SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP)

Testing Of Low PAH Improved Fish Smoking Stove (Ahotor Oven)

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Cover photo: Taking the weight of fish after smoking (Credit: IRR)

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ACRONYMS

CCM	Centre for Coastal Management
CEWEFIA	Central and Western Region Fishmongers Improvement Association
COMFISH	Collaborative Management for a Sustainable Fisheries Future
CoP	Chief of Party
CPUE	Catch Per Unit Effort
CR	Central Region
CRC	Coastal Resources Center at the Graduate School of Oceanography, University of Rhode Island
CRCC	Central Regional Coordinating Council
CSLP	Coastal Sustainable Landscapes Project
CSO	Civil Society Organization
DA	District Authorities
DAA	Development Action Association
DAASGIFT	Daasgift Quality Foundation
DFAS	Department of Fisheries and Aquatic Sciences
ERF	Environmental Review Form
ETP	Endangered, Threatened and Protected
FAO	Food and Agricultural Organization of the United Nations
FC	Fisheries Commission
FoN	Friends of Nation
FtF	Feed the Future
GoG	Government of Ghana
GSA	Ghana Standards Authority
GSO	Graduate School of Oceanography, University of Rhode Island
HM	Hen Mpoano
LOE	Level of Effort
LoP	Life of Project
MCS	Monitoring, Control and Surveillance
NGO	Non-Governmental Organization
SFMP	Sustainable Fisheries Management Program
SMEs	Small and Medium Enterprises
SNV	Netherlands Development Organization
SS	Spatial Solutions
SSG	SSG Advisors
UCC	University of Cape Coast
URI	University of Rhode Island
USAID	United States Agency for International Development
USG	United States Government
WASH	Water, Sanitation and Hygiene
WR	Western Region

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EXECUTIVE SUMMARY

This report presents the findings from a Controlled Cooking Test (CCT) on an improved fish smoking stove called the AHOTOR OVEN design by the combine effort of SNV, FRI, FC and NAFPTA under the USAID funded Sustainable Fisheries Management Project. The Project aims at ending overfishing of key stocks important to local food security through a multi-pronged approach:

- Improved legal enabling conditions for co-management, use rights and effort-reduction strategies
- Strengthened information systems and science informed decision-making
- Increased constituencies that provide the political and public support needed to rebuild fish stocks
- Implementation of applied management initiatives for several targeted fisheries ecosystems

The performance test was carried out in Wenniba fishing community. This is part of the SFMP post-harvest activities strategies; to promote for the adoption of fish smoking technology that produces fish with less PAH and also uses less fuelwood in order to enhance environmental sustainability and livelihoods. In addition, to ensue technology transfer, the event serves as an opportunity for testing and comparing stove performance (energy and production efficiencies).

In this event, SFMP/SNV Ghana therefore consulted the Regional Testing and Knowledge Centre at CSIR - Institute of Industrial Research, to conduct a comparative test to assess the performances and efficiencies of the AHOTOR OVEN technology in comparison with the Chorkor oven

The testing approach adopted was the Controlled Cooking Test (CCT) using six (6) wooden trays/shelves under the same conditions and procedures and the results were compared for fuel efficiencies and emissions. The raw data obtained from the measurements and tests were recorded for off-line analyses using the CCT 2.0 version (Rob Bailis, 2004).

From the statistical analysis (t-test) there was a significant difference of 31.8% between the Traditional Chorkor oven and Ahotor Oven @ 95% for specific fuel consumption (i.e. percentage difference in fuel savings of 31.8%) by using the Ahotor Oven. There was no significant difference for the total cooking time and processing rate (i.e percentage difference in time savings and processing rate were of 14.57% and 7.22% respectively by using the Chorkor stove). It was determined that the average CO and PM2.5 emissions for Ahotor Oven were 12.35% and 12.79% respectively and there were no significant differences in the means during the emissions test.

