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POLICY RECOMMENDATIONS AND SMALLHOLDER GUIDELINES FOR IMPROVED FISH SMOKING SYSTEMS

POLICY RECOMMENDATIONS AND SMALLHOLDER GUIDELINES FOR IMPROVED FISH SMOKING SYSTEMS

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PREPARATION OF THIS DOCUMENT

This document showcases the outcomes of investigations carried out in Ghana into the efficacy of the FAO-Thiaroye fish processing technique (FTT) to yield smoked products with low polycyclic aromatic hydrocarbon (PAH) levels. Over the past 15 years, scientific evidence has shown the occurrence of high PAH levels in traditionally smoked fish. The United Nations Food and Agriculture Organization (FAO) developed the FTT to address the concern. The innovation was introduced in Ghana in 2014. The efficacy of FTT to yield products with low and safe PAH levels was evaluated from a risk assessment perspective in Ghana by the University of Ghana and Ghent University with the support of FAO. Following the dissemination of the study results in September 2016, a second phase of research was recommended to allow for a more comprehensive risk assessment for PAH in smoked fish and to provide policy recommendations and smallholder guidelines for fish smoking, under the support of the project FMM/GLO/103/MUL "Enable women to benefit more equally from agri-food value chains". Consumer acceptability of FTT products was also evaluated. This document presents the findings of the second phase (Phase II) of the study and, where required, a consolidation of data from both study phases. The document also presents policy recommendations and smallholder guidelines proposed for fish smoking.

The document is presented in two parts. Part 1 details the study, its findings and recommendations. Small-holder guidelines based on the study findings are presented in Part 2.

ABSTRACT

In developing countries, traditionally smoked fish are highly contaminated with polycyclic aromatic hydrocarbons (PAHs). This is mainly due to the use of wood-fueled traditional kilns for processing the commodity. An improved kiln, the FAO-Thiaroye Technique (FTT), has been introduced to address the concern and was assessed in Ghana for its efficacy. It was found that the FTT drastically lessens PAH contamination in smoked fish and also affords public health protection against risks associated with that hazard. The findings call for policy actions to underpin efforts for improving the safety and market access of smoked fish in Ghana and other low- and middle-income countries.

CONTENTS

ABBREVIATIONS AND ACRONYMS

ANOVA	analysis of variance
BaP	benzo(a)pyrene
BMDL	benchmark dose level
EFSA	European Food Safety Authority
EU	European Union
EUML	EU maximum limit
FAO	Food and Agriculture Organization of the United Nations
FTT	FAO-Thiaroye fish processing technique (and kiln)
GC-MS	gas chromatography mass spectrometry
IAFI	International Association of Fish Inspectors
MOE	margin of exposure
PAHs	polycyclic aromatic hydrocarbons
QDA	quantitative descriptive analysis
RASFF	Rapid Alert System for Food and Feed
US	United States of America
USD	US dollar

EXECUTIVE SUMMARY

Smoked fish is an important animal protein source in Ghana. However, the traditional methods by which the commodity is produced exposes consumers to high levels of polycyclic aromatic hydrocarbons (PAHs), which are known to be carcinogenic. This predisposes consumers to potential health challenges linked to PAH exposure in food. The extent to which this is the case in Ghana was evaluated by screening smoked fish from informal markets in the country for the hazard. Since the FAO-Thiaroye fish processing technique (FTT) has been demonstrated to address the PAH problem, it was further evaluated against traditional kilns. Consumer acceptance of smoked products from the FTT versus the traditional kilns was also evaluated. The findings demonstrated the high PAH levels associated with traditional kilns, and the efficacy of the FTT in that regard. Consequently, a risk assessment showed that should the FTT be used instead of traditional kilns to smoke fish in Ghana, consumers will be protected from PAH public health risks related to smoked fish consumption. It was also found that, overall, consumers are likely to accept products from the new kiln because they did not show a significant preference for traditional kiln-smoked fish products.

Highlights of policy recommendations and smallholder guidelines proposed from the findings are as follows:

1. Policy recommendations:
    - Government commitment to support a national programme for the dissemination of FTT in pursuance of Sustainable Development Goals 3, 8 and 12.
    - Government initiation and support for public education on the health impact of PAHs, the link between traditional smoking methods and exposure to PAHs, and how improved smoking kilns, such as the FTT, help to address the concern.
    - Standards setting and provision of support for the establishment and/or resourcing of accredited laboratories for compliance testing.
    - Enforcement of regulatory standards.
    - Creation of market incentives to encourage the production of smoked fish using improved kilns.
    - "Greening" the smoked fish value chain by shifting from wood-fuel to renewable energy sources such as biochar.
    - Include the development and use of improved kilns in national research and academic and educational agenda.

2. Guidelines for smallholders (a guideline for processors has been proposed and provides information on the following):
    - How traditional fish smoking practices affect the safety of products as well as the health and income of processors.
    - How the FTT can help improve product safety and the health and income of processors.
    - How smallholders can obtain best value from their enterprise by adopting and committing to responsible use of the FTT.

PART 1: STUDY BACKGROUND AND FINDINGS

1. BACKGROUND

Smoked fish is a major source of animal protein in Ghana (FAO, 2014a; Atta-Mills *et al*., 2004). However, traditional methods for producing the commodity expose consumers to cancer risks. This is because the methods rely on burning firewood as fuel to cook and flavour fish on one of two main types of kilns: the Chorkor smoker and metal drum kiln. This practice of using firewood as fuel to preserve or process food by smoking is known to result in high amounts of carcinogenic compounds called polycyclic aromatic hydrocarbons (PAHs) in the food (Gehle, 2009; Stolyhwo and Sikorski, 2005). Studies have linked the occurrence of PAHs in smoked fish in Africa to the practice of smoking fish (Olabemiwo *et al.*, 2011; Palm *et al*., 2011).

PAHs are strictly regulated on international markets such as the European Union (EU), which is a key outlet for Ghanaian fishery products. Data from the Rapid Alert System for Food and Feed (RASFF) show that smoked fish from Africa are frequently rejected at EU borders due to unacceptable PAH levels. This contributes to postharvest losses of the commodity (Penarubia *et al*., 2017). The listing of such rejections on the RASFF negatively impacts the credibility of the exporting countries as far as the supply of safe food is concerned. Beyond the immediate economic loss arising from the destruction of such non-conforming products, even more economic injuries are incurred with respect to lost market access and reduced consumer confidence. In 2003, it was estimated that one in every four air-freight consignments of smoked fish entering the United Kingdom from Africa were detained, from which quantities with a retail value of up to USD 640 000 were destroyed per detained unit (Ward, 2003). Côte d'Ivoire lost about USD two million as a result of a self-ban of smoked fish exports following RASFF alerts (Penarubia *et al*., 2017). Between 2013 and 2016, Ghana recorded ten RASFF notifications of unacceptable PAH levels in smoked fish, of which five suffered border rejections.

The use of traditional kilns for fish smoking, therefore, presents the dual demerits of compromising public health and reducing market access for the products. Consequently, in 2017, the International Association of Fish Inspectors (IAFI) requested governments (especially those in developing countries) to prioritize the reduction of PAHs health risks associated with the consumption of smoked fish produced on the continent.[1] The statement noted that while the average exposure of consumers in the EU to PAHs[2] averaged 3–4 ng/kg body weight/day from all sources, the estimated average from smoked fish only in West Africa was close to ten times the EU exposure.

Although the maximum limits for PAHs have not been established by the Codex Alimentarius Commission, guidelines for reducing PAHs have been developed through different instruments. Section 12 of the Code of Practice for Fish and Fishery Products – on smoked fish, smoke-flavoured fish and smoke-dried fish (CAC/RCP 52-2003) – provides examples of technological guidance to be used for developing control measures and corrective actions. The Code of Practice for the Reduction of Contamination of Food with PAH from Smoking and Direct Drying Processes (CAC/RCP 68-2009) was an important initial text for national authorities and manufacturers, and was followed by other work in this area. The last and most relevant instrument is the Standard for Smoked Fish, Smoke-flavoured Fish and Smoke-dried Fish (CODEX STAN 311–2013), which was adopted in 2013 and amended in 2016. These Codex texts identify the use of wood fuels, distance between food being smoked and heat source, fat content of food, smoking duration, smoking temperature, and cleanliness and maintenance of equipment as important parameters affecting the occurrence of PAHs on products during smoking. By their design, traditional kilns enhance the possibility of these parameters to facilitate the occurrence of PAH in smoked products.

[1] http://www.iafi.net/resources/Documents/IAFI%20Statement%20on%20PAH%20FinalEN.PDF

[2] Specific reference was made to benzo(a)pyrene, which is a key regulatory marker of PAHs in food. The other markers are chrysene, benzo(a)anthracene and benzo(b)fluoranthene.

To address this concern, the Food and Agriculture Organization (FAO) of the United Nations – in collaboration with the Ghana office of the Stichting Nederlandse Vrijwilligers (Netherlands Development Organization) – introduced an improved fish smoking technology called the FAO-Thiaroye fish processing technique (FTT or FTT-Thiaroye) in Ghana in 2014. The FTT was specifically designed in Senegal under the aegis of FAO for producing smoked fish with low PAH levels (FAO, 2014b; Ndiaye *et al*., 2015), and its features leverage the Codex guidelines mentioned earlier (i.e. CAC/RCP 52-2003; CAC/RCP 68-2009; CODEX STAN 311–2013).

The efficacy of FTT in the aforementioned regard was investigated through a collaborative study conducted by the University of Ghana and Ghent University with the support of FAO (Bomfeh *et al*., 2016). The findings demonstrated that fish smoked using the FTT had significantly lower levels of PAHs than those smoked with traditional kilns, regardless of the fish species or product type (i.e. smoked-soft or smoked-dry product[3]). Additionally, PAH levels in FTT products were lower than EU regulatory limits[4], whereas traditional kiln products exceeded the limits significantly.
The findings were presented at a webinar organized by the FAO-led Food Safety Technical Network in September 2016 at the FAO headquarters in Rome. This forum underscored the significance of the work with regards to meeting food safety objectives in Ghana and in other countries where hot-smoking of fish is practiced. The forum recommended further studies to allow a wider coverage of market sampling and a consumer survey to be conducted in Ghana, and to support a comprehensive risk assessment of PAHs. This was done to strengthen policy advice and develop small-holder guidelines for fish smoking. A survey of consumer acceptance of fish smoked with the FTT was also recommended. This led to the commission of the second phase (Phase II) of the study under the project FMM/GLO/103/MUL "Enable women to benefit more equally from agri-food value chains". Details of the design and findings of the study are herein presented.

