STANDARDIZATION OF THE KILN SMOKE OVEN IN SIERRA LEONE

Josephine May Kabba
Ministry of Fisheries and Marine Resources, Sierra Leone
mayruth88@gmail.com

Supervisor:
Jónas Baldursson: jonasb@matis.is

ABSTRACT

Post-harvest loss remains a challenge in Sierra Leone´s artisanal fisheries sector due to inadequate fish handling, processing, and storage capacity. Smoking is the primary processing method used by the fish processors. This study aimed to standardise the method of smoking fish using the improved smoking kilns introduced by Matis and the Icelandic government. A comparative analysis was conducted between the traditional Chorkor oven and the new and improved Matis oven, optimising the latter. Two experiments were conducted using both the traditional oven (chorkor) and the Matis oven with fresh herring. In Experiment A, gutted and ungutted fish were smoked, determining the time and quantity of wood required for the fish to reach optimal temperature in each oven. Smoked products were graded using sensory evaluation and compared. In Experiment B, two Matis ovens - one modified by extending the length of the steel plate covering the fire chamber and the other unmodified – were used to smoke 87.1 kg of different groups of fish. The time and wood used to smoke the fish, and the quality of the smoked fish products were compared. The average volume of fish smoked, and the average fuel (wood) used per hour for both ovens showed that the Matis oven was more efficient. Less wood was required to smoke the same weight of fish, which resulted in a higher loss of water content after smoking compared to the traditional oven. The results from Experiment B suggest that the Matis oven can be optimised and made more efficient by extending the steel plate length to the back of the oven to retain heat and prevent it from escaping. However, it is recommended to perform further experiments on heat distribution.

Keywords: Matís oven, kiln smoke oven, post-harvest loss, artisanal fisheries, fish smoking, Sierra Leone.

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1 INTRODUCTION

The global demand for protein is increasing due to population growth, with projections indicating that the global demand for animal-derived protein will more than double by 2050 (Henchion et al., 2017). In addition to increased demand due to population growth, increased demand for protein globally is also driven by socioeconomic changes such as rising incomes, increased urbanisation, and aging populations, where the contribution of protein to healthy aging is increasingly recognised, as well as recognition of the role of protein in a healthy diet.

The global demand for fish as food is increasing not only because of population growth but also because it is recognised as a safe source of animal protein that is widely available and affordable to most people, regardless of socioeconomic status (O. Alabi et al., 2015). According to Getu and Misganaw (2015), fish are an important source of animal protein, particularly in African countries where the high cost, risk of disease, and low genetic potential of indigenous species, among other factors, have raised the cost of livestock almost out of the reach of low-income groups.

The fishery sector is a vital component of the Sierra Leone economy. Sierra Leone's fisheries are worth an estimated harvestable value of over 100 million USD annually with a total biomass value of approximately 500 million USD. It provides direct employment to approximately 200,000 people and indirect employment to approximately 600,000. This sector contributes 12% to the country’s Gross Domestic Product (GDP) and is the most important activity along the coastline (MFMR, 2020).

Conteh (2018) reported that the total annual production in the artisanal sector is approximately 120,000 metric tons which helps feed low-income fishing communities. Approximately 80% of the catch landed is produced by artisanal fisheries, which support the livelihoods and food security of thousands of coastal communities (Daboh, 2019). This sector comprises of approximately 641 landing sites across coastal communities. With 12,000 wooden canoes, the major gears used by artisans include driftnets, ring nets, and beach seines.

Small pelagics dominate the marine artisanal fisheries. According to Jalloh (2009), the clupeids *Sardinella maderensis*, *Sardinella aurita*, and *Ethmalosa fimbriata* constitute over 60% of the total artisanal landings in Sierra Leone. The demersals are mainly the groupers (*Lutjanus*), crocus (*Pomadasy*), and Gwangwa. Most fish caught by small-scale fishermen in Sierra Leone

are sold shortly after landing, either for human consumption or further processing such as smoking (Conteh, 2018).

Getu and Misganaw (2015) stated that although fish have become a readily available source of animal protein, poor handling and processing results in lower prices or sometimes large quantities of fish being discarded. Fish are frequently in poor condition when they are landed in small-scale fisheries, either because of exposure to high temperatures during storage and transportation to the landing site or physical damage caused by poor handling at sea, during processing, and poor processing techniques.

Fish processing is performed differently in industrial and artisanal sectors. In the industrial sector, fish are usually received from fishing trawlers, as well as bought from the artisanal sector (mainly croakers). Some industrial fishing establishments are involved in fish processing, such as sorting, washing, packaging, placing in blast freezers, and cooling. Primary and secondary processing, such as filleting, heading, and canning, are currently not performed in Sierra Leone because of the lack of modern processing facilities. Fish are also sorted, washed, packaged onboard trawlers, and transferred to cold rooms onshore (in these processing facilities).

Smoking remains the most used method for processing and preserving fish in the artisanal sector in most developing countries. Other processing methods include drying, fermenting, salting, and frying; however, these are not commonly used in Sierra Leone. Fish processing by hot smoking is an age-long practice performed by fish processors in most parts of the world (Mindjimba et al., 2019). Fish smoking in Sierra Leone is characterised by the use of traditional smoking ovens (bandas) with different types of wood, and this is mostly done by women.

1.1 Rational for Project

According to Kallon et al. (2016), quality assurance is difficult to maintain along the fish value chain in the artisanal sector because of the lack of infrastructure. Post-harvest loss remains a challenge in this sector because of the inadequate capacity for fish handling and processing (Adeyeye & Oyewole, 2016). Landed fish are immediately sold or smoked, as there are no cold rooms to store them. Smoking is the main processing method used by fish processors in the artisanal fisheries subsector. There has been a traditional type of smoke oven for so long, but this has health and environmental issues due to the incomplete combustion of the wood used, and the smoke produced contains chemicals such as polycyclic aromatic hydrocarbons (FAO, 2019). It produces a large amount of smoke, is time-consuming, and requires a large amount of

fuel (wood). Traditional smoking involves low moisture content and high heat. A new and improved smoking kiln (known as the Matis oven) has been introduced to help deliver safe and high-quality products through the efficient smoking of fish. Therefore, this study aims to standardise the method of smoking fish using these improved smoke ovens to improve quality assurance in the smoking of fish and minimise post-harvest losses. It also aims to promote smoking of fish in a less hazardous, healthier, and environmentally friendly way.

1.2 Aim and Objectives

The study's overall goal is to standardise the method of smoking fish using improved smoking kilns and to deliver a handbook for smoking in Sierra Leone. The specific objectives include the following:

- Conduct a comparative analysis between the traditional Chorkor oven and the new and improved Matis oven (structural differences, fuel usage, energy required, heat distribution).
- Optimisation of the use of the Matis oven.
- Map out procedures for training on different smoking methods.
- Map out simple procedures for constructing and maintaining the Matis oven.
- Compare the effect of salting after smoking fillets/split fish.

2 LITERATURE REVIEW

2.1 Post-harvest losses in Artisanal Fisheries

Millions of rural communities get food, nutrition, income, and employment through small-scale fisheries (SSFs) (Kaminski et al., 2020). According to Akande and Diei-Ouadi (2010), small-scale fisheries in Africa contribute over 60% of the fish supply to domestic and regional markets as well as export-oriented processing units. Teh and Sumaila (2013) estimated that 22 ± 0.45 million are small-scale fishers out of the estimated 260 ± 6 million people involved in global marine fisheries, encompassing full-time and part-time jobs in the direct and indirect sectors. They further explained that West African small-scale fisheries are labour-intensive, geographically dispersed, mainly unlicensed, and difficult to manage, making employment and the number of people depending on them difficult to quantify, resulting in an underestimation of the costs and benefits of fisheries.

Post-harvest losses occur at all stages in the fish supply chain, especially during the handling and processing stages (Adeyeye & Oyewole, 2016). This is because of a lack of adequate facilities and equipment across the value chain, expensive and inaccessible processing technologies, excessive cost of value addition, labelling, packaging, low technical and financial capacity to meet certification standards, and poor access to adequate finance.

According to Kaminski et al. (2020), fresh fish and shellfish are highly perishable products owing to their biological composition. with high food loss owing to spoilage, particularly in low-income countries. The value of fish as a source of macro and micronutrients is widely acknowledged. Fish products are essential in the diets of approximately 200 million Africans who rely on fish as their primary source of protein, and reducing post-harvest losses would help increase fish supply. Gyan et al. (2020) reported that post-harvest fish losses (PHFL) in developing countries due to spoilage amount to approximately 10–20 million tons of fish per year. Getu and Misganaw (2015) claimed that an estimated 20 million tons of fish per year are discarded at sea, which is another form of post-harvest loss. They also cited that poor handling problems, such as the lack of hygienic practices, non-gutting of fish, and rough handling, contribute to post-harvest losses. Fish waste from small-scale fisheries has the potential to be utilised in several by-products, such as fish oil, thereby increasing the revenue of the fish industry (Kaminski et al., 2020).

2.2 Fish Processing in the Artisanal Fisheries

Fish is highly perishable, deteriorating quickly and losing quality after harvest. Therefore, fish must meet their nutritional requirements. Olapade et al. (2021) stated that it must be properly handled and processed as soon as it is harvested to avoid deterioration. Gates (2015) stated that processing also creates new products, although its main aim is preservation.

O. Alabi et al. (2015) explained that all activities associated with fish and fish products between the time the fish are caught or harvested and the time the final product is delivered to the consumer are referred to as fish processing. Fish processing requires control measures to ensure that hygienic standards are attained.

Fish processing methods in Africa include drying, fermentation, salting, smoking, and frying. According to Adeyeye and Oyewole (2016), they are performed mainly to extend their shelf life so that they are suitable for human consumption for longer periods. They also explained

that, depending on consumer preference, fish can be sold fresh, dried, frozen, smoked, or fermented.

Kallon et al. (2016) observed that smoking is the preferred method of preservation in the artisanal sector owing to the lack of modern processing facilities, refrigerators, cold rooms, and storage facilities.

2.3 Fish Smoking

Smoking has long been used as a method of preservation (Rizo et al., 2015). In Africa, and especially in Sierra Leone, smoking is the only processing and preservation technique performed on a large scale in the artisanal sector. This is because of the lack of modern infrastructure. According to Newland (2020), the nutrition, biological state, and effects of harvesting and handling determine the suitability of fish for the production of high-quality smoked products. Therefore, handling fish before smoking is very important.

According to Hilderbrand (2001), hot smoked fish are preserved by controlling the moisture content of the product and must have reached a temperature of at least 60 °C (145 °F) for not less than 30 minutes when smoking. To kill the 'indicator' spoilage bacteria during smoking, the temperature should be increased gradually from 35 °C to 50 °C, and finally to 60 °C. These bacteria indicate that fish are unfit for consumption because they are not properly handled and processed. After smoking, the fish were maintained at a temperature of approximately 3 °C (38 °F) to prevent bacterial growth.

