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SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP)
Implementing Post-Harvest Value Chain Improvements In Small-Scale Fisheries In Elmina, Ghana

Presented to the African Network on Fish Technology and Safety Regional Meeting: Professionals / Experts Meeting in Support of Fish Safety, Technology and Marketing in Africa November 14-16, 2017

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ACRONYMS

ANTFS	African Network on Fish Technology and Safety
CCT	Control Cooking Test
CEWEFIA	Central and Western Region Fishmongers Improvement Association
CRC	Coastal Resource Center
CSIR	Council for Scientific and Industrial Research
EnDev	Energising Development
EU	European Union
FAO	Food and Agricultural Organization
FRI	Food and Research Institute
FTT	Thiaroye Processing Technique
GSA	Ghana Standards Authority
IFSS	Improved Fish Smoking Stoves
MSME	Micro Small and Medium Enterprises
PAH	Polycyclic aromatic hydrocarbons
SFMP	Sustainable Fisheries Management Project
SNV	Netherlands Development Organization
UCC	University of Cape Coast
URI	University of Rhode Island
USAID	United States Agency for International Development
VSLA	Village Savings and Loan Associations

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IMPLEMENTING POST-HARVEST VALUE CHAIN IMPROVEMENTS IN SMALL-SCALE FISHERIES IN ELMINA, GHANA

[i]Antwi, H. and [ii]Beran, K.

SUMMARY (ENGLISH)

Fish smoking is the most widely used method for processing fish in Ghana, yet traditional fish smoking methods and techniques used to process fish lead to financial losses and health concerns. There is a need to improve fish quality relative to food safety, food security and value addition given health, economic and environmental concerns within the small-scale fishery post-harvest sector in Ghana. Post-harvest value chain improvements supported by the USAID/Ghana Sustainable Fisheries Management Project implemented in the small-scale fishery post-harvest sector in Ghana aim to improve fish hygiene and handling practices and preservation techniques through the adoption of improved fish smoking technology to produce safe, healthy fish for consumption and sale. These aims are reflected as recommendations by the Food and Agriculture Organization of the United Nations Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication to ensure sustainable and secure small-scale fisheries world-wide. Fish are particularly prone to pathogenic contamination resulting from unhygienic conditions and handling during and post-harvest which puts consumers at risk of food borne diseases through microbial and chemical contamination. A study conducted by the University of Cape Coast in Ghana on microbial profiles and chemical contents of smoked fish sampled in Ghanaian markets, including Elmina, revealed that bacteria, yeasts and molds from smoked fish were either heat resistant, or introduced through contamination after smoking. Elevated levels of polycyclic aromatic hydrocarbons (PAHs) were recorded on all smoked fish samples in this study. This suggests certain types of smoked fish in Ghanaian markets is unwholesome for human consumption and poses a public health risk. Improved Fish Smoking Stoves in Ghana designed to address these concerns is supported under the five-year (2014-2019) Sustainable Fisheries Management Project. Factors which impact rate of adoption or rejection of new technological innovations need to be identified.