1.1 Phase II study objectives

1. To determine smoked fish consumption habits in the Brong Ahafo and the Upper East Regions of Ghana;
2. To determine the levels of PAHs (benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene and chrysene) in smoked *Sardinella* sp. ("herrings"[5]), barracuda (*Sphyraena* sp., called "odoe" in parts of Ghana) and tilapia (*Oreochromis* sp.) from selected informal markets in the Greater Accra, Brong Ahafo and the Upper East Regions of Ghana;
3. To evaluate consumer acceptability of smoked fish processed using the FTT and Chorkor smoker;
4. To conduct a food safety risk assessment for PAH levels in smoked fish in Ghana using the margin of exposure approach, with consolidated data from study Phases I and II; and
5. To make policy recommendations and propose smallholder guidelines based on the consolidated findings of the entire study (Phases I and II).

[3] There are two forms of smoked fish products in Africa: Smoked-soft and smoked-dry. They differ principally in their final moisture content. Smoked-soft products typically have a moisture content above 30 percentand are meant to be consumed within a few days, whereas smoked-dry products typically have a moisture content below 20 percentand have a shelf life that can exceed six months.
[4] EU PAH limits are: BaP -2 µg/kg and PAH4 – 12 µg/kg (EC. Regulation No. 835/2011, amending No. 1881/2006). PAH4 is the sum of benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene and chrysene.
[5] *Sardinella* sp. are colloquially called herring in Ghana.

2. METHODOLOGY

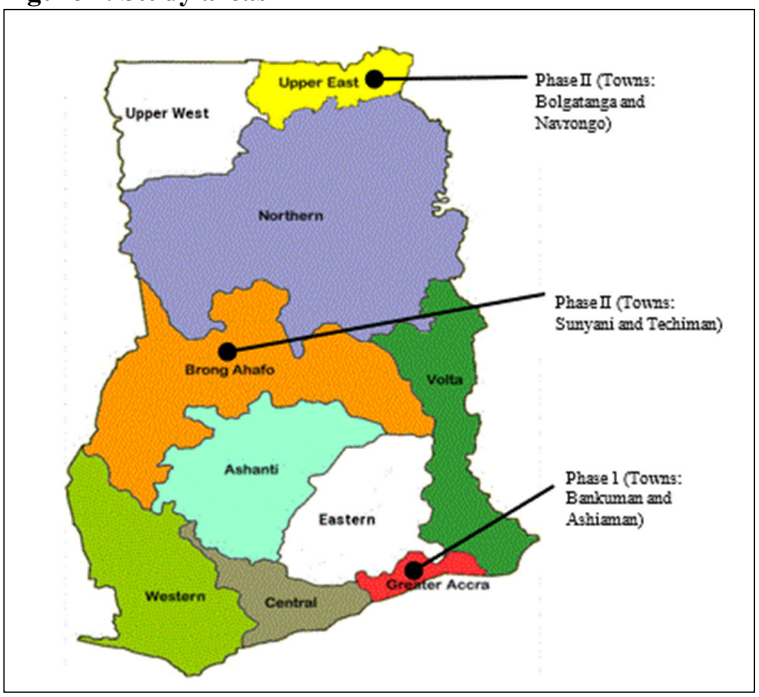
2.1 Overview

Consumer surveys were conducted to determine smoked fish consumption habits in two inland regions of Ghana. Samples of smoked herring, barracuda and tilapia were then purchased from informal markets in each region and tested for PAH levels. Data from the survey and PAH tests were used for food safety risk assessment for the hazard using the margin of exposure approach. Consumer acceptability of the Chorkor smoker and FTT products were tested by soft-smoking fresh chub mackerel (*Scomber japonicus*) with each kiln, and subjecting the products to a quantitative descriptive test and a consumer preference test.

2.2 Study area

In Phase I of the study, consumer surveys and informal market fish sampling were carried out in the Greater Accra Region of Ghana (a southern, coastal region of the country). In Phase II, the survey and sampling were conducted in the Brong Ahafo and Upper East Regions (inland regions, see Figure 1). Additional market sampling was done in the Greater Accra Region to supplement data from Phase I. The focus on the three regions allowed for the coverage of the northern, central and southern zones of the country vis-à-vis fish consumption habits and informal market sampling.

Figure 1. Study areas



2.3 Details of supplementary consumer survey

Using a semi-structured questionnaire, a cross-sectional survey was conducted in Sunyani and Techiman in the Brong Ahafo Region, and in Bolgatanga and Navrongo in the Upper East Region. From each community, 150 willing respondents were recruited to participate in the survey. Sample sizes were determined using the OpenEpi® tool. Survey questions focused on the frequency of smoked fish consumption and the quantities thereof. Portion size estimations were facilitated by showing respondents 50 g of smoked-dry herring, based on which respondents estimated their usual portion sizes as multiples of the exhibit.

2.3.1 Determination of quantities of fish consumption per day

For each fish commodity, the quantity consumed per day (in g/day or kg/day) were calculated using data on frequencies of consumption and reported quantities usually consumed in a day. For example, for a consumer who reported consuming 100 g of smoked-soft herrings once a week, the consumption per day was calculated as 100 g x 1/7 day = 14.3 g/day (or 0.0143 kg/day). This procedure was used to calculate the daily consumption of each product for each consumer in each region. Mean, median and 95th percentile values for the g/day and kg/day values for each region and across regions were then computed using the appropriate Microsoft Excel® functions.

2.4 Supplementary informal market sampling

Samples of smoked fish (smoked-soft and smoked-dry herrings and odoe; smoked-dry tilapia) were purchased from informal markets in Accra (Adabraka and Madina), Sunyani, Techiman, Bolgatanga and Navrongo. Five samples of each product were purchased from each market in the Brong Ahafo and Upper East Regions. For Greater Accra, two more samples of each fish were purchased to supplement the results of the three samples collected in Phase I.

2.5 Laboratory analysis for PAHs

For each field sample, ten fishes were pooled and homogenized using a Warren® Heavy Duty Commercial blender. Homogenates were vacuum packed in units of 250 g with the Henkelman® JUMBO 42 vacuum packaging machine and kept frozen at -22ºC, and analysed by an ISO 17025-accredited gas chromatography mass spectrometry (GC-MS) method in a commercial laboratory (SGS, Antwerp, Belgium).

2.6 Sensory evaluation

Two sensory tests were conducted in sequence to determine consumer acceptability of chub mackerel smoked-soft produced using the FTT and Chorkor smoker. The first test was a quantitative descriptive analysis (QDA®) that focused on highlighting the differences in sensory attributes of the products, followed by a determination of the degree to which the attributes differed in intensity. This was followed with a consumer acceptance test that evaluated which product consumers preferred in light of the differences revealed in the QDA®. All sensory tests were conducted in the Sensory Science Laboratory of the University of Ghana.

2.6.1 QDA® assessment protocol

A 14-member trained panel from the Sensory Science Laboratory of the University of Ghana evaluated the samples. Assessors first described and scored samples of traditionally smoked-soft chub mackerel bought from the informal market. During that exercise, assessors agreed on a list of attributes that described the product.

The check-all-that-apply method was used to establish the applicability of listed attributes to the test product. In the check-all-that-apply method, each assessor evaluated the product using the agreed attribute list. Only attributes that were used consistently by half or more of the panel were included in the final list of attributes for the evaluation. The final selected attributes were appearance, aroma, flavour, texture (in hand and in mouth) and aftertaste.

Sample preparation and serving

FTT products were labelled INS, whereas Chorkor smoker products were labelled QPR. The tail and head portions of fish were cut off. The remaining sections were cut transversely in two portions, each of which was split along the backbone into two halves and de-boned.

Assessors were served a portion of each product on a nine-inch white disposable plate. Each assessor was also given a disposable fork, knife, tissue and bland biscuit crackers (to use as palate cleanser between sample tastes). Samples were served to assessors in a randomized balanced order using the Williams' Design in Compusensecloud Service as a Software (SaaS®, Guelph, Canada). Table 1 shows the details of samples served to assessors.

Table 1. Sample details

Sample source	Serving description	Code
Chorkor smoker	Quantity: 3 pieces / Weight: 80 g	QPR
FTT	Quantity: 3 pieces / Weight: 80 g	INS

Scoring

Intensities of individual attributes were scored on a 15-cm intensity line scale using Compusense Cloud® (Guelph, Canada) with 15-cm mark as the highest intensity of sensory perception.

Statistical analysis

The data was analysed with the sensory product characterization function in XL-Stat (Addinsoft®, France). A two-way analysis of variance (ANOVA) with interaction between assessor and product was used.

2.6.2 Consumer acceptance test

Ninety Ghanaians from the University of Ghana community volunteered for the test by completing a recruitment questionnaire. The selection criteria were willingness to participate, not being allergic to seafood, and that one be a regular consumer of smoked chub mackerel.

Sample preparation followed the same procedure used for the QDA®. Using a nine-point hedonic scale – with 1 being 1 "Dislike Extremely" and 9 being "Like Extremely" – assessors scored the appearance, texture, flavour, aftertaste and overall liking of smoked-soft chub mackerel processed using the FTT and the Chorkor smoker.

2.7 Food safety risk assessment

The margin of exposure (MOE) approach described by the European Food Safety Authority (EFSA) was used to estimate the degree of concern necessary for managing potential PAHs-related health risks associated with smoked fish consumption in Ghana. MOE is a dimensionless number representing the ratio between the lower limit of the benchmark dose level ($BMDL_{10}$) for a given PAH to the dietary exposure of consumers to the same hazard (EFSA, 2008). Thus,

$$MOE = BMDL_{10} / \text{dietary exposure} \quad (1)$$

The Joint FAO/World Health Organization (WHO) Expert Committee on Food Additives, following a review of available data on occurrence and toxicity of PAHs, derived $BMDL_{10}$ values of 100 µg/kg bw/day for benzo(a)pyrene (BaP). EFSA also uses 340 µg/kg bw/day for PAH4 (EFSA, 2008). These $BMDL_{10}$ values were used for MOE calculations in this study.

2.7.1 Estimating dietary exposure

Dietary exposure to PAH was estimated as:

Dietary exposure = (Q x C) / bw (2)

where: Q = quantity of product consumed per day (kg/day)
C = concentration of PAH in product (µg/kg)
bw = body weight (using an estimated adult body weight of 60 kg)

For children, dietary exposure was estimated as one-third the adult exposure.