Fish smoking in the artisanal sector in Sierra Leone is limited to the use of traditional methods, as it is still not fully developed, unlike that in other countries. According to Olapade et al. (2021), women in this sector are mostly involved in smoking fish and selling them. They mostly buy fresh fish at landing sites. Thorpe et al. (2014) explained that fish are transported in bowls by these women and their children, or sometimes they pay for help to get them to the smoking facilities where they are processed. These smoked fish are sold either in nearby local markets or farther inland. Women prefer to smoke their fish in smaller settings at home, close to their homes, or smaller processing facilities. Thorpe et al. (2014) noted that using group-processing facilities is more of an exception than the rule.

Adeyeye and Oyewole (2016) reported numerous benefits of smoking fish. Smoking increases the shelf life, produces the desired flavour, and is used in soups and sauces. It reduces waste during bumper catches (high catch) and allows for storage during seasons when there is less

catch. It increases the availability of protein to people year-round and makes it easier for fish to be packed, transported, and marketed. However, the disadvantage of using traditional smoking ovens is that they produce poor-quality smoked fish, as evidenced by higher polycyclic aromatic hydrocarbon (PAHs) concentrations, which are hazardous to public health and inefficient because they use large amounts of wood and produce large amounts of smoke (Alabi et al., 2020).

2.4 Fish Species mostly smoked in the Sierra Leone artisanal fisheries sector.

Commercially important pelagic species in Sierra Leone include Sardinella (*Sardinella aurita* and *Sardinella maderensis*), bonga (*Ethmalosa fimbriata*), horse mackerel (*Trachurus trecae, Trachurus trachurus, Decapturus rhonchus, and Decapterus punctatus)*, and the Chub mackerel (*Scomber japonicus*). These highly productive pelagic stocks migrate along the northwest African coast, where they are exploited by the artisanal and industrial sectors using different fishing methods and different fishing gear (Sheriff et al., 2009). The small pelagic fishery in Sierra Leone is a common property resource that is targeted by many artisanal fishermen.

Clupeids, particularly bonga and herring, dominate artisanal fish catches (Jalloh, 2009). The remaining catches are primarily demersal species. Clupeids (*Ethmalosa fimbriata, Sardinella spp.)* account for roughly 60% of artisanal fishery production and are primarily harvested using a purse seine.

Practically all species of fish available in the country can be smoked, and it has been estimated that 70–80% of the domestic marine and freshwater catch is consumed in smoked form (Adeyeye & Oyewole, 2016). Species, such as Barracuda (Figure 1b) are smoked and exported to the United States on a small scale and sold to local markets. Herring (Figure 1a) is sold in all markets in the country. This study focuses on herring, as it is almost always sold in Sierra Leone and is available throughout the year. Jalloh (2009) noted that the round herring, *Sardinella aurita*, is a migratory species and has an offshore distribution in the upwelling areas and the flat sardinella, *Sardinalla maderensis* is usually found inshore in estuaries and bays.

(a)  (b) 

Figure 1: Smoked herring (a) and smoked barracuda (b)

2.5 Types of smoking ovens in Sierra Leone

2.5.1 Traditional ovens (bandas)

Different types of traditional ovens are used in fish smoking in Africa, including round mud and kilns of different types, or cut drum ovens with low batch capacities and long smoking times (Adeyeye & Oyewole, 2016). The main traditional ovens used especially in the western rural coastal communities in Sierra Leone, are called ‘bandas’ and are mainly rectangular in shape and constructed of mud bricks. Along one of the longer sides of the oven, a stokehole is cut for the wood to be fired up during smoking. According to Adeyeye and Oyewole (2016), thick iron bars are placed across the top of the base to support the layers of fish to be smoked, and the fish are arranged on pieces of wire mesh and placed on the supporting iron rods.

There is no barrier between the fish and the fire; therefore, the fire is directly under the fish. In other communities, such as Yeliboya in the north, these are table-like structures constructed with logs of wood and housed in a low roof enclosure made with logs and thatch (FAO, 2019).

The oven shown in Figure 2 (a) is rectangular in shape and is constructed from mud. Thick iron bars are placed across the top of the base to support the layers of fish to be smoked. A stokehole is cut along one of the longer sides of the oven. The fish are arranged on pieces of wire mesh and placed on the supporting iron rods.

a. Traditional oven at Tombo b. Traditional oven at Yeliboya

Figure 2: Different types of traditional fish smoking ovens (bandas) in Sierra Leone

Olapade et al. (2021) noted that poor quality fish products, health risks, and hazards due to lack of control over temperature and smoke density are associated with the use of these traditional ovens. This is because fish are exposed to open fires and contamination. Large quantities of wood are needed, as ovens are inefficient. However, these bandas are still constructed in these communities because of the low cost of materials, and they can also be easily constructed.

2.5.2 Improved smoked ovens.

Over the years, different institutions, such as FAO, Njala University through its Department of Aquaculture and Fisheries Management, and the Ministry of Fisheries and Marine Resources (MFMR), have introduced different smoking ovens in Sierra Leone. The Altona oven was introduced by GTZ in Tombo. The FAO flagship innovation, the dual fish smoking and drying system known as the FAO-Thiaroye processing technique (FTT) has been introduced in six countries in Africa (Mindjimba et al., 2019) and according to FAO will be piloted in Sierra Leone.

Whole fish are exposed to smoke, in which smoke from incomplete wood burning comes in direct contact with the product. However, improved smoking ovens, such as the Matis oven, have been designed to separate dripping oil from the embers. This will lower the contamination of smoked fish with polycyclic aromatic hydrocarbons (PAHs) compared to that of traditional ovens. The improved smoking kilns have been piloted at the Tombo community in Sierra Leone

to help deliver safe and quality products through efficient smoking and improve the working conditions of fish processors (Gissurarson, 2019). This can be achieved by using less fuel (wood), less smoke, and therefore, fewer health risks. Better quality smoked fish will be produced in a shorter period of time than traditional ovens. This also leads to a higher income for processors. However, it is labour-intensive as the metal racks are too heavy to be removed by one person alone, and so men are paid to put the rack full of fish in and out of the oven. The smoking kiln is constructed as part of a system as shown in Figure 3.

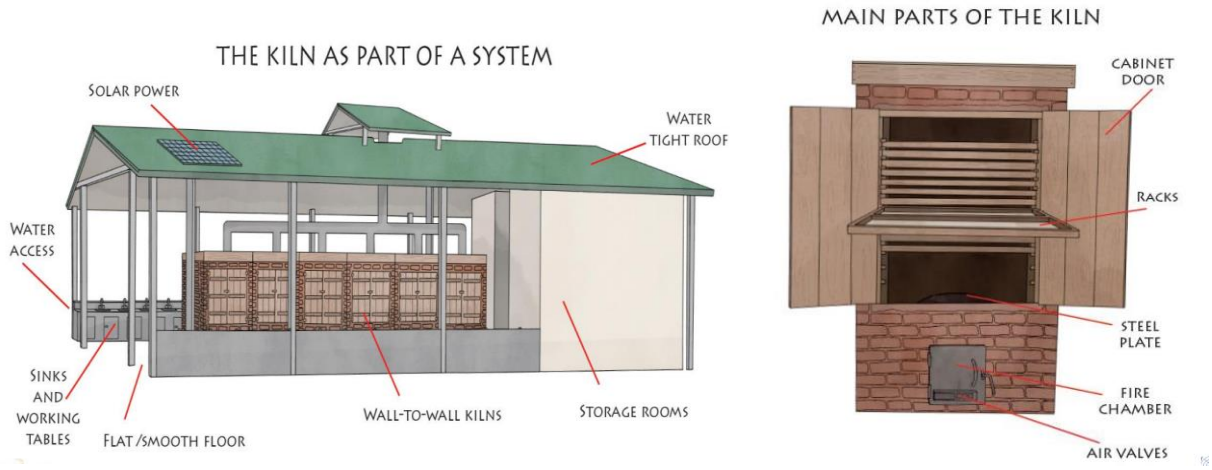

Figure 3: Improved smoking kiln (Matis oven) as part of a system and the main parts of the smoking kiln (Gissurarson, 2019)**.**

The Matis oven was initially made of bricks, metal, and wood, but the wooden racks and doors were changed to metal as the fish processors learned to use it and transitioned from the old ovens to these improved ones. There is a fire chamber with an air valve to regulate the temperature of each kiln and a chimney to remove the smoke. A metal steel plate covers the fire chamber and prevents the flames from reaching the fish and fish oil from dropping directly on the fire.

3 METHODOLOGY

3.1 Materials

The experiments in this study focused on herring, as it is almost always sold smoked in Sierra Leone and is available throughout the year. Wood was used to smoke the fish using both a traditional oven and an improved smoking kiln (Matis Oven). Fish samples were purchased from Tombo landing sites one day before each experiment. The samples were stored on ice until smoking. The fish was weighed before and after smoking using an electronic weighing

scale. Experiments were performed using traditional smoke ovens as well as new and improved smoke ovens. The ovens were filled to their optimal capacity, the average volume of fish smoked per hour was estimated, and the average fuel used was estimated.

3.2 Experimental Design

3.2.1 Experiment A

This experiment was conducted to test and compare two different smoking methods (the traditional and improved methods). Traditional smoke ovens and new and improved smoke ovens were used to hot smoke the fish to determine the time it took the fish to reach a certain temperature where it was considered hot smoked. The two groups of fish listed below were smoked separately in both ovens.

- Whole ungutted fish
- Whole, scaled, and gutted fish

Whole ungutted: - 120.0 kg of herring with average length of 16 cm was smoked using the Matis oven whilst 38.0 kg of the same herring was smoked using the traditional oven. The fish was weighed, washed, and packed on the rack. It was laid flat on the racks and not too clustered together. The racks were then placed in the oven and the cabin doors of the oven were closed. The temperature of the Matis oven was recorded before firing the wood. A small quantity of wood was added to the fire chamber and lit up. Wood was gradually added during the smoking process to obtain the desired temperature, and temperature readings were taken after 30 minutes and then every 15 minutes after that. For the traditional oven, the fish were also weighed, washed, and packed on the mesh over the stokehole, and then the wood was lit. The fish were smoked until they were considered fully smoked in both the ovens.

For whole, scaled, and gutted fish, the same procedure was applied, but after weighing, the fish were scaled, gutted, and washed thoroughly. It was then weighed again before packing on the racks for the Matis oven and on the wire mesh supported by iron rods for the Chorkor oven. 120.0 kg of fish was smoked using the Matis oven while 42.4 kg of fish was smoked using the Chorkor oven. The fish were smoked until they were considered fully smoked by both the ovens.

3.2.2 Experiment B

This experiment was performed to optimise the method of Matis smoking. This was done by smoking different pre-processed fish, such as scaled, gutted, filleted, split, and salted. Two Matis ovens, one modified by extending the length of the steel plate covering the fire chamber

and the other unmodified, were used to smoke a total of 87.1 kg of fish each. As in Experiment A, the fish were bought and processed days before the experiment and stored on ice until they were processed and smoked. The following quantities of fish were smoked for both ovens:

- Gutted fish – 12.1kg
- Gutted, scaled, and split fish – 30.0 kg.
- Filleted fish – 30.0 kg
- Salted/brined split fish – 15.0 kg.

