EVALUATION OF THE HERRING (*SARDINELLA* spp.) VALUE CHAIN IN TOMBO, SIERRA LEONE

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ABSTRACT

This study examines the roles of the main actors in the herring fishery (Sardinella spp.) value chain in Tombo, Sierra Leone. Specifically, it compares the production yield of the smoke ovens, evaluates the value chain system of the herring, identifies key market chain actors in the value chain, evaluates the value of the fish at each stage of the chain, and determines the best oven. Both primary and secondary data were used, and the collected data were assessed using descriptive and inferential statistical tools. Even though there is an issue with inadequate storage and preservative facilities, it is clear from the results shown in the profile of the herring value chain actors and the experiments that all actors want to maintain the quality of their products for a higher price. The results revealed that the key actors in the herring value chain are harvesters, fish mammies, fish processors, fish traders, and consumers. According to the study, improved smoke ovens can help maintain the quality of herring fish, increase the profit of fish processors, and reduce the health hazards associated with traditional smoke ovens. Therefore, it is recommended that improved smoke ovens be adopted in the herring value chain in coastal communities.

Keywords: Herring value chain, *Sardinella* spp., smoke ovens, fish mammies, artisanal fisheries, Sierra Leone.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Fisheries in Africa

Africa's oceans are renowned for having an abundance of fisheries resources (Belhabib et al., 2019). In addition to being a crucial contributor to national income, it is a substantial source of nutritional security and livelihoods (Asche et al., 2021, Wentink et al., 2017). Fisheries in Africa are characterised by extensive small-scale fisheries that provide a significant number of jobs (de Graaf & Garibaldi, 2015; Obiero et al., 2019) that provide active fishermen with a means of subsistence (Belhabib et al., 2019). Fishing is a subsistence activity that is often nearly exclusively carried out by women, as fish processing and marketing are two post-harvest economic activities that account for the majority of employment in the fishing industry (de Graaf & Garibaldi, 2015). In West African fisheries activities, the marine artisanal sector is the major contributor to GDP (Ayilu et al., 2016), and some jobs are created through value chain development; therefore, employment multiplier effects are impressive. However, facilities for post-harvest processing and fish preservation are frequently insufficient in rural fishing communities in Africa. Despite its importance, the fishing industry suffers from significant post-harvest losses, which are estimated to be 35–40% of the landed catch and account for approximately 25% of the annual global catch (Adeyeye & Oyewole, 2016).

1.2 Fisheries in Sierra Leone

The extent of the local currents causes a significant upwelling, which places Sierra Leone within one of the most productive marine ecosystems in the world (Heymans & Vakily, 2002; Seto et al., 2017). The economy of Sierra Leone is heavily dependent on marine fisheries which considerably support livelihoods as they are an important source of income and job security. In addition, they play an important role in the food supplements of the people, as fish make up 80% of the total animal protein consumed by Sierra Leoneans (Thorpe et al., 2009, Katikiro & Macusi, 2012). In 2018, it was stated that the fisheries sector contributes about 12% of the country's GDP, and quoting a report of the FAO, it is said that about 1.6 million tons of fish, amounting to USD 2.5 billion, are reported annually (Conteh, 2021). This sector comprises three subsectors: artisanal, industrial, and inland fisheries and aquaculture. Approximately 60% of the overall artisanal fisheries production mainly consists of small pelagic species known as clupeids (*Ethmalosa fimbriata and Sardinella maderensis*), and there are 641 locations along the coastline where fish can be landed, with Tombo being the largest (Mawundu, 2011).

1.3 Tombo community in the Artisanal sector

The Tombo fish landing site is 52 km from Freetown and is among the largest fishing communities in the Western Area (Olapade & Tarawallie, 2014) (Figure 1). It is a representative of small-scale fisheries, and the most common species caught in this area are small pelagics known as clupeids (*Herring* spp. and bonga *(Ethmalosa fimbriata)*) (Okeke-Ogbuafor et al., 2020). Fishermen in this area who specialise in catching herring spp. frequently utilise a Ghana boat equipped with a ring fishing net for this operation. There are approximately 70 Ghana boats in this community (Okeke-Ogbuafor et al., 2020), and the catch is primarily consumed by local people. The actors involved in preservation and trading are typically women, including

fish mammies, fish processors, and fish traders. In this community, smoking is the most popular method of fish preservation, using a traditional smoke oven (banda).

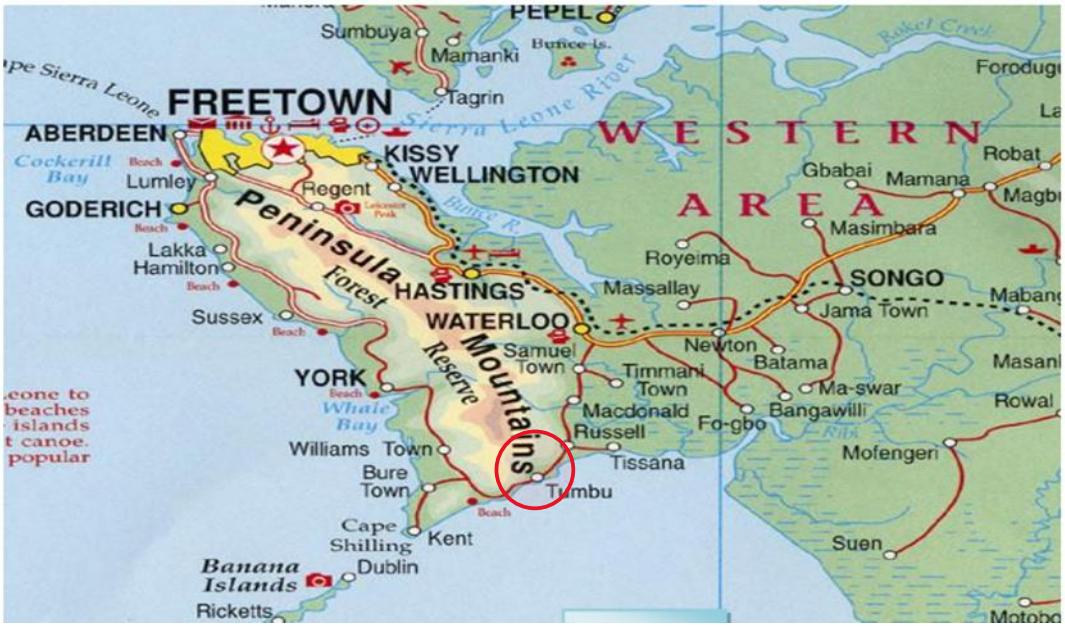

Figure 1:Map of the study area (Mawundu, 2011)

1.4 Fish Smoking

This is one of the oldest forms of preserving fish to increase its shelf life. Various methods are used to smoke fish, which vary in different parts of the world (Kitts et al., 2023). Smoking is the most widely used technique in many African nations, as facilities for post-harvest processing and fish preservation are frequently insufficient in rural fishing communities. Despite its importance, the fishing industry suffers from significant post-harvest losses, which are estimated to be 35–40% of the landed catch and account for approximately 25% of the annual global catch (Adeyeye & Oyewole, 2016). According to research, smoking fish not only imparts the necessary flavour and aroma but also increases the fish's shelf life by acting as a deterrent to spoiling agents, decreasing pH, imparting colour, and hastening the drying process (Michael et al., 2019). In most of Gambia, Senegal, Nigeria, Sierra Leone, and Cameroon, fixed-surface traditional smoke ovens (banda) are still in use. They range in size from enormous enlarged rectangular ovens to cylindrical mud ovens. Despite the increased vulnerability of women to indoor and outdoor pollution and the health problems associated with fish processors, which are mostly caused by their inability to control heat, smoke, and fuel inefficiency, these are employed to preserve and limit post-harvest deterioration. Improved fish-smoking technologies resulted from this, and they have developed over time (Feka et al., 2022, Kallon et al., 2017).

In Sierra Leone, the traditional smoke oven (Banda), which is made of concrete blocks and is often rectangular, is the most widely used smoking tool. It is a raised platform with an open-top base covered with thick wire mesh supported by a layer of iron rods, where the fish are laid out for smoking. A stokehole is cut along one of the longer sides of the oven; this serves as the furnace entrance, allowing the wood to be passed through and providing access to the fire. A few drawbacks are the loss of heat through the stokehole and around the mesh, which leads to inefficient fuel use, and the need to handle fish more than necessary while smoking because the rack where the fish are placed is open. Pieces of fish can fall into the fire, especially if the mesh is damaged, and there is difficulty in controlling the heat and smoke, which can lead to health problems for fish processors. In Tombo, a prototype of the most recent smoke oven was constructed in 2018 through a project funded by Iceland. The Matís smoke oven is made of bricks, has several removable wooden racks, has a metal frame inside that holds the racks, an enclosed furnace that controls the combustion rate, and a chimney that controls the smoke. This smoke oven minimises many health risks and, most importantly, allows the smoking of more fish at once than the traditional smoke oven (Bandas).