For each consumer, the value of Q for each product was calculated from the survey data (section 2.3.1). Also, the value of C was obtained from BaP and PAH4 concentration data from the informal market sampling (section 2.4). The values of Q and C were substituted into equation (2) to obtain the dietary exposure of BaP and PAH4 in each product for each consumer. The resulting individual dietary exposure values were substituted into equation (1) to obtain the MOE of each product for each consumer.

The mean, median and 95th percentile dietary exposure and MOE for all consumers in each survey region and across all survey regions were computed using the corresponding Microsoft Excel® functions.

MOEs less than 10 000 were interpreted as denoting a potential health concern for which risk management action may be required and vice versa (EFSA, 2008).

3. RESULTS

3.1 Consumer survey

3.1.1 Demographics

Overall, more females (61 percent) than males (39 percent) participated in the survey. The majority were aged between 30 and 39 years (33 percent), and had a tertiary level of education (30 percent) (Figures 2 and 3). Table 2 provides details of the demographic characteristics of respondents from each region.

Figure 1. Gender of respondents across regions

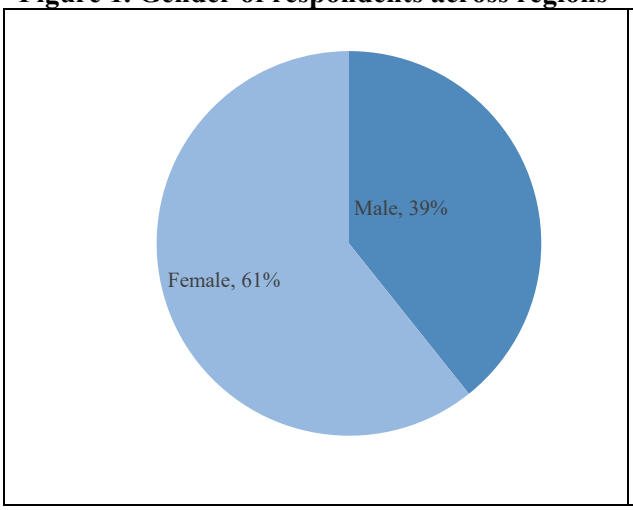


Figure 2. Age of respondents across regions

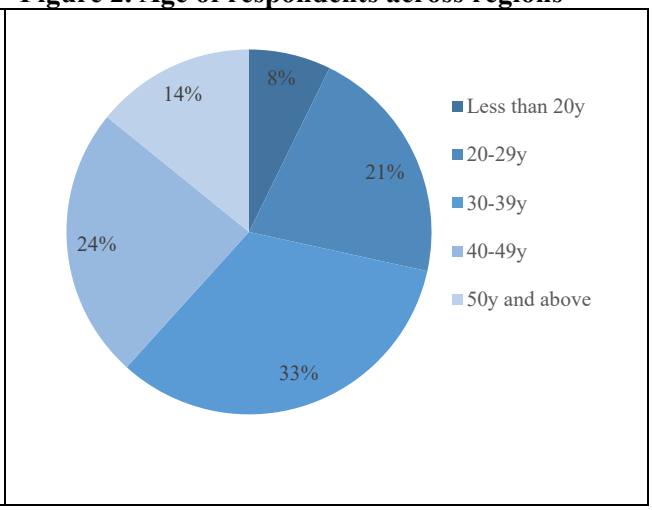


Figure 3. Educational level of respondents across regions

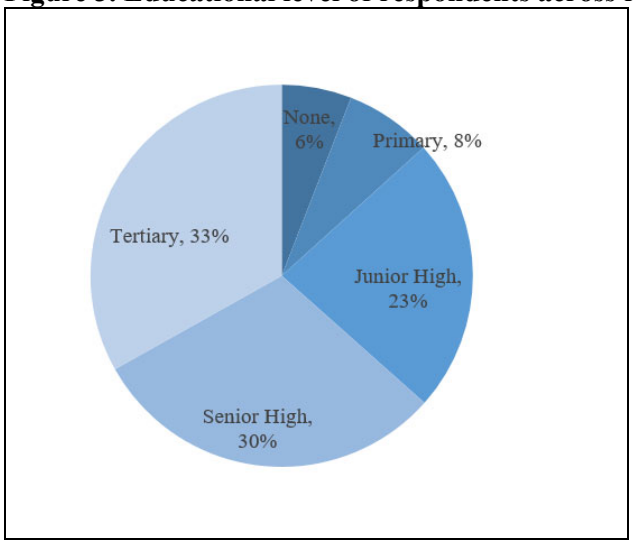


Table 2. Summary of demographic information across regions

Demographic		Number of respondents		
		Greater Accra Region (Phase I data, n=212)	Brong Ahafo Region (n=300)	Upper East Region (n=300)
Gender	**Male**	76	115	128
	Female	136	185	172
Age	**Less than 20**	21	21	17
	20–29	50	42	80
	30–39	70	85	115
	40–49	39	94	63
	50+	32	58	25
Level of education	**None**	30	1	17
	Primary	16	20	24
	Junior High School	50	57	82
	High School	64	128	54
	Tertiary	52	94	123

3.1.2 Consumption of smoked fish

The reported quantities of smoked fish consumed across the regions were particularly high (Table 3). Consumption in the Greater Accra Region was higher ($p<0.05$) than consumption in each of the other two regions. Across the regions, smoked herring was consumed more frequently and in greater quantities than barracuda (Table 3). This could be partly due to the greater availability of the former than the latter. For example, during the informal market sampling period, smoked-soft barracuda was not found on the markets in the Upper East and Brong Ahafo regions.

Table 3. Reported quantities of smoked fish consumed across regions

Regions	Measure	Smoked-soft herring (kg/day)	Smoked dry herring (kg/day)	Smoked-soft barracuda (kg/day)	Smoked-dry barracuda (kg/day)	Total (kg/day)
Greater Accra Region	Mean	0.045	0.040	0.018	0.019	0.121
	Median	0.043	0.021	0.007	0.005	0.103
	95th percentile	0.150	0.122	0.065	0.074	0.257
Brong Ahafo Region	Mean	0.018	0.009	0.003	0.012	0.043
	Median	0.006	0.005	0.003	0.014	0.036
	95th percentile	0.065	0.021	0.005	0.028	0.090
Upper East Region	Mean	0.033	0.016	0.003	0.007	0.059
	Median	0.022	0.005	0.003	0.005	0.054
	95th percentile	0.086	0.065	0.006	0.021	0.138
All regions	Mean	0.030	0.020	0.007	0.012	0.069
	Median	0.021	0.014	0.003	0.005	0.052
	95th percentile	0.086	0.065	0.043	0.028	0.179

3.2 PAH levels in smoked fish on informal markets

The average PAH levels in products from each market are shown in Tables 4, 5 and 6. Across the markets, the range of BaP was 14–87 µg/kg, higher than the EU maximum limit (ML) of 2.00 g/kg for the compound. PAH4 values also ranged from 180 to 790 µg/kg, as shown in Tables 5 and 6. These values exceed the EU ML of 12 µg/kg by up to 66 times. Reference is made to EU standards because the Ghana Standards Authority presently adopts those standards for fish exports to the EU (GSA, 2014).

Smoked-soft products had lower PAH levels than their smoked-dry forms across all markets (Figures 4 and 5), possibly due to the longer exposure of the latter to smoke and heat during processing.

Overall, variability in informal market PAH data was high because the product sources and quality characteristics on each sampling day could have been different (lack of traceability in informal food trade). Traditional processing methods have not been standardized, –hence consistent product characteristics are not guaranteed.