The same quantity of fish was smoked in both the modified Matis oven and unmodified oven. The different groups of processed fish were placed on different racks and placed in the ovens. The fish in the modified oven took 6 hours whilst those in the unmodified oven took 4 hours 15 minutes to finish smoking all the groups of fish although some groups such as the salted and filleted fish were removed as they were considered cooked before the end of the smoking time. The fish were processed, weighed, and washed before being laid flat on racks. The different group of fish were packed on different racks.

The fish products from both the modified and unmodified Matis ovens were displayed after smoking and assessed by four panellists. They observed, tasted, and touched the products and graded them according to the sensory grading scale (Excellent-5 to unsuitable -1). Four groups of fish were smoked: gutted, split, fillets, and salted. Each group was evaluated and graded.

The experiment involved the following measurements and actions to determine the efficiency of the ovens:

- Weight changes in fish before and after smoking for all smoking methods.
- Quantity of wood used in smoking for both traditional and improved ovens.
- Temperature of the fish during smoking.
- The time it takes for the fish to reach a core temperature of 60 °C when the fish is considered cooked.
- A 5-point sensory scale for smoked and salted fish will be developed to rank the products based on colour, salt taste, and texture of the fish.
- The modified Matis oven was compared to the others in terms of fuel consumption and time taken to smoke fish.
- Weight loss during smoking.
- Average volume of fish smoked per hour.

- Average weight of wood used per hour.
- Measuring the weight of smoked product per unit of wood used
- The mean weight loss of fish per kilogram of wood burnt and
- Weight loss during smoking.
- Smoking time.
- Temperature profile for both modified and unmodified ovens

4 RESULTS AND DISCUSSIONS

4.1 Experiment A

4.1.1 Results from Experiment A

Chorkor or Traditional oven

Two chorkor ovens were used to smoke 38.0 kg of whole ungutted fish and 42.4 kg of whole gutted fish using 26.8 kg and 25.2 kg of wood respectively. The ungutted fish lost 55.8% of their weight after smoking for 3 hours and 11 minutes. On average, 11.9 kg of fish was smoked per hour using this method, while 8.4 kg of wood was used per hour to smoke this quantity as shown in Table 2. The smoked gutted fish exhibited a weight loss of 60.3%. This method smoked 11.8 kg of fish per hour on average, while 7.0 kg of wood was used per hour to smoke this quantity.

Matis oven

One of the Matis ovens was used to smoke 120.0 kg of ungutted fish for 6 hours and 48 minutes with 33.7 kg of wood, resulting in a weight loss of 57.3%. The average volume of fish smoked per hour using this method was 17.6 kg, and the average amount of wood used per hour was 4.9 kg as seen in Table 2. Smoking 120.0 kg of gutted fish for 6.8 hours with 32.4 kg of wood in another Matis oven resulted in a weight reduction of 75.7% which was much higher than that of the gutted fish. The average quantity of wood used per hour was 4.8 kg, and the average volume of fish smoked per hour was 17.6 kg.

Table 1: Weight loss of fish after smoking. $W_{L=}$ Weight Loss

	Oven	Smoke time (hrs)	Ave. weight (kg of fish smoked/hr)	Ave. weight of wood used/hr	kg wood used/ Fish kg	Average W_L of fish/ kg wood burnt
Ungutted fish	Chorkor	3.2	11.9	8.4	0.7	0.8
	Matis	6.8	17.6	4.9	0.3	2.0
Gutted fish	Chorkor	3.6	11.8	7.0	0.6	1.0
	Matis	6.8	17.6	4.8	0.3	2.8

Table 2: Experimental and calculated data comparing chorkor (traditional) and Matis ovens.

	Oven	Initial Weight of fish (Kg)	Final Weight of fish (Kg)	% weight loss (W_L)
Ungutted fish	Chorkor	38.0	16.8	55.8
	Matis	120.0	51.3	57.3
Gutted	Chorkor	42.4	16.8	60.3
	Matis	120.0	29.2	75.7

Figure 4 shows a comparison of the average volume of fish smoked per hour and the average volume of wood used per hour for both ovens. The Matis oven used 4.9 kg of wood to smoke 17.6 kg of ungutted fish every hour. This is almost half the quantity of wood (8.4 kg) used by the Chorkor oven to smoke just 11.9 kg of fish for the same 1 hour. Both ovens smoked almost the same volume of gutted fish per hour as the ungutted fish; 17.6 kg for the Matis oven and 11.8 kg for the chorkor. The Matis oven and Chorkor oven also used 4.8 kg and 7.0 kg of wood to smoke these volumes of fish per hour.

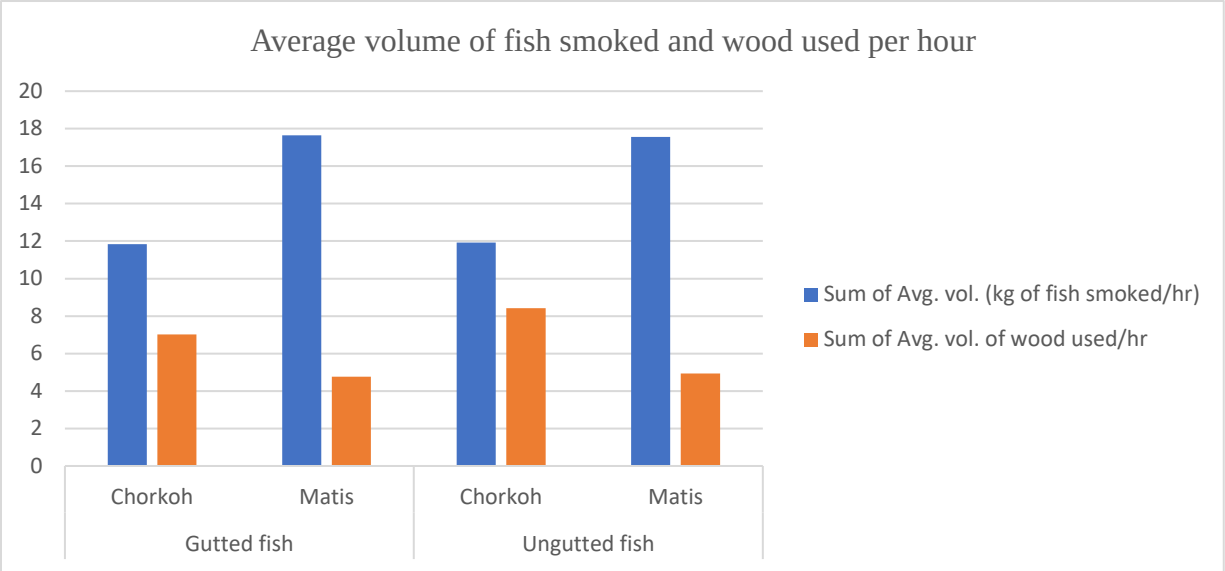

Figure 4: Chart showing the Average volume of smoked fish and wood used per hour in each oven.

Temperature

The temperature of the fish increased with an increase in the oven temperature, as shown in Figure 5. The temperature profile of the oven started at 37 °C and continued to increase gradually to 86.5 °C over two hours. The temperature then began to decrease as the wood burned. Subsequently, wood was added to the oven to increase the temperature. However, the core of the fish attained its highest temperature at 57 °C after 6 hours, after which there was little change in the temperature of the fish core. This could be attributed to the fact that the fish had reached its optimal temperature. At this point, the fish was undergoing the cooking process.

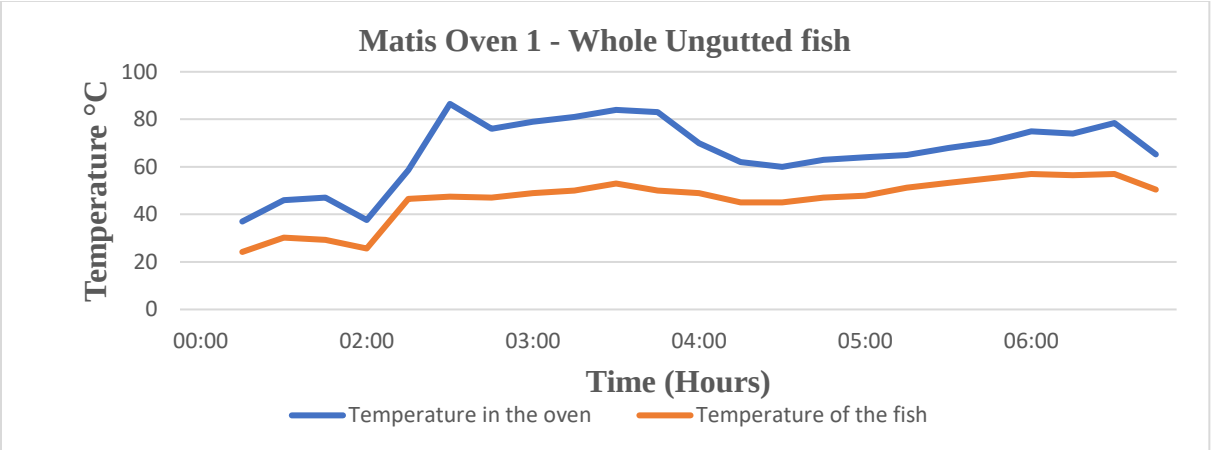

Figure 5: Temperature profile of whole ungutted fish smoked using a Matis oven.

While the temperature in the Matis oven gradually increased over time, the traditional oven did not start at a low temperature. In this oven, the fire was lit directly under the fish, which was placed on wire meshes supported by iron rods. The traditional technology is not enclosed; hence, heat and smoke are not retained rather the fish is mostly smoked by the exposed flames and smoke, which might be the reason why the rise in temperature by this technology is not gradual.

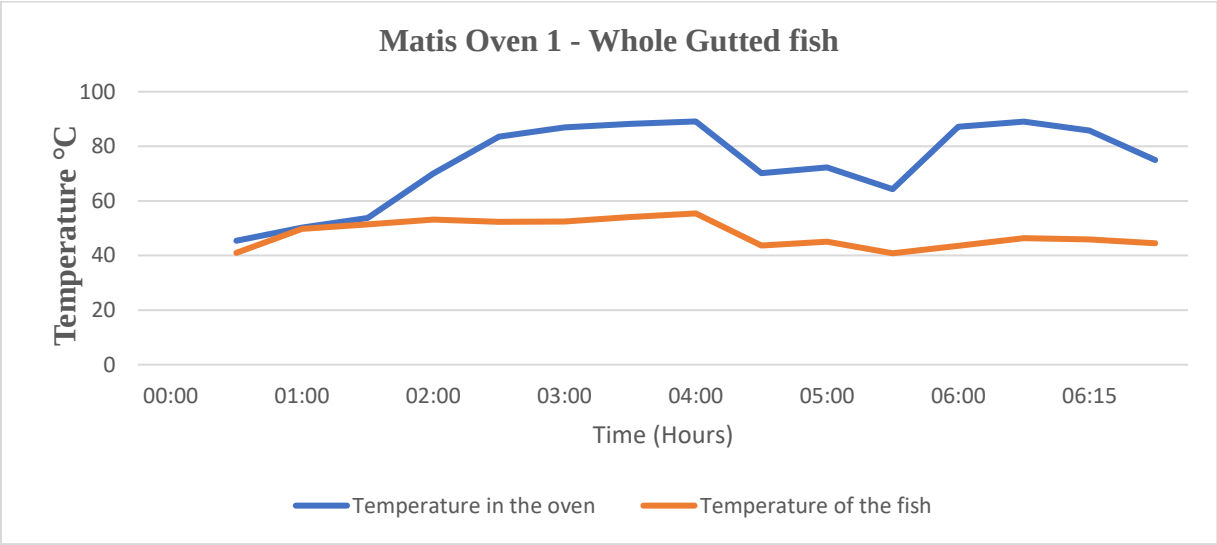

Figure 6: Temperature of whole gutted fish smoked using a Matis oven.