Average heat losses from the combustion chambers through the walls to the surroundings were recorded to be 48^{o} C and 42.7^{o} C for the Traditional Chorkor stove and Ahotor Oven respectively. The Ahotor Oven proved safer and efficient to be employed when compared to the Traditional Chorkor stove. It was therefore recommended that the Ahotor Oven could be promoted for the Fish processing communities.

Smoked fish analysis has proven that the Ahotor stove smoked fish with low PAH levels than the Chorkor and the Morrison stove. The Ahotor stove produces fish with 73% less content of BaP and 36% less of PAH4; the regulated PAHs. This implies that, employing the use of the Ahotor stove, unconsciously, more healthy fish will be introduced into the Ghanaian market.

INTRODUCTION

The United States Agency for International Development (USAID) has committed funds to the implementation of the Sustainable Fisheries Management Project (SFMP) in Ghana for five years.

The objective is to rebuild marine fisheries stocks and catches through adoption of responsible fishing practices. The project will contribute to the Government of Ghana’s fisheries development objectives and USAID’s Feed the Future Initiative.

The project is being implemented by the Coastal Resource Center (CRC) of the University of Rhode Islands (URI) through a consortium of international and local partners, including SNV Netherlands Development Organization.

SNV under the Sustainable Fisheries Management Project consulted the Regional Testing and Knowledge Centre at CSIR - Institute of Industrial Research, to conduct a comparative test to assess the performances and efficiencies of the AHOTOR OVEN technology in comparison with the Chorkor oven

About CSIR

The Council for Scientific and Industrial Research (CSIR) is a semi-autonomous organisation with the mandate to pursue the implementation of government policies on scientific research and development, encourage coordination of scientific research for the management, utilization and conservation of the natural resources of Ghana; and to advise Government on scientific and technological advances likely to be of importance to national development.

The CSIR now operates under the mandate of CSIR Act 521 of 1996, which among other things, empowers it to commercialize its research activities. The mission of CSIR is to become the force of accelerated social and economic development of Ghana through examining, exploring and creating science and technology catalysts for public and private wealth creation. The CSIR oversees 13 research institutes of which Institute of Industrial Research (IIR) is one.

The Institute of Industrial Research (IIR)

The Institute of Industrial Research is one of the leading research institutes of CSIR; among its duties, is to assist in poverty reduction through the creation of opportunities for generating and increasing incomes within the Small and Medium-scale Enterprises (SMEs); contribute towards food security, and apply cost-effective industrial technologies that are both environmentally friendly and commercially viable. The Institute is one of the Regional Testing and Knowledge Centres supported by the United Nations Foundation through the Global Alliance for Clean Cookstoves.

The Institute of Industrial Research projects include the following:

- Mitigation of the global warming problem (CO2), reduction of pollutant emission;
- Higher efficiency of Ghana’s energy utilization;
- Strengthening the competitive position of IIR through innovation of process technologies;
- Increase knowledge in the production and application of energy such as wind, hydro, solar, fuel cells, biofuels, cookstove and fuel testing;
- Reduce energy waste in industry and commercial institutions through energy audit program.

The CSIR-IIR research, develop and promote technologies which include renewable energy, industrial processes, new materials development, improved sanitation, locally equipment fabrication, repair/maintenance and calibration, and information technology.

Objectives of Research

The objective of this assignment is to;

- • Conduct performance and efficiency test of the Ahotor Oven and the Chorkor stove.
- • Conduct a comparative test between the Ahotor Oven and the Chorkor stove using Controlled Cooking Test (CCT) protocol.

EXPERIMENTAL METHODS AND PROCEDURES

Brief Description of Fish Smoking Ovens

Ahotor Oven

The Ahotor oven is built mainly with 5” sandcrete blocks and Portland cement. It has two combustion chambers which are partitioned and built with burnt bricks. The combustion chamber enhances efficient combustion of wood releasing less smoke. This makes using the stove very friendly. Inside the combustion chamber is a grate that allows for more oxygen for efficient burning of wood.