Figure 4. BaP levels in smoked-soft vs smoked-dry herring

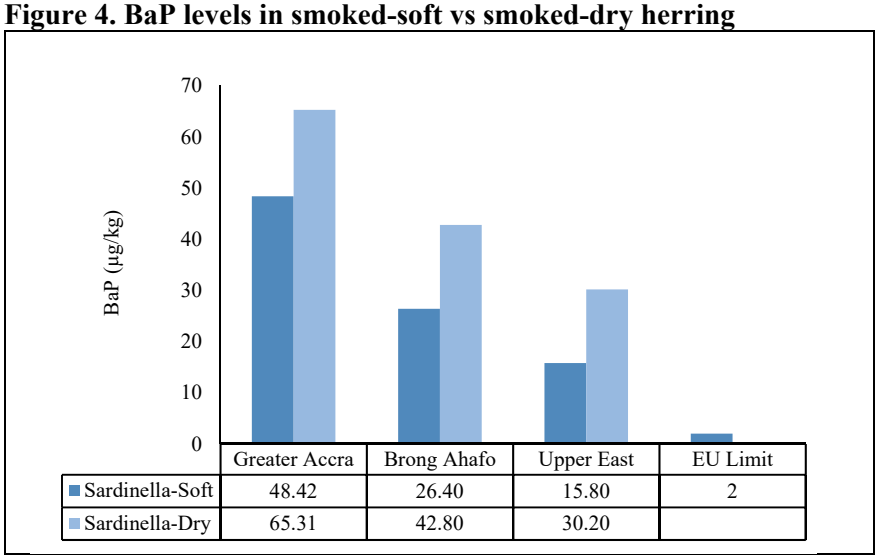


Figure 5. PAH4 levels in smoked-soft vs smoked-dry herring

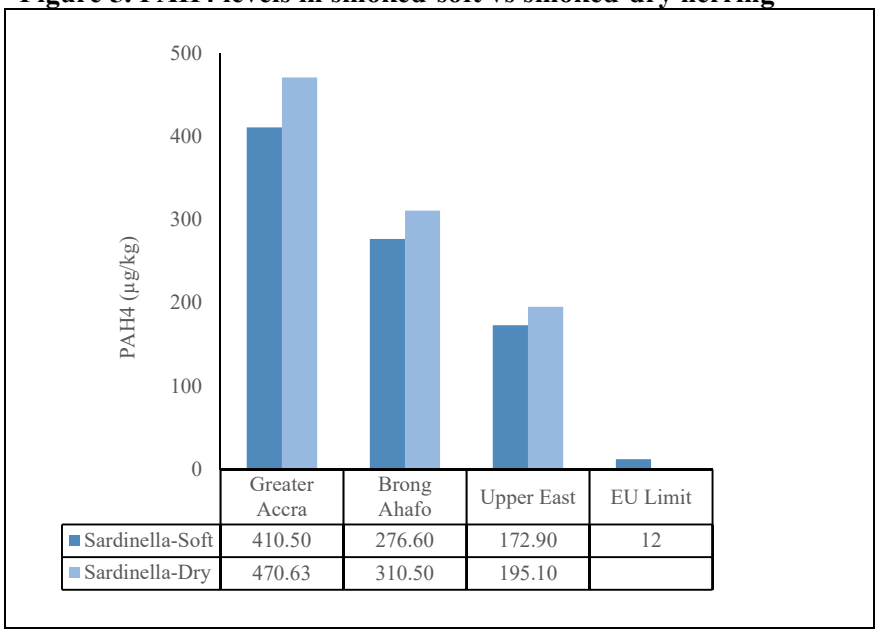


Table 4. PAH levels in smoked herring from selected informal markets in Ghana

	Smoked-soft				Smoked-dry			
	BaP (µg/kg)		PAH4 (µg/kg)		BaP (µg/kg)		PAH4 (µg/kg)	
Adabraka	48.58 ± 13.68		407.80 ± 65.14		62.24 ± 8.08		434.46 ± 120.17	
Madina	48.26 ± 11.29		413.21 ± 67.28		68.38 ± 24.12		506.80 ± 220.50	
Sunyani	15.80 ± 1.17		180.40 ± 8.59		29.80 ± 1.94		288.20 ± 8.59	
Techiman	37.00 ± 1.41		372.80 ± 18.76		55.80 ± 3.82		332.80 ± 32.22	
Navrongo	17.00 ± 2.10		169.80 ± 13.12		31.60 ± 21.59		192.80 ± 141.91	
Bolgatanga	14.60 ± 18.41		176.00 ± 7.46		28.80 ± 16.50		197.40 ± 97.33	

Table 5. PAH levels in smoked barracuda from selected informal markets in Ghana

	Smoked-soft		Smoked-dry	
	BaP (µg/kg)	PAH4 (µg/kg)	BaP (µg/kg)	PAH4 (µg/kg)
Adabraka	64.26 ± 10.11	479.66 ± 116.09	56.06 ± 17.72	479.10 ± 203.40
Madina	87.13 ± 20.77	624.38 ± 153.43	32.92 ± 26.47	669.20 ± 84.73
Sunyani	na	na	55.80 ± 5.46	376.20 ± 20.97
Techiman	na	na	76.80 ± 3.31	796.40 ± 0.00
Navrongo	na	na	52.00 ± 18.89	534.60 ± 213.31
Bolgatanga	na	na	40.40 ± 18.41	417.40 ± 162.61

na = product not available on market during sampling period.

Table 6. PAH levels in smoked tilapia from selected informal markets in Ghana

	Tilapia	
	BaP (µg/kg)	PAH4 (µg/kg)
Adabraka	na	Na
Madina	na	Na
Sunyani	na	Na
Techiman	na	Na
Navrongo	25.00 ± 0.63	255.80 ± 6.85
Bolgatanga	37.00 ± 16.50	322.00 ± 241.01

na = product not available on market during sampling period.

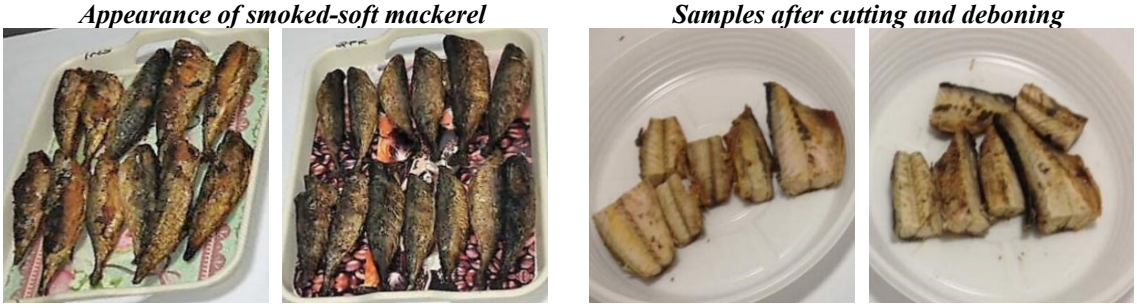
3.3 Sensory evaluation of smoked chub mackerel (FTT vs Chorkor smoker)

3.3.1 Quantitative descriptive test (QDA®)

Attributes with significant differences were appearance, where the Chorkor smoker had darker coloured smoked products than FTT-smoked products (Figure 6) and texture, where FTT products had a drier, harder mouth feel and in-hand) texture while Chorkor smoker products had a softer mouth feel with a flaky texture in-hand. No significant differences were found in aroma, flavour and aftertaste attributes (Figure 7).

Figure 6. Smoked chub mackerel for sensory test (INS = FTT product; QPR = Chorkor smoker product)

Appearance of smoked-soft mackerel ***Samples after cutting and deboning***



INS **QPR** **INS** **QPR**

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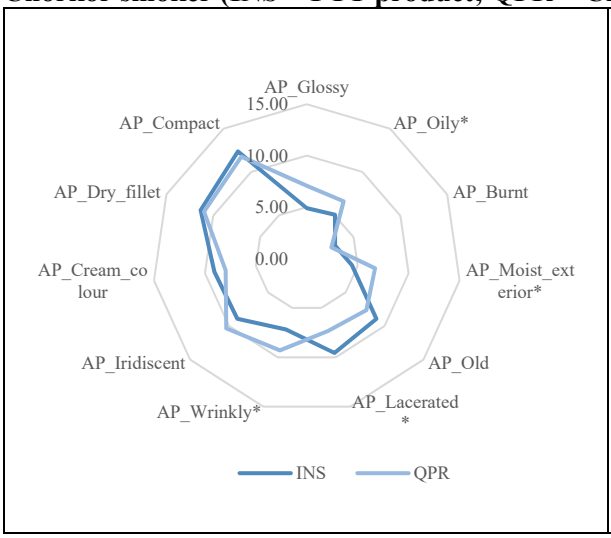
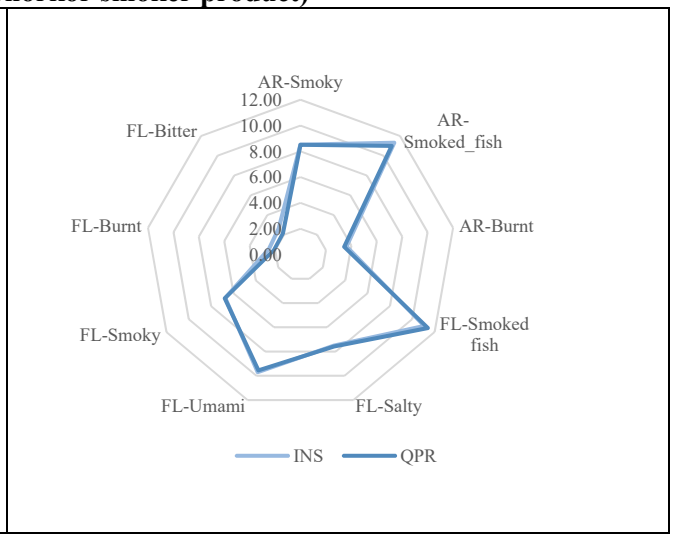
The QDA® findings suggested that product appearance and texture were likely to be important determinants of consumer preference for products from either kiln.

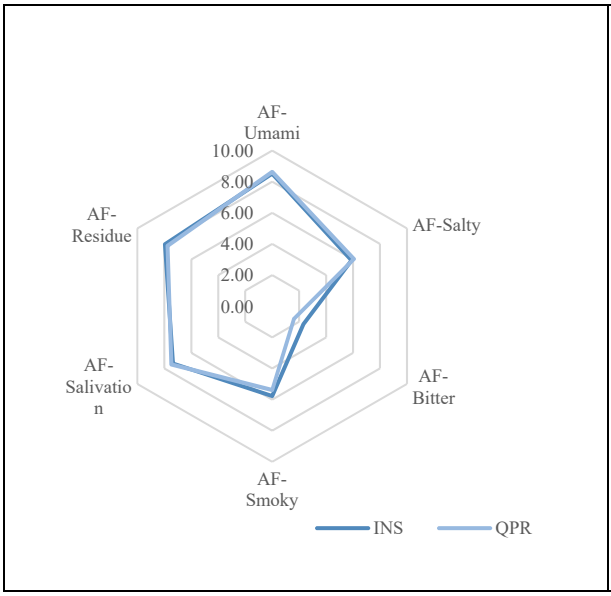
Figure 7. Comparison of sensory attributes of chub mackerel processed with the FTT kiln vs a Chorkor smoker (INS = FTT product; QPR = Chorkor smoker product)



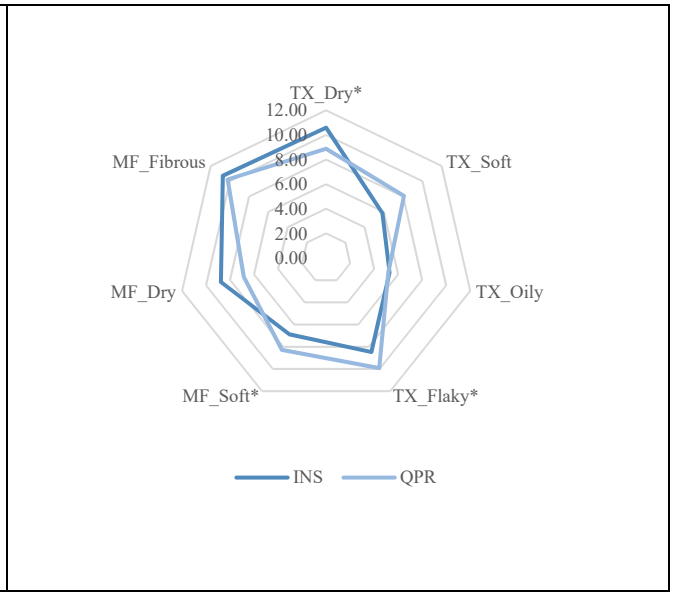
Appearance profile. Significant differences found.



Aroma and flavour profile. No significant differences found.



Appearance profile. Significant differences found.



Texture profile (in-hand and mouth feel). Significant differences found.

3.3.2 Consumer acceptance test

Given the differences in the appearance and texture of products from the FTT and Chorkor smoker (from the QDA® results), the consumer acceptance test was conducted to determine which products were preferred.

Demographics of assessors

There were more males (59 percent) than females (41 percent) among the assessors. The majority (64 percent) of respondents were aged 18–24 years. The demographic characteristics of the assessors are summarized in Figures 8, 9 and 10.