Figure 2: Rectangular traditional smoke oven.

Figure 3: Matís smoke oven

2 RESEARCH AIM

This study aims to evaluate the fish (Herring spp.) value chain in Tombo, Sierra Leone.

2.1 Specific objectives

- Identify key value chain actors;
- Evaluate the value of fish at each stage of the chain;
- Compare the production yield of the smoke ovens;
- Conduct sensory analysis of fresh and smoked fish.

3 MATERIALS AND METHODS

The study was conducted within the Tombo fishing community, and the activities undertaken were conducted in phases. The first phase involved administering questionnaires through interviews with key actors. The second phase comprised of experiments performed to assess the preservation of fish quality by comparing production yields and conducting sensory analysis.

3.1 Assessment of the value chain

Analysis was done utilising quality and cost data from actors at each stage of the herring value chain to reveal the quality and price moving between them as well as identify the types of relationships existing between them. Fishers and other actors who actively engage in fishing herring as their primary source of income were interviewed, and data were collected using the multistage stratified random sampling technique. The actors interviewed were herring harvesters (n=40), smoked herring fish processors (n=30), fresh and smoked herring fishmongers (n=30), consumers (n=30), net menders (n=10), fish mammies (n=20), smoked oven owners (n=20), and boat builders (n=10). Questionnaires were developed to obtain data on the price and average quality at each stage of the supply chain. Furthermore, data on the preferred smoke oven i.e the traditional smoke oven (Banda) or the improved Matís oven was collected. Inputs from the trading relationships, as well as earnings from each actor, were identified and described using the information gathered, and notes were taken during the interviews.

3.2 The surveys

The major data and information for the herring value chain were gathered through interviews with the different actors, and the questionnaires included questions on daily operations, quantitative data on their input prices, and profit estimates. Each actor provided information on the price of the herring sold and purchased, as well as the average quality and amount of fish sold during both the high and lean seasons. Furthermore, questions related to the smoke ovens and the acceptance of the products by end users were asked. A few personal questions were asked, challenges they faced during their activities, and what value they added to the product before selling. The questionnaires were prepared and sent to the research assistants working with the Iceland Support to Sierra Leone Fisheries Management (ISSLFM) project in Sierra Leone for administration.

The data gathered were used to create a detailed flowchart showing the relationships between actors, price, and quality flow. Another aspect is the profit earned by most actors, which was calculated as the difference between the total input cost and sales price. A simple sensory graded scale, shown in Tables 1 and 2, was also developed to grade both fresh and smoked herring, and it served as a guide for the interviewee, as some of the questions required grading of the product.

Table 1: Physical sensory chart for fresh fish

GRADE	STATE	SCORE	EYES COLOR	BODY/SCALE	GILLS	SMELL
A+	Excellent	10	Bright/shiny	Firm, scales intact	Bright red	Like sea
A-	Very good	9	Bright	Firm, scales intact	Red	Like sea
B+	Good	8	Slightly grey	Firm, scales intact	Dark red	Like sea
B-	More than average	7	Slightly grey	Firm, scales intact	Slightly slimy	Like sea
C+	Average	6	Grey	Loose, scales not too intact	Slimy, dark red	Fishy
C-	Fairly good/ below average	5	Slightly dull	Loose, scales not too intact	Whitish slimy, dark red	Fishy
D	Damage	4	Dull	Skin damage, scales not intact	Slimy and greyish	Fishy

Table 2: Physical sensory chart for smoked fish

GRADE	SCORE	COLOR	SMELL	TOUCH
A	5	Golden brown	Freshly smoked	Slightly soft
B	4	Light brown	Smoky	Compact
C	3	Brown	Less smoky	Dry
D	2	Dark brown	Fishy	Hard

3.3 The experiments

Three experiments were conducted to compare the effects of ovens on the quality and yield of fish, evaluate the profitability of fish processors within the value chain, and assess the judgement of end purchasers through sensory analysis.

3.3.1 Experiment 1: Preservation of quality

The goal of the first experiment was to compare the ability of the two smoke ovens to preserve quality. Twenty-four whole ungutted herring fish were purchased from the landings in the Tombo community and transported to the processing facility. The physical sensory chart above was used to direct fish purchases to achieve desirable results. After landing, six fish with grade "A" qualities were purchased, followed by six pieces of fish with grade "B" characteristics and six pieces of fish each with grade "C" and grade "D" characteristics. They were then weighed, washed, and labelled, and there were two sets of each graded category of fish (A-D), one set for the Matís smoke oven and the other for the traditional smoke oven. Each set of 12 herrings was divided into four portions, then graded and labelled according to quality (A-D) before being smoked together in the traditional smoke oven and another set of 12 in the Matís smoke oven. The labelled fish were laid on the racks of the smoke ovens and placed into the two ovens to be smoked until it was deemed to be hot smoked. The fish were similarly smoked in both ovens as

fish processors usually do, and once it was done, it was taken out and put on a tray to cool. Each set of graded smoked fish had its weight recorded (to calculate the yield), and their labels were kept confidential. Subsequently, consumer perceptions of smoked fish were assessed through sensory analysis. Ten experienced fish traders evaluated the products of the two ovens, and the smoked herring from the two smoke ovens were graded by ordering the graded smoked herring without being aware of the actual quality grade of the displayed herring. The results of these evaluations were recorded.

3.3.2 Experiment 2: Production yield comparison of the smoke ovens

The second experiment compared the two smoke ovens (traditional and Matís smoke ovens) to determine which produced a higher yield. This brought attention to the advantages of the smoked herring fish processors, who are important players in the value chain. The yield was evaluated by calculating the input cost of smoking herring and the output obtained. The fresh herring bought from landings in the Tombo fish landing site for this experiment was washed, weighed, and placed on the racks of the smoke ovens. The amount of fish needed to fill the ovens and all costs for fish, wood, labour, and transportation associated with the smoking process were documented. The fish were then placed in smoke ovens and allowed to smoke on the racks within the smoke ovens before being removed and allowed to cool. To determine the approximate pricing, each batch of smoked herring from the two ovens was sold separately. The difference between the total income and the entire cost is known as the net benefit. The product price of the fish sold represents the processor's total revenue, and the total cost is the sum of all incurred expenses. The processor's regular costs include the purchase of fresh fish, wood, labour, and transportation (Jueseah et al., 2020). After the processed fish were sold, the profit from each smoked oven was determined.

3.3.3 Experiment 3: Sensory analysis of the fresh herring

Consumer awareness and purchasing intentions regarding the various quality categories of herring were evaluated through a sensory analysis experiment that was carried out during the administration of questionnaires through interviews with customers. Using the quality sensory chart as a guide, four pieces of whole, ungutted herring were purchased from the landings in the Tombo community. The raw fish were rated in terms of quality from "A" (excellent quality), "B", "C", and "D", with "A" herrings being rated as the highest quality, "B" herrings being rated as good, "C", "average", and "D" herring being rated as damaged. Customers who were uninformed of the quality grading label were asked to evaluate and provide their thoughts on the intention to purchase each piece of herring shown. These four pieces of herring were labelled according to the four quality categories and displayed on trays. Customers who were uninformed of the quality grading label were asked to evaluate and provide their thoughts on the intention to purchase each piece of herring shown. These four pieces of herring were labelled according to the four quality categories and displayed on trays. Their opinions were recorded and analysed.

4 RESULTS AND DISCUSSION

Here, the major findings from the experiments and questionnaires are discussed, along with a thorough explanatory analysis of the research that is displayed in tables, graphs, and flowcharts.

The herring supply chain in Figure 4 allows us to identify all the key actors and displays the average quality and value cost of herring per kilogram at each stage. The key value chain actors in the herring fish (fresh and smoked) value chain were harvesters, fish mammies, fish processors, fish traders, and consumers. It also shows the passage of herring from the harvester at the wharf to the final consumer in the market. During this flow, the study shows that the presence of the labourers and the people that help during the processing of the herring are very important, but they are not recognised in the value chain. The change in price as it moves away from harvesting to the consumer is one of the essential factors noticed at every stage of the value chain. This could be due to the effects of distance, availability, and preservation methods used. The quality of the fish decreases as it travels further from the source because the fresh fish is not stored adequately, whereas the quality of the herring can be preserved if it goes straight through the smoking process. Although the value chain is structured, it is not formal, as it is not supported by formal policies, procedures, and systems designed to optimise the performance of each activity and the overall value chain. The average fish net cost was converted to USD using the exchange rate for 2023 the year the research was conducted.