LA MISE EN ŒUVRE DES AMÉLIORATIONS DANS LA CHAÎNE DE VALEUR APRÈS CAPTURE DE LA PÊCHE ARTISANALE À ELMINA AU GHANA

RÉSUMÉ

Au Ghana, le fumage est la méthode la plus répandue pour la transformation du poisson. Cependant, les méthodes de fumage et les techniques de transformation du poisson traditionnelles actuellement utilisées entraînent des pertes financières et des problèmes de santé. Étant donné les préoccupations sanitaires, économiques et environnementales dans le sous-secteur après capture de la pêche artisanale au Ghana, il est nécessaire d'améliorer la qualité du poisson renforçant ainsi la sécurité alimentaire, la sûreté des aliments et la valeur ajoutée des produits de la pêche. Les améliorations dans la chaîne de valeur après capture, appuyées par le Projet de Gestion Durable de la Pêche de l’Agence des États-Unis pour le développement international (USAID) et apportées au sous-secteur après capture de la pêche artisanale au Ghana, ont pour objectif d’améliorer les pratiques de manutention et d’hygiène des poissons et les techniques de conservation en mettant en œuvre de nouvelles technologies de fumage des poissons qui favorisent la production des aliments sûrs, sains et propres à la consommation et à la vente. Ces objectifs sont reflétés dans les recommandations de l'Organisation des Nations Unies pour l’alimentation et l’agriculture consignées dans un document intitulé « Directives volontaires visant à assurer la durabilité de la pêche artisanale dans le contexte de la sécurité alimentaire et de l’éradication de la pauvreté » qui a pour but de garantir une pêche artisanale durable et sûre au niveau mondial. Les poissons sont particulièrement susceptibles à la contamination pathogène résultant des conditions non hygiéniques et de la manipulation pendant et après la capture, ce qui expose les consommateurs aux risques de maladies alimentaires par contamination microbienne ou chimique. Une étude menée par l'Université de Cape Coast au Ghana sur les profils microbiens et la composition chimique des échantillons de poisson fumé prélevés dans des marchés ghanéens, y compris ceux d’Elmina, a révélé la présence des bactéries, des levures et des moisissures dans le poisson fumé ce qui suggère qu’elles ont été soit thermorésistantes lors du processus du fumage soit introduites par contamination après le fumage. Des niveaux élevés d'hydrocarbures aromatiques polycycliques (HAP) ont été enregistrés sur tous les échantillons de poisson fumé analysés dans cette étude. Cela suggère que certains types de poisson fumé disponibles dans les marchés ghanéens sont malsains pour la consommation humaine et présentent un risque pour la santé publique. Le Projet de Gestion Durable de la Pêche de cinq ans (2014-2019) appuie Improved Fish Smoking Stoves in Ghana, un projet axé sur la mise en œuvre des fours améliorés pour le fumage du poisson au Ghana qui a été conçu pour répondre à susdites préoccupations. Les facteurs qui influent sur le taux d'adoption ou le rejet des nouvelles innovations technologiques doivent être identifiés.

2.0 INTRODUCTION

Ghana is particularly dependent on fish as an affordable and accessible source of protein and micronutrients. Fish accounts for 60 percent of animal derived protein consumed in the Ghanaian diet (FAO, 2016). The most widely used method of processing fish in Ghana is smoking. Tens of thousands of fish smoking stoves are reported to be operating, mainly by women, along Ghana's coastline and around Lake Volta (Kwarteng, Nsiah and Aziebor, 2016). There are multiple benefits to smoking fish, to enhance flavour, reduce waste in the absence of refrigeration, extend shelf life and facilitate storage and distribution of fish within and outside of Ghana. Fish that is properly smoked and stored has a shelf-life of five months or more (Gordon, Pulis and Owusu-Adjei, 2011). However, traditional methods and stoves used to smoke fish raise environmental, economic and health-related concerns. Inefficient stoves result in waste of costly inputs such as fuelwood which lower profit margins and contributes to forest depletion. Smoking fish also raises hazards associated with polycyclic aromatic hydrocarbons (PAHs) which can negatively impact human health (Lokuruka, 2016). According to the FAO/WHO Codex Alimentarius Commission, the formation of PAHs in smoked fish is dependent on various factors some of which include type of wood used to smoke fish, duration of and temperature during smoking, cleanliness and maintenance of equipment and its design, specifically the combustion chamber which influences smoke density inside the chamber (CAC/RCP 68, 2009). Inefficient stove technology coupled with unhygienic fish handling practices during processing puts consumers who eat smoked fish at high risk of food borne diseases. Hence, there is a need to improve fish quality relative to food safety and value addition through adoption of improved fish processing technology within the post-harvest fishery sector in Ghana and elsewhere.

The objectives of this paper are to examine how post-harvest value chain interventions are contributing to improved fish quality, higher income generation and food security in small-scale fisheries in Ghana, including Elmina through:

- Improving hygiene and handling of fish products after harvest
- Technological development and transfer of Improved Fish Smoking Stoves
- Adoption of improved fish processing technology by processors

The United States Agency for International Development Ghana Sustainable Fisheries Management Project (SFMP) is supporting research, development and implementation of post-harvest value chain improvements to address these concerns by promoting hygienic fish handling, processing and marketing practices and creating incentives for adoption of Improved Fish Smoking Stoves[iii] (IFSSs) under a five-year sustainable fisheries management project (2014-2019). Many objectives under SFMP are reflected as recommendations within the Food and Agriculture Organization (FAO) of the United Nations *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication* (FAO, 2015). *The Guidelines* (FAO, 2015) advocate reducing post-harvest loss, building on local innovation using cost-efficient technologies and culturally appropriate technology transfers to produce good quality fish for both export and domestic markets in a responsible, safe and sustainable manner, deterring for example, waste of inputs such as fuelwood in small-scale fish handling and processing (Section 7.3, 7.5). *The Guidelines* advocate for investments in appropriate infrastructures, organizational structures and capacity development across the post-harvest subsector to improve income and livelihood security in small-scale fisheries and recognizes the role of women in the post-harvest sector and need for improvements to facilitate women's participation in such work (Section 7.2, 7.3).