Series of wooden trays are stalked on the top of the combustion chamber which has an opening on top. The edges of the trays fitting very well preventing smoke leakages from the sides.

The stove also has a fat collecting system that prevents fats, water, blood from the fish dropping into fire to burn and increase PAH levels. These fat and blood are channel out and collected from outside.

The AHOTOR oven can hold fish capacity of over twenty (20) trays at a time with an incorporated truncated pyramid shape chimney to the design.

Chorkor Stove

The stove is built mainly with clay mixed with small quantity of sand at the 4:1 proportion has been adopted. This means that for every four (4) proportion of clay used in volume, a one (1) volume proportion each of sand was added. The trays are loaded on top of the combustion chamber but no interlocking device. The handles at the ends are chamfered for easy gripping of hands when carrying. The Chorkor stove is design to hold a capacity of eight (8) trays which dimensions are outside (1060 x 820 x 60 mm) and inside of 1035 x 795 x 60 mm (L x B x H) given a wire mesh surface area of 0.823 m2 without a chimney. The overall dimensions are 2060 x 1360 x 540 mm (L x B x H) with wall thickness of 150 mm and a firepot (front loading for the fuelwood) of dimensions 380 x 400 mm (LxH). Figure 1 shows photograph of the Ahotor Oven and Chorkor stove at Winneba.

Figure 1 Photographs of Ahotor Oven and Traditional Chorkor Stove

Materials and Methods

Fuel Used

Sample of Yaya fuelwoods were obtained from bundled batches as shown in Figure 2. It was determined to have qualities of an average hardwood with a calorific value of 19734 kJ/kg. The average dimension of the fuel was measured to be of length 57.9±2.5 cm and a width of 10.4±1.3 cm

Figure 2 Bundled fuel ready to use

Figure 3 Measurement of wood's moisture content

Moisture Content

The moisture content of the fuel was determined by using moisture meter Voltcraft FM-300 (Conrad Electronics SE, Hirschau) which measurement was in dry basics. Five (5) samples of the fuel were collected at random and measurements were taken at four (4) locations in each fuel selected for a bundle of wood as shown in Figure 3. Average values were therefore determined and converted in wet basics. The moisture content was determined to be 61.1%.

Atmospheric Conditions

The stoves were tested in the field which is well ventilated with a light breeze. The atmospheric conditions (temperature and humidity) were determined with a temperature, humidity and clock meter THC-2 and the average temperature of 30.5oC and relative humidity of 61.8% were recorded.

Experimental Procedures

For Controlled Cooking Test (CCT), the same weight of fuelwood and fish were weighed for each stove accordingly. The cook was to prepare a good quality smoked fish product where time to cook and amount of fuel used were measured after completion of operation. An electronic weighing scale (KERN DE 60 K1 DL) of maximum weight of 60 kg and resolution of 0.5 g was used to weigh the fuelwood and fish for both before the process as presented in Figure 4a and 4b respectively. Figure 5 depicts smoking of fish using both Ahotor Oven and Chorkor stove respectively during the CCT with the Indoor Air Pollution (IAP) meter attached to the cook, in order to measure and record the possible inhalation of emission (i.e., CO and PM 2.5) for some few minutes. Final weighing of the smoked fish is presented in Figure 6.

Figure 4 Sample of weighing (left) fuelwood and (right) fish before testing.

Figure 5 Fish smoking on the (left) Ahotor Oven and (right) Chorkor stove respectively using IAP meter.

Figure 6 Weighing of smoked fish

RESULTS AND DISCUSSION

The constructed Ahotor Oven and Chorkor stove were carried out under CCT protocol and each stove was repeated two times for processing a quantity of fish. Although the tray sizes are not the same, the cook was supplied with the same weight of fish for the process. Comparison was determined between the stoves performance.

The statistical significant analyses (t-test) and summary among the two stoves results have been presented with a confidence level of 95%. Table 1 below depicts the raw processed data for the stoves.