Figure 8. Gender of assessors

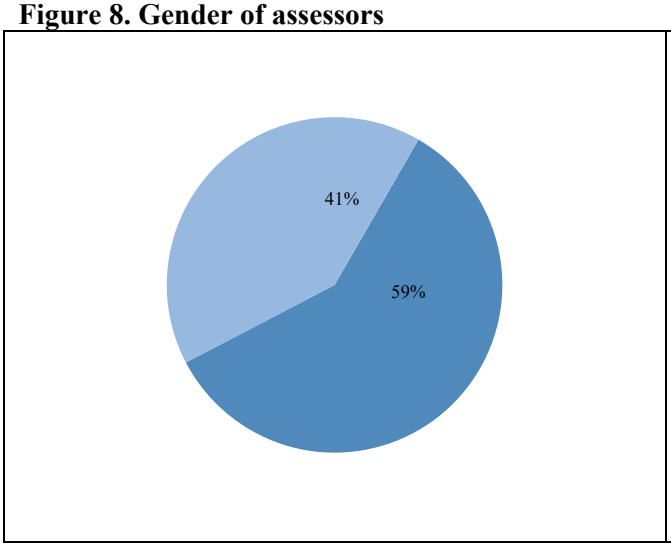


Figure 9. Age of assessors

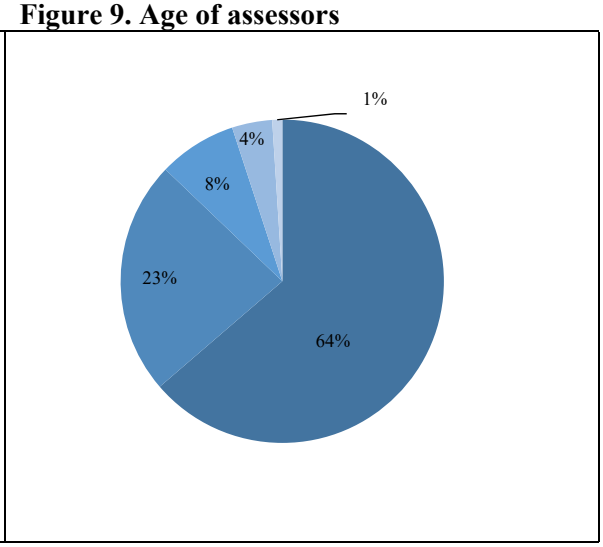
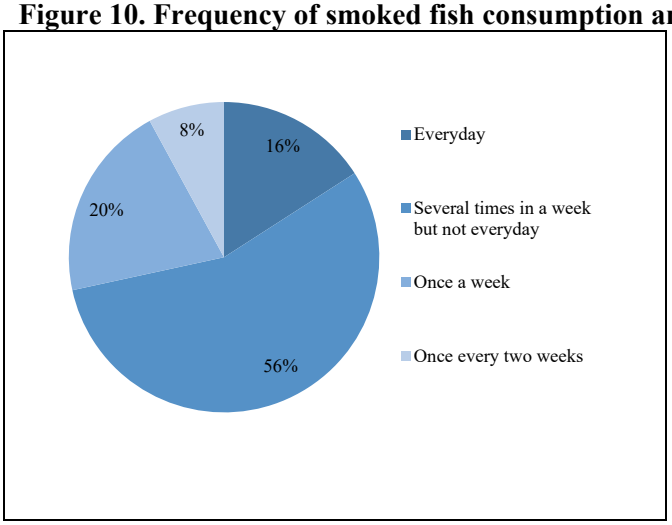


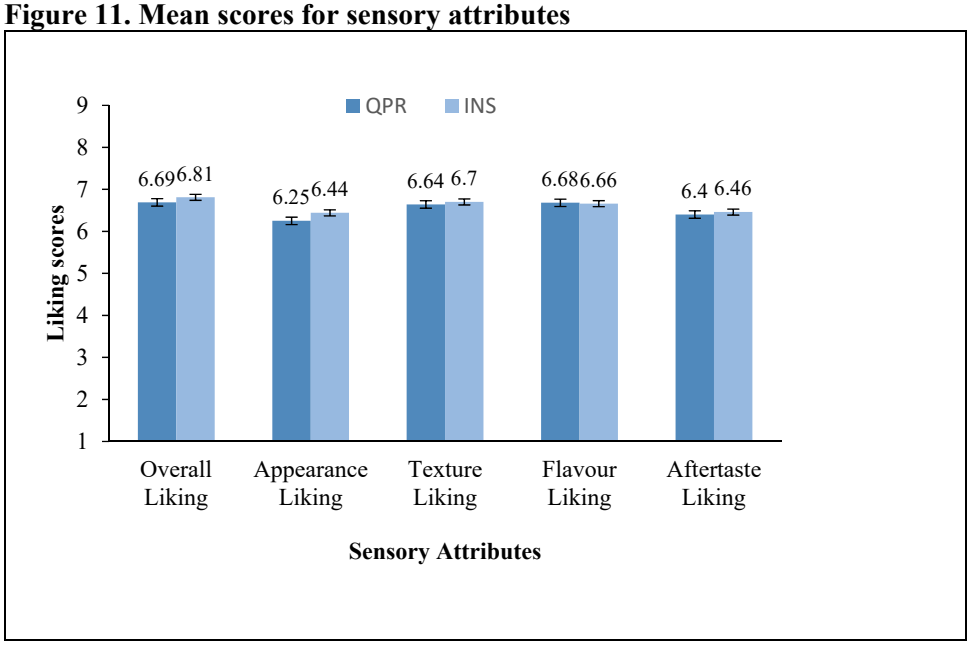
Figure 10. Frequency of smoked fish consumption among assessors



Mean attribute scores

For all attributes, there were no significant differences between the mean scores (p-value >0.05) for FTT and Chorkor smoker products, as shown in Figure 11. Therefore, although the QDA® results showed differences in appearance and texture scores, the consumer acceptance test results suggest that those differences did not influence consumer preference. Thus, on the basis of the test attributes, consumers are likely to accept FTT products just as much as Chorkor smoker products. The distribution of "liking" scores are given in Appendix II.

Figure 11. Mean scores for sensory attributes



3.4 Food safety risk assessment

Tables 7 and 8 show the exposure and MOE values for all products for the respective regions. Generally, as observed with the data on PAH levels, FTT products presented the least exposure to PAHs, the highest MOE values, and hence the least concern for risk management. The results suggest that whereas traditional kilns products pose a PAH public health concern, FTT products do not.

Table 7. BaP dietary exposure and corresponding margin of exposure (MOE) for all products

Source of fish (all types and forms)	Population		BaP Exposure (µg/kgbw/day			MOE		
	Age group	Region of Ghana	Mean	Median	95th perc.	Mean	Median	95th perc.
Informal markets	Adults	Greater Accra	0.0970	0.0827	0.2065	1 031	1 209	484
		Brong Ahafo	0.0341	0.0289	0.0723	2 930	3 460	1 383
		Upper East	0.0435	0.0393	0.0999	2 298	2 542	1 001
		All Regions	0.0524	0.0397	0.1377	1 910	2 517	726
	Children	Greater Accra	0.0323	0.0276	0.0688	3 092	3 628	1 453
		Brong Ahafo	0.0114	0.0096	0.0241	8 791	10 381	4 149
		Upper East	0.0145	0.0131	0.0333	6 894	7 627	3 002
		All Regions	0.0175	0.0132	0.0459	5 729	7 550	2 179
Chorkor smoker	Adults	Greater Accra	0.0998	0.0850	0.2123	1 002	1 176	471
		Brong Ahafo	0.0351	0.0297	0.0744	2 850	3 365	1 345
		Upper East	0.0447	0.0404	0.1028	2 235	2 472	973
		All Regions	0.0538	0.0409	0.1416	1 857	2 447	706
	Children	Greater Accra	0.0333	0.0283	0.0708	3 007	3 529	1 413
		Brong Ahafo	0.0117	0.0099	0.0248	8 550	10 096	4 035
		Upper East	0.0149	0.0135	0.0343	6 705	7 417	2 919
		All Regions	0.0179	0.0136	0.0472	5 572	7 342	2 119

Metal drum kiln	Adults	Greater Accra	0.0725	0.0618	0.1543	1 379	1 619	648
		Brong Ahafo	0.0255	0.0216	0.0540	3 922	4 631	1 851
		Upper East	0.0325	0.0294	0.0747	3 076	3 402	1 339
		All Regions	0.0391	0.0297	0.1029	2 556	3 368	972
	Children	Greater Accra	0.0242	0.0206	0.0514	4 138	4 856	1 944
		Brong Ahafo	0.0085	0.0072	0.0180	11 766	13 894	5 553
		Upper East	0.0108	0.0098	0.0249	9 227	10 207	4 017
		All Regions	0.0130	0.0099	0.0343	7 668	10 104	2 916
FTT	Adults	Greater Accra	0.0014	0.0012	0.0031	69 667	81 758	32 738
		Brong Ahafo	0.0005	0.0004	0.0011	198 096	233918	93 489
		Upper East	0.0006	0.0006	0.0015	155 344	171 858	67 639
		All Regions	0.0008	0.0006	0.0020	129 099	170 122	49 102
	Children	Greater Accra	0.0005	0.0004	0.0010	209 002	245 273	98 214
		Brong Ahafo	0.0002	0.0001	0.0004	594 287	701 754	280 468
		Upper East	0.0002	0.0002	0.0005	466 032	515 575	202 917
		All Regions	0.0003	0.0002	0.0007	387 298	510 367	147 307

Note: MOE values in red are below 10 000 and denote public health concerns requiring risk management action.

