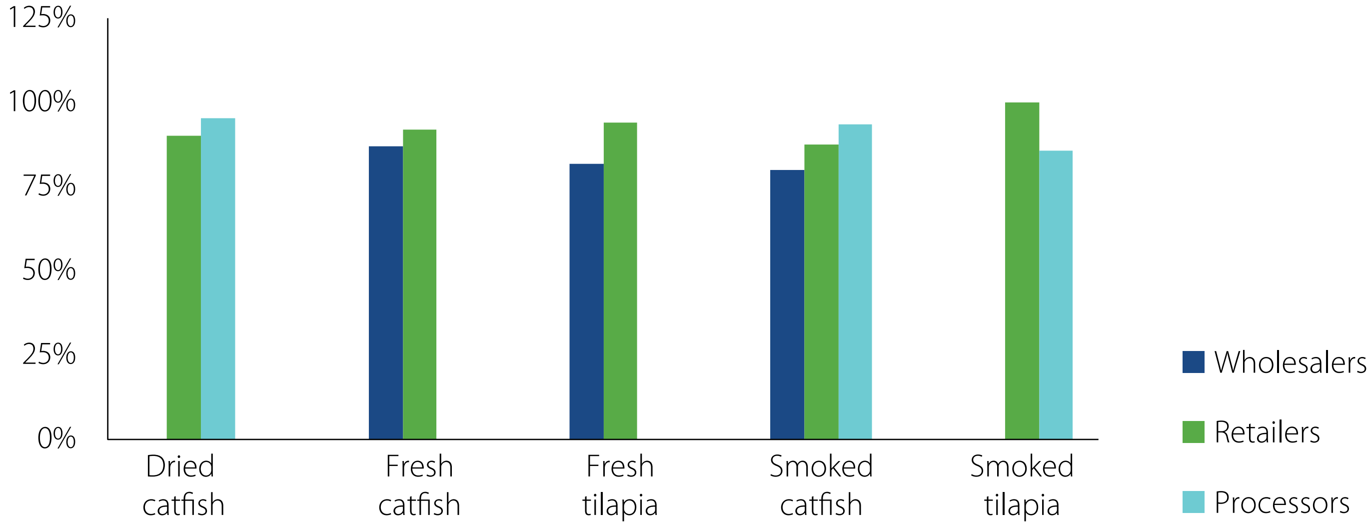

Figure 5. Percentage of value chain actors making a profit.

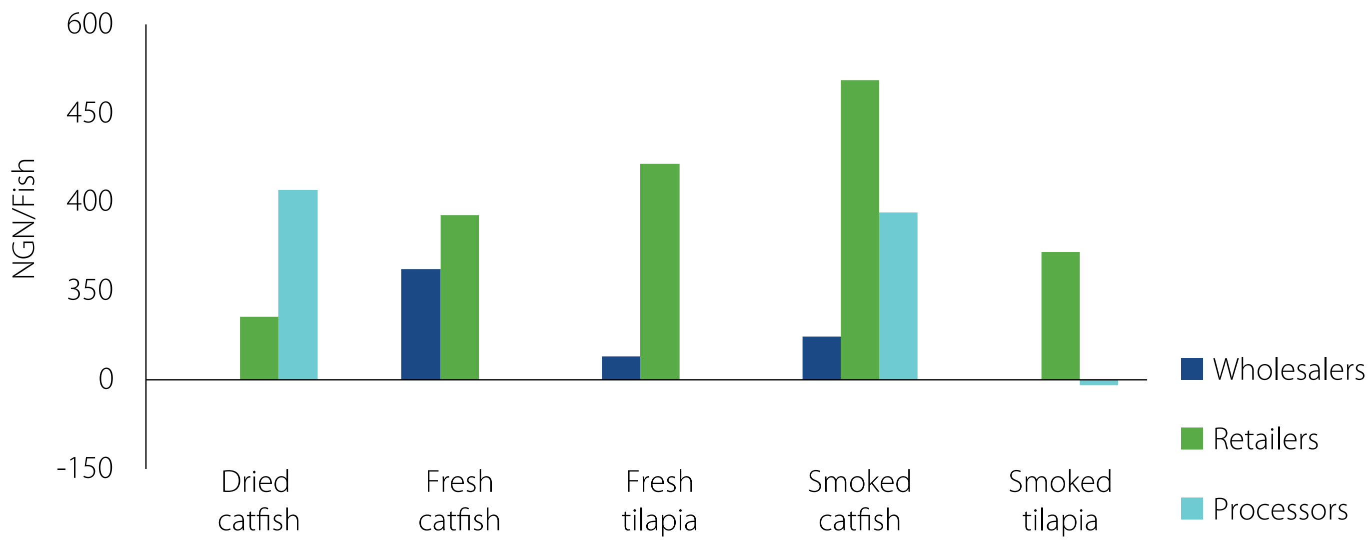

Figure 6. Profit per fish per value chain node.

Table 5 shows average and median profit generated per value chain actor across different fish products. On average (both mean and median), most chain actors engaged in fish value chains made a profit. However, our data distribution is skewed, which means that a few observations (value chain actors made extreme positive or negative profit) have substantial impact on average (mean) values. Therefore, in Table 5, median profit is considered a more accurate indicator of profit compared to average profit. In general, fish value chains in Nigeria are economically viable, as over 80% of post-farmgate value chain actors are making a profit.

Value (measured in NGN) is not only created through direct fish trading through value chains (Figure 6). It is also created through services such as labor and transportation, and value chain actors use both as part of their business operation. Although labor (opportunity cost in the case of family labor), transportation and other operational activities are costs associated with producing and transforming fish products for chain actors, they are considered value for service providers such as laborers and transporters. We captured value created through labor and transportation per fish for key aquaculture value chains in Nigeria. Labor value created throughout the value chains ranges from NGN 0.4 per fish for fresh catfish at the wholesaler level to NGN 21.5 per fish for dried catfish at the retailer level (Figure 7). In a similar vein, the value addition of transporters ranges from NGN 0.8 for fresh tilapia to NGN 9.5 per fish for dried catfish, both at the retailer level (Figure 8).