The temperature profile in Figure 6 shows the same trend as that in Figure 5. The trend of temperatures for fish smoking increased slowly to the highest temperature at 89.1 ℃, correlating with the temperature increment of the fish. The temperature increased in the oven and directly contributed to the fish core temperatures achieved in the smoking chamber. The temperature of the fish, however, became constant (43.7 ℃ to 44.5 ℃) even with an increase or decrease in the temperature of the oven for 2 hours and 18 minutes. This crucial stage was the cooking process of herring, since moisture is consistent with the goal of the hot-smoking method.

Sensory Evaluation

Table 3: Sensory evaluation of ungutted fish from both ovens.

Ungutted						
	Matis			Chorkor		
Panelist	**Colour**	**Taste**	**Texture**	**Colour**	**Taste**	**Texture**
1	5	5	5	4	4	3
2	5	4	4	4	4	3
3	4	5	5	3	3	3
4	5	5	5	3	4	2
Average	4.8	4.8	4.8	3.5	3.8	2.8

Table 4: Sensory evaluation of gutted fish from both ovens.

Gutted						
	Matis			Chorkor		
Panelist	**Colour**	**Taste**	**Texture**	**Colour**	**Taste**	**Texture**
1	4	4	3	2	2	3
2	4	3	3	2	2	3
3	3	4	3	2	3	2
4	4	4	2	2	2	2
Average	3.8	3.8	2.8	2.0	2.3	2.5

After smoking, a sensory evaluation test was conducted for both ungutted and gutted smoked fish from each oven using the 5 – point sensory scale provided on smoked fish to rank the products based on taste, colour, and texture. Four people were selected to look at the smoked fish, taste it, feel it, and grade it according to the 5- point sensory scale provided describing the smoked fish. They were not trained panellists but were only asked to describe smoked fish using the sensory scale provided.

Most individuals who participated in the sensory evaluation process agreed that the smoked ungutted fish from the Matis oven was better than that from the Chorkor oven. It had a golden-brown colour, a delicious smoky and meaty flavour, and a smooth, soft, and compact texture. On the other hand, they observed that the colour of the fish from the chorkor oven was darker

(brown) than that of the fish from the Matis oven, and had a less smoky and meaty flavour, with a rough texture.

Of the four individuals who participated in the evaluation, three rated the gutted smoked fish from the Matis oven as good, with a light brown colour, less smoky and meaty taste, and rough texture. Conversely, they found the gutted smoked fish from the traditional oven to be of lesser quality, with a dark brown colour, slightly bitter taste, and hard, lumpy texture. This could be attributed to the high temperature and direct exposure to the fire.

4.1.2 Discussions for Experiment A

Comparing the average volume of fish smoked per hour and the average fuel used per fish for both ovens in Figure 1, it is evident that the Matis oven was more efficient. This is because less wood is required to smoke the same weight of fish and results in a higher loss of water content after smoking when compared to the traditional oven. The percentage of weight lost after smoking the whole gutted fish was more than that of the whole ungutted fish. During the smoking process, some changes in the proximate composition occurred, mainly because of water evaporation. Consequently, the weight of the fish was measured. To prolong the shelf life of smoked fish, it is recommended that the estimated moisture content be kept low, typically around 20–30%, to inhibit the growth of bacteria.

Smoking the gutted fish using the Matis oven took almost the same number of hours as that of the ungutted fish, but with a lower quantity of wood. This is also the case for ungutted and gutted fish smoked using a Chorkor oven. However, some studies have suggested that gutted fish may require less time to smoke, resulting in a higher loss of water content compared to whole gutted fish. Sensory evaluation of the gutted smoked fish indicated that the quality and colour were darker than those of the ungutted smoked fish because of excessive smoke, which could be attributed to the possibility that it was smoked for a slightly longer duration than necessary.

The average quantity of wood used to smoke an average volume of fish per hour was calculated and compared for each oven. The average volume of fish smoked using the Matis oven was 17.6 kg, compared to 11.9 kg of fish smoked in the Chorkor oven, in an hour. The average quantity of wood used for the Chorkor oven per hour of smoking almost doubled that used for the Matis oven. According to the results, the Matis oven smoked more fish with a smaller quantity of wood than the Chorkor oven which used almost twice the quantity of wood used in the Matis oven to smoke a smaller quantity of fish per hour.

Hot-smoked fish are preserved by reducing the moisture content of the product and should have reached a temperature of at least 60 °C (145 °F) (Hilderbrand, 2001) for not less than 30 minutes when smoking. To kill the 'indicator' spoilage bacteria during smoking, the temperature should be increased gradually from 3 °C to 5 °C and finally to 6 °C. The test smoking performed after the construction of the Matis oven in Sierra Leone also showed that the optimal temperature of the oven required to smoke the fish should not exceed 90 °C, and the temperature of the core of the fish should not exceed 60 °C, as fish protein denaturation begins at a smoking temperature of 40 °C. However, at 75 °C, the denaturation rate increases substantially (Odoli et al., 2019). For the experiment, the temperature of the oven smoking the ungutted fish increased to the highest of 85.6 °C almost three hours after the start of smoking, and the fish core attained its highest temperature of 57 °C after six hours of smoking. This was sufficient for the fish to be cooked and did not lose too much water or become dry.

Overall, the evaluation indicated that the smoked fish products from the Matis oven were of better quality than those from the Chorkor oven, with better colour, taste, and texture compared to those from the traditional Chorkor oven. Moreover, the ungutted smoked fish was found to be of better quality than the gutted fish during the sensory evaluation. The sensory evaluation and the time taken to smoke the gutted fish suggested that it might have been smoked longer than necessary. This is because processors are not familiar with smoking this type of pre-processed fish (degutted fish).

4.2 Experiment B

4.2.1 Results from Experiment B

This experiment was performed to optimize the Matis smoking method by smoking different pre-processed fish. Two Matis ovens, one modified by extending the length of the steel plate covering the fire chamber and the other unmodified, were used to smoke 87.1 kg of fish each. The fish which was smoked in the modified oven lost 75.6% of their weight after smoking for 6 hours using 27.0 kg of wood, as shown in Table 5.

The salted fish were the first group of fish to be considered smoked by visual examination after 2 hours 53 minutes of smoking in the modified oven, as indicated in Table 1. However, it had the lowest percentage of weight loss compared to the other groups of fish. The filleted fish was

the second set of fish to be considered smoked after 4 hours and 7 minutes of smoking in a modified oven.

Table 5: Data comparing the % weight loss of different fish processes in the modified oven.

Type of processed fish	Initial weight of Fish (Kg)	Final weight of Fish (Kg)	Smoke time (Hours)	% of Weight lost
Gutted	12.1	2.6	6.0	78.4
Splitted	30.0	7.2	6.0	76.0
Filleted	30.0	7.4	4.1	75.4
Salted	15.0*	4.1	2.9	72.5
Ave. % weight loss				75.6

*****Before salting

Fish from the Unmodified oven lost 74.8% of its weight after being smoked for 5 hours and 15 minutes with 22.0 kg of wood, as shown in Table 6. Salted fish were also the first group of fish to be considered smoked in the unmodified oven. However, the filleted fish smoked for the entire duration of smoking in an unmodified oven.

Table 6: Data comparing the % weight loss of the different fish processes from the unmodified oven.

Type of processed fish	Initial weight of Fish (kg)	Final weight of Fish (kg)	Smoke time (Hours)	% of Weight lost
Gutted	12.1	3.4	5.3	71.7
Splitted	30.0	6.6	5.3	78.1
Filleted	30.0	6.3	5.3	79.2
Salted*	15.0	4.5	2.1	70.2
Ave. % weight loss				74.8

*Before salting

Table 7: Data comparing smoke time, kg of wood used, and weight loss for both ovens.

Type of Oven	Initial weight of Fish (Kg)	Final weight of Fish (Kg)	Weight Difference (Loss in weight) (Kg)	Smoke time (hours)	Weight of wood (Kg)
Modified	87.1	21.3	65.8	6.0	27.2
Unmodified	87.1	20.7	66.4	5.3	22.0

It was observed that the modified oven had a longer smoking time and greater total weight loss than the unmodified oven.

The weight loss of smoked fish products varied among the different ovens. The scaled and gutted fish had the highest weight loss of 78.4% for the modified oven, while the highest weight loss for the unmodified oven was in fillets with 79.2% (the highest for the entire experiment). It should be noted that different groups of fish were packed on the same rack number for both ovens (from Racks 1 to 12), which also affected the smoking rate of each processed fish. A few fillets on rack 11 of the modified oven started to burn because of the high temperature at the bottom as compared to those on rack 7.

Temperature

The temperature profiles of ovens and gutted fish are shown in Figure 7. The temperature was recorded every 30 minutes and then later every 15 minutes. The temperature of the gutted fish increased with increasing temperature of the ovens. The temperature of the modified oven increased until it reached 85.3 ℃ which was the highest after 4 hours. The temperature of the fish was also at its highest of 62.4 ℃ at the same time. However, the fish's temperature remained consistent (50.9 ℃ to 53.4 ℃) despite changes in oven temperature for two hours. After 6 hours when the fish were considered cooked, the oven temperature started to decrease, while the fish maintained its temperature. This was because the fish had achieved its optimal temperature. Figure 7 shows how the fish was cooked over time.