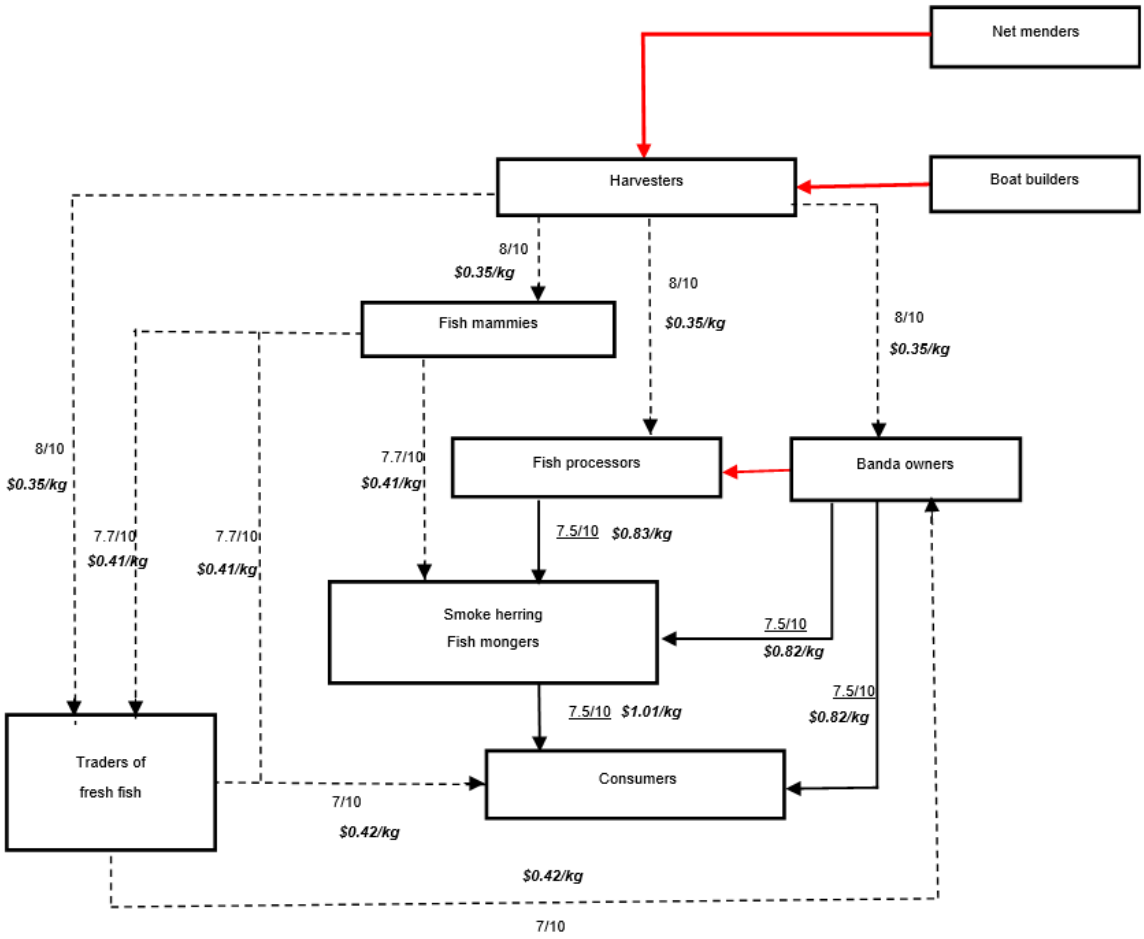

Figure 4: Flow chart of herring supply chain

4.1 Descriptive statistics

Table 3 shows that activities such as fishing, boat building, and net mending which are labour-intensive, are 100% dominated by males, whereas women dominate fish processing and trading activities. It was also discovered that 5% of men own traditional smoke ovens that are available for fish processors to rent and smoke fish.

Table 3: General profile of all the actors

%	Net menders	Boat builders	Harvesters	Fish mammies	Fish processors	Smoke oven owners	Traders of fresh or smoked fish / Fish mongers	Consumers
GENDER								
Female	0	0	8	100	100	95	100	100
Male	100	100	92	0	0	5	0	0
EDUCATION LEVEL								
None	50	50	42	95	83	80	73	50
Primary	30	10	48	5	10	15	13	30
Secondary	20	40	10	0	7	5	13	20
Tertiary	0	0	0	0	0	0	0	0
AGE								
Below 30 years	0	20	10	0	17	0	37	47
Between 30-40	60	30	45	10	30	20	60	30
Above 40	40	50	45	90	53	80	3	23
ADDRESS								
Tombo	100	90	98	85	83	90	20	100
Close to Tombo	0	10	2	15	7	10	30	0
Far from Tombo	0	0	0	0	10	0	50	0
MARITAL STATUS								
Single	10	10	5	10	0	5	7	20
Married	70	80	92	85	97	95	93	80
Divorced	20	10	3	5	3	0	0	0
YEARS IN JOB	21	20	17	21	18	23	12	0

The results indicate that 90% of fish mammies were older than 40 years during the survey, and 80% of those who had smoke ovens were also older than 40, which may suggest that the longer you engage in fishing activities, the better your chance and ability to save, which will allow you to make investments. In addition, 45% of harvesters are middle-aged, followed by 60% of those engaged in activities like fish trade and net menders, who are also fishermen; this demonstrates that these activities demand energy to be effective.

The study demonstrates that the illiteracy rate is relatively high among these actors and is significantly greater among women than among men. Only 15% of females completed the formal primary level of schooling, compared to an average of 29% of males. The secondary level, which 40% of boat builders earned, was the highest level of schooling found in this study. None of them had completed tertiary education.

Although 50% of the fish sellers are located outside of Tombo, it was discovered throughout the study that 80% of the actors resided in the Tombo community, suggesting that fishing-related businesses and fishing provide employment opportunities for residents in this coastal region. In addition, the average years of experience of the interviewees are ten years, and 80% of them are married, as shown in Table 3**.**

The information provided by the actors interviewed for this study indicates that they started fishing activities at a young age; hence, the average years of experience in the artisanal fishing sector is 19. This might be one of the reasons why their level of education is quite low, because

they pay more attention to finding ways to earn money than to education. As shown in Table 3, 90% of them are married, and this may be because their wives and children help in these activities, as the wives will help in the fish processing to preserve the fish, whilst older children can help in transporting their fish and in the laying of fish during the smoking process.

4.1.1 Harvesters

These individuals harvest fish for their livelihood, using traditional fishing techniques. They comprise fishermen, fishermen who own a boat, and boat owners who do not fish. The research revealed that 78% of fishermen above the age of 40 owned a boat (Figure 5A). This activity is mostly labour intensive; therefore, it is dominated by men. Despite fishing being their main occupation, more than 50% of fishermen do not own a boat (Figure 5A); they depend on others that are boat owners, and they are paid according to the amount of fish caught daily (Figure 5F); therefore, earnings from this activity are not stable.

The boats used by the herring fishers are motorised Ghana boats, with 92% of the boats using forty horsepower (40Hp) engines (Figure 5B and C). All interviewees reported that their main fishing gear is a ring net (Figure 5I), but there are no suitable storage facilities on these boats (Figure 5E). Therefore, the fish caught are not properly preserved; they are simply placed into the open space of the boat with no ice during the fishing trip (Figure 5K).

Boat owners always decide the price of fish, supply fish to the other actors in the value chain, and the price of fish is based on the relationship between the buyer and the harvesters (Figure 5R). Additionally, they frequently take informal credit for the maintenance of the boat and for the everyday operations of fishing and purchasing fishing gear from other actors (Figure 5D).

According to the fishermen who participated in the study, the best fishing season lasts from October to January (Figure 5L), but fishermen over 40 years of age can catch a significant amount of fish throughout the year, which may be due to their many years of fishing experience. It was also confirmed that all catches were transferred from the boat to the landing site by labourers who were paid with fish after completing the task (Figure 5N). The fundamental reason why the value of fish is currently low compared to the profits made by other key herring value chain actors is that these communities lack adequate refrigeration facilities, leaving them with no option but to frequently loan the fish they have not sold (Figure 5H) to their customers.