A. Wholesalers				
Fish type	**Number of wholesalers**	**Average profit**	**Median profit**	**Standard deviation**
Dried catfish				
Fresh catfish	214	2,065,723	158,528	13,330,631
Fresh tilapia	33	277,917	91,777	5,759,713
Smoked catfish	5	125,133	46,349	172,545
Smoked tilapia				
B. Retailers				
Fish type	**Number of retailers**	**Average profit**	**Median profit**	**Standard deviation**
Dried catfish	10	46,675	25,832	69,320
Fresh catfish	187	591,479	64,060	1,519,496
Fresh tilapia	34	827,572	168,290	1,795,406
Smoked catfish	8	699,310	38,772	1,748,036
Smoke tilapia	5	72,410	33,127	89,461
C. Processors				
Fish type	**Number of processors**	**Average profit**	**Median profit**	**Standard deviation**
Dried catfish	42	220,136	58,009	593,183
Smoked catfish	170	1,175,234	185,224	2,997,357
Smoked tilapia	35	-33,366	613,000	7,317,978

Table 5. Profit among value chain actors (NGN).

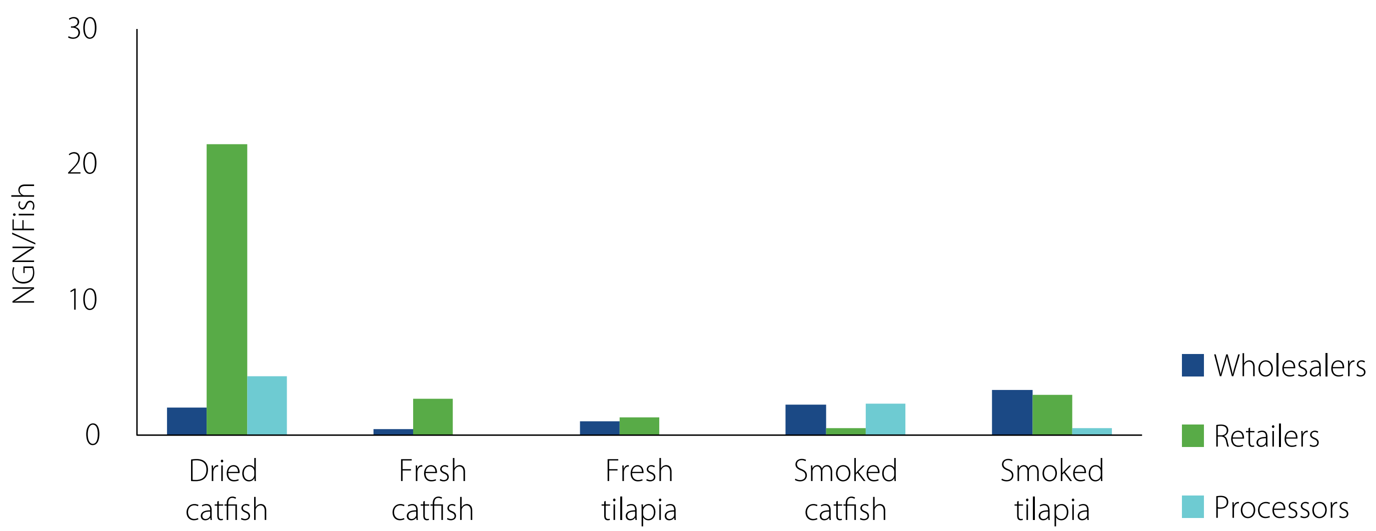

Figure 7. Value created through labor, per fish.

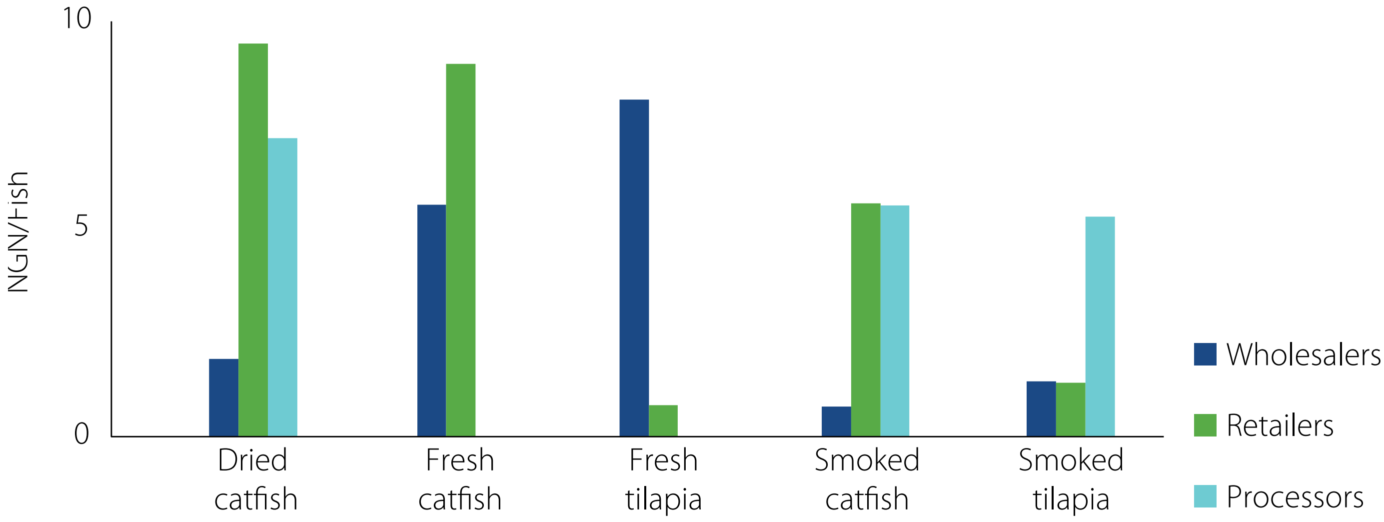

Figure 8. Value created through transportation, per fish.