Table 8. PAH4 dietary exposure and corresponding margin of exposure (MOE) for all products

Source of fish (all types and forms)	Population		Exposure (µg/kgbw/day			MOE		
	Age group	Region of Ghana	Mean	Median	95th perc.	Mean	Median	95th perc.
Informal markets	Adults	Greater Accra	0.8550	0.7286	1.8196	398	467	187
		Brong Ahafo	0.3007	0.2547	0.6372	1 131	1 335	534
		Upper East	0.3835	0.3466	0.8807	887	981	386
		All Regions	0.4614	0.3502	1.2132	737	971	280
	Children	Greater Accra	0.2850	0.2429	0.6065	1 193	1 400	561
		Brong Ahafo	0.1002	0.0849	0.2124	3 392	4 005	1 601
		Upper East	0.1278	0.1155	0.2936	2 660	2 943	1 158
		All Regions	0.1538	0.1167	0.4044	2 211	2 913	841
Chorkor smoker	Adults	Greater Accra	0.6003	0.5115	1.2774	566	665	266
		Brong Ahafo	0.2111	0.1788	0.4473	1 611	1 902	760
		Upper East	0.2692	0.2433	0.6183	1 263	1 397	550
		All Regions	0.3239	0.2458	0.8517	1 050	1 383	399
	Children	Greater Accra	0.2001	0.1705	0.4258	1 699	1 994	798
		Brong Ahafo	0.0704	0.0596	0.1491	4 832	5 705	2 280
		Upper East	0.0897	0.0811	0.2061	3 789	4 192	1 650
		All Regions	0.1080	0.0819	0.2839	3 149	4 149	1 198
Metal drum kiln	Adults	Greater Accra	0.1170	0.0879	0.2876	2 905	3 869	1 182
		Brong Ahafo	0.1219	0.1033	0.2584	2 788	3 293	1 316
		Upper East	0.1555	0.1405	0.3571	2 187	2 419	952
		All Regions	0.1871	0.1420	0.4919	1 817	2 395	691
	Children	Greater Accra	0.0390	0.0293	0.0959	8 715	11 607	3 547
		Brong Ahafo	0.0406	0.0344	0.0861	8 365	9 878	3 948
		Upper East	0.0518	0.0468	0.1190	6 560	7 257	2 856
		All Regions	0.0624	0.0473	0.1640	5 452	7 184	2 074
FTT	Adults	Greater Accra	0.0075	0.0064	0.0160	45 222	53 070	21 251
		Brong Ahafo	0.0026	0.0022	0.0056	128 587	151 840	60 685
		Upper East	0.0034	0.0030	0.0077	100 836	111 556	43 906
		All Regions	0.0041	0.0031	0.0107	83 800	110 429	31 873
	Children	Greater Accra	0.0025	0.0021	0.0053	135 667	159 211	63 752
		Brong Ahafo	0.0009	0.0007	0.0019	385 761	455 520	182 056
		Upper East	0.0011	0.0010	0.0026	302 509	334 668	131 717
		All Regions	0.0014	0.0010	0.0036	251 401	331 287	95 619

Note: MOE values in red are below 10 000 and denote public health concerns requiring risk management action.

4. CONCLUSIONS

The findings of the study suggest the following:

4.1 PAHs in smoked fish on informal markets in Ghana

Smoked fish on informal markets in Ghana have high PAH levels that significantly exceed acceptable regulatory limits. Given that smoked products on such markets are invariably processed by traditional methods, the causal importance of such methods to the observed food safety problem could be considered significant. The PAH levels in products on the market were also higher than in products sampled directly from processing sites. The higher levels in the former may be attributed to the possibility of re-smoking and environmental contamination.

4.2 Consumer acceptability of fish processed with FTT and Chorkor kiln

Although there were differences in the appearance and texture attributes of FTT and Chorkor smoker products, the differences did not affect consumer preference. It follows, therefore, that on the basis of the assessed attributes, consumers are just as likely to accept FTT-smoked products as they do Chorkor-smoked products. Moreover, if consumers are educated on the safety of FTT-smoked products and the PAH challenges associated with traditional kiln products, the preference is likely to shift to FTT-smoked products.

4.3 Food safety risk assessment

The margin of exposure values show that the potential PAH health risks associated with the consumption of smoked products from traditional kilns in Ghana are of such a magnitude that risk management action is necessary to address the concern. The values further show that should the FTT be adopted in the country, such risk management actions will not be necessary.

5. POLICY RECOMMENDATIONS

With a per capita intake of 27.6 kg of fish per year, which is more than the world average of 19 kg, fish makes up about 60 percentof animal protein in Ghanaian diets and accounts for 16 percentof household food expenditure (GLSS, 2008). Over 70 percentof fish landings in the country are processed by traditional hot-smoking using the Chorkor smoker or the metal drum kiln. Therefore, smoked fish is an important food commodity that supports food and nutrition security in Ghana. The commodity also provides livelihood support to women as recognized in the African Union Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa.

The fishery sector in Ghana is said to contribute at least 5 percentof the country's gross domestic product (GEPC, 2010). The contribution of smoked fish in that regard is significant, given that in 2003 alone, Ghana exported 6 031 metric tons of smoked fish valued at more than USD 3 million. In 2011, the country's export of smoked herrings alone was estimated at USD 340 000[6]. Therefore, any compromise on the safety of the product undermines public health, livelihood support and foreign exchange earnings.

As demonstrated in the consolidated findings of this collaborative study, the PAH levels in smoked fish produced by traditional methods are higher than the limits considered safe per EU regulations. Indeed, such high levels of the hazard have resulted in border rejections of Ghanaian smoked fish at EU borders. The rejections are listed on the RASFF, with serious negative impacts on the country's foreign exchange earnings and credibility vis-à-vis the production of safe food. As shown in Table 9, ten EU border rejections of Ghana's smoked fish were recorded between 2013 and 2016 due to unacceptable PAH levels.

Table 9. RASFF alerts on unacceptable levels of PAHs in smoked fish from Ghana, 2013–2016

Date	Country issuing alert	Notification details as provided by RASFF
16-Dec-2016	United Kingdom	Benzo(a)pyrene (81.2 µg/kg), polycyclic aromatic hydrocarbons (sum of PAH4: 507.9 µg/kg), benzo(a)anthracene (163.1 µg/kg), chrysene (198.4 µg/kg) and benzo(b)fluoranthene (65.2 µg/kg) in smoked catfish (*Clarias* sp.) from Ghana
13-Dec-2016	Germany	Benzo(a)pyrene (5.64 µg/kg) and polycyclic aromatic hydrocarbons (sum of PAH4: 60.92 µg/kg) in salted smoked sardines (*Sardinella* sp.) from Ghana
27-Jul-2016	United Kingdom	Benzo(a)pyrene (27.6 µg/kg) and polycyclic aromatic hydrocarbons (PAH4 sum: 166.9 µg/kg) in smoked sardinellas from Ghana
04-Jul-2016	United Kingdom	Benzo(a)pyrene (80 µg/kg) and polycyclic aromatic hydrocarbons (sum PAH: 596 µg/kg) in salted smoked fish (*Lattes* sp.) from Ghana
26-May-2014	Belgium	Benzo(a)pyrene (6.2 µg/kg) and polycyclic aromatic hydrocarbons PAH4 (46.1µg/kg) in smoked sardinellas (*Sardinella aurita*) from Ghana
6-Mar-2014	Germany	Benzo(a)pyrene (35 µg/kg) in smoked sardines (*Sardinella aurita*) from Ghana
3-Feb-2014	Belgium	Benzo(a)pyrene (36.7 µg/kg) and PAH4 (221 µg/kg) in smoked sardines (*Sardinella aurita*) from Ghana
2-Jan-2014	United Kingdom	Benzo(a)pyrene (33 µg/kg) in smoked sardinella (*Sardinella* sp.) from Ghana
9-Aug-2013	Belgium	Benzo(a)pyrene (45.1 µg/kg) in smoked fish from Ghana
16-May-2013	Germany	Benzo(a)pyrene (61.2 µg/kg) in dried fish from Ghana, via Belgium

Source: Result of PAH alert search at https://webgate.ec.europa.eu/rasff-window/portal/?event=searchForm&cleanSearch=1

[6] http://www.factfish.com/statistic-country/ghana/herrings,+smoked,+including+fillets,+export+value

In the Malabo Declaration of 2014, African heads of state committed to halve postharvest losses by 2025. It is critical to recognize that compromises on the safety of smoked products are considered postharvest losses (Diei-Ouadi and Mgawe, 2011), as witnessed, for example, in the destruction of consignments of smoked fish that do not conform to the regulations of international markets.

Beyond their impact on foreign exchange earnings (e.g. postharvest losses and negative impacts on in the country's international credibility on safe food production), high PAH levels seriously compromise public health. The risk assessment in the study shows that the high levels of PAHs in Ghana's smoked fish, combined with the country's high consumption of the commodity, translate into a public health issue that should be a policy priority. Indeed, the situation detracts from the country's gains towards the United Nations Sustainable Development Goal (SDG) 3. This is particularly so given that the risk for women to the deleterious impact of PAHs is compounded by their occupational exposure to the hazard.

Human exposure to PAHs occurs through three routes: food, skin contact and inhalation. Women who are smoked fish processors are exposed to all three routes. Studies in Côte d'Ivoire showed that such women suffered various debilitating conditions such as ocular pathologies (conjunctivitis, cataract, keratitis) and respiratory problems such as breathing difficulties (Anoh *et al*., 2017). Acute effects such as eye irritation, skin irritation, nausea, vomiting and confusion arising from such exposures are also probable (Bølling *et al*., 2009; Kim *et al*., 2013), without precluding the possibility for chronic effects such as leukemia and cancer to follow in the future. This, therefore, compromises their access to good health and well-being (SDG3) and decent work (SDG8), thereby detracting from the nation's commitment to the pursuit of SDG5.

The continued use of traditional kilns to process the most important animal protein in Ghana presents adverse impacts on food safety, nutrition, public health, livelihoods and economic development in the country. Moreover, it undermines Ghana's commitment to the African Union Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa, the Malabo Declaration, and the Code of Conduct for Responsible Fisheries.

The Ghana policy document "Fisheries Management Plan of Ghana 2015–2019"[7] states a categorical commitment on the part of the Government to the long-term conservation of fish stocks and safety of fish products. In pursuance of this, it is noteworthy that this study presents compelling evidence that should drive a shift away from traditional methods of fish smoking as a means to control the PAH problem associated with the commodity. The International Association of Fish Inspectors (IAFI) has also made a call to governments, particularly in developing countries, to show stronger commitment to tackling the problem of high PAH levels in smoked fish.

In view of the foregoing, the following policy considerations are recommended:

5.1. Supporting a national programme for the dissemination of FTT

Using the findings of the study as a launch pad, it is recommended that the Government champions or supports the piloting of the FTT in Ghana. An enabling environment should also be created for private investments into the roll-out of the kiln. A participatory approach in its adoption is encouraged as feedback from processors may inform design modifications that could facilitate adoption of the innovation. In Burkina Faso, for example, the innovation has been adapted to a kiln that suits the processing needs of the context, thus leading to a new setup called FTT-Dafing.