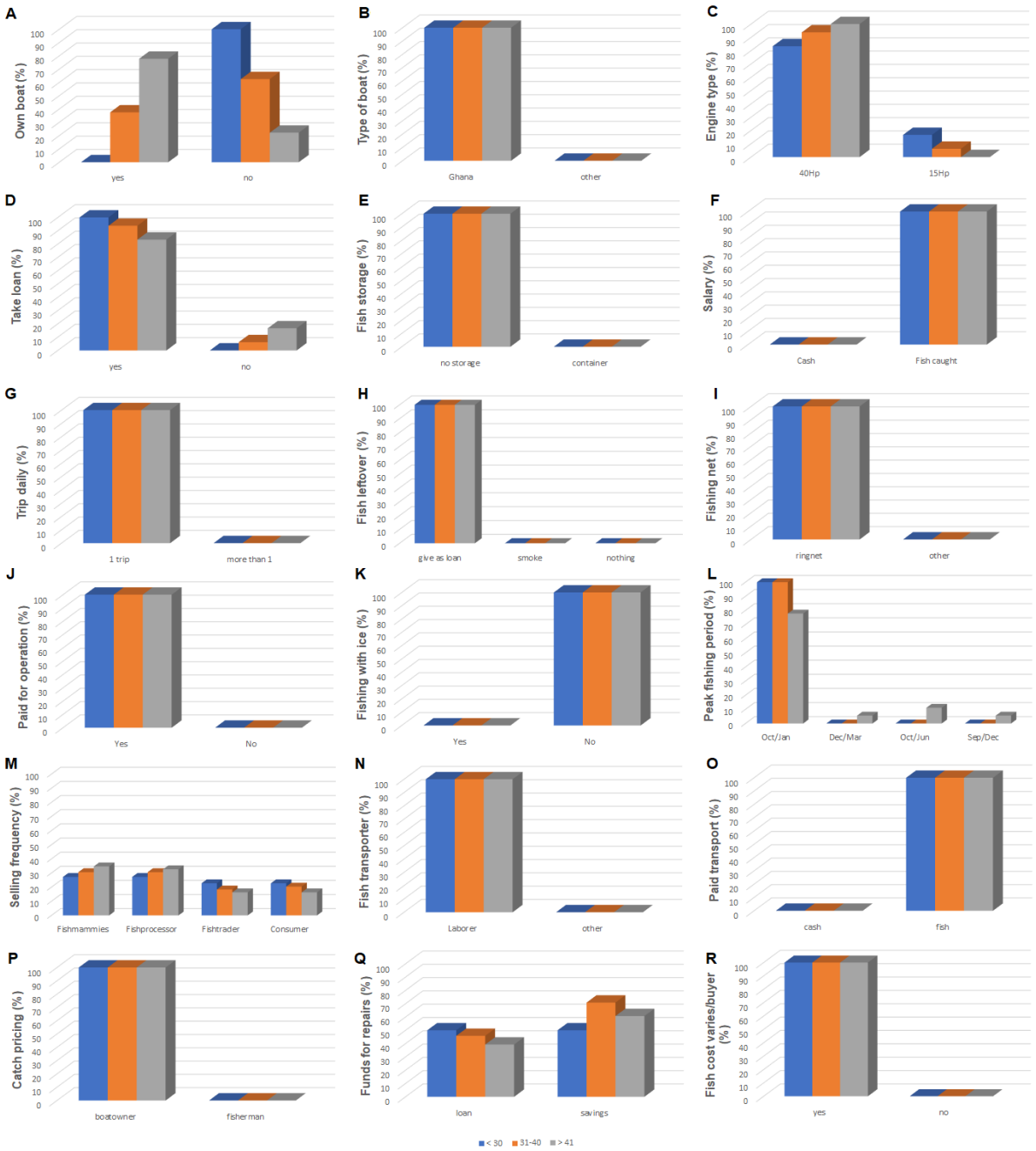

Figure 5: Bar graphs showing an overview of harvesters in the herring value chain in Tombo

4.1.2 Fish mammies

Mammies are referred to as elderly women in Sierra Leone, and fish mammies are women with a high financial status in the artisanal sector. They finance fishing activities and market fish products; hence, they typically invest directly in fish capture (Sandi, 2010).

They are also known as agents, and they provide money as informal credit to boat owners and fishermen (Figure 6F) in exchange for being paid with fish instead of money. This group, which is predominantly female, is a pillar of the artisanal fishing sector, as they buy fish in large quantities (Figure 6K) and mostly pay for their fish in cash to fishers (Figure 6D). Lending money

to fishermen elevates them to a position of importance; hence, they receive discounts and are classified as first-class purchasers of fish harvested (Figure 6G).

According to the study, the interviewees from this category sell either fresh or smoked fish; however, it was observed that women between the age of 31 and 40 sell fish to consumers only which might indicate that they buy a lesser amount of fish compared to women above 41 who sell their fish to fish traders, fish processors, and consumers (Figure 6C). The means of preserving fish are either by adding ice to the fresh fish or smoking the fish before selling (Figure 6E), 64% of them smoke their fish, and their place of business is in the interior inland communities where the value of fish is high due to insufficient flow of fish (Figure 6A&B). Fish that were not sold that day were either loaned to customers, smoked, or taken home to be sold the next day (J).

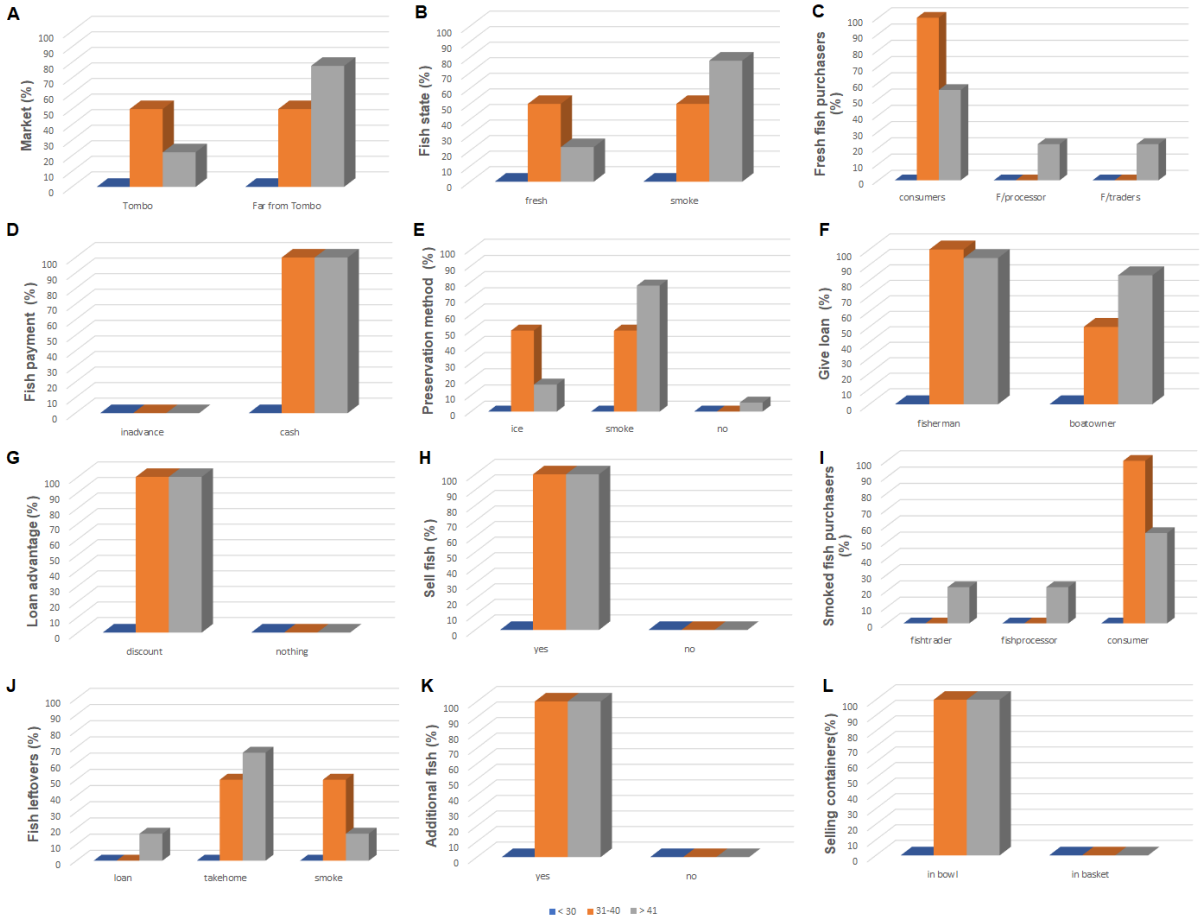

Figure 6: Bar graphs showing an overview of fish mammies in the herring value chain in Tombo

4.1.3 Fish processors

This group processes and sells only smoked fish, either wholesale or retail, to fish traders and consumers (Figure 7D). The study reveals that more than 50% of respondents process fish every day (Figure 7A), and over 50% of them have a contract with either boat owners or fishermen for fish supply; however, only 20% of them pay for their fish supply in advance (Figure 7C). The fish are purchased in big bowls which serve as standard measurements, and with the help of labourers, the fish are taken to the processor's desired destination (Figure 7F&I).