Gender and inclusiveness

We separated the financial performance of value chain actors by gender and age. In general, fish processors, followed by retailers and wholesalers, generate higher value per fish traded throughout the value chains. Male value chain actors make a higher profit per fish at the processor (NGN 287) and retailer (NGN 305) levels compared to their female counterparts (NGN 278 for processors and NGN 269 for retailers). At the wholesaler level, however, female wholesalers make more profit per fish (NGN 179) than male wholesalers (NGN 172) (Figure 9). Different age groups of value chain actors are engaged in fish value chain activities in Nigeria.

Ages range from less than 18 years old to over 45. By age, data shows that almost all value chain actors, regardless of gender and age, make a profit, except those aged 18 to 25 at the wholesaler level (Figure 10). Value created per fish for each age group ranges from NGN –215 among those 18 to 25 years old at the wholesaler level to NGN 419 among those 45 years or older at the retailer level. This wide variation is because when we divide our dataset into different age groups the sample size per group becomes small, especially for those in the 18–25 age group. This may also be due to the inability of this age group to raise adequate capital or to qualify for a loan to meet the economic threshold for wholesale buying.

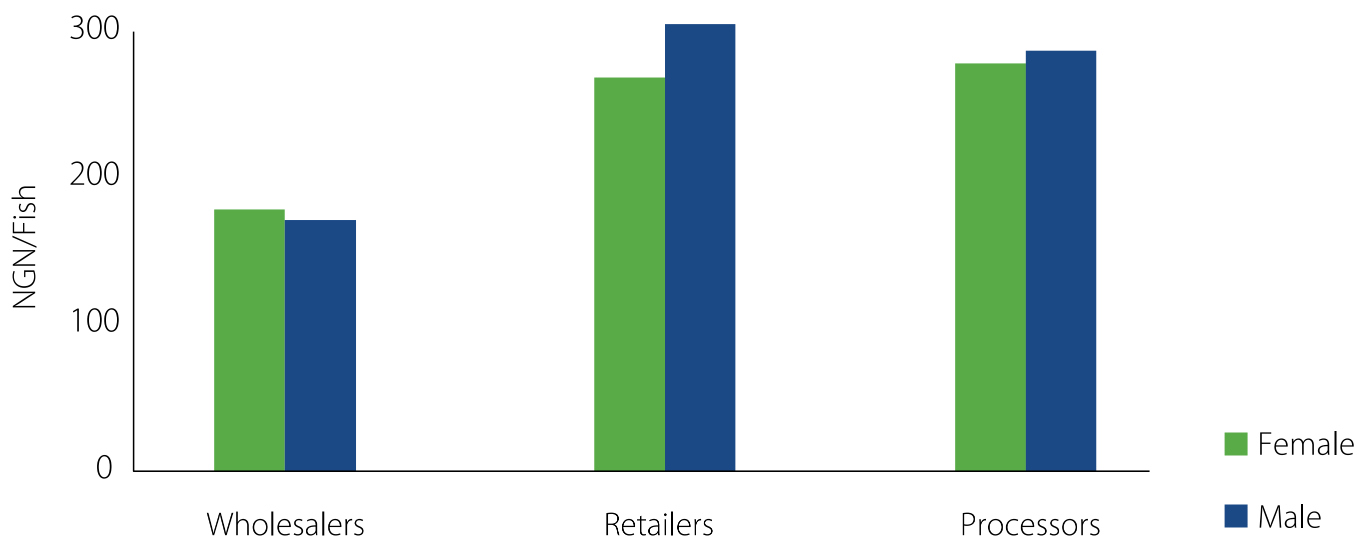

Figure 9. Profit per fish per value chain actor, by gender.

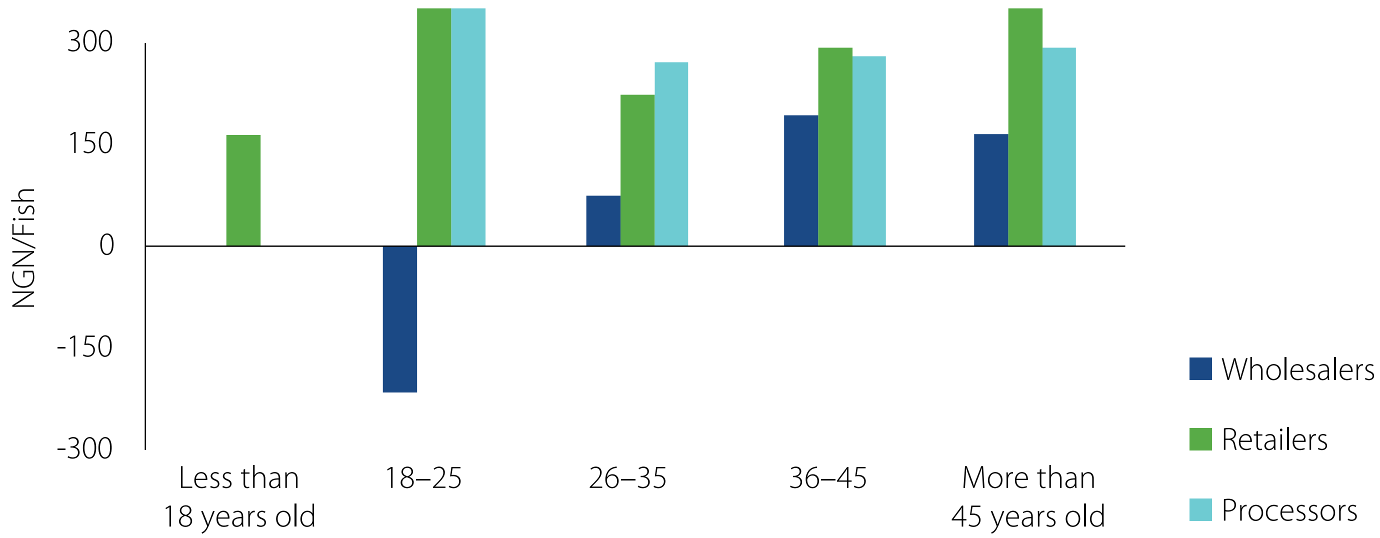

Figure 10. Profit per fish per value chain actor, by age.