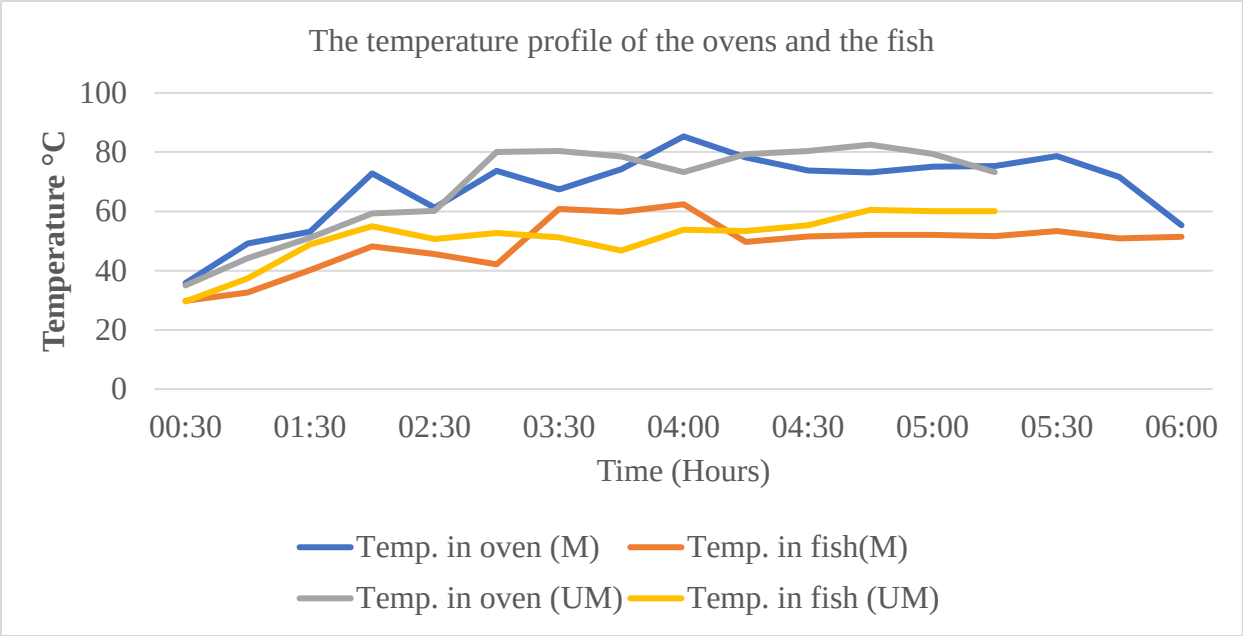

Figure 7: Temperature profiles of modified and unmodified ovens and gutted fish.

The temperature profile for the unmodified oven reached its optimal temperature of 82.5 ℃ after 4 hours and 30 minutes of smoking, as shown in Figure 7, which correlates with the optimal temperature of 60.5 ℃ for the fish core. The temperature profiles for both ovens were similar but had a time difference of 45 minutes when each reached its optimal temperature.

Sensory Evaluation

The fish products from both the modified and unmodified Matis ovens were graded, as shown in Tables 8 and 9, according to the sensory grading scale presented (Unsuitable 1 to excellent-5). The standard deviation of most of the scores of the panellists was low and close to the mean for each parameter, indicating that the panellists agreed with the quality parameters. There were some parameters, especially in the unmodified oven where the panellists were not in agreement, with the highest being in the taste of the split fish from the unmodified oven. This shows that the gradings by panellists were widely spread, as two assessors gave a low score of 2 and 3, while the other panellists gave a high score of 5.

Table 8: Sensory evaluation for the smoked fish products from the modified Matis oven

	Group- Gutted			**Group B - Splitted**			**Group C- Filleted**			**Group D-Salted**		
Panellists	**Colour**	**Taste**	**Texture**	**Colour**	**Taste**	**Texture**	**Colour**	**Taste**	**Texture**	**Colour**	**Taste**	**Texture**
1	4	5	5	5	4	4	5	5	5	5	5	5
2	3	4	4	4	4	4	4	5	5	4	4	4
3	4	5	5	5	5	4	4	5	4	5	5	5
4	4	4	4	5	5	4	3	4	5	4	5	3
Average	**3.8**	**4.5**	**4.5**	**4.8**	**4.5**	**4.0**	**4.0**	**4.8**	**4.8**	**4.5**	**4.8**	**4.2**
Ste. Dev	**0.5**	**0.6**	**0.6**	**0.5**	**0.6**	**0**	**0.9**	**0.5**	**0.5**	**0.6**	**0.5**	**1.0**

After the evaluation of all fish groups, as seen in Tables 8 and 9, it was observed that all the fish products smoked using the modified oven were good, had a smoky and meaty taste, and were relatively smooth in texture. Most individuals who participated in the sensory evaluation process agreed that the colour of the fish products from the unmodified oven was light brown and smooth in texture but had a less smoky and meaty taste.

Table 9: Sensory evaluation of smoked fish products from the unmodified Matis oven.

	Group A- Gutted			**Group B - Splitted**			**Group C- Filleted**			**Group D-Salted**		
Panelists	**Colour**	**Taste**	**Texture**	**Colour**	**Taste**	**Texture**	**Colour**	**Taste**	**Texture**	**Colour**	**Taste**	**Texture**
1	4	4	4	4	3	4	2	3	3	3	5	5
2	4	3	4	4	2	3	3	3	4	3	4	3
3	5	5	4	3	5	4	4	5	4	5	5	5
4	4	4	4	5	5	4	3	4	3	4	5	5
Average	**4.2**	**4.0**	**4.0**	**4.0**	**3.8**	**3.8**	**3.0**	**3.8**	**3.5**	**3.8**	**4.8**	**4.5**
St. Dev	**0.5**	**0.8**	**0**	**0.8**	**1.5**	**0.5**	**0.81**	**1.0**	**0.6**	**1.0**	**0.5**	**1.0**

The sensory evaluation indicated that the filleted fish from the unmodified oven had the lowest score, with an average colour of brown, less smoky, and meaty, and had a smooth texture. This was because they had smoked for too long. The modified oven had better quality than the unmodified oven with better colour, taste, and texture compared to the unmodified oven, but this difference was relatively small when compared to the chorkor oven.

4.2.2 Discussions for Experiment B

This experiment proved that the hot smoked fish reached a temperature of at least 60 °C, and this was attained faster when the fish were pre-processed (gutted, split, and filleted) than when

it was smoked whole and used less fuel (wood). The modified Matis oven had better quality products after smoking, although it took an additional 45 minutes to smoke than the unmodified oven and used more wood. This was probably because it took more time for the oven to be heated, as the steel plates might be thicker and needed more wood at the start, whereas the unmodified oven had been in use. However, the modified oven had the highest temperature which means that there was sufficient heat to cook the fish until it reached its optimal temperature. An increase in temperature at the bottom of both ovens, close to the steel plate, affected the fillets, as a few started to get burnt just before they were removed from the ovens. It is therefore advisable not to place pre-processed fish, such as fillets, and salted fish on the bottom racks close to the steel plate.

It is also possible that since visual inspections were used to determine when the fish had been smoked the fish in the modified oven could have been smoked longer than necessary. As the optimal temperature for the fish was achieved sooner in the modified oven than in the unmodified oven. This also explains the higher quantity of wood used as the longer the fish is smoked the more wood is used. The unmodified oven would also not have been smoked enough, as it reached its optimal temperature later and had a lower quality score during the sensory evaluation compared to the modified oven.

It was estimated that a lot of moisture evaporated during smoking in both ovens, which is what the fish processors need to increase the shelf life. The difference in weight loss between the ovens was 0.8%, which is relatively insignificant. Additional training on regulating the temperature of the modified oven and determining when the fish is cooked is needed, as there were more fluctuations in the modified oven temperature during the experiment. The optimal core temperature of the fish was attained sooner in the modified oven but continued to be smoked for 1–2 hours more. However, it is recommended that further experiments, especially the heat distribution in the two ovens, be performed before deciding whether to modify the ovens.

It is possible that the temperature at the bottom of the modified oven was too high, as the fillets at the bottom rack started to burn. Overall, the quality of the fish products was better than that of the unmodified oven. For smoking times of 5 hours and 15 minutes, the gutted fish from the unmodified oven had less weight loss (Table 2), indicating that it was not cooked enough compared to those from the modified oven which also had higher scores during the sensory

evaluation. However, the fillets were overcooked as they were smoked for the entire smoke time together with the gutted and split, while those in the modified oven were removed 4 hours and 7 minutes after smoking and had a good-quality score (Tables 1 and 2). This was why its quality evaluation was lower than that of the fillets in the modified oven, as they may have been smoked longer than necessary.

Although the unmodified oven used less wood and had a shorter smoking time, the quality of the unmodified oven in general indicated that the products were slightly undercooked and might have needed more time to cook well (except the fillets). The quality of the fish products from the modified oven was well cooked and was good according to the sensory evaluation, even though it took a longer time to smoke and used more wood.

The estimated moisture content from the weight loss attained by fish from both ovens was good, as it was at the recommended percentage of 25%, which would increase the shelf life of the product. According to Amos and Paulina (2017), the percentage weight loss for smoked catfish and tilapia ranged from 70% to 80%, and smoke drying significantly reduced the moisture content of fish (9-17%). This is because smoked dried fish with a moisture level greater than 20% spoils after five days (Sikoki & Aminigo, 2001). This is important because processors and fishmongers do not have access to cold storage, where they can store their products. The products from the modified oven also had the highest average weight loss after smoking (Table 1).

Processors in the community are challenged with access to ice, and the available ice is very expensive. Therefore, the fish processors and fish mongers were not in total acceptance of these pre-processing techniques, as they presume that it is time-consuming and labour-intensive, especially for small pelagic species such as herring. They further noted that they could not afford to buy the quantity of ice required to maintain quality while implementing these techniques. This is because they had to do everything by hand (manually) and did not have the technical know-how to do it faster. They were a bit dismayed at the ‘waste’ after heading, splitting, and filleting the fish and at the weight loss after processing. However, after smoking, the processors were impressed by the quality of the fish. They reiterated that if the processing time was not too long and they could easily do it, they would consider using these processing methods. The processing time can be shortened by conducting a series of training sessions on these pre-processing techniques and encouraging them to incorporate them into their daily fish-smoking practices. The more they practice these techniques, the faster they become. Simple

filleting machines can also be introduced to make processing much easier and less labour intensive. There is also a need to develop a market for this type of processed fish, noting that there is a significant loss in weight, and there is a need to find a use for the waste through training, for example, fish meal and oil for livestock and fish feed.

The results of Experiment B indicate that the Matis oven could be modified and made more efficient by extending the length of the steel plate to the back of the oven to trap heat and prevent it from escaping. Nevertheless, it is suggested that further experiments, such as measuring heat distribution, be carried out to determine the heat distribution and the part of the oven that has the highest heat to prevent fish products from getting burnt.

5 CONCLUSION

This research showed that the new and improved technology of the Matis oven will improve the way processors smoke their fish and hence the quality of the product. Compared to traditional ovens, this study also confirms that the Matis oven uses less wood, smokes fish faster, and produces better-quality products. The Matis oven's vertical structural design allows it to smoke large quantities of fish and improve the health of the processors, as it contains the smoke inside the cabin and prevents processors from inhaling it.

The temperature in the Matis oven and the fish can be regulated to reach a temperature of at least 60 °C (145 °F). To kill the 'indicator' spoilage bacteria during smoking, the temperature should be increased while reducing the moisture content of the product which extends the shelf life.

The results from experiment B suggest that the Matis oven can be optimised and made more efficient by extending the steel plate length to the back of the oven to retain heat and prevent it from escaping. Further experiments, such as heat distribution experiments, are recommended to provide further scientific evidence on the efficiency of the Matis oven.

The fish processors and fish mongers were not in total acceptance of these pre-processing techniques as they presumed that it is time-consuming and labour-intensive, even though they agreed that the fish products were of better quality. Premium prices for processed fish products are likely to convince them that, after all, it is not a waste of time, as customers are readily willing to pay premium prices for the extra labour put into degutting and filleting the fish before smoking.

