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SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP)

Post-harvest Processing Stove Performance Report

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ACRONYMS

AOR	Administrative Officer Representative
ASSESS	Analytical Support Services and Evaluations for Sustainable Systems
CEMAG	Community Environmental Monitoring and Advocacy Group
CCLME	Canary Current Large Marine Ecosystem
CCM	Centre for Coastal Management
CDCS	Country Development Cooperation Strategy
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
DFID	*Department for International Development*
DO	Development Objective
EBM	Ecosystem-Based Management
EG	Economic Growth
EMMP	Environmental Mitigation and Monitoring Plan
ERF	Environmental Review Form
ETP	Endangered, Threatened and Protected
FAO	Food and Agricultural Organization of the United Nations
FASDEP	Food and Agriculture Sector Development Program
FASDP	Fisheries and Aquaculture Sector Development Program
FC	Fisheries Commission
FCWCGG	Fisheries Committee for the West central Gulf of Guinea
FEU	Fisheries Enforcement Unit
FHI	Family Health International
FoN	Friends of Nation
FtF	Feed the Future
HM	Hen Mpoano
GCLME	Guinea Current Large Marine Ecosystem
GIFA	Ghana Inshore Fishermen's Association
GIS	Geographic Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit
GLM	Generalized Linear Models
GNAFF	Ghana National Association of Farmers and Fishermen
GNCFC	Ghana National Canoe Fishermen’s Council
GoG	Government of Ghana
GSA	Ghana Standards Authority
GSO	Graduate School of Oceanography, University of Rhode Island
ICFG	Integrated Coastal and Fisheries Governance
ICM	Integrated Coastal Management

ICT	Information, Communication Technology
IEE	Initial Environmental Examination
IR	Intermediate Results
IUCN	International Union for Conservation of Nature
IUU	Illegal Unreported Unregulated
JICA	Japan International Cooperation Agency
LEAP	Livelihood Enhancement Against Poverty
LOE	Level of Effort
LOGODEP	Local Government Development Program
LoP	Life of Project
MCS	Monitoring, Control and Surveillance
METASIP	Medium Term Agricultural Investment Program
METSS	Monitoring, Evaluation and Technical Support Services
MFRD	Marine Fisheries Research Division
MOFAD	Ministry of Fisheries and Aquaculture Development
MOU	Memorandum of Understanding
MPA	Marine Protected Area
MSME	Micro Small and Medium Enterprises
MSP	Marine Spatial Planning
M&E	Monitoring and Evaluation
NAFAG	National Fisheries Association of Ghana
NGO	Non-Governmental Organization
NC	National Committee
NRM	Natural Resources Management
PMEP	Performance Monitoring and Evaluation Plan
PMP	Performance Management Plan
PPP	Public Private Partnerships
RAVI	Rights and Voices Initiative
RCC	Regional Coordinating Council
RFA	Request for Application
RPA	Rapid Partnership Appraisal
SAMP	Special Area Management Plans
SFMP	Sustainable Fisheries Management Program
SMEs	Small and Medium Enterprises
SNV	Netherlands Development Organization
SS	Spatial Solutions
SSG	SSG Advisors
STEP	Sustainable, Transparent, Effective Partnerships
STWG	Scientific and Technical Working Group
UCAD	University Cheikh Anta Diop
UCC	University of Cape Coast
URI	University of Rhode Island
USAID	United States Agency for International Development
USG	United States Government
WA	West Africa
WARFP	West Africa Regional Fisheries Development Program
WASH	Water, Sanitation and Hygiene
WR	Western Region

EXECUTIVE SUMMARY

This report presents the findings from a Controlled Cooking Test (CCT) on fish stoves based on locations. The performance tests were carried out at Azizanyea, Ada-Foah on Morrison and a Chorkor stoves; Association of Women for Environment Project (AWEP) stove and another model of the Chorkor stove – Otuam; KOSMOS Oven, Tullow Oven and KOSMOS Chorkor at Ankobra all fishing communities and the FAO-Thiaroye Fish Processing Technology (FTT) stove at Ghana Standards Authority, Accra. This is part of the activities under the Sustainable Fisheries Management Project (SFMP) for the promotion and adoption of clean cooking and other renewable energy technologies in support of fish processing industries, 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 Morrison and Chorkor, AWEP, another type of Chorkor at Otuam, KOSMOS Oven, Tullow Oven, KOSMOS Chorkor and FTT stove technologies.