3.0 METHODOLOGY

Methods used in this paper include desktop research using secondary sources on microbiological profiles and chemical contaminants of smoked fish, evaluations of the technological performance of IFSSs in Ghana and technology transfer and diffusion theory. Qualitative methods, such as direct and participant observations and key informant interviews conducted by the authors in Elmina and other coastal fishing communities in Ghana from June to August, 2017 validate these findings. Data on the SFMP training interventions, using TraiNet, the USAID's database for capturing and reporting information on training activities was also used.

4.0 RESULTS

4.1 Improving hygiene and handling of fish products after harvest

Fish are particularly prone to pathogenic contamination resulting from unhygienic conditions during handling and after harvest (Lokuruka, 2016). Unhygienic fish handling and processing practices puts consumers at high risk of foodborne diseases through microbial and chemical contamination after catch until consumption. A preliminary study (SNV, 2017) conducted by the Centre for Coastal Management at the University of Cape Coast on microbial profiles of samples (n=10) of smoked fish purchased from markets in six coastal towns, including Elmina, revealed that bacteria, yeasts and molds from smoked fish were either heat resistant or introduced through contamination during the cooling process, results summarized in Table 1. Coliforms were beyond the tolerable limits (SNV, 2017). Smoked fish were also subject to fecal contamination possibly due to poor handling and processing under unhygienic conditions (SNV, 2017). In the same study (SNV, 2017), fifteen types of PAHs were detected at different levels except Naptaline from another sample (n=19) of smoked fish, results summarized in Table 2. The type of stove used, where known, is shown in Tables 3, 4 and 5 which includes the Chorkor and Morrison stove (SNV, 2016). The type of stove used for samples taken from markets was not identified (SNV, 2016). All smoked fish sampled (n=19) under this study (SNV, 2017) recorded elevated levels of PAHs, which exceeded the maximum acceptable limit established by the European Commission for four carcinogenic PAHs (Pyrene, Benzo(a)anthracene, Chrysene and Benzo(a)Pyrene). This study suggests that certain types of smoked fish in Ghanaian markets, including Elmina, are unwholesome for human consumption and poses a public health risk (SNV, 2017). This study validates the need to educate processors and consumers on hygienic fish standards and best processing practices for domestic consumption.

The SFMP is supporting efforts to adopt safe and hygienic fish handling practices through trainings and other means of awareness creation and sensitization in coastal regions of Ghana. Hygienic fish processing, packaging and handling training is hands-on, beginning with personal hygiene practices (i.e. hand washing), determining and maintaining fish quality from capture to consumption (i.e. use of ice, insulated containers on board fishing vessels and environmental sanitation on land) and preserving fish through better packaging and labelling, storage and marketing. These practices play a key role in advancing food safety in the supply chain and can increase profits along the value chain. Qualitative data obtained through key informants following SFMP trainings suggest neatly packaged fish increases sales and participants receive a higher price for improved quality fish packaged under hygienic conditions. Since 2016, 695 fish processors, including 81 persons in Elmina have received hygienic fish handling training under the SFMP (TraiNet, 2017). In Elmina, the SFMP is supporting construction of a model small-scale fish processing center managed by the Central and Western Fishmongers Improvement Association (CEWEFIA) that can serve as a demonstration site for improved post-harvest practices for fish processors catering to the local market. To capitalize and sustain improvements in the post-harvest sector, processors many of whom are women-owned

Micro, Small and Medium Enterprises (MSMEs) receive business management training under this project. The training involves categorizing costs, financial record keeping, profit and loss analysis as it relates to fish processing. The goal of the training is to help raise income levels of MSMEs. Since 2016, 710 fish processors have received business development training in Ghana under the SFMP (TraiNet, 2017).