Tables 6 and 7 show gender and age disaggregated by average and median profit generated per value chain actor across different fish products, respectively. On average (both mean and median), most chain actors, regardless of gender and age group, who engaged in fish value chains made a profit, except for those age 18–25 at the wholesaler level. Our data distribution is skewed, however, which means that a few observations (value chain actors made extreme positive or negative profit) have substantial impact on average (mean) values. Therefore, in Tables 6 and 7, median profit is considered a more accurate indicator of chain actors' profit compared to the average profit.

A. Wholesalers				
Sex	**Number**	**Average profit**	**Median profit**	**SD profit**
Female	105	336,180	160,955	540,629
Male	152	2,713,876	115,095	16,005,546
B. Retailers				
Sex	**Number**	**Average profit**	**Median profit**	**SD profit**
Female	169	210,743	46,696	582,486
Male	75	1,460,689	496,500	2,397,717
C. Processors				
Sex	**Number**	**Average profit**	**Median profit**	**SD profit**
Female	99	126,709	84,900	4,315,886
Male	149	1,310,934	184,798	3,191,341

Table 6. Profit (NGN) of value chain actors, by gender.

A. Wholesalers				
Age category	**Number**	**Average profit**	**Median profit**	**SD profit**
18–25	3	-329,401	-17,967	765,673
26–35	38	379,808	61,105	2,569,256
36–45	100	2,437,780	190,603	15,822,908
Over 45	116	1,642,979	116,539	10,994,017
B. Retailers				
Age category	**Number**	**Average profit**	**Median profit**	**SD profit**
18–25	11	380,389	179,896	712,859
26–35	63	719,549	91,688	1,219,460
36–45	93	514,181	73,205	1,565,986
Over 45	76	628,835	49,497	1,782,175
C. Processors				
Age category	**Number**	**Average Profit**	**Median Profit**	**SD Profit**
18–25	8	1,528,405	541,845	2,836,005
26–35	58	898,348	89,478	3,126,884
36–45	62	1,491,486	188,565	3,434,341
Over 45	85	614,560	102,813	1,546,783

Table 7. Profit (NGN) of value chains actors, by age.

Although women are actively engaged in different segments of the value chains, the median profit in Table 6 shows that women-owned businesses are smaller, based on profit, than their male counterparts, particularly at the processor and retailer levels. This might be because of a lack of access to capital and business development and technical knowledge. In general, women played important roles across the value chain in all surveyed states, except Kano, where men dominated almost all value chain activities. A slight majority of participants (66 out of 121) in the FGDs indicated that increasing the access of women and youths to capital could better position them to play a better role in fish value chains in Nigeria, while almost a third (39 out of 121) said that business, technical know-how and management training could do so.

Youths are actively engaged across all segments of aquaculture value chains, but their role depends on the segment of their value chain. In general, the younger age group (18–25) is less represented across all value chain activities (Table 7). This might be because of a lack of access to capital and knowledge of the business, which makes it hard for this age group to enter the market. Similarly, the results of the FGDs showed that parents prefer their children to get educated to find white-collar jobs rather than venturing into aquaculture activities. FGD participants indicated that means to empower young people across the value chains include financial support and government grants (45 out of 121) and business training programs (33 out of 121). The vast majority of participants (92 out of 121) indicated that aquaculture is an attractive business to young people. Youths are likely to remain involved in the aquaculture value chain in the long term, as it is a profitable business, economically sustainable and can be done as a part-time job, such as before or after school hours.

Environmental performance

We use the fish transportation model and transportation time to measure post-farmgate environmental performance. Among post-farmgate value chains actors, 34.5%–48.5% use a wheelbarrow to transport different types of fish across the value chains, 17.6%–37.1% use a car or truck, 15.2%–21.1% use a motorcycle and 8%–15.6% use a motorized rickshaw or three-wheeler. Between 0.4% and 3.1% of value chain actors use other modes transportation, such as headloads, bicycles, boats, etc. (Table 8). This may indicate that post-farmgate value chain actors prefer nonmotorized means to keep their operational costs down and/or a majority are transporting fish over short distances. It also indicates that most trading and marketing are local in nature, resulting from a lack of transportation with cold storage facilities.

Excluding processing and storage time, duration of fish movement across the post-farmgate value chain is short. This short timeframe is expected, as value chain actors prefer to sell fish fresh because of the lack of a cold chain. The average time it takes for different fish products to move from one value chain actor to the next (or to consumers) ranges from 0.75 to 3 hours for wholesalers, 0.16 to 1.62 hours for retailers and 1.33 to 1.58 hours for processors (Table 9). The low average transportation times indicate that movement of fish along the value chain is short so that they are sold fresh and relatively unspoiled. However, there were some examples of transportation times up to 24 hours, which could potentially make the fish unsafe for human consumption because of a lack of proper fish storage facilities, including cold storage. Time spent transporting fresh fish between value chain actors does not appear to cause any significant live fish mortality or spoilage.

Mode of transportation	Wholesalers	Retailers	Processors
Headload	1.1%	3.1%	1.7%
Bicycle	0%	0.4%	0.4%
Motorcycle	17%	21.1%	15.2%
Ox-cart	0%	0%	0%
Boat	1.9%	0.8%	0%
Car/truck	37.1%	17.6%	23.2%
Public transportation	0%	1.2%	0%
Wheelbarrow	34.5%	40.2%	48.5%
Rickshaw/three-wheeler (nonmotorized)	0.4%	0%	0.4%
Rickshaw/three-wheeler (motorized)	8%	15.6%	10.1%
Other	0%	0%	0.4%

Table 8. Mode of fish transportation, post-farmgate.

Type of fish	Wholesalers	Retailers	Processors
Fresh tilapia	1.63	1.23	1.38
Frozen tilapia	1	0.16	1.5
Smoked tilapia	0.75	1.31	1.33
Fresh catfish	2.08	1.58	1.89
Dried catfish	3	1.62	1.58
Smoked catfish	1.19	0.84	1.39

Table 9. Hours of fish transportation per value chain actor.