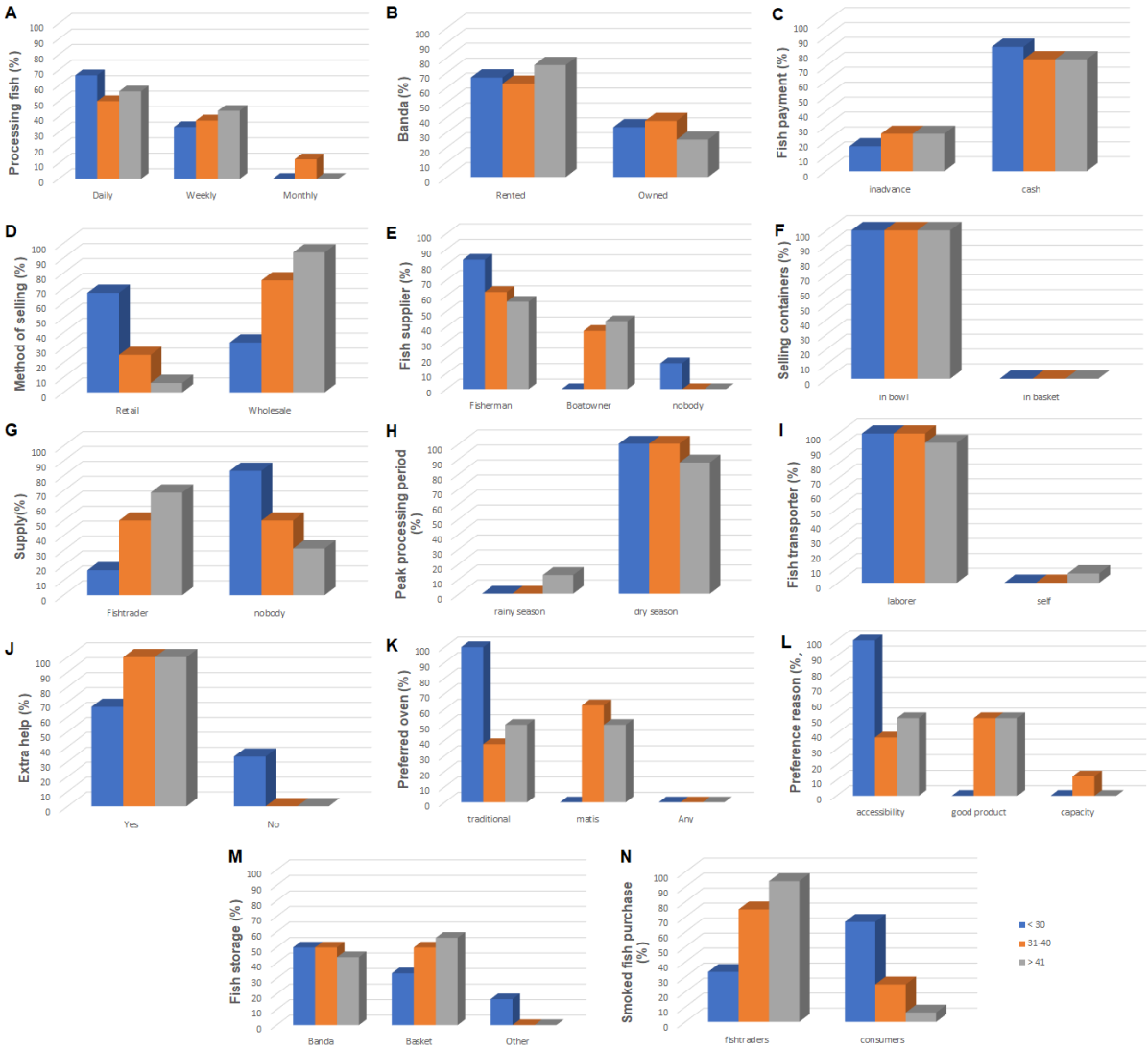

Figure 7: Bar graphs showing an overview of fish processors in the herring value chain in Tombo

Their peak processing period is during the dry season (Figure 7H), although over 60% of fish processors do not own smoke ovens (Figure 7B), and the traditional smoke oven is primarily utilised. More than 80% of the fish processors interviewed said that they selected the traditional smoke oven for their fish processing because it was the only smoke oven they had access to, while the ones that had the opportunity to use the Matís smoke oven said that they preferred it as it produced good products and its smoking capacity was huge compared to that of the traditional smoke oven (Figure 7K and L). It was also confirmed that during fish processing, 90% of processors above 30 years of age employed extra help which might be due to the energy needed for the laying of the fish and more hands needed to hasten the process to maintain the quality of the fish (Figure 7J). Meanwhile, 50% of fish processors below the age of 30 do not employ extra help, which may be because they might not buy a large amount of fish compared to the older fish processors. Almost 40% of them said that they usually use the smoke oven as storage, while others use baskets to store their smoked fish (Figure 7M) which implies that they lack proper storage facilities for their smoked fish.

According to the study, 67% of younger processors prefer to sell their products in retail, while 94% of processors who are 40 years of age and over prefer to sell their products wholesale (Figure 7D), and most of them have contracts to supply fish traders with smoked fish (Figure 7G).

4.1.4 Fish traders

These are people who buy fish in bulk from wholesalers (either fresh or smoked) (Figure 8A) and sell it to consumers at retail prices; they rely on this business for their livelihood. This activity of selling fish is a daily routine for more than 90% of them (Figure 8C), and they employ labourers to transport their fish to their desired destination. Approximately 40% of them take about a week to sell their products (Figure 8B). According to the survey, over 80% of fish traders above the age of 40 sell only fresh herring (Figure 8A), which is a daily activity for them, and they do not have leftovers (Figure 8B); hence, it might be because they preserve the quality of their fish, as it was observed that they always preserve their fish with ice (Figure 8E). However, they only had peak sales during the rainy season, whereas 30% of those below the age of 40 had average peak sales throughout the year (Figure 8I). Of these fish traders, 59% purchased their products already processed (smoked) by fish processors (Figure 8F), but very few had knowledge about the Matís smoke oven (Figure 8G).

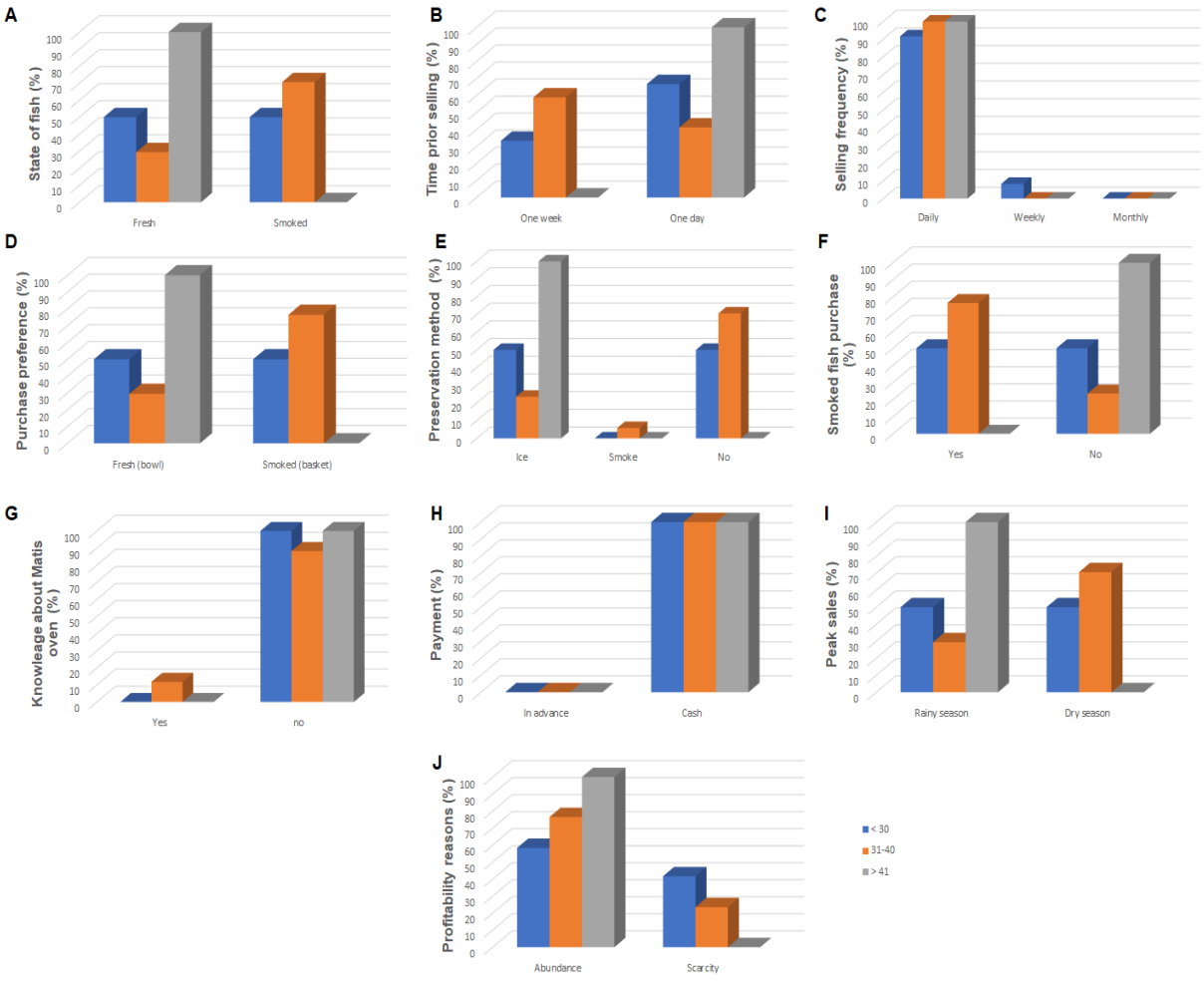

Figure 8: Bar graphs showing an overview of fish traders in the herring value chain in Tombo

4.1.5 Consumers

These are the end users of herring (fresh and smoked). The interviewees confirmed that they eat fish every day (Figure 9D), approximately 60% of them who were above 30 years of age bought fish in Tombo two to four times a week (Figure 9E), and above 75% of them bought both fresh and smoked herring (G&F). According to the information gathered, approximately 50% of the respondents did not notice a difference between smoked herring from the traditional smoke oven and smoked herring from the Matís smoke oven (Figure 9A). More than 80% of the few who could recognise the difference said that they preferred the product from the Matís smoke oven (Figure 9B) because it tasted better and looked more attractive (Figure 9C).