6 RECOMMENDATIONS

- Train fish processors on the proper use of the Matis oven, how to regulate the temperature of the oven to prevent their fish from getting burnt, and how to keep the oven clean after use.
- Train oven technicians on simple procedures for constructing and maintaining a new and improved Matis oven.
- Sensitise and train fish processors on the importance of degutting and practising other fish processing techniques, such as filleting, brining, before smoking, and how the 'waste' of these processing methods can be used.
- Introduce a micro-credit scheme to encourage fish processors to replace their traditional ovens in their smaller settings at home or smaller processing facilities with single or more units of the Matis oven.
- The Matis oven could be modified and made more efficient by extending the length of the steel plate to the back of the oven to trap heat and prevent it from escaping However, further experiments should be performed to understand how this heat is distributed in the oven to prevent the fish from burning.
- Add simple temperature gauges to the Matis ovens to help inform the processors when to regulate the fire to prevent their fish from burning and to avoid constantly opening the cabin doors.

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APPENDIX 1: TRAINING MANUAL ON PROCEDURES FOR SMOKING FISH USING THE MATIS OVEN

TRAINING MANUAL ON SIMPLE PROCEDURES FOR SMOKING FISH USING THE MATIS OVEN FOR DIFFERENT SMOKING METHODS

Josephine May Kabba
Ministry of Fisheries and Marine Resources
7th Floor, Youyi Building, Brookfields, Freetown, Sierra Leone
mayruth88@gmail.com

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1. INTRODUCTION

The Improved Smoking Kiln (The Matis Oven)

Fish smoking is the most prevalent form of processing and preservation method in the artisanal sector. In this sector, fish smoking is mainly performed by women. All species can be smoked, but processing before smoking can vary according to the species, their size, and the targeted market. Traditional fish smoking ovens, such as the chorkor, expose processors to risks, such as heat and smoke inhalation. They use a large amount of wood, the fire has direct contact with the fish, and it takes a long time to smoke the fish.

Improved smoking ovens, such as the Matis oven, are designed to separate dripping oil from the embers. Compared to traditional ovens, this lowers the contamination of smoked fish with polycyclic aromatic hydrocarbons (PAHs). The improved smoking kilns have been piloted at the Tombo community in Sierra Leone to help deliver a safe and high-quality product through efficient smoking and improve the working conditions of fish processors (Gissurarson, 2019). This could be achieved using less fuel (wood), less smoke, and fewer health risks. Better quality smoked fish will be produced in a shorter period of time than traditional ovens. This also leads to a higher income for processors.

The Matis oven is made of bricks, metal, and wood, but wooden racks and doors have been changed to metal as the fish processors learn to use it and transition from the old ovens to these improved ones. There is a fire chamber with an air valve to regulate the temperature of each kiln and a chimney to take the smoke out. A metal steel plate covers the fire chamber and prevents the flames from reaching the fish and the fish oil from dropping directly on the fire.

Aim and Objectives

The overall goal of the training is to provide a simple step-by-step method on how to use the Matis oven to smoke fish using different processing techniques. The specific objectives include the following:

- To increase knowledge of the importance of using the Matis oven.
- Outline the personal hygiene fish processors should practice when processing or smoking fish.
- To outline a simple step-by-step procedure for the use of a Matis oven to smoke fish.

PERSONAL HYGIENE FOR FISH PROCESSORS

When handling fish, observe the following:

- Wear clean protective clothes, hairnets, and gloves.
- Wash hands before handling fish.
- No spitting, coughing, or sneezing around the fish (do not handle fish when sick).
- Do not touch your nose or mouth
- Do not consume food or drinks in the smoking area
- Trim fingernails and cover wounds
- Remove all jewellery
- Recommended regular health checks.

Figure 8: The improved kiln (Matis) smoke oven at Tombo

COMPONENTS OF THE MATIS SMOKE OVEN AND THEIR FUNCTIONS

Component	Picture	Functions
Cabinet racks and doors		The cabinet consists of shelves, racks, and cabinet doors. The racks are used to pack the fish. The shelves hold the racks in position. The doors are closed during smoking to prevent the heat and smoke from escaping.
Steel Plate		A steel plate is used to cover the fire chamber. This prevents the flames from reaching the fish and the fish oil from dropping directly on the fire.
Fire Chamber		The fire chamber is where the wood, charcoal, small branches, paper, or sawdust are used to set the fire.

Fire chamber door and air valve		The fire chamber door is important as it prevents air escaping into the fire chamber. It should always be closed except when wood needs to be added or reduced to increase or decrease the temperature. The air valve is used to regulate the temperature in the oven. It should be opened to allow the oxygen to fire up the wood or closed to quench the fire.
Chimney		The chimney takes the smoke out of the oven, and out of the smoking facility into the open air above. Less smoke where the fish processors are smoking the fish leading to better health.

STEP-BY-STEP SMOKING PROCEDURES

Before smoking

Step 1

Buy fresh and good quality fish and transport it to the smoking facility.

Step 2

Sort by size and wash the fish using portable water. Other processing techniques that can be adapted by the fish processors can be descaling, filleting, splitting, brining, or seasoning the

fish before smoking. Good quality fresh fish yields good quality smoked fish, as well as good value and increased family income.

Step 3

Pack the fish on the racks. Use clean racks and put the racks on a clean platform when arranging the fish.

Step 4

Place racks with fish in kilns and close the doors before you fire up the kiln.

Step 5

Fire up the oven or kiln. Use good wood and cut the wood to fit the fireplace. Use charcoals, small branches, paper, or sawdust to set the fire. Do not use kerosene, plastic bags, or other chemicals to start the fire to prevent the fish from being contaminated by these chemicals.

Figure 9: Fish processing and washing (a); Fish processors packing the fish on the rack.

Figure 10: Packed fish ready to be placed in the oven (a); Rack been placed in the oven (b)

During Smoking

Step 6

Close the door during smoking to maintain temperature and avoid inhaling smoke.

Step 7

Regulating the fire: - Use the air valve on the fire door to regulate the temperature in the oven. It should be opened to allow the oxygen to fire up the wood or closed to quench the fire. It can be opened to allow air to enter and increase the temperature or closed to decrease the temperature. A lower quantity of wood should be used when starting to smoke, so that the starting temperature is from 30ºC to 40 °C, and then the temperature is gradually increased to 60 °C which is the optimum temperature for smoking fish. It takes 6 to 8 hours to smoke whole fish and 4 to 5 hours to smoke split fish and fillets using the Matis oven.

Step 8

Removal of racks during smoking: Racks should not be removed during smoking. For big fish, wait until the fire goes down to remove racks to turn fish.

Figure 11: Closed oven during smoking (a); Fire chamber door with the air valve and lock (b).

After Smoking

Step 9

Removal of the racks: Use clean gloves/cloths to remove the racks and place them on a clean surface. Leave the rack to cool in a clean environment free from flies.

Step 10

Packaging the fish: Handle the fish with care when packing to avoid breakage. Have clean hands to avoid contamination. Pack the fish in a clean basket/bowl and clean packaging materials. Do not use cement paper or dirty cartons or newspapers.

Step 11

Storage: Store smoked fish in a clean environment under cool temperatures with low humidity. The storage room should be free from insects and rodents and should not be used to store chemicals. It should only be used to store smoked fish. Smoked fish should be stored away from fresh fish to prevent contamination and to keep it safe and fit for human consumption.

Step 12

Transportation: The smoked product should be transported in clean vehicles or by labourers who practice good hygiene (clean hands, clothes, etc.). The basket/bowl containing packed fish must be covered and not compressed in the basket or bowl to avoid breakage which leads to a reduction in price.

Step 13

Marketing: Sell fish in a clean market and keep fish away from insects and rodents. Ensure good personal hygiene, that is, wash hands before handling fish and avoid spitting, coughing, or sneezing around fish (do not handle fish when ill).

APPENDIX 2: TRAINING MANUAL ON CONSTRUCTION AND MAINTENANCE OF THE NEW AND IMPROVED MATIS OVEN.

TRAINING MANUAL ON SIMPLE PROCEDURES FOR CONSTRUCTING AND MAINTAINING THE NEW AND IMPROVED OVEN (THE MATIS OVEN)

Josephine May Kabba
Ministry of Fisheries and Marine Resources
7th Floor, Youyi Building, Brookfields, Freetown, Sierra Leone
mayruth88@gmail.com

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INTRODUCTION

Rational for the training

According to Kallon et al. (n.d.), quality assurance is difficult to maintain along the fish value chain in the artisanal sector because of the lack of infrastructure. Post-harvest loss remains a challenge in this sector, owing to the inadequate capacity for fish handling and processing (Adeyeye & Oyewole, 2016). Landed fish are immediately sold or smoked, as there are no cold rooms to store them. Smoking is the main processing method used by fish processors in the artisanal fisheries subsector. There has been a traditional type of smoke oven for so long, but this has health and environmental issues due to the incomplete combustion of the wood used, and the smoke produced contains chemicals such as polycyclic aromatic hydrocarbons (FAO, 2019). It produces a large amount of smoke, is time-consuming, and requires a large amount of fuel (wood). Traditional smoking involves low moisture content and high heat. A new and improved smoking kiln (known as the Matis oven) has been introduced to help deliver safe and high-quality products through the efficient smoking of fish. This will lower the contamination of smoked fish with polycyclic aromatic hydrocarbons (PAHs) compared to that of traditional ovens. Therefore, this study aimed to standardise the method of smoking fish using these improved smoke ovens to improve quality assurance in the smoking of fish and to minimise post-harvest losses. It also aims to promote smoking of fish in a less hazardous, healthier, and environmentally friendly way.

Aim and Objectives

The overall goal of the training was to map out simple procedures for constructing and maintaining the Matis oven. The specific objectives include the following:

- To increase knowledge of the importance of using a Matis oven.
- To help participants gain knowledge through simple procedures for constructing a Matis oven.
- To outline simple procedures for cleaning the Matis oven

SIMPLE STEPS TO CONSTRUCT THE MATIS OVEN.

The main parts of the kiln are as follows:

1. The structure (brick walls)

2. The fire chamber (including the plate and the valve)
3. Cabinet (including door, door frame, hinges, lock, shelves, and racks)
4. Roof (including wooden top and metal chimney)

The new design was created to eliminate the laborious process of turning the fish or interchanging tray positions during smoking. It also prevents direct contact between the fire and fish. Smoke and heat help fish to cook, smoke, and gain flavour.

There is a fire chamber with an air valve to regulate the temperature of each kiln and a chimney to remove the smoke. A metal steel plate separates the fire chamber and cabinet, and prevents the flames from reaching the fish and fish oil from dropping directly on the fire. The cabin was designed to contain both heat and smoke.

The Structure (brick walls)

The Matis oven is a simple, well-structured oven designed to smoke fish in a healthier manner using less wood. It is a solid structure composed of bricks, metals, and wood. Clay bricks are used to construct an oven, as they retain heat which is very important in fish smoking. The clay bricks are layered with cement mortar and constructed to wall height on the sides, as shown in Figure1. The front of the solid structure is where the cabinet, racks, and fire chamber are located. The cabin should be sufficiently deep to allow the racks to fit and the door to be closed easily. The clay bricks, central position, and firing chamber ensures uniform smoking.

Figure 12: The Matis ovens as part of a system (consisting of 12 ovens at Tombo)

Figure 13: Solid structure made from bricks, metal, and wood (Gissurarson, 2019).