Nutrition

Fish processing

In assessing the nutritional value of products, consideration was given to the type of processing, ingredients added and the fish parts removed. Fish processing is a profitable practice. However, most processors add different ingredients, such as salt and oil, which could change the nutritional composition of the fish. Many also remove parts of the fish during processing.

It is known that processing reduces the nutritional benefits of fish. Also, smoking can decrease the availability of proteins, essential amino acids and micronutrients, and it increases the amount of carcinogenic polycyclic aromatic hydrocarbons if the fish are not smoked safely (Adeyeye 2016). In a similar vein, drying fish can reduce protein and amino acid bioavailability (Bereket Abraha et al. 2018). Among surveyed processors, smoking is the most common fish processing method in Nigeria (77%) followed by drying (18%). Other processing practices occur on a limited basis, such as freezing, grilling, frying and filleting (Table 10).

Approximately two-thirds of surveyed processors (150 out of 235) reported adding different ingredients to their fish during processing (Table 11). The most common ingredients are salt (61%) followed by oil, salt-free flavorings and flavorings containing salt. The addition of these ingredients is likely to reduce the nutritional benefits of eating fish. Salt increases the risk of hypertension and cardiovascular disease, which has the potential to exacerbate the increase in diet-related chronic diseases that are common in Nigeria (National Population Commission and The DHS Program ICF 2019; WHO 2020). The consumption of one salted fish contributes, on average, one-fifth of the recommended daily maximum sodium intake for adults, and the addition of *maggi* seasoning would contribute further to sodium intake, as it is very high in sodium, at 9255 mg per 100 g (WHO 2020).

Processing method used	Number	Share
Smoking	185	77.7
Drying	44	18.5
Freezing	3	1.3
Filleting	1	0.4
Frying	2	0.84
Grilling	3	1.26
Total	**238**	**100**

Table 10. Processing methods used in Nigerian aquaculture.

Foods and flavorings added	Frequency of foods added		Quantity added (g)	
	Number	%	Mean	SD
Salt	144	61.3	1.2	2
Oil	13	5.5	0.92	0.6
Other	48	23.4	0.73	1
Salt-free flavorings (e.g. garlic, ginger, pepper)	24	10.2	NR*	NR
Flavorings containing salt (e.g. maggi seasoning)	14	6	NR	NR
Undefined seasonings	10	4.3	NR	NR
No foods or flavorings added	85	36.2	NA	NA
Total**	**235**	**100**	**NA**	**NA**

** Not reported*
*** Total respondents differ from the total as some respondents added multiple foods or flavorings*

Table 11. Ingredients added to processed fish.

Fish processing is done on an ad hoc basis, meaning how much fish are smoked or dried depends on the processor's preferences and skills. Among FGD participants, 16 out of 39 highlighted that heat variability to smoke fish is a challenge that reduces the quality and safety of processed fish, while 13 out of 39 said the same of processing time. Investments that target standardizing fish processing practices would likely generate substantial benefits in financial, nutritional and food safety terms to tackle improper and unsafe practices in fish processing.

Removing parts of fish

Most processors remove parts of the fish during processing, often multiple parts. Viscera (internal organs) are the most common parts removed from the fish, followed by the gills, eggs, tails, fat and spine (Table 12). While many processors remove parts of the fish, just over half (54%) reuse the offcuts for other purposes, mostly selling these offcuts (11%) to other value chain actors (Table 13). A few processors use the offcuts for their own consumption (3%) or repurpose them into secondary products (6%).

Parts of fish removed	Frequency of parts removed		Average weight of the part removed (g)	
	Number	%	Mean	SD
Viscera	151	64.3	1.99	1.96
Gills	83	30.2	1.16	1.69
Undefined	14	5.1	N/A	N/A
Eggs	13	4.7	NR	NR
Tail	7	2.6	2.36	1.65
Fat	3	1.1	NR	NR
Spine	2	0.7	1	0
Bile	1	0.4	NR	NR
Scales	1	0.4	NR	NR
Total respondents who reported parts removed*	**159**	**67.7**	**1.58**	**1.89**
No parts removed	**76**	**32.3**	**0**	**0**

**Total respondents differ from the number of responses as respondents frequently reported removing multiple parts of the fish*

Table 12. Parts of fish removed during processing.

The viscera of fish are high in protein and fat (Villamil et al. 2017) and can be used to produce value-added products. These offcuts can be processed into fishmeal or processed food for human consumption (Deraz et al. 2015). About 46% of offcuts are discarded or fed to dogs (Table 13). Further research is required to determine the feasibility potential of processing disposed offcuts to produce value-added fish products.

Food safety

We examined the two variables of storage and time during fish transportation to measure food safety issues. Storage and transportation times varied with different fish products. The lack of a cold chain forces chain actors to buy and sell fish in a short timeframe in order to avoid fish loss. In Nigeria, fish is generally traded fresh. However, small fish (less than 300 g) or unsold fresh fish (larger than 300 g) are processed to preserve them and avoid fish spoilage (loss).

Fresh catfish are mostly transported alive along the value chain (99%), as consumers prefer to buy them fresh (alive). Tilapia are moved along the value chain either on ice (38%) or using other means (43%) and predominately transported after death (84%). Value chain actors transported under a quarter (15%) of catfish using other storage modes. Processed fish are mainly transported in bags without water or ice (Table 14). Transportation time varies greatly among different products, but the vast majority of fish products takes less than 4 hours to move along the value chains (Figure 11).

Use	Number	%
Discarded	123	46.1
Processed into a secondary product	15	5.6
Sold direct to consumers	5	1.9
Sold to another value chain actor	29	10.9
Used for own consumption	9	3.4
Other	86	32.2
Total	**267**	**100**

Table 13. Use of by-products at the processor level.