The stoves were carried out for a 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).

The test results indicated that most of the stoves do not meet the EnDev requirements of 40% fuel saving. Only the Morrison stove was better among the stoves which were 36.7% when compared to the Chorkor-Ada.

Comparisons were not made among the stoves since they were not constructed with measurement and dimensional standards. The tray dimensions also lack a uniform dimensions.

We therefore recommend that the stoves and accessories should be of standardized measurement.

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1.0 INTRODUCTION

1.1 About CSIR

The Centre 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 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.

1.2 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 (CO_2), 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 and cookstove testing
- Reduce energy waste in industry and commercial institutions through energy audit.

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.

1.3 The Project Synopses

SNV (Netherlands Development Organization) Ghana is committed to combating deforestation, to increasing the profitability of agro-processing businesses in Ghana and to improve the working environment for women entrepreneurs. Through the introduction of energy efficient and clean cooking technologies, all these targets can be addressed. Improved stoves have the potential to significantly reduce fuelwood consumption and excessive exposure to heat and smoke. The Sustainable Fisheries Management Project is a 5 year intervention aimed at introducing improved cooking and other renewable energy technologies to agro-processing communities.

The project serves as an opportunity for testing and comparing stove performance (energy and production efficiencies). The emergence of new stove technologies creates the need to compare stove performance in fuel efficiency and in other relevant parameters to enhance knowledge on potential to promote improved stove technologies. An accurate and comparable measurement of stove performance will help SFMP/SNV, consumers/end users, and businesses (stove building entrepreneurs) to make decisions about replacing traditional Chorkor stove with improved technologies, understanding well which benefits can be attained from such an investment.

In this event SFMP/SNV Ghana has sought the support of the Regional Testing and Knowledge Centre of the CSIR – Institute of Industrial Research as Consultant to conduct comparative tests to assess the performances and efficiencies of the Morrison, FTT, AWEP, KOSMOS Oven, Tullow Oven and KOMOS Chorkor Fish Stove technologies at Azizanyea, Ada-Foah and Ghana Standards Authority (Greater Accra Region), Otuam (Central Region) and Ankobra (Western Region).

The Project period was from 16th June – 16th July, 2015.

2.0 OBJECTIVES

The objective of this assignment is to

1. Conduct performance and efficiency test of stoves at various locations Ada Foah, Otuam, Ankobra and Ghana Standards Authority.
2. Conduct a comparative test between the Morrison and Chorkor-Ada; AWEP and Chorkor-Otuam; KOSMOS Oven, TULLOW Oven and Chorkor-KOSMOS; Chorkor-KOSMOS and FTT stoves using Controlled Cooking Test (CCT) protocol.

3.0 EXPERIMENTAL METHODS AND PROCEDURES

3.1 Brief description of wood fuel improved Fish Stoves:

3.1.1 Morrison Stove:

The stove is built mainly with clay; mixed with saw dust and water. Recently, the idea of mixing clay with saw dust at the 4:1proportion has been adopted. This means that for every four (4) proportion of clay used in volume, a one (1) volume proportion each of saw dust was added. The top of the combustion chamber has an opened wooden tray embedded in the stove frame upon which series of trays are stalked. Tray dimensions are 2337 x 960 x 75 mm (L x B x H). The ends of the trays are designed such that it gives a good interlocking which also prevent smoke leakages. The Morrison Fish Stove is design to hold a capacity of eight (8) trays with a last tray lined with a jute bag to filter and trap most smoke inside the system which controls the smoke through a small chimney made from a galvanized pipe of diameter 105 mm and length 1220 mm. The design is with the elevated chimney make it suitable for fish smoking. The overall dimensions are 2400 x 1200 x 720 mm (L x B x H) with wall thickness of 200 mm and two (2) firepots (front loading for the woodfuel) of dimensions 380 x 420 mm (L x H). The two combustion chambers are partitioned and can allow either chamber to be used in some cases.