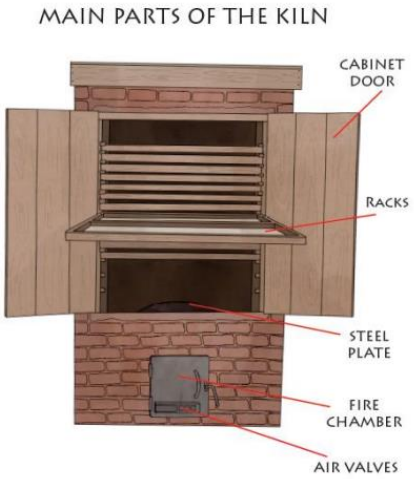


Figure 14: Main parts of the kiln (Gissurarson, 2019).

Fire Chamber

The firing chamber is located at the bottom of the oven beneath the cabinet where the racks are stacked. The fire chamber should go up to the back of the oven wall and should not be too wide; it should be just enough to hold at least four to five sticks. It is covered with a steel plate (Figure. 4) which prevents fire but allows smoke to pass through the sides. There is a door to the fire chamber, which is made from metal, through which wood is added. It has a lock which holds

the door in place when closed. There is an air valve that helps regulate the fire. It can be opened to allow air to enter and increase the temperature or closed to decrease the temperature. The measurements of the chamber door and the air valve are shown in Figure 6.

Figure 15: Fire Chamber

Figure 16: Fire chamber door with air valve and locks

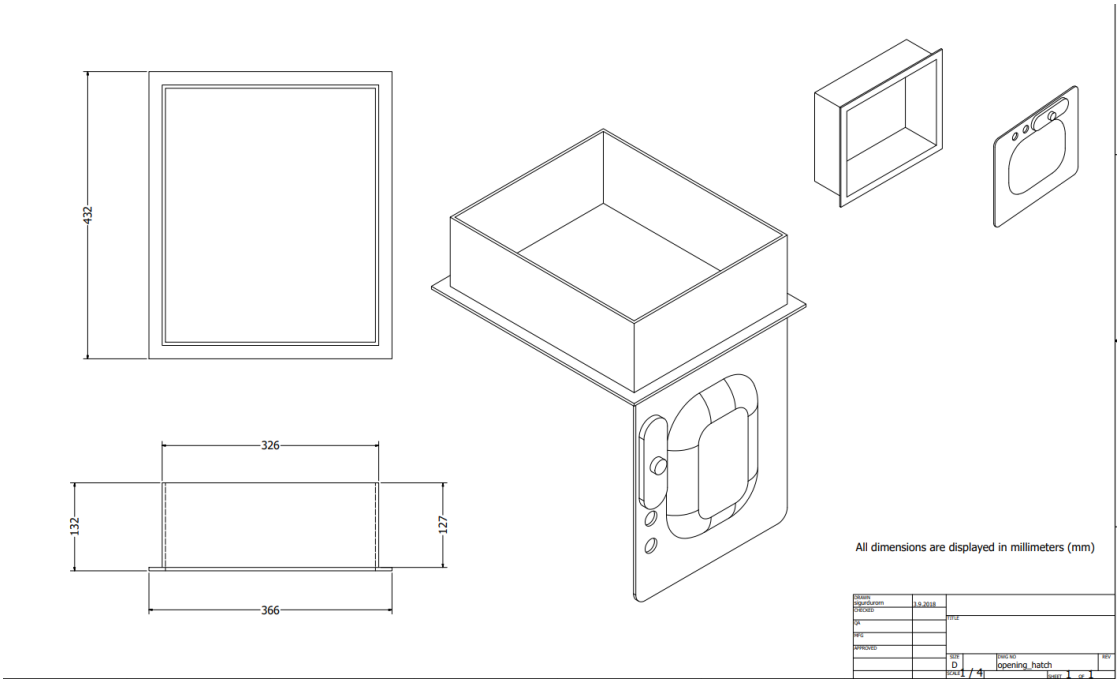


Figure 17: Design of the fire chamber door with the air valve and measurements

Steel Plate

A metal steel plate separates the fire chamber and cabinet and prevents the flames from reaching the fish and fish oil from dropping directly on the fire. This steel plate should be made to cover the length and width of the fire chamber from the back of the oven to the front. It should be 134 cm and 75 cm wide depending on the size of the oven. Results from the experiment conducted indicated that the Matis oven could be modified and made more efficient by extending the length of the steel plate to the back of the oven to trap heat and prevent it from escaping.

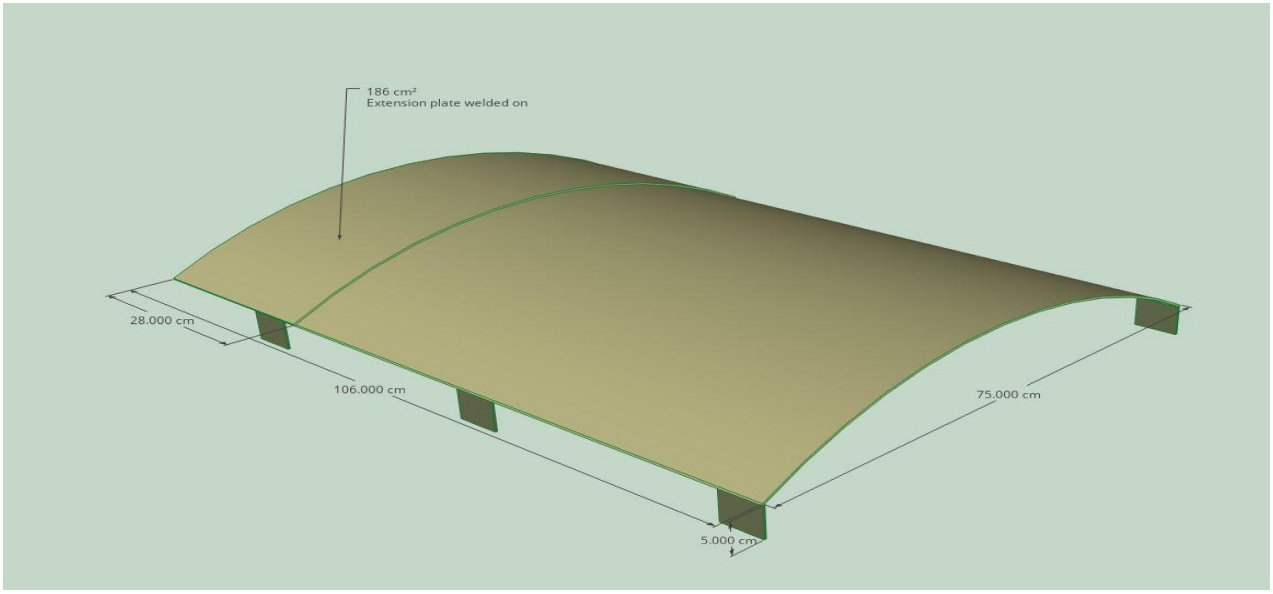


Figure 18: Steel plate to cover the fire chamber.

The Cabinet

Shelves

As shown in Figure 3, the cabinet consists of shelves, racks (to pack the fish), and cabinet doors. The shelves can be made of wood or metal and should be designed to allow easy "push-in and pull-out" of racks. There should be at most twelve (12) shelves with 6.73 cm (Figure 11) between shelves to avoid clustering and allow the racks to fit well and to be pulled easily. The length of the shelf should be 140 cm from the back of the oven and the width should be approximately 32 cm so that the racks can fit comfortably. Drawings with measurements of the shelves are presented in Figures 8, 9, 10 and 11 below.

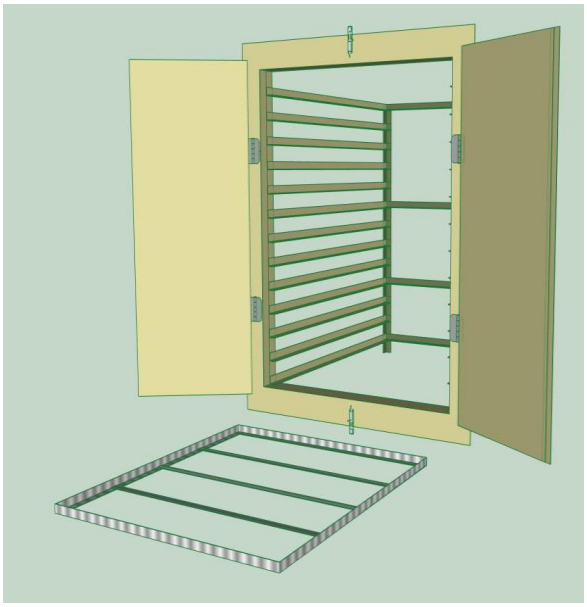


Figure 19: Design of the cabin with shelves

Figure 20: Metal shelves

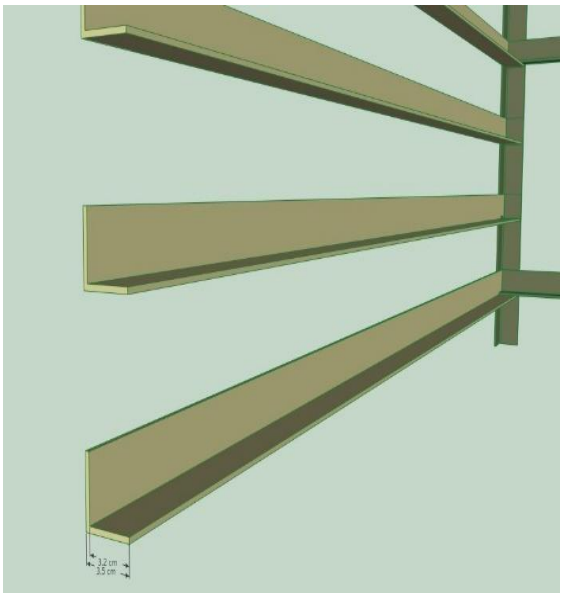


Figure 21: Width measurements of the shelves

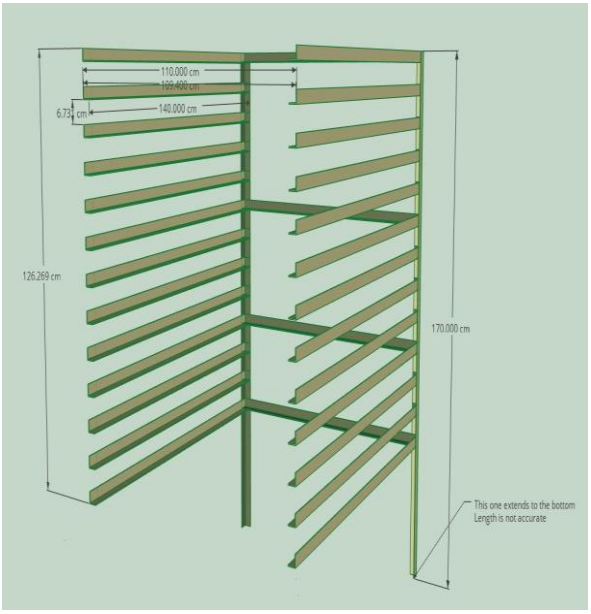
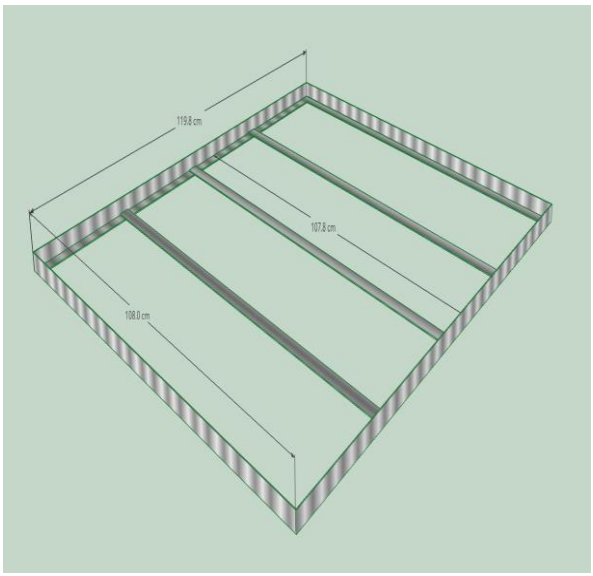