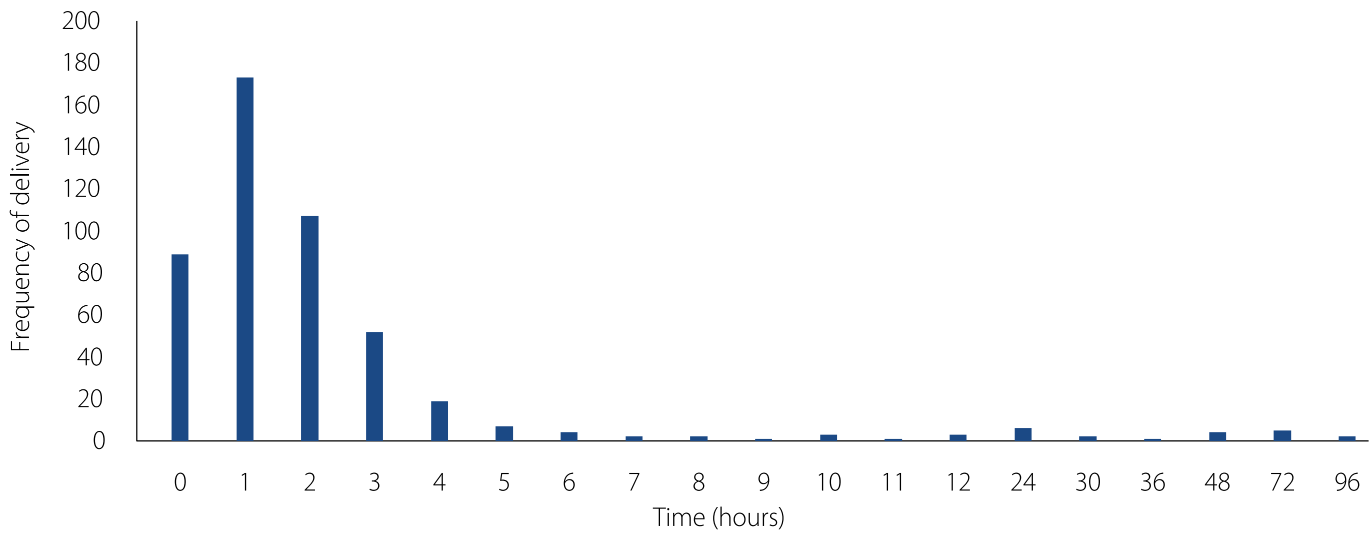

Figure 11. Duration of fish transportation.

Food safety measures are not consistently practiced along the value chains. Most value chain actors (65%) do not use closed or sealed containers to transport fish, which exposes the fish to environmental contaminants (Table 15). Over half (56%) of the value chain actors monitor the temperature of both the water and the fish at some point during transportation and storage. However, temperature checks are done by hand rather than using a thermometer. Although chain actors use simple transportation and storage techniques, it appears that fish loss is minimal, especially as all parts of the fish are consumed or used elsewhere. However, the current storage model and long transportation times are likely to contaminate fish along the value chain and create food safety problems.

Type of fish		Fresh tilapia		Frozen tilapia		Smoked tilapia		Fresh catfish		Dried catfish		Smoked catfish		Total	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%
Transported live or dead	Alive	9	16	0	0	0	0	365	99	0	0	0	0	374	81
	Dead	49	84	3	100	5	100	2	1	11	85	13	93	83	18
	Not applicable	0	0	0	0	0	0	2	1	2	15	1	7	5	1
	Total	**58**	**100**	**3**	**100**	**5**	**100**	**369**	**100**	**13**	**100**	**14**	**100**	**462**	**100**
Storage mode	In water	8	14	0	0	0	0	308	83	0	0	0	0	316	68
	On ice	22	38	1	33	0	0	1	0	0	0	0	0	24	5
	On salt	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	In an insulated box	0	0	0	0	0	0	1	0	1	8	1	7	3	1
	Other	25	43	2	67	3	60	55	15	12	92	11	79	108	23
	Not applicable	3	5	0	0	2	40	5	1	0	0	2	14	12	3
	Don't know	0	0	0	0	0	0	0	0	0	0	1	7	1	0
	Total	**58**	**100**	**3**	**100**	**5**	**100**	**370**	**100**	**13**	**100**	**14**	**100**	**463**	**100**

Table 14. Fish transportation modes.

	Do you use a closed or sealed container for transportation?		Is the temperature of the fish monitored at any point while under your possession?	
	n	%	n	%
Yes	219	31	396	56
No	454	65	279	40
Don't know	30	4	29	4
Not applicable	-	-	-	-
Total	**703**	**100**	**704**	**100**

Table 15. Hygiene and food safety measures.

Similarly, some of the post-harvest fish handling practices are non-hygienic, which could possibly contaminate fish along the value chain. About 12% of value chain actors did not have access to toilets and 6% have no access to clean water (Table 16). The majority of value chain actors (76%) did not use gloves while handling fish. About 34% of chain actors did not clean their hands prior to handling fish. Although fish has proven nutritional benefits for humans, non-hygienic post-farmgate fish handling practices could contaminate fish and offset any benefit that consumers might get from consuming fish. Investment strategies that target improving these practices will likely generate substantial food safety and hygiene benefits.

	Are there toilets available at your work site?		Is there access to clean water at your work site?		Do you practice hand-washing?		Does you use gloves?	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Yes	547	78%	615	88%	422	60%	111	16%
No	81	12%	43	6%	239	34%	534	76%
Sometimes	76	11%	43	6%	42	6%	58	8%
Don't know	-	-	1	0%	1	0%	1	0%
Total	**704**	**100%**	**702**	**100%**	**704**	**100%**	**704**	**100%**

Table 16. Post-harvest fish handling sanitation practices.

Discussion and conclusion

To the best of the authors' knowledge, this is the first nationally representative study to evaluate post-farmgate fish value chains in Nigeria. The study covers eight states that represent different regions in Nigeria based on aquaculture production potential and socioeconomic and nutrition characteristics. We identified five key value chains that supply fish to Nigerian consumers: fresh catfish, fresh tilapia, smoked catfish, dried catfish and smoked tilapia. Our post-farmgate value chain map found similar results to those of studies on coastal fisheries, including Odebiyi et al. (2013) in Ogun State and Adebayo et al. (2016) in Adamawa State. We found that fish goes through up to three post-farmgate value chain actors before reaching consumers: wholesalers, processors and retailers. Fish is mostly sold fresh because of the lack of cold chains in Nigeria, but this does not result in any substantial fish loss, as value chain actors either smoke or dry unsold fresh fish to avoid spoilage. Although fish is preferably traded fresh, processed fish products are common and highly profitable.

