Present status of smoked fish processing at Mahakanadarawa reservoir in Mihintale, Sri Lanka.

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Abstract Fish smoking has become a popular processing method in Mahakanadarawa reservoir, with the potential for substantial demand among frequent visitors to Anuradhapura. This industry generates considerable income for the local livelihoods and reduces the post-harvesting losses. Government and Non-government Organizations have recognized the necessity of expanding the smoked fish industry in this area. However, there is a scarcity of scientific information on this vital industry. This study focuses on the current state of smoked fish production in the Mahakanadarawa reservoir. A field survey was conducted to determine the types of fish and fuel wood used, the type of technology they apply, and the challenges they encounter in both storage and in the supply chain to the consumer. The majority of smoked fish processors were found to be directly connected with fishing in the Mahakanadarawa reservoir and when there is a surplus catch, fishers produce smoked fish. Although tilapia is the most abundant smoked fish in the study area, snakehead is the most popular fish with a higher commercial value. Hence, breeding strategies should be used for such commercially important species. Smoking technologies in the study area are still at an extremely rudimentary level, leading to substantial processing losses due to uneven exposure to heat and smoke. Different types of fuelwoods are used by the processors to enhance the characteristic colour and smoky aroma that enticed their buyers. These types of woods may have essential anti-oxidant and bactericidal properties in addition to their distinctive flavour, colour, and aroma, and as such, further studies are recommended. Most of the smoked fish producers do not have adequate technologies for packaging and storage their products. Majority uses paper-based cartons and discarded Styrofoam boxes. Such paper-based materials generally absorb the valuable fish oil while poorly sealed Styrofoam containers are attributed to rancidity and growth of molds. Thus, empowering them with sufficient technologies and resources may reduce postharvest losses and lead to ensuring the catering of growing consumer demand throughout the year.

Keywords: Fish processing, fish smoking, fuelwoods, post-harvesting losses

INTRODUCTION

Inland fisheries in Sri Lanka are a significant source of food production, ensuring considerable nutritional security to the country. There are over eighteen thousand individuals employed in the inland fisheries and aquaculture-based fisheries sector (MFAR 2020), hence, the government and Non-Governmental Organizations (NGOs) are often trying to develop this sector for poverty reduction and rural development. Nonetheless, there are still significant harvest losses and post-harvest losses at different stages along the supply chain to the consumer. Post-harvest losses are typically attributed to poor processing techniques, inadequate storage facilities, and quality maintenance during distribution in Sri Lanka.

Smoking is one of the oldest practices used for the preservation, flavouring, or slow cooking of fish. This technique is based on a combination of drying and deposition of naturally produced chemicals during the incomplete thermal combustion of woods. There are two major smoking methods: hot smoking and cold smoking. The hot

method is often combined with much more heat, therefore, fish are fully cooked and have a better taste with longer shelf life (Aremu et al. 2013). In this method, the temperature could vary in a range depending on the moisture and the flavour of the food (Kwaghvihi et al. 2020). Accordingly, this usually consumes a large quantity of fuelwood. In the cold smoking, the temperature essentially should be kept below the cooking temperature, primarily designed to enhance the flavour of the fish while keeping its nutritive value (Visciano et al. 2006).

Smoke is generated by incomplete combustion woods; however, all types of woods cannot be used for smoke. It depends on the hardness of the wood, the aroma of the smoke, the taste, and the ideal colour of the processed fish (Visciano et al. 2008). Additionally, high-quality smoked fish producers are concerned about the characteristic anti-microbial (usually bactericidal) and anti-oxidant abilities of the smoke (Visciano et al. 2008). These effective chemicals can be deposited on the surface providing additional protection against food poisoning bacteria (Sikorski and Kolodziejska, 2002).

Wood smoke may contain some chemicals (e.g., polycyclic aromatic hydrocarbons-PAH's, formaldehyde, dioxins, and heavy metals), which may cause adverse health impacts (Kwaghvihi et al. 2020). However, it depends on the quantity of such chemicals in the smoke, and hence, advanced technologies have been found in this industry to filtering those harmful chemicals in the smoke (e.g., electrostatic precipitation which can absorb carcinogenic compounds).