3.1.2 Chorkor Stove (Ada-Foah):

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 to control the smoke. The tray dimensions are 1560 x 950 x 60 mm (L x B x H) with a small chimney made from a galvanized pipe of diameter 105 mm and length 1220 mm. The design is with the elevated chimney make it suitable for fish smoking. The overall dimensions are 1510 x 1120 x 620 mm (L x B x H) with wall thickness of 150 mm and two (2) firepots (front loading for the woodfuel) of dimensions 440 x 380 mm (L x H) with a common combustion chamber and two (2) firepots (front loading points for the woodfuel) of dimensions 380 x 420 mm (L x H).

3.1.3 AWEP Stove:

The stove is built mainly with clay; mixed with sandcrete and water. Recently, the idea of mixing clay with saw dust at the 4:1proportion has been adopted. This means that for every four (4) proportion of clay used in volume, a one (1) volume proportion each of sandcrete was added. Series of wooden trays are stalked on the top of the combustion chamber has an opening. Tray dimensions are outside (1575 x 753 x 70 mm) and inside of 1135 x 642 x 52 mm (L x B x H) given wire mesh surface area of 0.73 m^2. The edges of the trays are does not allow good interlocking device which also prevent smoke leakages. The AWEP Stove can hold a capacity of eight (8) trays but without a chimney incorporated to the design. The overall dimensions are 1300 x 880 x 620 mm (L x B x H) with wall thickness of 150 mm and a single firepot (front loading for the woodfuel) of dimensions 420 x 460 mm (L x H).

3.1.4 Chorkor Stove (Otuam):

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 (1295 x 950 x 50 mm) and inside of 1055 x 900 x 50 mm (L x B x H) given a wire mesh surface area of 0.95 m^2 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 two (2) firepots (front loading for the woodfuel) of dimensions 440 x 380 mm (L x H) with a common combustion chamber and two (2) firepots (front loading points for the woodfuel) of dimensions 350 x 420 mm (L x H).

3.1.5 KOSMOS Oven:

The oven is built mainly with fired-bricks. Six (6) metal-trays are stalked on metal shelf inside the combustion chamber where woodfuels are packed side-by-side the lower tray at the fire pots. The overall dimensions of the oven are 2115 x x1650 x 1500 mm (L x B x H) and a brick wall thickness of 200 mm including a chimney of 540 x 460 x 2800 mm (L x B x H) incorporated to the design. The oven has dual firepots (front loading for the woodfuel) of dimensions 340 x 300 mm (L x H) as presented in Figure 1 a. Tray overall dimensions are 1075 x 870 x 25 mm and wire mesh surface area of 0.94 m^2

3.1.6 TULLOW Oven:

The oven is built mainly with fired-bricks. Eight (8) metal-trays are stalked on metal shelf inside the combustion chamber where woodfuels are packed side-by-side the lower tray at the fire pots similar to the KOSMOS Oven. The overall dimensions of the oven are 2930 x 1650 x2070 mm (L x B x H) and a brick wall thickness of 200 mm including a chimney of 960 x 465 x 2880 mm (L x B x H) incorporated to the design. The oven has dual firepots (front loading for the woodfuel) of dimensions 395 x 360 mm (L x H) as presented in Figure 1 a. Tray overall dimensions are 1290 x 770 x 25 mm and wire mesh surface area of 0.99 m^2

3.1.7 Chorkor-KOSMOS Stove:

The oven is built mainly with fired-bricks. The quantity of trays is not restricted but can take twelve (12) wooden trays per batch which are stalked on the combustion chamber. The overall dimensions of the oven are 1855 x 1200 x 810 mm (L x B x H) and a brick wall thickness of 235 mm at the front and back and 265 mm at the sides with no chimney incorporated to the design. The stove has dual firepots (front loading for the woodfuel) of dimensions 440 x 550 mm (L x H) and the tray overall dimensions are 1780 x 470 x 65 mm with a wire mesh surface area of 1.05 m^2.