5.2. Government initiation and/or support for education and campaigns on:

a) health impacts of high PAHs exposure
b) health implications of continued use of traditional hot-smoking methods
c) health benefits of consuming smoked products from improved kilns

[7] https://mofad.gov.gh/wp-content/uploads/2016/07/FISHERIES-MANAGEMENT-PLAN-OF-GHANA.pdf

Such education should target processors, consumers and other actors in the fish value chain.

It is crucial that the messages conveyed in educational materials or programmes do not demonize the hardworking women who, by their smoked fish processing and trade, support food and nutrition security and earn their livelihoods. The language for the education should not unnecessarily cause scaremongering among consumers, but should emphasize the positive note that processing methods are being improved for the benefit of all.

5.3. Government commissioning and support for research

Given the present call on governments to undertake evidence-based decision making, Ghana should prioritize investments in research such as evaluating the health impact of traditional fish smoking on women and the environment, as well as conducting risk assessments on PAHs and other hazards in the smoked fish value chain. This will provide sound evidence for education and campaigns. In Côte d'Ivoire, the adoption of the FTT was facilitated by the dissemination of the findings of a research conducted by the University of Abidjan that showed deleterious effects of traditional fish smoking practices on the health of processors.

5.4 Development and enforcement of standards

Based on research evidence and Codex normative instruments, the Government should set appropriate standards to regulate both the process and products of hot-smoking. There should also be a commitment to enforcing such standards by equipping the appropriate regulatory agencies to effectively carry out their mandates.

5.5. Capacity building for national reference laboratories

There should be investments in establishing accredited laboratories to run tests on hazards such as PAHs. For years, as a result of a lack of capacity to grant clearance for smoked fish exports, the Ghana Standards Authority relied on laboratories in Europe to conduct tests for PAH, with obvious financial implications for the country. Recent checks suggest the Ghana Standards Authority is in the process of acquiring accreditation for the analysis. The support of the Government in that regard is crucial, not only for this hazard, but for all others relevant to international trade and public health protection.

5.6 Creation of market incentives for smoked products from improved kilns

a) *price differentiation*: To encourage processors to adopt safer ways of smoking fish (e.g. using the FTT), the value added to the products through improvements in their safety should be monetized by allowing premium pricing for the products. Mechanisms for price differentiation (such as packaging and labelling) suitable for the context should be explored. Mechanisms for traceability to control fraud (i.e. passing off traditionally smoked fish as products from improved kilns) should also be explored. The participation of the private sector in this regard will be vital. For example, retailers could champion the distribution of packaged smoked fish from improved kilns, by noting that these products are low in PAH.

b) *government support for (international) market access*: Processors of safer fish products should be supported to gain access to both high-end domestic markets and international markets. Key for international market access should be the presentation of risk assessment evidence for the commodity vis-à-vis PAH. Support should also be provided to ensure that processors seeking to export have valid certifications in, and documented compliance to, the appropriate food safety management systems (e.g. HACCP).

5.7 Shift from dependence on fuel wood for (fish) smoking

As has been shown in the study, the use of firewood results in high PAH levels in products, whereas the use of fully-lit charcoal in combination with heat retention stones results in low PAH levels. Besides the

impact of kiln design, fuel choice is a critical factor that influences the extent of PAH contamination in smoked fish. Therefore, commitments should be made to investigate alternative, renewable sources of fuel (such as biochar) in hot-smoking applications, bearing in mind the cost–benefit analysis.

5.8 Mainstreaming in the curriculum of schools and academia

Academic and research institutions must spearhead (or be kept abreast of) developments in improved fish smoking technologies. The University of Ghana, for example, has shown leadership by updating its course material on animal products processing technologies to include the FTT. This should be done in other educational settings, including vocational and technical schools.

PART 2: SMALLHOLDER GUIDELINES IN IMPROVING THE SAFETY OF SMOKED FISH IN GHANA THROUGH THE USE OF THE FTT

Traditional fish smoking

Fish smoking is an important practice for preserving fish. It provides income for fish processors and food for all. However, the traditional methods of smoking fish can erode these benefits. Traditionally, fish is smoked with firewood as fuel on several types of kilns. In Ghana, the most widely used kilns are the Chorkor smoker and the metal drum kiln.

Figure 12. Metal drum kiln in use

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Figure 13. Chorkor smoker in use

© FAO/Kennedy Bomfeh

Health challenges with traditional kilns

The use of traditional kilns in fish smoking has been found to cause serious health challenges for processors and results in unsafe products. This is due to certain harmful compounds found mainly in the wood smoke (PAHs), which have the potential to cause cancer. Research in Côte d'Ivoire has shown that women using traditional kilns such as the drum kiln and Chorkor smoker suffer health problems such as eye defects (cataracts, conjunctivitis, keratitis) and breathing difficulties. In the long term, PAHs can cause cancer. It is, therefore, important to use smoking kilns that do not expose processors to wood smoke and protect consumers from unsafe fish.

How PAHs are produced

The smoke from burning wood, vehicle tyres and refuse contain PAHs. During fish smoking, PAHs are produced when the firewood emits smoke. PAHs are also produced when fish fat drips into the heat source, and generates smoke. In addition, high heat from the fire can cause some of the fat in the fish to be heated to such a degree that PAHs are produced.

How PAHs affect the health of processors, their livelihoods, and food safety

The potential health outcome of exposure to PAHs is cancer. For this to occur, PAHs have to enter a person's body, and they get into the human body through three main paths: the mouth (by eating food containing the compounds), the lungs (by breathing in smoke), and the skin.

Effect on health of processors

When using the traditional kilns, at the same time as processors breathe in smoke from the firewood, their skin is also in contact with the smoke. They also eat what they produce, and so, those who smoke fish are exposed to all three paths by which PAHs can enter the body. As a result, they are at risk of

suffering the adverse health effects of such exposure. Aside from PAHs, other substances such as carbon monoxide, nitrogen dioxide and several types of particulate matter are found in the smoke. These also have various serious health impacts on the eyes (blurred vision, cataract, blindness), the lungs (acute lower respiratory infection, cancer), and the heart (chronic obstructive pulmonary disease). High smoke exposure has also been linked to low birth weight and stillbirth.

Figure 14. Smoke exposure during traditional fish smoking

© FAO/Kennedy Bomfeh

Effect on the livelihood of processors

a) Domestic and regional markets
When PAH levels in smoked fish are higher than acceptable limits, the product becomes unsafe. This reduces the value of the product. As consumers are becoming more aware of the PAH problem in traditionally smoked fish, this may affect their acceptance of such products. Processors are, therefore, likely to lose on the market either through low patronage of products, or being offered lower prices.

b) International markets
On the international market, products with PAH levels exceeding regulatory limits suffer outright rejection and destruction. This has happened many times in Europe, as shown in the information from the European Union Rapid Alert System for Food and Feed (RASFF). This in turn has direct effects on the livelihoods of processors and exporters.

The Fisheries Commission of Ghana – in partnership with the Ghana Standards Authority (GSA) – is developing a classification system for smoked fish. This tool recognizes the use of the FTT as being in compliance with PAH levels for export markets. Processors who use the FTT will, therefore, qualify to receive the endorsement of GSA to export smoked fish to more rewarding markets.

Effect on food safety (consumer health)

High PAH levels in smoked fish potentially exposes consumers to the risk of cancer.

The need for improved kilns

The traditional kilns, in their present form, do not produce safe products as far as PAH levels are concerned. Efforts have, therefore, been made through years of scientific research to introduce an improved kiln to address the problem. The result of the many years of trials and innovations is the FTT.

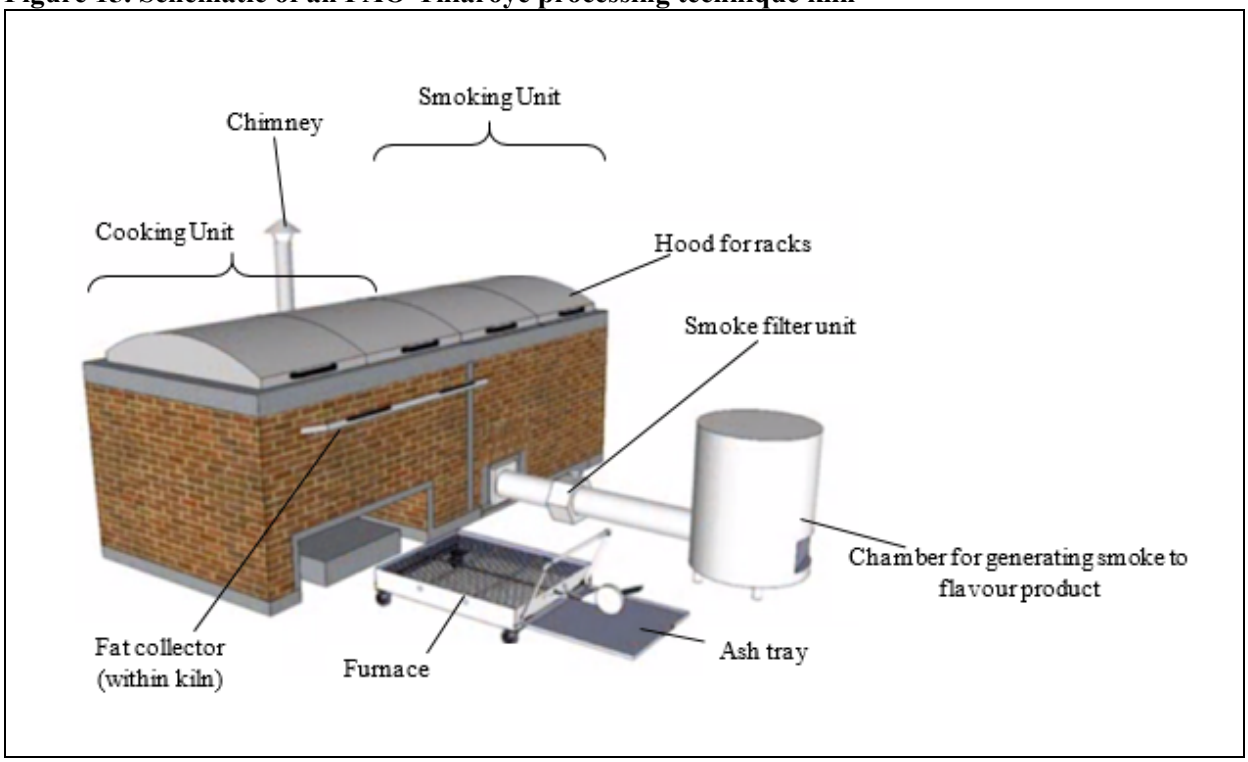
Differences between the FTT and traditional kilns

The main differences between the FTT and a traditional kiln are summarized in Table 10.