Smoked fish associated with Mahakanadarawa reservoir

Mahakanadarawa (1457 ha) is a reservoir at Mihintale in Anuradhapura District, Sri Lanka. It sustains a productive freshwater fishery and the most common food fish are Tilapia (*Oreochromis niloticus*), Snakehead (*Channa striata*), Mrigal (*Cirrhinus mrigala*), and Catla (*Catla catla*). Other species include Mas pethiya (*Puntius sarana*), Hunga (*Heteropneustes fossilis*), Climbing perch (*Anabas testudineus*), and freshwater prawn (*Macrobrachium rosenbergii*).

Fish smoking has become a popular processing method in this area (Figure 1), because such products draw great attention from local and regional consumers. These fish smoking cottage practices support considerable income generation to the local livelihoods allowing them to reduce the post-harvesting losses. Additionally, it secures their protein supplement throughout the year, and also makes it easier to storage and transport to different areas as a value-added product. As a result of the prolonging lockdown situation in the country, local people have developed a strong affinity for freshwater fishes and their value-added products. However, traditional smoking techniques in this area have yet to be upgraded with sophisticated technologies. Their traditional ovens do not usually yield quality products due to uneven temperature and smoke density, and also pose work-related health risks. Hence, the focus of this study is on the present status of smoked fish in this region, and production potential for high market value.

Fig 1 Smoked fish products available in Mahakanadarawa reservoir.

METHODOLOGY

Study Area

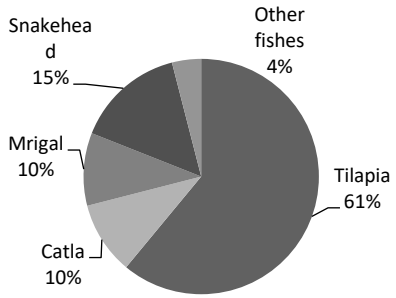
This study was conducted in July 2021 in selected villages (GN division 564: Pothana and 582 Bogahayaya) in Mahakanadarawa reservoir, Mihintale. The selection of these villages was based on the following reasons: First, they were intimately involved with fisheries at Mahakanadarawa reservoir and smoked fish supply chain. Second, the Divisional Secretariat office had highlighted the necessity for implementing an effective livelihood system for these communities. Additionally, not just in our study location, but also across Sri Lanka, there was a lack of information and published data on this vital industry.

Research design

A field survey was designed focusing on household smoked fish producers assuming that it would be capable for quantify the existing situation of the study area. The interviewed population consisted of year-round producers and seasonal producers. The semi-structured questionnaire was used for data collection through a face-to-face interview. The questionnaire covered: most abundant fishes, most suitable fire woods for an attractive product (especially for characteristic colour of the smoked fish), the technology they use, problems they face in both storage and supply chain to the consumer.

Results

In total, 14 smoking processors were actively involved with this industry in both villages. The most prevalent fish types in the Makanadarawa region were identified by analyzing a ten-kilogram sample from each processor; there are four major fish species (tilapia, snakehead, catla, and mrigal) that are common in the study area (Figure 2).



	Average Price per Kg
Tilapia (Large)	1500 LKR
Tilapia (Small)	1200 LKR
Catla	1600 LKR
Mrigal	1600 LKR
Snakehead	1800 LKR
Other fish	1000 LKR

Fig 2 Smoked fish types in a sample of ten-kilograms from each processor (left) and average price per a kilogram of smoked fish (right)

Additionally, the average price of the smoked fish was examined; Tilapia is the most prevalent fish in Mahakanadarawa, although their prices vary depending on their size. Larger tilapia have the greatest price (1500 LKR per Kg), whereas smaller ones have a lower price (1200 LKR per Kg). The most expensive smoked fish in the study region is snakehead (1800 LKR per Kg).

The fuelwood is preferred in the study area depending on the distinctive colour of the product. As a result, many smokers favour on Maila and Teak, as well as Tamarind, Palu, and Weera (Figure 3).

The majority of smoked fish producers at Mahakanadarawa do not use adequate technology and space for their fish processing units. More than half of fish processors (57%) do not gut and clean their fish in a hygienic environment (Figure 4). Their smoking houses are not at a satisfactory level; most of them are not fully covered (Figure 5), hence they are unable to regulate the smoke and heat well. Paper-based containers or discarded Styrofoam cartons (86%) are used to pack and store the processed fish. Instead of having separate storage rooms for the smoked fish, most of them (79%) keep in a separate area of their homes (Table 1)