Table 1 Controlled Cooking Test statistical results (t-test) for the cookstoves

1. CCT results: Stove 1(CHORKOR)	***units***	***Test 1***	***Test 2***	***Test 3***	***Mean***	***St Dev***
Total weight of food cooked	g	40802	33955	35330	36695.7	3622
Weight of char remaining	g	289	671	577	512.3	199
Equivalent dry wood consumed	g	12472.9	10979.7	10211	11221.3	1150
Specific fuel consumption	g/kg	305.7	323.4	289	306	17.2
Total cooking time	min	235	239	240	238	2.6
2. CCT results: Stove 2 (AHOTOR OVEN)	units	Test 1	Test 2	Test 3	Mean	St Dev
Total weight of food cooked	g	43477	37098	36435	39003.3	3888.5
Weight of char remaining	g	344	559	1151	684.7	417.9
Equivalent dry wood consumed	g	9288	7610.2	7539.9	8146	989.6
Specific fuel consumption	g/kg	213.6	205.1	206.9	208.6	4.5
Total cooking time	min	286	252	280	272.7	18.1
Comparison of Stove 1 and Stove 2		% difference		T-test	Sig @ 95%?	
Specific fuel consumption	g/kg	**0.31846**		9.5132	YES	
Total cooking time	min	**-0.1457**		-3.2741	YES	
		CHORKOR STOVE		**AHOTOR OVEN**		
Processing rate	g/min	154.18		143.04		
% Yield		**7.22481**				

Total Weight of Food Cooked

The total weight of food cooked for the Chorkor stove and Ahotor Oven were determined and compared for significant difference between the means as presented in Table 2.

Table 2 Significant difference for total weight of food cooked between the means of the stoves

Stove/Oven	**Chorkor Stove**	**Ahotor Oven**
Total weight of food cooked (g)	36695.7	39003.3
Significant level @95% confidence level between stoves		NO
% difference		5.9

Weight of Char Remaining

The weight of char remaining after cooking for the Chorkor stove and Ahotor Oven were determined and compared for significant difference between the means as presented in Table 3.

Table 3 Significant difference for weight of char remaining between the means of the stoves

Stove/Oven	Chorkor Stove	Ahotor Oven
Total weight of char remaining after cooked (g)	512.3	684.7
Significant level @95% confidence level between stoves		YES
% difference		25.2

Equivalent Dry Wood Consumed

The equivalent dry wood consumed for the Chorkor stove and Ahotor Oven were determined and compared for significant difference between the means as presented in Table 4.

Table 4 Significant difference for equivalent dry wood consumed between the means of the stoves

Stove/Oven	Chorkor Stove	Ahotor Oven
Equivalent dry wood consumed (g)	11221.3	8146
Significant level @95% confidence level between stoves		YES
% difference		27.4

Specific Fuel Consumption

The specific fuel consumption for the Chorkor stove and Ahotor Oven were determined and compared for significant difference between the means as presented in Table 5.

Table 5 Significant percentage for specific fuel consumption difference between the means of the stoves

Stove/Oven	Chorkor Stove	Ahotor Oven
Specific fuel consumption (g/kg)	306	208.6
Significant level @95% confidence level between stoves		YES.
% difference		31.8

Total Cooked Time

The total cooked time for the Chorkor stove and Ahotor Oven were determined and compared for significant difference between the means as presented in Table 6.

Table 6 Significant percentage for specific fuel consumption difference between the means of the stoves

Stove/Oven	Chorkor Stove	Ahotor Oven
Total cooked time (min)	238	272.7
Significant level @95% confidence level between stoves		NO
% difference		-14.6

The processing rate for the Chorkor stove and Ahotor Oven were determined and compared for significant difference between the means as presented in Table 7.