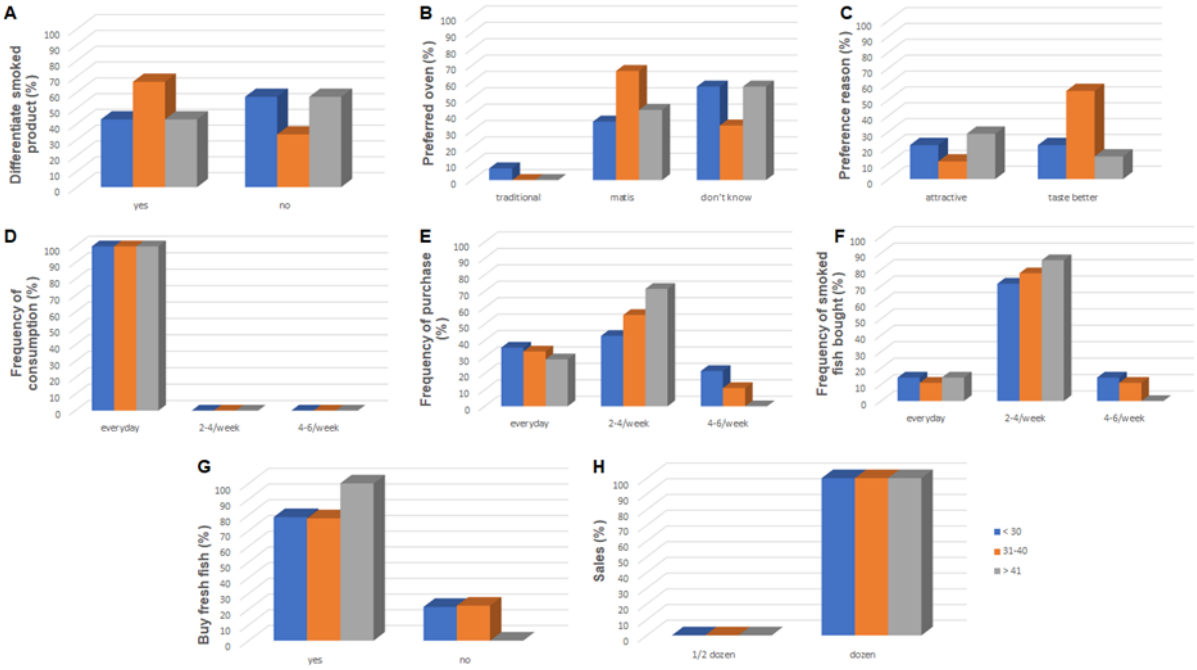

Figure 9: Bar graphs showing an overview of herring fish consumers in the herring value chain in Tombo

4.1.6 Traditional smoke oven owners

These individuals own smoke ovens (Banda) and rent them out to other fish processors who cannot afford them. According to the present study, more than 80% of the smoke oven owners reside in the Tombo community (Table 3), and more than 60% of them are fish processors (Figure 10A); hence, over 60% of the smoke oven owners also process herring fish. Throughout the study, it was found that other actors, such as fishermen and fish traders, also owned smoke ovens that could be rented, with 20% of these people owning smoke ovens for rental and not engaging in any other fish-related activities (Figure 10A).

With an average of 20 years of experience in artisanal operations, it was noted that during the dry seasons, rentals were at their highest levels, and during the wet seasons, rentals declined (Figure 10D). The majority of them hire additional labour for cleaning, fish laying, and smoke oven upkeep (Figure 10E). Smoke oven owners who process herring have a contract with either fishermen or boat owners to supply them with fresh fish. It was observed that there are no smoke oven owners below the age of 30, and 80% of them are above 40 years (Table 3) which might

indicate that in the process of owning a smoke oven, they need to have saved some capital for the construction of the oven.

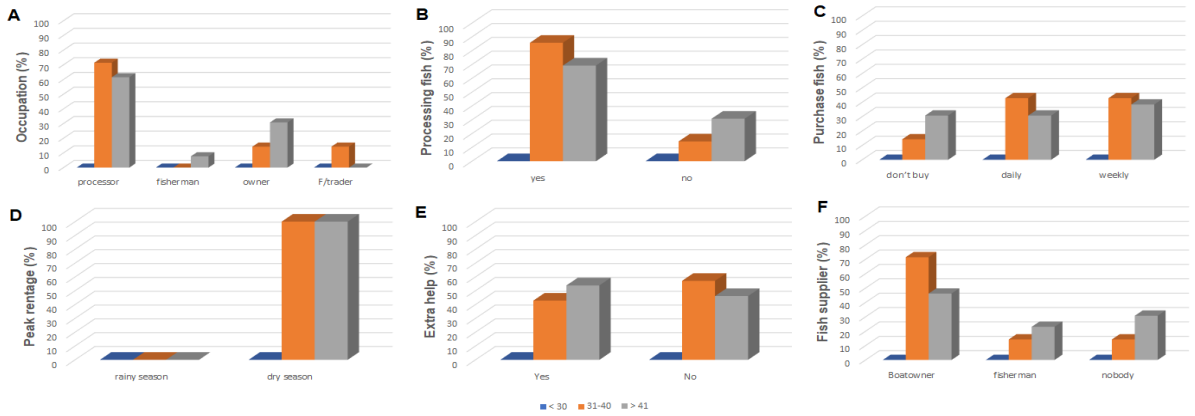

Figure 10: Bar graphs showing an overview of traditional smoke oven owners in the herring value chain in Tombo

4.1.7 Net menders

To ensure that a net remains effective, it is repaired, and timely repairs extend the useful life of the net. Net menders can be found in every fishing community, and they are typical fishermen who fix damaged nets. Fifty% of net menders were between 30 and 40 years of age, and over 60% of them mended their fishing nets weekly (Figure 11A). They usually have their peak mending period during the dry seasons (Figure 11C) because this activity is done outdoors, and there is mostly no shed found in the study area for this activity; therefore, it will not be comfortable to mend these nets during the rainy season compared to the dry season, and it is always done in a group (Figure 11B).

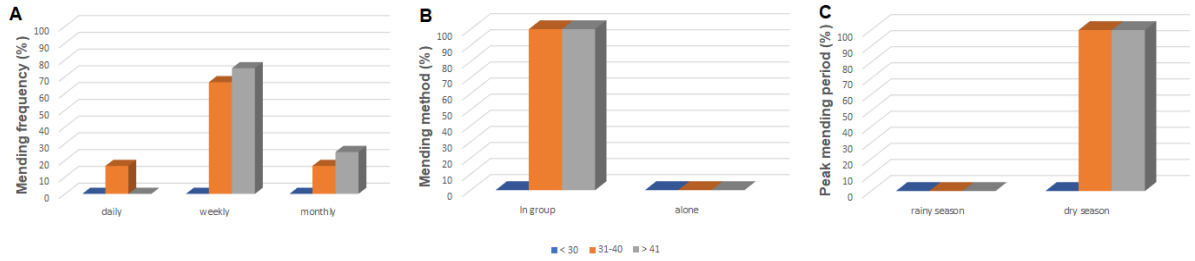

Figure 11: Bar graphs showing an overview of net menders in the herring value chain in Tombo

4.1.8 Boat builders

They are also known as small craft artisanal boat builders, as they do boat construction and maintenance upon the fishermen's request, either on a regular basis or whenever boats have issues. According to the information provided, boat building is a seasonal activity in the study area, and boats are built mostly during the dry season (Figure 12B). More than 70% of the interviewees said that a boat can be built within one to two months if the building accessories are readily available, and a boat builder can build a boat in a year. Due to the seasonal nature of the job, all of the interviewees had a second source of funds which was fishing, and it was also noticed that more than 80% of them lived within the Tombo community (Table 3).