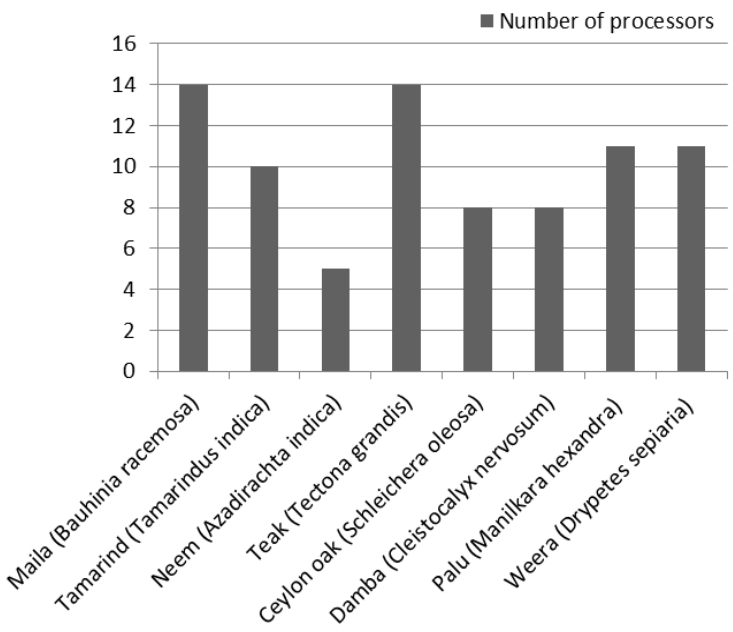


Fig 3 Fuelwoods often used for smoked fish processing in Mahakanadarawa

Fig 4 Non-hygienic gutting and cleaning techniques in the study area.

Fig 5 Poorly designed smoking units in the study area.

Table 1 Condition of the fish processing units, smoking houses and the storage facilities at Mahakanadawa.

Type of the smoking house	Fully covered 22%	Semi covered 64%	Open 14%
Gutting and cleaning space	Separate closed space 29%	Separate open space 57%	No specific space 14%
Storage	Storage room 7%	Separate space at home 79%	No specific space 14%
Packing	Cardboard/ discarded Styrofoam boxes 86%	Open floor 14%	Advanced packing methods 0%

Fish processors are mostly (86%) located along the main road, with their own retail shops focusing on frequent visitors at Anuradhapura. In addition to their own retail outlets, some processors carry their products to other areas where tourists are most likely to be located. There is already number of wholesalers that have joined with, offering favourable prices to fish processors. However, their availability in hotels and supermarkets is still limited (Figure 6).