Table 7 Significant percentage difference for processing rate between the means of the stoves

Stove/Oven	Chorkor Stove	Ahotor Oven
Processing rate (g/min)	154.18	143.04
Significant level @95% confidence level between stoves		NO
% difference		7.22

Emissions

During the test, emissions such as CO and PM2.5 were measured using the Indoor Air Pollution (IAP) meter. The recorded values of Carbon Monoxide (CO) and Particulate Matter (PM2.5) emissions have been presented in Figure 7 and Figure 8 respectively. From Figure 7, the CO emission for the Chorkor Stove was determined and compared to the Ahotor Oven for significant percentage difference between the means as presented in Table 8.

Table 8 Significant percentage difference for CO emission between the means of the oven

Stove/Oven	Chorkor Stove	Ahotor Oven
Carbon monoxide emission (g/min)	15.59	13.66
Significant level @95% confidence level between stoves		YES
% difference		12.38

This shows average CO reduction of 12.38% by using the Ahotor Oven as compared to the Traditional Chorkor stove. The maximum spike (32.72 g/min) emission by using the Chorkor stove as shown in the graph was due to the method of igniting the fire which represented 48.5% as compared to 16.85 g/min for the Ahotor Oven.

From Figure 8, the PM2.5 emission for the Chorkor stove was determined and compared to the Ahotor Oven for significant percentage difference between the means as presented in Table 9.

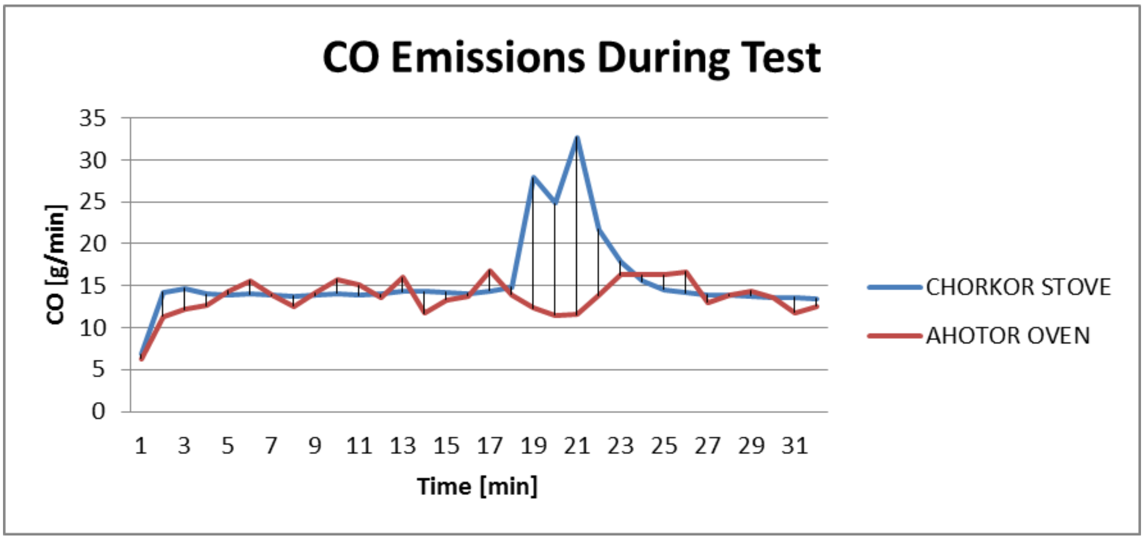

Figure 7 Samples of CO measured using the IAP for the Chorkor Stove against Ahotor Oven

Table 9 Significant percentage difference for $PM_{2.5}$ emission between the means of the stoves.