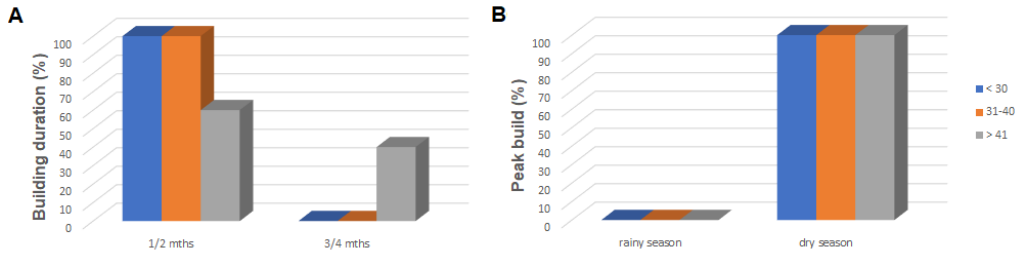

Figure 12: Bar graphs showing an overview of boat builders in the herring value chain in Tombo

4.2 Production yield comparison of the smoke ovens

According to Experiment 2, the results comparing the traditional smoke oven inputs to those of the Matís smoke oven showed that the Matís smoke oven can smoke 68% more fish per batch despite using 33% more wood (**Error! Reference source not found.**). After the fish were sold, using the profit formula by Jueseah et al. (2020), it was clear from the sales figures that the Matís smoke oven generated 86% more earnings than the traditional oven (**Error! Reference source not found.**), proving that it was more profitable. During the smoking process, it was also observed that the Matís oven produced less smoke in the environment than the traditional oven, indicating less environmental air pollution. **Error! Reference source not found.** shows the products from both the traditional smoke oven and Matís smoke oven.

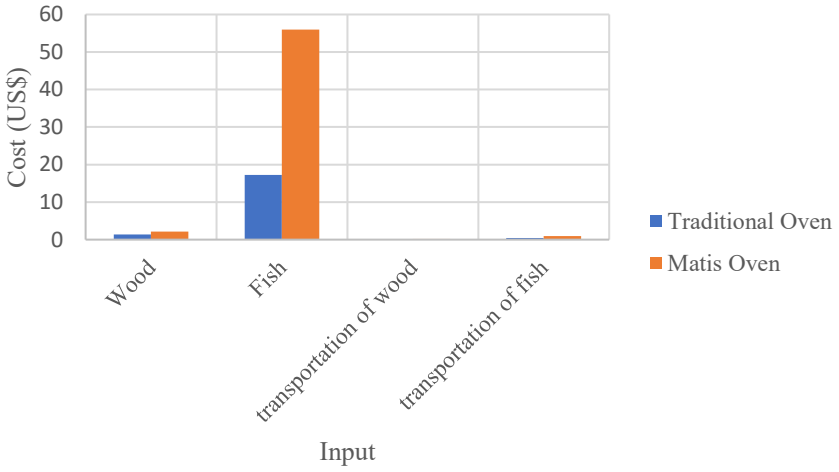

Figure 13: Bar graphs showing different interactions that boat builders have with the herring value chain of Tombo

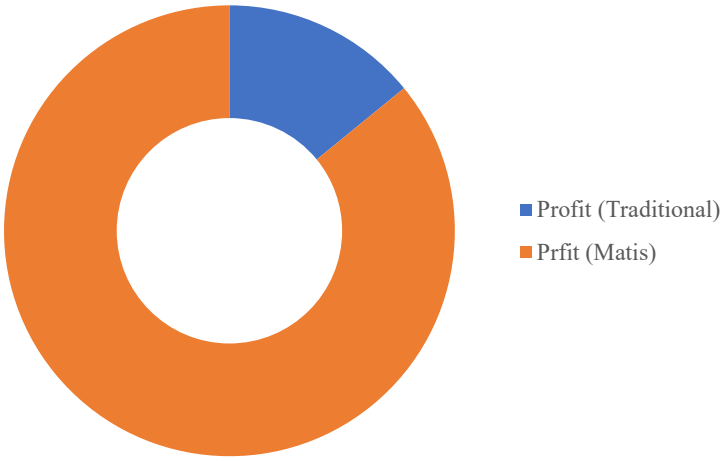

Figure 14: Inputs cost comparison of Matis and Traditional smoke oven

Figure 15: Sales and profits comparison of Matis and Traditional smoke oven

4.3 Preservation of quality

According to the table below, '3' represents the amount of fish for each portion, 'M' represents the Matis smoke oven, 'T' represents the traditional smoke oven, 'A, B, C, and D' represent the quality grading of the herring fish, and the yield is the weight loss of the herring after smoking (Table 4).

In deriving the average yield (water content loss from the fish) from Experiment 1, the product in the Matís oven was found to have lost more water content than that in the traditional oven, although the difference was not significant. This indicates that reduced water content in fish minimises spoilage as it decreases the opportunity for bacterial development (Ezembu & Onwuka, 2015; Iheanacho, 2017). Hence, more water loss from the products in the Matís oven indicates better production.

Table 4: Water content loss of the smoked graded fish from both smoke ovens

Grade of fish	Quantity in the Matis smoke oven	Yield (%)	Quantity in the traditional smoke oven	Yield (%)
A	3 (MA)	0.055	3 (TA)	0.065
B	3 (MB)	0.055	3 (TB)	0.063
C	3 (MC)	0.050	3 (TC)	0.063
D	3 (MD)	0.050	3 (TD)	0.060

4.3.1 The ordering quality of smoked fish

After the smoking process from Experiment 1, the herring were placed in a mixed order on a tray with their quality grading label hidden (Figure 13) and were evaluated by 10 fish traders. The fish traders performed a simple physical sensory assessment and provided their ordering quality opinion from the first-grade to the eighth-grade option of the smoked herring from both smoke ovens (Figure 14).

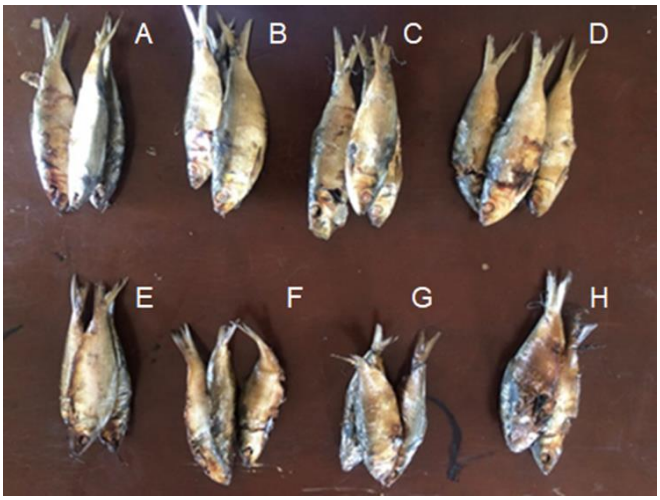

Figure 13: Smoked fish samples from both smoke ovens (A to H).

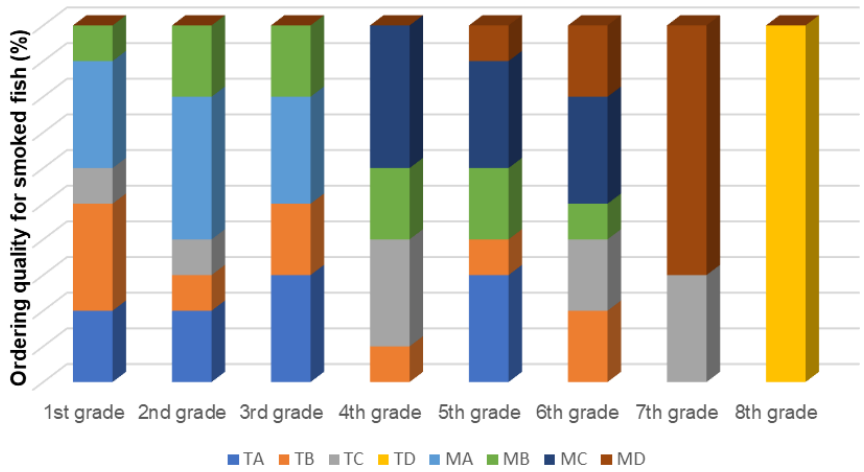

Figure 14: Results shown after labelled herrings from experiment 1 are evaluated (T represents traditional smoke oven, M represents matis smoke oven, A to D represents quality grading of the smoked herring fish)

The general overview of Figure 14 indicates that the categories A and B graded fish from both ovens have similar behaviour. In comparing the two ovens, the Matis smoke oven had a greater percentage of the first, second, and third grades, and the grade 'A' fish from Matis was rated in the first three ranks, whereas the grade 'A' fish from the traditional smoke oven was rated up to the fifth rank. Hence, the product from the Matis smoke oven was rated as the best by most of the evaluators. This indicates that when a quality 'A' fish is used, the matis smoke oven can preserve its quality better than the traditional smoke oven. For the low-quality grade 'D' fish, all the evaluators said that the product from the traditional smoke oven was worse than that from the Matis smoke oven. There was a significant difference between the products from both ovens, indicating that for low-quality fish, it is better to use the Matis smoke oven, as it can maintain quality better than the traditional smoke oven.