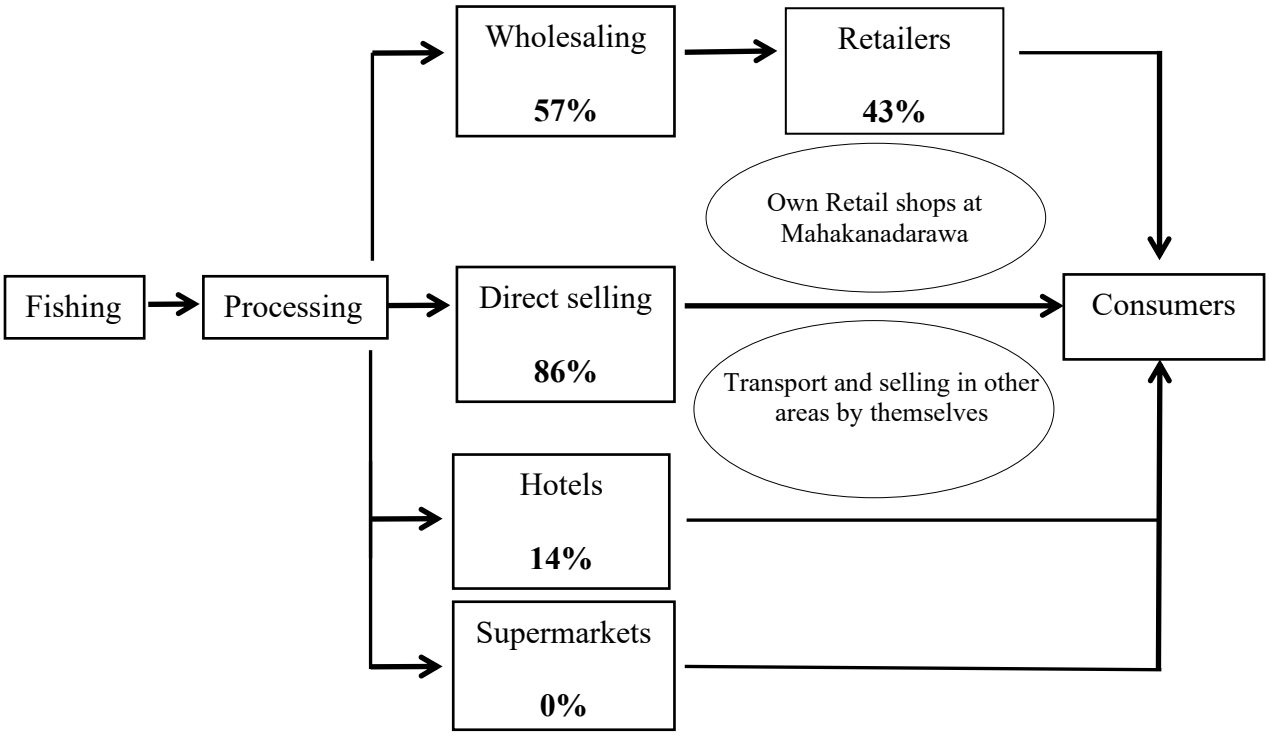


Fig 6 The supply chain of the processed smoked fish in the study area

DISCUSSION

Fish are highly susceptible to deterioration and therefore usually suffering from post-harvest losses which can cause a significant impact on fishing communities (Ahmed 2008). Smoking is a preservation technique to increase the shelf-life of fish due to dehydration, anti-microbial and anti-oxidant properties of the smoke. Smoke and related techniques often give characteristic flavour, odder, colour, and texture to the food. Smoked fish processing is popular since recently in the study region, Mahakanadarawa reservoir. We observed that majority of smoked fish processors were

directly involved with fishing in the Mahakanadarawa reservoir; they used to process smoked fish when they were unable to reach a fair market price for their fresh meats as a result of surplus catch. The necessity to expand the smoked fish industry in Mahakanadarawa has recently drawn the attention of government and non-government bodies looking into improve local livelihood, hence, the findings of our study might be useful for their operations.

Consumer preference of the smoked fish

The abundant smoked fish in the study area is tilapia (Figure 2); they are particularly susceptible to post-harvesting losses since the majority of them are too small for selling in the market in fresh form. Average 4-5 kilograms of fresh flesh needed to produce one kilo of smoked tilapia, majority of the weight reflects the non-consumable head area in the final product. Even though smoking is effective in reducing post-harvesting losses in tilapia, the non-consumable heads still contribute to waste. Conversely, snakehead (Sinhala name: Lula) is the most preferred fish by the consumers and has high commercial value for the processed product (Figure 2). This fish is reputed as a rich source of nutrients for breastfeeding mothers. Though protein composition is identical to tilapia, snakeheads are rich in calcium, phosphorous, and iron (Wimalasena and Jayasuriya 1996). However, the snakehead harvest is considerably low in the Mahakanadarawa reservoir, and hence, introduction of enhancement strategies should be considered. Although, catla (*Catla catla*), mrigal (*Cirrhinus mrigala*), mas pethiya (*Puntius sarana*), hunga (*Heteropneustes fossilis*), and kavaiya or climbing perch (*Anabas testudineus*) are used for making smoked fish, consumer preference is comparatively poor.

Smoked fish technologies at Mahakanadarawa reservoir

Traditional fish processors in this region still rely on extremely rudimentary technologies, mainly they learnt from their neighbouring fish processors. They used to stack fish on wire meshes and smoking them over an open fire, and therefore, most of them were not entirely covered as a smoking house (Table 1). Consequently, substantial processing losses might be detected as a result of the uneven exposure to heat and smoke. Their conventional ovens cannot regulate the heat and smoke, resulting under-cooked or over-cooked fish. To reduce the production losses and improve the quality of the smoked fish, traditional processing methods should be upgraded to innovative technologies. However, adapting to new technologies is dependent on their literacy level as well as infrastructure resources such as electricity, space, water supply. Majority of fish processors in this rural area are still not economically strong enough to afford such technologies and machines. Therefore, government and non-governmental bodies have to assist them. Provision of adequate training on such technologies, after-sale repairs, and machinery maintenance should all be taken into consideration.