4.2 Technological development and transfer of Improved Fish Smoking Stoves

Fish smoking technology to preserve and process fish for consumption has evolved over time. Prior to the 1970s, the types of stoves used for smoking fish were cylindrical and made of mud or metal (Hall, 2011). While the cost of construction was low, there were considerable disadvantages such as inefficient use of inputs (i.e. fuelwood and time) and insufficient capacity which was a problem during the peak season when large volumes of fresh fish were landed. These shortcomings were addressed with the introduction of the Chorkor stove, the most commonly used stove for fish smoking in Ghana today which was developed by the FAO in collaboration with the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR) in Ghana in 1969 (Kwarteng, Nsiah and Aziebor, 2016). The SFMP has supported research and development of IFSS models, including the Morrison and Ahotor stove. The Morrison stove was developed by Morrison Energy Limited, a private enterprise in Ghana in 2008. The Morrison stove was promoted in 2015 under the SFMP given its fuel-efficiency advantage over the Chorkor smoker, however, unacceptable levels of PAHs found in fish using this stove type resulted in its discontinuation and prompted a new phase of research and development to better understand PAH issues in relation to fish smoking technology and design stove components which specifically aim to reduce PAHs (CSIR and Kwarteng, 2016). The Ahotor was developed in 2016 by local and international consultants with guidance from SNV, CSIR and the Fisheries Commission, along with testing support from the Ghana Standards Authority and the CSIR-Institute of Industrial Research (Avega and Tibu, 2017). The Ahotor incorporates specific design features such as a drip collector and a combustion system shown to reduce PAHs levels (CSIR and Kwarteng, 2016). With support from the SFMP, the Netherlands Development Organization (SNV) has been conducting PAHs analyses for fish smoked by the Ahotor stove. In 2016, a PAH analysis conducted by the Ghana Standards Authority (GSA) on fish smoked by the Ahotor stove showed 5.9 µg/kg and 53.1 µg/kg for BaP and PAH4 respectively (CSIR and Kwarteng, 2016). The most recent PAH analysis of fish smoked by the Ahotor stove was conducted in September and October, 2017 by the GSA. The analytical test report from the GSA shows three separate samples were drawn, each sample of smoked fish weighed 1 kg. This report states two samples exceeded the European Union (EU) maximum residue limit (MRL) of 12 µg/kg, and one sample was within this limit for smoked fish. The first of the two samples exceeding the EU MRL showed 5.78 µg/kg for Benzo(a)anthracene, 5.72 µg/kg for Chrysene, 0.80 µg/kg for Benzo(b)fluoranthene and 0.50 µg/kg for Benzo(a)pyrene totalling 12.80 µg/kg. The other sample which exceeded the EU MRL showed 8.91 µg/kg for Benzo(a)anthracene, 8.82 µg/kg for Chrysene, 0.20 µg/kg for Benzo(b)fluoranthene and 0.22 µg/kg for Benzo(a)pyrene totalling 18.15 µg/kg. The sample of smoked fish within the EU MRL showed 0.38 µg/kg for Benzo(a)anthracene, 0.38 µg/kg for Chrysene, <0.1 µg/kg for Benzo(b)fluoranthene and 1.07 µg/kg for Benzo(a)pyrene totalling 1.83 µg/kg. Based on energy assessment studies conducted on IFSSs, the Ahotor stove is more fuel-efficient than the Chorkor stove (CSIR and Kwarteng, 2016). In this study, three tests following the Control Cooking Test (CCT) protocol were conducted comparing the Chorkor and Ahotor stove on specific fuelwood consumption. The mean fuelwood consumption for the Chorkor stove was 306 g/kg and the mean fuelwood consumption for the Ahotor stove was 208.6 g/kg (CSIR and Kwarteng, 2016). A t-test for the comparison of the means was performed, the difference was statistically significant[iv] based on a confidence level of 95 percent (CSIR and Kwarteng, 2016). This is noteworthy given demand and consumption for fuelwood is likely to increase in Ghana with its rate of depletion outstripping regeneration which contributes to forest degradation (Kwarteng, 2015). The Ahotor stove is the current IFSS technology being promoted under the SFMP. The SFMP is also supporting the introduction of FAO Thiaroye Processing Technique (FTT) through installation of a FTT stove for a privately-owned, small-scale fish and agricultural processing center in Elmina to process fish for local and export markets.