Table 10. Operational differences between the FAO-Thiaroye Processing Technique (FTT) and traditional kilns

Traditional kilns (e.g. Chorkor smoker and metal drum kiln)	FTT
Uses firewood as fuel	Uses completely combusted charcoal combined with heat retention stones as fuel
Simultaneous cooking and smoking	Separate cooking and smoke flavouring unit operations
Direct smoking	Indirect smoking
Smoke not filtered	Smoke filtered with a food grade filter such as the "sponge" cucumber (*Luffa* sp.)
Fish fat drips into fire	Fish fat drains out over fat collection tray into an external container

Figure 15. Schematic of an FAO-Thiaroye processing technique kiln



Source: Ndiaye *et al*., 2015.

How to acquire an FTT

There are two options for getting an FTT installed. If a processor already has a Chorkor smoker in good condition, then the components of the FTT can be retro-fitted to the existing base. This has the advantage of requiring less upfront investment. However, if a processor does not have a Chorkor smoker base, the FTT can be built from scratch. In either case, interested parties in Ghana can contact the FAO Regional Office in Accra, which will link them with personnel trained to install the kiln.

How the FTT works and differs from traditional kilns

Unlike traditional kilns[8], the FTT uses fully-lit charcoal mixed with heat retention stones (such as broken pottery) to cook fish in a smokeless operation. After the fish are cooked, they are flavoured for a brief period with filtered smoked. This ensures that products are not exposed to smoke for long periods unlike with traditional kilns. This significantly limits the amounts of PAHs deposited on the products during the process. The filtering also helps to further reduce PAH levels.

During fish smoking, as the fish is being cooked, fat usually drips into the heat source. This fat, when burned in the heat source, produces smoke that also contains PAHs. This occurs unhindered in traditional kilns. However, in the FTT, the fat collector receives all fish fat drippings and drains them out into an external container. Therefore, the fat is not burned in the fire, and so less PAHs are produced.

The three main features described above – fuel type, indirect smoking with filtered smoked and use of fat collector – all contribute to ensure that FTT products have very low PAH levels.

Materials for generating smoke in the FTT

Moistened sugarcane bagasse or coconut husk can be used to generate smoke to flavour fish. These materials are also used in traditional fish smoking.

Figure 16. Sugarcane bagasse

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Figure 17. Coconut husk

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[8] A manual on FTT is freely available online at: http://www.fao.org/3/a-i4174e.pdf
Instructional videos on FTT are also freely available at: https://www.youtube.com/watch?v=4ehj-lNscb8, https://www.youtube.com/watch?v=nmLak9hDLXM, https://www.youtube.com/watch?v=nk7eaZWTifs

Figure 18. Generating smoke to flavour fish.
The smoke is contained when the chamber is closed

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Smoke filter

The smoke filter is made of moistened sponge cucumber from the vine of *Luffa* sp. It is effective in trapping some of the smoke constituents.

Figure 19. Smoke filter before use

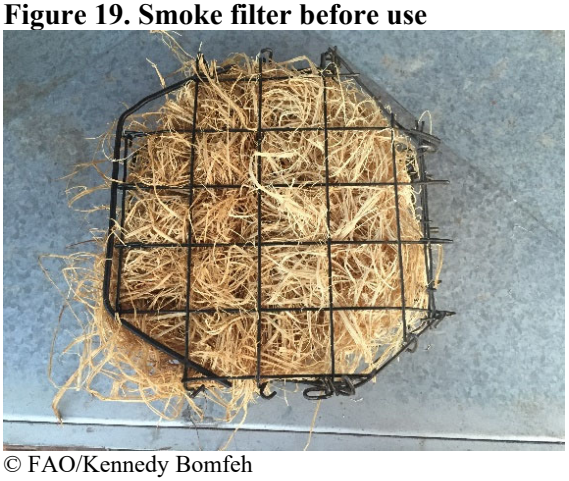

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Figure 20. Smoke filter after use

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Benefits of FTT

The benefits of using the FTT include:

- smoked products from the innovation have low PAH levels and are, thus, safer;
- processors are protected from excessive smoke exposure;
- value is added to products with the potential for more economic benefits (higher price);
- environmental protection by preventing fuelwood use and generating less smoke; and
- the products from FTT meet international food safety regulations on PAHs, hence they can be exported.

Important additional guidance to obtain optimum performance from the FTT

To get the best performance from FTT, the following are recommended:

- do not use firewood as a cooking fuel;
- always use the fat collector when processing, and keep it clean;
- always use the filter when smoke-flavouring, and replace the darkened filter with a fresh, clean filter;
- follow general good practices for fish smoking; and
- when in doubt, check and follow the FTT manual and instructional videos.

FTT maintenance

To obtain optimum performance, the FTT needs to be kept in good condition. The following are general maintenance tips for keeping the kiln in good condition:

- regularly clean the fat collector to avoid fat residue buildup;
- check and replace the smoke filter when it becomes dark;
- empty the ash tray after processing to enhance combustion; and
- regularly inspect and clean fish trays, and keep all other parts of the kiln clean at all times.

It is recommended that reference be made to the manual and instructional videos on the FTT, which are freely available online.

6. REFERENCES

Anoh, K.P., Yapo, O.B. & Ouattara, S. 2017. *Sante des femmes transformatrices, sécurité sanitaire des produits et impact environnemental des systèmes de fumage de poisson dans les communautés de pêche artisanale- étude pour des systèmes alimentaires durables*. Projet pilote FAO-dans les communautés de Grand-Lahou - GCP/RAF/488.

Atta-Mills, J.E., Alder, J. & Sumaila, U.R. 2004. *The decline of a regional fishing nation: The case of Ghana and West Africa.* Natural Resources Forum, 28:13–21.

Bølling, A.K., Pagels, J., Yttri, K.E., Barregard, L., Sallsten, G., Schwarze, P.E. & Boman, C. 2009. Health effects of residential wood smoke particles: the importance of combustion conditions and physicochemical particle properties. *Particle and Fibre Toxicolology,* 6:20. (also available at https://doi.org/10.1186/1743-8977-6-29).

Bomfeh, K., Jacxsens, L., De Meulenaer, B., Amoa-Awua, W.K., Tandoh, I. & Afoakwa, E.O. 2016. *Meeting food safety targets in shifting from traditional to new fish smoking systems: A case study in Ghana*. A collaborative study by FAO, University of Ghana and Ghent University. Final Report.

Codex Alimentarius Commission. 2003. *Code of practice for fish and fishery products*. CAC/RCP 52-2003. Rome, FAO and the World Health Organization.

Codex Alimentarius Commission. 2009. *Code of practice for the reduction of contamination of food with polycyclic aromatic hydrocarbons (PAH) from smoking and direct drying processes*. CAC/RP 68-2009. Rome, FAO and the World Health Organization.

Codex Alimentarius Commission. 2013. *Standard for smoked fish, smoke-flavoured fish and smoke-dried fish*. CODEX STAN 311–2013. Rome, FAO and the World Health Organization.

Diei-Ouadi, Y. & Mgawe, I. 2011. *Post-harvest fish loss assessment in small-scale fisheries: A guide for the extension officer*. Rome, FAO. (available at www.fao.org/docrep/014/i2241e/i2241e.pdf).

EFSA (European Food Safety Authority). 2008. Polycyclic aromatic hydrocarbons in food. Opinion of the Panel on Contaminants in the Food Chain. *EFSA Journal*, 724:1–114.

FAO. 2014a. *Fishery and aquaculture statistics*. FAO Year Book 2014. Rome, FAO. (available at www.fao.org/3/a-i5716t.pdf).

FAO. 2014b. *Overview, parts, use and maintenance of FTT Thiaroye*. Three-part videos on FTT-Thiaroye with the following links: www.youtube.com/watch?v=zgqPlYNUL7A; www.youtube.com/watch?v=yxtG3VL1WNw; www.youtube.com/watch?v=xFW05he_TC8. Videos uploaded 29 September 2014. Retrieved on 28 April 2018.

Gehle, K. 2009. Toxicity of polycyclic aromatic hydrocarbons. Agency for Toxic Substances and Disease Registry – Case studies in environmental medicine. Atlanta, Georgia. (available at https://www.atsdr.cdc.gov/csem/pah/docs/pah.pdf).

GEPC (Ghana Export Promotion Council). 2010. *The export of fish from Ghana*. Accra, Ghana. (available at http://www.gepcghana.com/fish.php)

GLSS (Ghana Living Standards Survey). 2008. Report of the fifth round. Available at http://www.statsghana.gov.gh/docfiles/glss5_report.pdf

GSA (Ghana Standards Authority). 2014. Fisheries Product Regulation (Subsidiary Legislation). Accra, Ghana.

Kim, K.H., Jahan S.A., Kabir, E. & Brown R.J. 2013. A review of airborne polycyclic aromatic hydrocarbons (PAHs) and their human health effects. *Environment International*, 60:71–80. (also available at https://doi.org/10.1016/j.envint.2013.07.019).

Ndiaye, O., Komivi, B.S. & Diei-Ouadi, Y. 2015. *Guide for developing and using the FAO-Thiaroye processing technique*. Rome, FAO. (available at www.fao.org/3/a-i4174e.pdf)

Olabemiwo, O.M., Alade, A.O., Tella, A.C. & Adediran, G.O. 2011. Assessment of polycyclic aromatic hydrocarbons content in smoked *C. gariepinnus* and *T. guineensis* fish species available in western Nigeria. *International Journal of Basic and Applied Sciences*, 11(2):135–150.

Palm, L.M.N, Carboo, D., Yeboah, P.O. & Quasie, W.J. 2011. Characterization of polycyclic aromatic hydrocarbons present in smoked fish from Ghana. *Advanced Journal of Food Science and Technology*, 3(5):332–338.

Penarubia, O.R., Randrianatoandro, A. & Diei-Ouadi, Y. 2017. *Background paper for the discussion on benchmarking of fish smoking systems in Africa: Advances in fish smoking and perspectives for a sustainable food system in Africa*. Meeting of professionals/experts in support of fish safety, technology and marketing in Africa, Elmina, Ghana, 14–16 November 2017.

Stołyhwo, A. & Sikorski, Z.E. 2005. Polycyclic aromatic hydrocarbons in smoked fish – a critical review. *Food Chemistry*, 91:303–311.

Ward, A. 2003. *A study of the trade in smoked-dried fish from West Africa to the United Kingdom*. FAO Fisheries Circular No. 981. Rome, FAO.

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