Figure 22: Design of the shelves

Racks

The racks are used to pack the fish for smoking. The fish must be laid flat and not too close together to avoid clustering and allow heat to pass through to the next rack on top. According to the original design by Matis, they were made from wooden frames with thick iron bars placed across the top of the base to support the layers of fish to be smoked. Measurements of these are presented in Figures 12 and 13 below. The width of the rack should be sufficiently thick to fit into the shelves and easily pulled out. Racks can be interchanged during smoking (the one up can be placed down and vice versa).



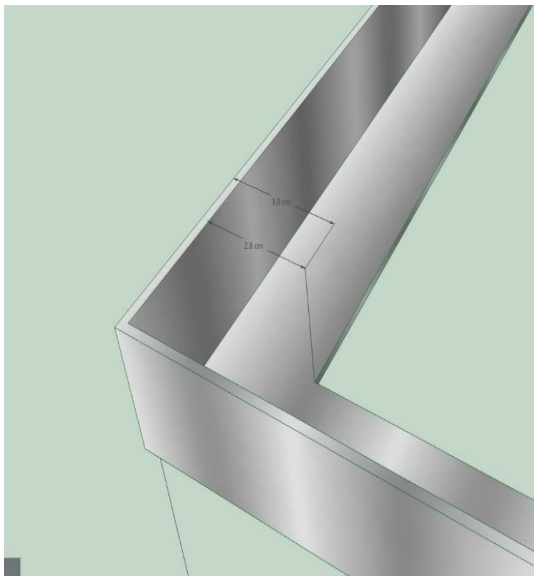
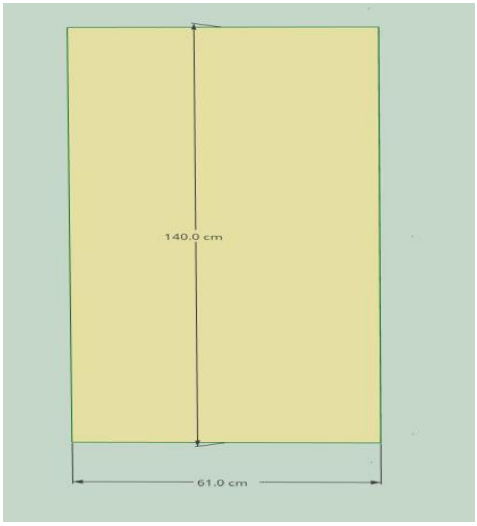


Figure 23: Design of racks with measurements. Figure 24: Measurements of width of racks

The cabin was designed to have doors that should be closed during smoking to help maintain the heat, maintain the temperature, and avoid inhaling smoke. They should be made of metal. The outer part of the door frame (Figure 16) should measure 155 cm in length and 132 cm wide and the inner length should be 132 cm and width 110 cm. It should be tightly fitted to the walls, and no space should be left underneath or on top of the door frames or doors to prevent air from moving in and out of the cabin. The measurements for the doors are presented below in Figures 14 and 15. The length should be 140 cm and width 61 cm. The hinges should also be tightly fitted, and the door should be able to swing freely on the hinges and not to be stiff when the door is closed. Figure 16 shows the door frames with measurements. The doors have locks which keep them from being opened while smoking as shown in Figure 17.



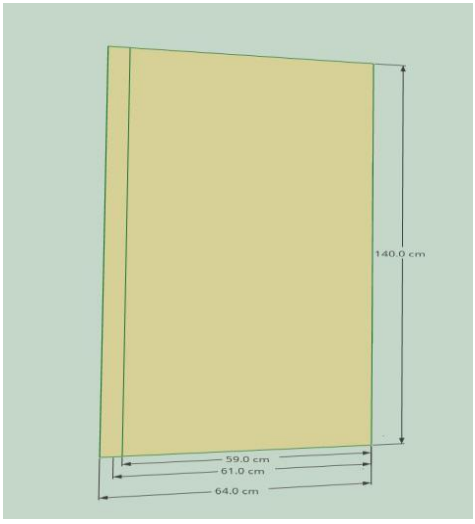


Figure 25: Front view of the door

Figure 26: Side view of the door with measurements

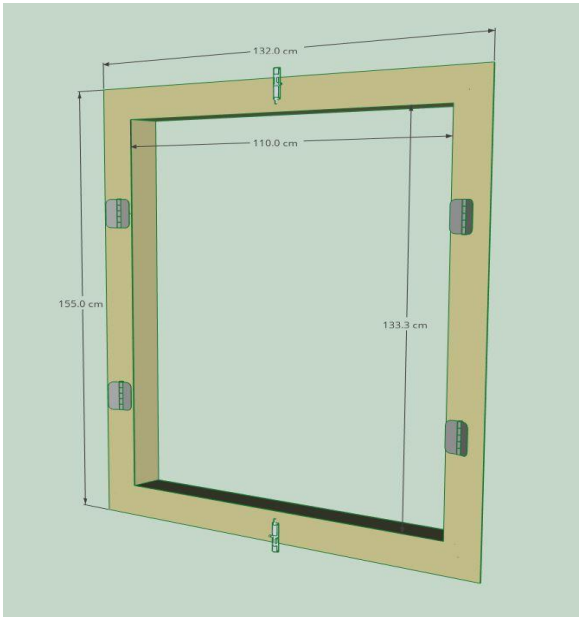


Figure 27: Cabinet door frame with hinges

Figure 28: Metal door with locks

Roof (including wooden top and metal chimney)

The roof of the smoking oven is concreted layered with a board (wooden) at the edges. The chimney (or chimneys depending on the number of ovens) are fitted into a hole at the middle of the roof. The chimney should not be too tight and narrow. It should be made of galvanised metal wide enough to fit into the hole and allow smoke to pass through it. The chimney should be sufficiently long to ensure that smoke is always directed above the immediate vicinity of the smoking area, protecting the processors from smoke inhalation and pollution.

Figure 29: Matis oven with chimney

CLEANING OF THE MATIS OVEN

Importance of cleaning the Matis oven

Cleaning is important for two reasons: preventing food poisoning (reducing spoilage) and extending the lifetime of the ovens (Tatterson & Windsor, 2001). Food-poisoning bacteria, however, can survive at cold temperatures, and food processed under unsanitary conditions can act as a carrier even when refrigerated. When fresh food comes in contact with a dirty surface, it quickly becomes contaminated and spoils. Bacteria will multiply quickly not only in the warm product but also in the dirt on the equipment. Cleaning of equipment and premises is therefore critical to avoiding contamination.

Cleaning plan

There should be a cleaning plan for the Matis smoke ovens. This should include cleaning procedures and responsible persons for cleaning the oven. Detergents and other cleaning agents and equipment used should be kept away from the oven. A checklist for cleaning the oven should be available to guide processors on how to clean.

Cleaning Procedures

The Matis ovens should be cleaned after every use when cooled down. Racks should be cleaned after smoking every batch of fish, while the rest of the oven should be cleaned weekly. Even equipment, such as knives, bowls, and aprons, should be washed after smoking. Depending on which part of the oven is cleaned, detergents, brushes, and brooms should be used to clean the smoking oven. Cleaning detergents to be used can include Vim Clorex powder, or liquid soap used for dish washing.

Racks

These should be removed and cleaned after smoking every day. Depending on the number of batches of fish smoked, the racks can be cleaned more than once a day. Cleaning should be done after every batch is smoked. Detergent should be mixed with water and used with a brush to remove the grease, oil, and fish particles from the racks. The corners of the racks should be cleaned, as they tend to collect dirt easily. Rinse with clean water and allow to dry before putting them back in the oven.

Figure 30: Racks in the oven

Figure 31: Clean racks on raised platform

After removing the racks, the shelves should also be cleaned with detergent mixed with water and soap to remove soot, grease, and oil that would have settled on the shelves. The back of the oven should also be cleaned with a long broom or brush to prevent dirt or soot from sticking to the walls.

Figure 32: Shelves in the oven

Figure 33: Oven with the racks removed and showing the back of the oven wall.

Steel Plates

It is recommended that the steel plate covering the fire be removed and cleaned once or twice a week to prevent the build-up of soot. Brush off the soot from the steel plate and dry wipe it before fixing it back in its position properly.

Figure 34: Steel plate removed and cleaned.

Figure 35: Opening where the steel plate covers.

Fire Chamber

The fire chamber should be swept, and all ashes removed after every smoking session. The build-up of ashes in the fire chamber prevents the wood from being fired up quickly.

Figure 36: Fire Chambers

Responsible Persons

The Matis oven can be cleaned by fish processors after smoking as it is simply constructed, and the oven parts can be taken out and cleaned separately and easily.

CONCLUSION

The removal of dirt and bacteria from soiled surfaces prevents fish from becoming contaminated. The simple structure of the oven makes it easy to be constructed, maintain, and clean. Materials needed for construction are locally available and can be performed by local people. Its size is also suitable for construction in the backyards of fish processors for easy access.

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CHECKLIST FOR CLEANING THE MATIS OVEN

Materials: - Water, brush, soap, broom

Cabin

1. Before cleaning the oven allow it to cool down after smoking.
2. Open the Cabin doors and remove racks.
3. Place the racks on the raised platform and not on the floor.
4. Use detergents such as Vim Clorex powder, or liquid soap (used for dishwashing) with soap and water to clean the racks.
5. Place the racks upright and leave them to dry on the raised platform.
6. Use a brush soaked with detergents and water to remove the soot from the shelves and use a towel soaked with water to remove detergents. Ensure that water is not sprayed into the oven.
7. Also use bush, water, and Vim or other liquid soap (used for dishwashing) to remove the soot from the cabin doors.

Fire chamber

1. Ashes should always be removed from the fire chamber before and after smoking.
2. After smoking, the ashes should be swept with a broom after the fire dies down.
3. The steel plate should be removed once or twice a week to remove the soot that has accumulated on it due to the fire and smoke.
4. Brush off the soot from the steel plate and dry wipe it before fixing it back in its position properly. Do not immerse in water.