4.3 Adoption of improved fish processing technology by processors

If adopted, technological innovations in post-harvest fish processing can generate social, economic, and environmental benefits for small-scale fisheries in developing countries. The adoption of technological innovations is often guided by diffusion theory, defined as the process by which an innovation is shared or communicated through certain channels over a period of time among members of a community or social system (Rogers, 1995). The result of this process is either adoption or rejection of the innovation, or new idea. Various models, stages and attributes of diffusion theory can be applied to determine rate of adoption of IFSSs. Data from an Independent Evaluation of the Morrison stove in Ghana conducted by the Fisheries Commission Post-Harvest and Monitoring and Evaluation Unit in 2016 provides an indication of potential rates of adoption of IFSSs (Odjidja et al., 2016). Before the Morrison stove, the Chorkor stove was the most common type of stove used according to this study conducted in four regions in Ghana, the difference is statistically significant[v] as shown in Table 6 (Odjidja et al., 2016). Regionally, there is a statistically significant difference[vi] with regards to preference in favor of the Morrison stove over previous stoves used, as shown in Table 7 (Odjidja et al., 2016). Preference for Morrison stove technology is attributed to less consumption of fuelwood (i.e. more fuel-efficient), less smoke emission or nuisance and better-quality products (Odjidja et al., 2016). Survey respondents also stated challenges such as affordability and development of defects and maintenance issues of the Morrison stove (Odjidja et al., 2016). Despite concerns related to design or maintenance, expectations of future improvements are high (Odjidja et al., 2016). The Ahotor stove bears many attributes preferred by users of the Morrison stove, including less consumption of fuelwood and more personal health benefits, such as less nuisance of smoke (Avega and Tibu, 2017). Research on factors which influence rates of adoption for the Ahotor stove in Ghana's small-scale marine fisheries sector based on diffusion theory is in progress and is supported by the SFMP.

5.0 CONCLUSION AND RECOMMENDATIONS

Given Ghana's dependence on and appetite for fish, there is a need to respond to food safety challenges confronting this sector, especially linked to controlling PAHs in smoked fish. Additional scientific studies for microbial profiles and PAHs levels in smoked fish are needed to determine the extent of this problem nationwide. A controlled, quantitative study to determine changes in profitability among fish processors using the Ahotor stove is recommended. The Ahotor stove aims to meet international standards for lower PAHs established by the European Commission while maintaining fuel-efficiency standards recommended by energy access partnerships such as Energising Development (EnDev) which promote access to sustainable energy. To-date, only one sample test has shown the Ahotor stove meets the European Union maximum residue limit for PAHs. It is premature to determine whether this current model will comply with EU PAHs requirements. The SFMP is conducting subsequent studies on levels of PAHs with the Ghana Standards Authority to establish consistent results showing lower PAHs levels and potential compliance with EU PAHs requirements. Positive attributes of the Ahotor stove, such as its fuel-efficiency and reduced PAHs levels should be highlighted and continue to inform outreach activities under the SFMP. The SFMP is continuing to promote and facilitate adoption of the Ahotor stove through fish smoking demonstration trainings, village savings and loans associations (VSLAs) and by training local artisans on construction of this stove model. The types of improved fish smoking technology discussed in this paper are examples of collaborative research, involving public and private sector institutions in Ghana with support from the SFMP with the goal of delivering safe food, increasing incomes for fish processors, ensuring workers' health and safety and protecting the natural environment. Understanding factors which influence rate of adoption and technological transfer of post-harvest value chain improvements can facilitate implementation and de-risk investments.

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[iii] IFSSs discussed in this paper include the Morrison and Ahotor stoves.

[iv] T-test = 9.513.

[v] Chi-square = 27.930, DF = 15, p-Value = 0.022, N =105.

[vi] Chi-square = 27.384, DF = 6, p-Value < 0.001, N=105.