Fish value chains in Nigeria are short and local. That is, fresh fish are often transported using unmotorized modes of transportation and move along the value chains within a few hours of harvest. Our findings show that fish value chains in Nigeria are economically viable, with over 80% of post-farmgate actors earning a profit. The weakest point in the value chain is at the wholesaler level, where the profit margin is lower than for other actors. Overall, most value chain actors, regardless of gender and age groups, reported a healthy profit margin. Our results support the growing body of literature that documents the profitability of fish value chains in different regions in Nigeria (Magdugu and Edward 2011; Olasunkanmi 2012; Odebiyi et al. 2013; Adebayo et al. 2016).

Women and youths (less than 35 years old) are actively engaged in fish value chains in Nigeria. Our study shows that women own about 50% of post-farmgate value chain activities (processing, wholesaling, retailing) while youths own 35%. Furthermore, like their male counterparts, women are able to generate profit from their aquaculture businesses. In general, women dominate fish retailing, while men are more engaged in wholesaling. Our data and results support the existing reports published on the active role of women in Nigerian fish value chains in the states of Lagos (Makinde et al. 2015), Adamawa (Adebayo and Pitan 2003; Adebayo et al. 2016) and Ondo (Adelke and Afolabi 2012). An exception is Kano in northern Nigeria, where women play a marginal role along fish value chains. Previous studies also reported that men dominate fish value chains in the north and northeastern regions of Nigeria (Veliu et al. 2009).

Our results show that fish processing is a profitable practice; however, most processors add different ingredients and remove parts of the fish during processing, which could change their nutritional composition. They also use improper post-farmgate handling practices, such as not washing hands and/or wearing gloves prior to handling fish and transporting fish in unsealed containers. Combined with the lack of a cold chain, these practices are likely to expose fish to contaminants that create food safety issues and offset the nutritional benefits of consuming fish. Our findings are in line with those of Grema et al. (2018) on food safety and hygiene practices along Nigerian fish value chains, where chain actors have good knowledge about food safety issues but have poor hygiene practices, such as not washing hands or wearing gloves.

Our study provides evidence, based on primary data, about the economic, environmental, social, nutritional and food safety performance of the post-farmgate fish value chain. These results are of interest to both private and public sector decision-makers and policymakers. The results provide quantitative data on value creation (fish sales, employment, service provision), social performance (women and youth empowerment), and environmental, nutritional and food safety challenges along fish value chains. Our study finds that, in general, fish value chains are profitable and inclusive, as women and youths own over half of post-farmgate value chain activities. This means that any investment to enhance fish value chains in Nigeria would likely generate not only additional financial benefits, in the form of profit, to value chain actors and the wider economy but also an inclusive benefit to different chain actor groups, such as men, women and youths.

This study highlights a few policy leverages in the context of enhancing food safety along the value chains in Nigeria. An important finding is that fish value chains in the country are short and local. Although short chains work best to keep fish fresh and reduce transaction costs, they make fish less available in inland areas compared to coastal and aquaculture production regions. Policy interventions should aim to conduct a cost-benefit assessment of the development of long chains, such as cold chains, to ensure that fish reach inland regions, specifically those that are farther away from coastal and aquaculture production zones. This will certainly increase operational costs along the value chain but will increase the availability of fish in inland areas of Nigeria. Additionally, given the lack of access to advanced transportation technologies, including refrigerated trucks and packaging technologies, the nutrition benefits of fish will likely be compromised if fish are exposed to contaminants and adverse environment conditions along the value chain, like heat and humidity.

Policy strategies that aim to develop, promote and impose food safety practices, like using gloves, washing hands and using sealed containers to transport fish, would likely improve food safety standards and consumer well-being. Additionally, fish processing is mostly done on an ad hoc basis, where chain actors use basic techniques to process fish. These include unstandardized practices where processors decide how much smoking or drying should be done, which could compromise quality and contaminate the fish. Investment plans that aim to improve processing and transportation technologies would likely enhance fish quality and food safety standards along the value chains. In general, the access of value chain actors to capital is limited, which makes it infeasible for actors to invest in technologies to improve post-farmgate fish handling standards. Therefore, access to capital through credit and/or grant systems to invest in fish production, processing and transportation technologies could be the key to unlocking the potential of aquaculture value chains in Nigeria.

Our study has a few limitations. First, as a snapshot of Nigerian fish value chains, our data is static. Static datasets do provide an overview of the aquaculture value chains at a specific time, such as last week; however, they lack important aspects of production seasonality and its impact on the performance and behavior of value chains actors. Second, our analysis is mostly descriptive, so it only describes the value chain and its performance indicators. Descriptive statistics do provide data-driven evidence of the current situation of aquaculture value chains, which forms the basis of policy analysis. However, they lack the ability to provide dynamic results where simulation models can inform policymakers of different policy scenarios and their likely financial gains and losses over different points in time, such as 1 year, 5 years, 10 years from now.

Further research should aim to collect data at different times, assuming enough funds and human resources. This would capture changes in fish value chain performance in both high and low production seasons. Furthermore, moving beyond descriptive analysis to develop tools to conduct what-if scenarios, such as has been done in Hamza et al. (2014), Dizyee et al. (2017 and 2019) and Ouma et al. (2018), would be a powerful analytical tool to support policymaking. Such a tool would provide an analytical framework to evaluate the likely impact of different policy interventions to improve the contribution of fish value chains—not only to the financial performance of value chain actors but also the well-being, food safety and nutrition availability (i.e. trade-off analysis) of consumers. Such a tool can be used to answer questions like the following: What would be the impact of a 20% increase in domestic aquaculture production on the price of fish, the profit for producers and post-farmgate chain actors, and the overall contribution of the aquaculture sector to the economy? What would be the impact of such an increase in domestic aquaculture production on creating dollar value by providing services along the value chain, such as employment, transportation and inputs? Who would be the winners and losers (e.g. in financial terms) from an increase in domestic aquaculture production?