Types of fuelwoods utilized in the study area

The type of fuelwoods directly affects the characteristic flavour, odder, and appealing colour of the final product (Kwaghvihi et al. 2020). Smokers in the study region favour Maila (*Bauhinia racemosa*), Tamarind (*Tamarindus indica*), Neem (*Azadirachta indica*), Teak (*Tectona grandis*), Ceylon oak (*Schleichera oleosa*), Damba (*Cleistocalyx nervosum*), Palu (*Manilkara hexandra*), and Weera (*Drypetes sepiaria*) for enhancing golden-redness colour and smoky aroma which attract their customers (Figure 3). Ceylon satinwood (*Chloroxylon swietenia*) and Mexican olender (*Thevetia peruviana*) are not used since they give unappealing contrast (typically black) to the fish. In addition to characteristic flavour, colour, and aroma, the type of woods is important because of their anti-oxidant and bactericidal properties. However, in Sri Lanka, such properties of fuelwoods are still inadequately studied.

Many studies have revealed that wood smoke contains a large number of compounds (e.g., polycyclic aromatic hydrocarbons-PAHs and nitrosamines), which are known to be harmful to human health (Stołyhwo and Sikorski 2005). The concentration of such carcinogenic compounds found in smoked fish depends on the type of wood used, the technique of smoking, and the amount of time the fish is exposed to the smoke. Moreover, such smoke may consist of harmful gases (e.g. CO_2, CO, NO_2, SO_2) as well as volatile organic compounds, all of which may cause serious occupational health issues (Zhang and Smith 2003). Hence, there has been growing interest in

introducing new technologies to the smoked fish processing industry (e.g., fuel efficient kilns with gas filters).

Food wastage in the supply chain

Most smoked fish producers are directly attached to the main road (i.e., their own small-scale retailing shops) focusing on local tourists, who frequently visit Anuradhapura and Mihintale. The processing of smoked fish is predominantly undertaken by women, while most men are engaged in fishing. Women spent full-time processing and selling smoked fish. However, they do not utilize particular processing houses or areas for gutting, splitting, and washing (Table 1). Consequently, in some situations, there are considerable losses due to predatory birds (mainly by crows). In addition, discarded waste of fish may attract such scavenging birds. Such fish wastes provide ideal breeding ground for houseflies (maggots) which are important pests of the final product.

Most fish processors do not have adequate space to store their products, and also use low-quality containers for storage and packing (Table 1). Thus, considerable losses have been observed mainly because of ants. Some processors utilize paper-based cartons (cardboard boxes), which often absorb the oil from the fish. The most common packing medium is discarded styrofoam (regiform) cool boxes and the products stored in these poorly sealed containers are deteriorated due to high rate of mold growth and rancidity (i.e., hydrolysis of oils when exposing to air and light) of the stored fish (Aremu et al. 2013). Hence, assistance to develop their storage facilities and provide them with moisture and oil resistant packing materials may be important to reduce the losses at the storage and transport. Additionally, it helps to improve its marketing on the retail display and provides an additional business potential at supermarkets (Worsfold et al., 2004).

How to archive good marketability

Smoked fish consumption is becoming popular in the studied area and potentially significant demand is likely to be from regular visitors to Anuradhapura. However, several factors should be improved in terms of supply and demand. Fish production in this reservoir is high during some seasons, especially during the periods of low water level but they do not have adequate space to process and store surplus catch. With sufficient storage facilities, fish processors may be able to maintain regular supplies for large-scale customers. Wood supply is becoming increasingly scarce in this area, hence, adequate wood supply or fuel-efficient kilns can be introduced. Despite the fact that funding agencies intend to introduce certain smoking units, most smokers feel that they will not use them since such products lack the characteristic colour of the smoked fish. They also claim that it would be detrimental to consumer preference for traditional products. Hence, it is suggested that appropriate legal protection for extracting fuelwoods be provided. Most people living in this rural area are having difficulty upgrading their smoking houses, processing rooms, and storage rooms, as well as obtaining enough water (e.g., borehole water supply). Providing them with financial support may enable them to develop such an infrastructure. Because the Anuradhapura is a popular tourist destination for domestic and international visitors, supermarkets have already established themselves for these consumers. Nevertheless, smoked fish products are not accessible at those food stores (Figure 6). Supplying smoked fish straight to supermarkets in proper packaging may be important to fetch at a higher price. At this point, various forms of value addition (e.g., pepper) can be coupled with this product to entice customers.

CONCLUSION

Fish smoking has a long tradition as a method of preserving and flavouring fish. In the study area, fishes such as snakehead have strong consumer preference over other species. Thus, enhancement strategies, through proper scientific studies should be established to improve their production. Most of the smoked fish producers still utilize basic technologies which may result in significant losses during processing, packing, and storage. Hence, advanced technologies should be introduced to reduce processing losses and keep a year-round supply.

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