APPENDIX

Table 1 Microbobial profiles of smoked, salted and fresh fish samples

ND: Not detected

Micro-organism	Microbial load (cfu/g) of fish samples in various states																
	Smoked (n= 10)										Salted (n = 2)		Fresh (n = 5)				
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}
Aerobic Plate Count	$9.2x10^3$	$2.1x10^4$	$2.9x10^4$	$9.1x10^3$	$1.5x10^4$	$1.4x10^4$	$9.5x10^4$	$4.3x10^4$	$1.5x10^4$	$1.4x10^4$	$1.6x10^3$	$1.7x10^3$	$2.4x10^4$	$2.2x10^3$	$2.8x10^3$	$1.7x10^4$	$1.8x10^5$
Coliform Count	<10	<10	176	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	48	20	40	40
E. coli	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Listeria monocytogenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Enterococcus sp.	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Bacillus cereus	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Staphylococcus aureus	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Salmonella spp.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Clostridium perferingens	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Vibrio	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Moulds	80	30	<10	<10	<10	60	<10	20	<10	<10	<10	<10	130	<10	20	60	<10
Yeasts	$2.1x10^3$	<10	$3.8x10^3$	<10	<10	$2.1x10^3$	<10	<10	<10	<10	<10	<10	$2.5x10^3$	<10	60	10	<10

Source: SNV, 2017

Table 2 Polycyclic Aromatic Hydrocarbon (PAH) levels in smoked and fresh fish samples

PAH	PAH concentrations (µg/Kg) in various fish samples																				Mean	St Dev	Var
	Sardines (n = 9)									Chub Mackerels (n = 8)								Anchovies (n = 3)					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	*QR		S	T			
NAP	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd	Nd
ACA	143.8	155.8	271.5	405.8	315.2	440.1	461.6	159.7	244.8	210.9	362.1	354.1	306.2	478.6	204.2	157.1	Nd	150.3	319.6	165.1	279.3	114.2	13055.6
ACE	12.4	19.0	37.8	52.8	47.1	38.5	82.5	21.1	26.8	26.5	37.1	29.2	34.6	51.9	3.2	22.0	Nd	17.4	41.7	25.8	33.0	17.8	317.1
FLU	5.9	11.5	233.5	300.1	208.2	214.2	386.4	105.8	140.8	150.1	197.1	186.2	183.5	305.2	21.5	20.1	Nd	143.3	206.1	185.1	168.7	104.0	10822.9
PHE	395.4	512.2	1012.2	1290.4	1198.1	613.2	1728.2	529.3	819.1	759.6	1109.9	547.1	1048.2	1201.5	652.2	499.5	Nd	682.8	1104.2	1101.1	884.4	351.9	123260.9
ANT	288.5	420.1	727.3	917.1	848.5	443.2	1219.9	372.5	84.5	110.5	129.2	396.9	748.6	864.5	468.1	362.4	Nd	480.4	786.2	783.1	550.1	310.7	96545.6
FLT	56.2	88.5	143	116.2	132.1	82.5	141.3	26.3	66.7	100.7	311.4	62.1	114.5	105.2	66.2	57.2	Nd	92.3	135.2	109.1	105.6	59.6	3548.1
PYR	56.8	89.3	142.8	115.8	132.1	81.2	141.1	23.2	66.8	100.6	311.1	61.4	114.4	105.8	67.1	58.2	Nd	90.1	134.1	109.2	105.3	59.6	3559.3
BAA	47.4	82.9	123.1	71.1	54.3	47.8	107.7	8.7	12.5	111.7	156.8	14.7	44.9	87.8	69.1	84.2	Nd	100.3	141.6	139.3	79.3	44.4	1967.9
CHR	49.3	85.1	141.7	72.1	142.8	50.8	49.5	5.7	105.0	108.3	149.2	16.7	51.9	94.1	71.8	93.7	Nd	107.7	152.1	61.8	84.7	43.1	1857.0
BBF	40.9	3.1	30.1	1.5	53.2	26.7	37.1	25.6	40.7	57.1	73.0	16.2	1.4	1.9	1.6	3.1	Nd	50.4	3.6	2.6	24.7	23.1	535.3
BKF	27.5	29.6	27.3	18.5	45.1	21.5	32.4	23.6	41.7	45.6	74.4	10.4	34.2	35.0	18.8	28.6	Nd	40.1	61.6	40.2	34.5	15.3	234.1
BAP	28.0	30.4	27.7	18.5	45.8	21.9	32.8	24.0	42.9	46.3	72.4	10.6	34.3	35.4	19.0	30.8	Nd	40.7	62.9	41.0	35.0	15.1	228.6
IND	1.3	1.1	1.1	1.1	11.9	1.7	6.1	3.1	7.6	8.4	15.2	1.9	1.4	1.5	Nd	1.1	Nd	2.6	4.6	2.1	3.9	4.1	17.3
DAA	1.8	1.6	1.5	1.2	16.4	2.3	8.3	4.2	10.4	11.5	20.7	2.6	2.0	2.1	Nd	1.6	Nd	3.5	6.3	2.9	5.3	5.7	32.3
BGP	1.4	1.1	1.1	1.1	16.1	1.9	8.5	4.3	10.5	11.7	21.1	2.1	1.6	1.5	Nd	1.1	Nd	3.6	5.9	2.5	5.1	5.8	34.4