References

Abraha B, Admassu H, Mahmud A, Tsighe N, Shui XW and Fang Y. 2018. Effect of processing methods on nutritional and physicochemical composition of fish: A review. *MOJ Food Processing & Technology* 6(4):376–82.

Adeyeye SAO. 2016. Traditional fish processing in Nigeria: A critical review. *Nutrition and Food Science* 46(3):321–35.

Bolwig S, Ponte S, Du Toit A, Riisgaard L and Halberg N. 2010. Integrating poverty and environmental concerns into value-chain analysis: A conceptual framework. *Development Policy Review* 28(2):173–94.

Deraz SF. 2015. Protein hydrolysate from visceral waste proteins of bolti fish (Tilapia nilotica): Chemical and nutritional variations as affected by processing pHs and time of hydrolysis. *Journal of Aquatic Food Product Technology* 24(6):614–31.

Dizyee K, Baker D and Rich KM. 2017. A quantitative value chain analysis of policy options for the beef sector in Botswana. *Agricultural Systems* 156:13–24.

Dizyee K, Baker D and Omore A. 2019. Upgrading the smallholder dairy value chain: A system dynamics ex-ante impact assessment in Tanzania's Kilosa district. *Journal of Dairy Research* 86(4):440–49.

Erkmen O and Bozoglu T. 2016. Spoilage of fish and other seafoods. *In* Erkmen O andBozoglu TF eds. *Food Microbiology: Principles into Practice*. New Jersey, US: Wiley. 301–06.

Gona A, Woji G, Norbert S, Muhammad H, Liverpool-Tasie LS, Reardon T and Belton B. 2018. The rapid transformation of the fish value chain in Nigeria: Evidence from Kebbi State. Micigan State University, USA. (No. 1879-2018-7730).

Grema HA, Kwaga J, Bello M and Onimisi HU. 2018. Assessment of food hygiene knowledge, attitudes and practices of fish handlers in Kaduna State, Nigeria. *Advances in Animal and Veterinary Sciences* 7(3):131–37.

Hamza K, Rich KM and Wheat ID. 2014. A system dynamics approach to sea lice control in Norway. *Aquaculture Economics & Management* 18(4):344–68.

Kaplinsky R and Morris M. 2000. A handbook for value chain research (Vol. 113). Brighton, UK: University of Sussex, Institute of Development Studies.

Khalili Tilami S and Sampels S. 2018. Nutritional value of fish: Lipids, proteins, vitamins, and minerals. *Reviews in Fisheries Science & Aquaculture* 26(2):243–53.

Madugu AJ and Edward A. 2011. Marketing and distribution channel of processed fish in Adamawa State, Nigeria. *Global Journal of Management and Business Research* 11(4).

Makinde Yetunde O, Afodu Osagie J, Balogun Olubunmi L, Awoyinka Iyabo R and Bello Taofeek A. 2015. Budgetary analysis and factors influencing profit level of culture fish enterprises by gender in Epe Local Government Area of Lagos State, Nigeria. *International Journal of Agriculture Innovations and Research* 3(6):1674-1678.

National Population Commission - NPC/Nigeria and ICF. 2019. Nigeria Demographic and Health Survey 2018. Abuja, Nigeria, and Rockville, Maryland, USA: NPC and ICF. 257–59.

Odebiyi OC, George FOA, Odulate DO, Agbonlahor MU and Olaoye OJ. 2013. Value-chain analysis for coastal fisheries development in Nigeria. *Global Journal of Science Frontier Research Agriculture and Veterinary* 13(11):6–15.

Olasunkanmi JB. 2012. Economic analysis of fish farming in Osun State, South-Western Nigeria. *In* Shriver AL, ed. Visible Possibilities: The Economics of Sustainable Fisheries, Aquaculture and Seafood Trade: Proceedings of the Sixteenth Biennial Conference of the International Institute of Fisheries Economics and Trade, July 16–20, 2012, Dar es Salaam, Tanzania.

Ouma E, Dione M, Birungi R, Lule P, Mayega L and Dizyee K. 2018. African swine fever control and market integration in Ugandan peri-urban smallholder pig value chains: An ex-ante impact assessment of interventions and their interaction. *Preventive Veterinary Medicine* 151:29–39.

[USAID] United States Agency for International Development. 2018. Nigeria: Nutrition Profile. Washington, DC: USAID. https://www.usaid.gov/sites/default/files/documents/1864/Nigeria-Nutrition-Profile-Mar2018-508.pdf

Veliu A, Gessese N, Ragasa C and Okali C. 2009. Gender analysis of aquaculture value chain in Northeast Vietnam and Nigeria. Washington, DC: World Bank.

Villamil O, Váquiro H and Solanilla JF. 2017. Fish viscera protein hydrolysates: Production, potential applications and functional and bioactive properties. *Food Chemistry* 224:160–71.

[WHO] World Health Organization. 2019. Food safety. Accessed June 4, 2020. Geneva: WHO. https://www.who.int/news-room/fact-sheets/detail/food-safety

[WHO] World Health Organization. 2020. Salt reduction. Accessed April 2, 2020. Geneva: WHO. https://www.who.int/news-room/fact-sheets/detail/salt-reduction

About WorldFish

WorldFish is a nonprofit research and innovation institution that creates, advances and translates scientific research on aquatic food systems into scalable solutions with transformational impact on human well-being and the environment. Our research data, evidence and insights shape better practices, policies and investment decisions for sustainable development in low- and middle-income countries.

We have a global presence across 20 countries in Asia, Africa and the Pacific with 460 staff of 30 nationalities deployed where the greatest sustainable development challenges can be addressed through holistic aquatic food systems solutions.

Our research and innovation work spans climate change, food security and nutrition, sustainable fisheries and aquaculture, the blue economy and ocean governance, One Health, genetics and AgriTech, and it integrates evidence and perspectives on gender, youth and social inclusion. Our approach empowers people for change over the long term: research excellence and engagement with national and international partners are at the heart of our efforts to set new agendas, build capacities and support better decision-making on the critical issues of our times.

WorldFish is part of One CGIAR, the world's largest agricultural innovation network.

For more information, please visit www.worldfishcenter.org