Stove/Oven	**Chorkor Stove**	**Ahotor Oven**
$PM_{2.5}$ emission (mg/min)	1036.29	903.78
Significant level @95% confidence level between stoves		NO
% difference		12.79

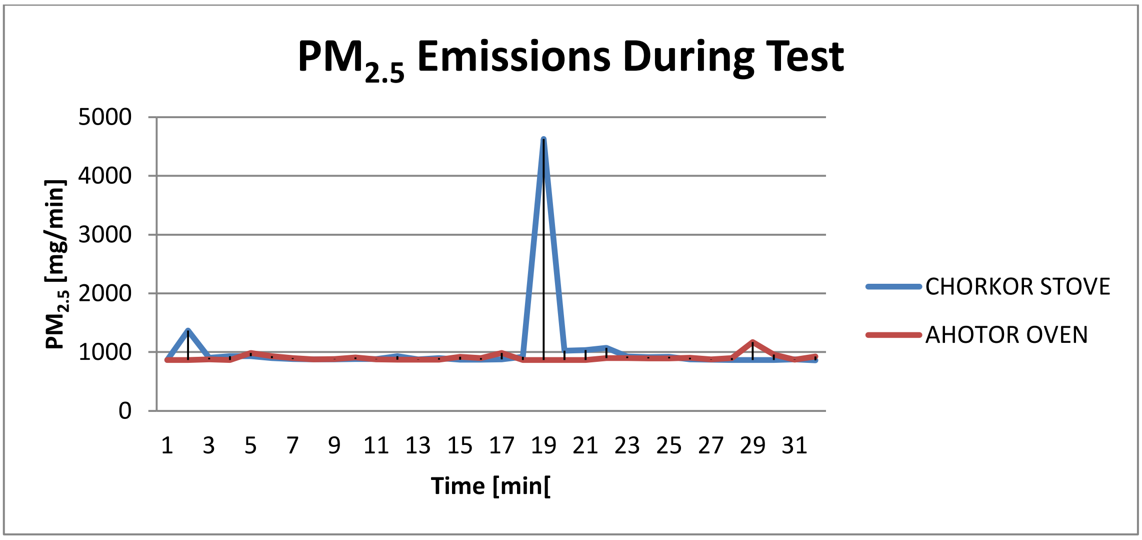

Figure 8 Samples of PM2.5 measured using the IAP for the Chorkor Stove against Ahotor Oven

This shows average PM2.5 reduction of 12.79% by using the Ahotor Oven as compared to the Traditional Chorkor stove. The maximum spike (4628.14 mg/min) emission by using the Chorkor stove as shown in the graph was due to the method of igniting the fire which represented 74.73% as compared to 1169.58 mg/min for the Ahotor Oven.

PAH ANALYSIS OF THE AHOTOR, MORRISON & CHORKOR OVENS

PAHs are a class of high lipophilic compounds that comprise of chemical compounds known to be potent carcinogens (Simko, 2002). Structurally, they consist of one or more aromatic ring and their structure is known to influence their toxicity. They are produced from the incomplete combustion of organic matter and exist in mixtures. So far, more than 600 PAH compounds have been identified.

PAHs formation in smoked foods depend on several variables in the smoking process, including type of smoke generator/stove, type of fuel used, combustion temperature, and degree of smoking (Garcia and Simal, 2005). Other factors include, fat content of fish species and cooking temperature.

Smoked fish is a delicacy in Ghana. This love for smoked fish has fuelled the expansion of fish smoking industry such that the industry is considered a dominant off-shoot of Ghana's fisheries sector. An estimated 70 – 80% of fish produced in Ghana is known to be consumed in smoked form. However the growth in this industry is not commensurate with advancement in technology or good practices.

The smoking industry in Ghana is largely unregulated with various oven types, hygienic issues and wood fuels used for smoking; as such the quality of smoked fish varies from place to place.

Smoked fish in Ghana is sold in-country with some units exported to other regional markets. Accessing the EU market has however proven quite difficult as the Union demands adherence to stringent regulations and standards regarding the sourcing, handling and processing of smoked fish. Amongst such standards, is the standard on Polycyclic Aromatic Hydrocarbons in smoked fish.

The Ahotor oven is designed as a retrofit to the Chorkor and Morrison stove with interventions to reduce the PAH content in smoked fish in the Ghanaian market. This retrofit system is intended to produce healthy fish for the Ghanaian and international market.