Total 1156.6 1531.3 2921.7 3383.3 3266.9 2087.5 4443.4 1337.1 1720.8 1859.5 3040.7 1712.2 2721.7 3372.0 1662.8 1420.7 Nd 2005.5 3165.7 2770.9 2398.96 905.6820078.0 *: The only fresh fish sample; Nd: Not detected (below the detection limit of 1.0 µg/Kg)
NAP = Naphthalene; ACA = Acenaphthalene; ACE = Acenaphthene; FLU = Fluorene, PHE = Phenanthrene; ANT = Anthracene, FLT = Fluoranthene; PYR = Pyrene; BAA = Benzo(a)anthracene; CHR = Chrysene; BBF = Benzo(b)Fluoranthene; BKF = Benzo(k)Fluoranthene; BAP = Benzo(a)Pyrene; IND = Indeno(1,2,3-c,d)Pyrene; DAA = Dibenzo(a,h)anthracene; BGP = Benzo(g,h,i)perylene
Source: SNV, 2017

Table 3 PAH levels (µg/kg) in smoke sardines on the Ghanaian market

PAH	Elmina, MS	Elmina CS1	Elmina, CS2	Elmina, CS/SM	Agona Nkwanta	Cape Coast	Moree	Sekondi	Axim, C
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthale	244.8	315.2	461.6	159.7	143.8	155.8	271.5	405.8	440.1
Acenaphthene	26.8	47.1	82.5	21.1	12.4	19	37.8	52.8	38.5
Fluorene	140.8	208.2	386.4	105.8	5.9	11.5	233.5	300.1	214.2
Phenanthrene	819.1	1198.1	1728.2	529.3	395.4	512.2	1012.2	1290.4	613.2
Anthracene	84.53	848.5	1219.9	372.5	288.5	420.1	727.3	917.1	443.2
Fluoranthene	66.7	132.1	141.3	26.3	56.2	88.5	143	116.2	82.5
Pyrene	66.8	132.5	141.1	23.2	56.8	89.3	142.8	115.8	81.2
Benzo(a)anthracene	12.5	54.3	107.7	8.7	47.4	82.9	123.1	71.1	47.8
Chrysene	105	142.8	49.5	5.7	49.3	85.1	141.7	72.1	50.8
Benzo(b)fluoranthene	40.7	53.2	37.1	25.6	40	3.1	30.1	1.5	26.7
Benzo(k)fluoranthene	41.7	45.1	32.4	23.6	27.5	29.6	27.3	18.5	21.5
Benzo(a)pyrene	42.9	45.8	32.8	24	28	30.4	27.7	18.5	21.9
Indeno(1,2,3-c,d)pyrene	7.6	11.9	6.1	3.1	1.3	1.1	1.1	1.1	1.7
Dibenzo(a,h)anthracene	10.4	16.4	8.3	4.2	1.8	1.6	1.5	1.2	2.3
Benzo(g,h,i)perylene	10.5	16.1	8.5	4.3	1.4	1.1	1.1	1.1	1.9
Total PAHs	1720.83	3267.3	4443.4	1337.1	1155.7	1531.3	2921.7	3383.3	2087.5

CS = Chorkor Stove; MS = Morrison Stove; SM = Unknown; Agona Nkwanta, Cape Coast, Moree, Sekondi are markets where samples were taken but the type of stove used to smoke fish was unknown.
Source: SNV, 2017

Table 4 PAH levels (µg/kg) in smoked Chub Mackerel samples from the Ghanaian market