4.3.2 Consumers' purchase intentions on graded fresh herring

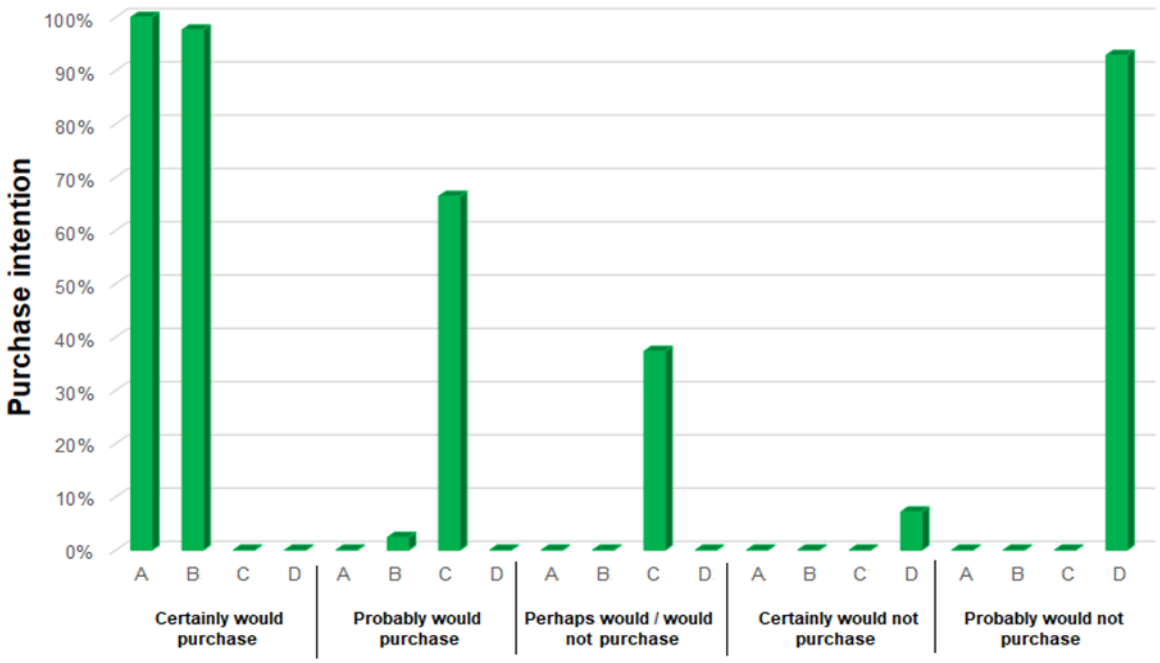

Figure 15: Purchase intention of consumers on graded fresh fish

During the personal interviews with consumers, they were asked to assess a set of herrings which were categorised by quality graded A to D (Table 1) as a guide and gave their purchase intention on each graded fish (A-D). The optional answers were certainly would purchase, probably would purchase, perhaps would or would not purchase, certainly would not purchase, and probably would not purchase.

The results obtained from the physical sensory analysis showed that consumers could determine the quality of the fish through simple physical sensory analysis. More than 90% of the respondents said they would certainly purchase grade 'A' and grade B 'herring. For grade 'C'

herring, 35% of the respondents said they may or may not purchase, while more than 90% said they would certainly not purchase grade 'D' herring.

The value chain in this survey shows that the key actors sell fish in different states, and the predominant method of preservation is the smoking of fish, also the catch can either be sold wholesale or retail as this was confirmed by the findings of another author Upadhyay et al (2020). A study from Northern Nigeria (Segun et al., 2022) revealed that the fishers from that landing site took an average of 12 hours per fishing trip, did not fish with ice, and their catch was exposed to direct sunlight, thus increasing the spoilage rate. It was reported that 67% of the fishers experience losses, their catch prices are reduced, and 23% of their fish caught are lost daily post-harvest. In Sierra Leone, fishers in the study area expose their catch to the same conditions but with an average fishing trip time of 8 hours per day; therefore, the rate of spoilage is reduced. However, if they increase the duration of their fishing trips, they are likely to have the same quality issues. Furthermore, apart from the fish mammies in the value chain, Omogbemi and Ogunjobi (2018) confirm the other key actors in a similar value chain of fish. However, a study by Breckwoldt et al. (2020) on the fish value chain in Ghana confirms similar key actors in the herring value chain.

Women in the artisanal sector are the ones who bring money home (Aswathy & Kalpana, 2019). Apart from fishing, net mending, and boat building, all other fishing activities are performed by women (Torell et al., 2019; Upadhyay et al., 2020). As in other countries, women are dominant and actively involved in most aspects of the artisanal fishing industry in Sierra Leone, including processing, trading, and boat ownership, as confirmed by Zhao et al. (2013). Above 80% of the women in this sector are married; however, stakeholders have an average of ten years of experience in these activities, with a very low level of formal education. This shows that fishing, fish processing, and other related jobs are traditional practices, and most actors get involved in early life to earn a living. This confirms the findings of other authors (Abolagba and Nuntah, 2011). In line with other authors Seto et al. (2017), 80% of the interviewees confirmed that they reside in Tombo; therefore, it can be inferred that fishing activities employ individuals in the coastal communities.

Fishermen and boat owners often receive informal financing from fish mammies and other sources. These unofficial loans can be used to pay for fishing gear and fund fishing expeditions (Breckwoldt et al., 2020). Fish mammies receive a discount and bargain prices in exchange for informal credits, which are mostly interest-free, from the fishermen in return for repayment in the form of fish at a cheaper price, and they operate at a larger scale of fish sales compared to other key actors. Comparable financial and refundable benefits have been reported for comparable fisheries in other parts of the world (Jueseah et al., 2020).

According to the study, harvesters have very little formal education; similar reports have been made in the artisanal sector in other nations (Alhabsi, 2012; Omogbemi & Ogunjobi, 2018). However, harvesters have a wealth of fishing experience, spending an average of 17 years engaging in fishing activities. As observed, herring boats do not have a special container to store their catch (Segun et al., 2022), and the ring fishing net is mostly used (Mawundu, 2011). They do ask for informal credits from other actors in the value chain, especially from fish mammies (Jueseah et al., 2020). Their salary is paid daily according to the fish caught, and more than 70% are married.

In a survey to document the fishing, fisheries management, and fish processing practices of the people in Ghana, it was found that purse seine and drift nets were the most commonly used gears, as opposed to the ring net used by the fishers in Tombo (Pardie & Campion, 2022). Their distribution system for the catch is similar in that it is divided into various portions, with one portion covering all costs associated with the fishing operation and the other portions going to the boat owner, crew members' salaries, and so forth as needed. Furthermore, it was established that fish smoking is a common fish preservation technique.

It was noticed that smoking is the most practiced preservative method in the study area, which is also in line with the findings of Kassam et al. (2017). During the survey, it was revealed that during the peak fishing period, catches are abundant, and a greater quantity of fish is smoked compared to the lean period (Alhaji et al., 2015).

Fish traders are present in all fishing communities. They are women who tend to focus more on the local market (Fröcklin et al., 2013) and are largely responsible for marketing fish as they deal with smaller-scale fish sales compared to fish mammies. This was also confirmed by Breckwoldt et al. (2020) in a report from Ghana. Their educational level is generally low as was also reported by Fröcklin et al. (2013)

According to the survey, net menders, boat builders, and smoke oven owners are indirectly connected to the herring value chain; therefore, they are not key actors. However, contrary to the artisanal system in Sierra Leone, where men predominate in net mending, women in other countries mend fishing nets (Fröcklin et al., 2013).

5 CONCLUSION

The most important actors in the herring value chain are harvesters, fish mammies, fish processors, fish traders, and consumers. An organised structure of the herring value chain helps to maintain quality, as there is a fast movement of herring from one actor to another, even if not formally. However, problems such as insufficient storage and preservation facilities have affected all actors due to the loss of fish quality, influencing prices.

The results from the simple physical sensory analysis test for both smoked and fresh fish revealed that end consumers could identify the quality of fish and confirmed that if the product was below average quality, they would not purchase it. Therefore, since one of the oldest and most common methods used for the preservation of fish is smoking, all actors that are directly dealing with fish tend to either directly or indirectly depend on smoke ovens. It was confirmed during the survey that the traditional smoke oven (Banda) is the most commonly used in this study area; however, there are some drawbacks regarding the efficiency, profitability, and health issues of this smoke oven for the fish processors. In this light, improved smoke ovens have emerged, and a prototype of the most recent improved smoke oven is at the fish landing site in Tombo, the Matrís oven. The results revealed that the Matís smoke oven can maintain fish quality compared to the traditional smoke oven (Banda), and it can increase profitability as it smokes more fish per batch and uses less wood than the traditional smoke oven.

6 RECOMMENDATIONS

- Develop a Fishery Management Plan for the Artisanal Sector with emphasis on the targeted small pelagic.
- Develop a proper management structure for all actors in the value chain, including labourers and fish layers.
- Make preservation facilities available to harvesters to maintain fish quality, thereby harnessing the full economic value of the fish.
- Popularise the Matis oven and replication of the technology in other coastal communities.
- Proper storage facilities for smoked fish products should be established.

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