PAH analysis carried out in 2014 indicated that, the levels of BaP and PAH4 in the Chorkor stove was 22µg/kg and 84 µg/kg respectively. The Morrison stove had higher values of PAH levels of 30 µg/kg and 110 µg/kg for BaP and PAH4 respectively. PAH analysis carried out on the Ahotor stove (2016) by GSA shows 5.9 µg/kg and 53.1 µg/kg for BaP and PAH4 respectively. The graph below compares performance by the Three (3) stoves.

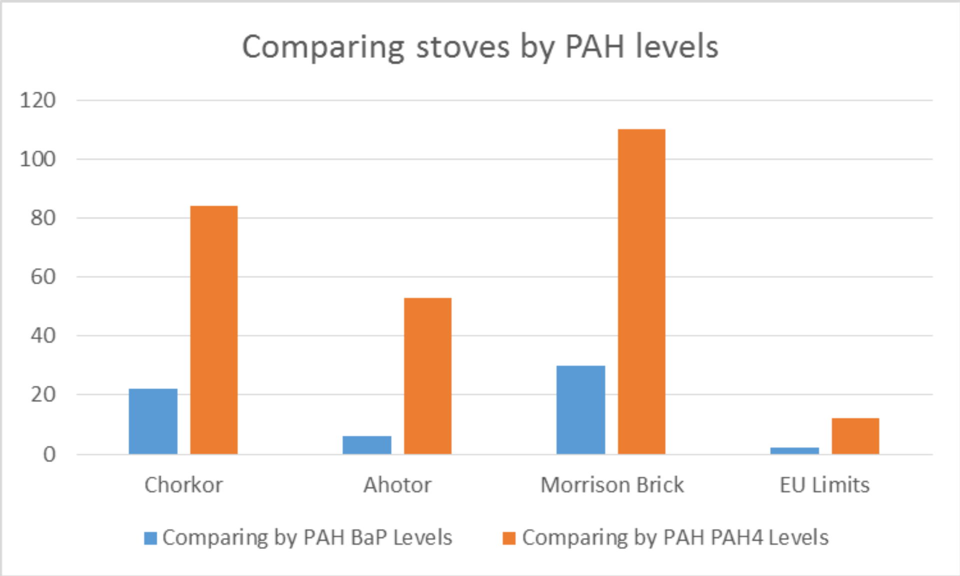

Figure 9 Comparing stove by PAH levels of their smoked fish

CONCLUSION

Controlled Cooking Test (CCT) was performed at Winneba for fish smoking and compared the fuel efficiencies and emissions of the constructed Ahotor Oven technology with the Traditional Chorkor stove.

Statistically significant analyses (t-test) indicated that there was a significant difference of 31.8% between the Traditional Chorkor stove and Ahotor Oven @ 95% for specific fuel consumption (i.e. percentage difference in fuel savings of 31.8%) by using the Ahotor Oven. There was no significant difference for the total cooking time and processing rate (i.e percentage difference in time savings and processing rate were of 14.57% and 7.22% respectively by using the Chorkor stove). For the emissions it was determined that the average CO and PM2.5 emissions for Ahotor Oven were 12.35% and 12.79% respectively lower than the Traditional chorkor stove. There were no significant differences in the means during the emissions test.

The average heat losses from the combustion chambers through the walls to the surroundings were recorded to be 48oC and 42.7oC for the Traditional Chorkor stove and Ahotor Oven respectively. It was established that the Ahotor Oven proved safer and efficient to be employed when compared to the Traditional Chorkor stove and therefore recommended that the stove can be promoted for the Fish processing communities.

The Ahotor stove produce fish with low PAH than the Chorkor and the Morrison stove. The Ahotor stove produces fish with 73% less content of the BaP and 36% less of PAH4; the regulated PAHs. This implies that, employing the use of the Ahotor stove, unconsciously, more healthy fish is introduced into the Ghanaian.

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