PAH	Cape Coast	Sekondi	Agona	Moree, CS	Axim	Elmina,MS/SM	Elmina CS/S
Naphthalene	ND	ND	ND	ND	ND	ND	ND
Acenaphthale	157.1	204.2	478.6	306.5	354.1	362.1	210.9
Acenaphthene	22	3.2	51.9	34.6	29.2	37.1	26.5
Fluorene	20.1	21.5	305.2	183.5	186.2	197.1	150.1
Phenanthrene	499.5	652.2	1201.5	1048.2	547.1	1109.9	759.6
Anthracene	362.4	468.1	864.5	748.6	396.9	129.2	110.5
Fluoranthene	57.2	66.2	105.2	114.5	62.1	311.4	100.7
Pyrene	58.2	67.1	105.8	114.4	61.4	311.1	100.6
Benzo(a)anthracene	84.2	69.1	87.8	44.9	14.7	156.8	111.7
Chrysene	93.7	71.8	94.1	51.9	16.7	149.2	108.3
Benzo(b)fluoranthene	3.1	1.6	1.9	1.4	16.2	73	57.1
Benzo(k)fluoranthene	28.6	18.8	35	34.2	10.4	74.4	45.6
Benzo(a)pyrene	30.8	19	35.4	34.3	10.6	72.4	46.3
Indeno(1,2,3-c,d)pyrene	1.1	ND	1.5	1.4	1.9	15.2	8.4
Dibenzo(a,h)anthracene	1.6	ND	2.1	2	2.6	20.7	11.5
Benzo(g,h,i)perylene	1.1	ND	1.5	1.6	2.1	21.1	11.7
Total PAHs	1420.7	1662.8	3372	2722	1712.2	3040.7	1859.5

CS = Chorkor Stove; MS = Morrison Stove; SM = Unknown; Agona, Cape Coast, Moree, Sekondi, Axim, Elmina are markets where samples were taken but the type of stove used to smoke fish was unknown.
Source: SNV, 2017

Table 5 Levels of PAH (µg/kg) in smoked Engraulis encrasicolus

PAH	Elmina, CS	Sekondi	Agona
Naphthalene	ND	ND	ND
Acenaphthale	319.6	150.3	165.1
Acenaphthene	41.7	17.4	25.8
Fluorene	206.1	143.3	185.1
Phenanthrene	1104.2	682.8	1101.1
Anthracene	786.2	480.4	783.1
Fluoranthene	135.2	92.3	109.1
Pyrene	134.1	90.1	109.2
Benzo(a)anthracene	141.6	100.3	139.3
Chrysene	152.1	107.7	61.8
Benzo(b)fluoranthene	3.6	50.4	2.6
Benzo(k)fluoranthene	61.6	40.1	40.2
Benzo(a)pyrene	62.9	40.7	41
Indeno(1,2,3-c,d)pyrene	4.6	2.6	2.1
Dibenzo(a,h)anthracene	6.3	3.5	2.9
Benzo(g,h,i)perylene	5.9	3.6	2.5
Total PAHs	3165.7	2005.5	2770.9

CS = Chorkor Stove; Elmina, Sekondi, Agona are markets where samples were taken but the type of stove used to smoke fish was unknown.
Source: SNV, 2017

Table 6 Previous processing technology used before the Morrison stove

Previous processing technology used	Regions in Ghana				
	Greater Accra	Volta	Central	Brong Ahafo	Average All Regions
No answer	0.00	0.00	8.33	0.00	1.91
Frismo oven	0.00	7.14	0.00	0.00	2.86
Traditional mud stove	5.71	16.67	0.00	0.00	8.57
Traditional metal drum stove	5.71	2.38	0.00	0.00	2.86
Chorkor smoker	77.14	73.81	70.83	100.00	75.24
Combination of processing technologies	11.43	0.00	20.83	0.00	8.57
Total	100.00	100.00	100.00	100.00	100.00

(Chi-square = 27.930, DF = 15, p-Value = 0.022, N=105)
Source: Odjidja et al., 2016

Table 7 Preference of Morrison stove to other stoves used

Prefer Morrison?	Regions in Ghana				
	Greater Accra	Volta	Central	Brong Ahafo	Average All Regions
No	51.43	4.76	37.50	0.00	27.62
Yes	48.57	95.24	58.33	100.00	71.43
No answer	0.00	0.00	4.17	0.00	0.95
Total	100.00	100.00	100.00	100.00	100.00

(Chi-square = 27.384, DF = 6, p-Value < 0.001, N=105)

Source: Odjidja et al., 2016