3.1.8 FTT Stove:

The oven is built mainly with fired-bricks. The quantity of trays is not restricted but can take six (6) wooden trays per batch which are stalked on the combustion chamber. The overall dimensions of the stove are 2400 x 1175 x 690 mm (L x B x H). The stove has two (2) chambers with dimensions 1050 x 920 for Chamber I and 1010 x 940 for Chamber II. The ash tray which located under Chamber I was made from a galvanized plate with dimensions 1000 x 985 x 75 mm (L x B x H). A chimney also made from a galvanized pipe with a diameter 100 mm and height 1530 mm located at the back of Chamber II. The stove uses charcoal for Chamber I and coconut fibre in Chamber II for browning of the fish after cooking in Chamber I which has a manually operated blower to supply air to the chamber. Overall dimensions of the wooden tray are 1230 x 1080 x 80 mm and inner dimensions are 1025 x 938 x 80 mm wire mesh surface area of 0.96 m^2.

Figure 1 shows photograph of constructed stoves Morrison and Chorkor (Ada-Foah); AWEP and Chorkor (Otuam); KOSMOS Oven, TULLOW Oven and Chorkor KOSMOS (Ankobra) and FTT (Ghana Standards Authority, Accra).

The trays were not of the same dimensions likewise the stoves. The designs and dimensions differ from location to location.

Figure 1 Photograph of testing stoves. Clockwise from top left: Morrison; Chorkor-Ada; Chorkor-Otuam; TULLOW Oven; FTT; Chorkor-KOSMOS; KOSMOS Oven; AWEP

3.2 Materials and Methods

3.2.1 Fuel used

Mangrove (*Bruguiera Gymnorrhiza* – Ada Foah; *Rhizophera Spp* – Otuam and *Bruguiera Sexangula*) were used as fuel with a higher calorific values of 20.4, 17.43 and 19.4 MJ/kg respectively from literature. Sample of woodfuels were obtained from bundled batches and measured at various positions. The average dimensions (L x D) of the fuels was determined to be 140.8±6.5 x 6.5±2.3 cm; 91.7±5.5 x 3.2±1.3 cm; 94.9±5.5 x 6.9±2.3 cm for Ada-Foah, Otuam and Ankobra respectively. Charcoal was used on the FTT stove at Ghana Standards Authority. Bundle of fuel ready for use and measurement of moisture content of the woodfuel have been presented in Figure 2 and Figure 3 respectively.

Figure 2 Bundled fuel ready for use

Figure 3 Measurement of woodfuel moisture content

3.2.2 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. Average values were therefore determined and converted in wet basics. The moisture content was determined to be 19.1%, 25%, 42.2% and 13% (for charcoal) at Ada-Foah, Otuam, Ankobra and Accra respectively.

3.2.3 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 values recorded were 30.2^{o}C and 72%; 28.3^{o}C and 74%; 27.7 ^{o}C and 80%, and 31.9 ^{o}C and 70% at Ada-Foah, Otuam, Ankobra and Accra respectively.

3.2.4 Experimental procedures

For Controlled Cooking Test (CCT), the same weight of woodfuel and fish were weighed to the cook accordingly. The cook was to prepare a good quality and refined product from the specimens where time to cook and amount of fuel used were measured before and 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 fuel and fish as presented in Figures 4 and 5 respectively. Figure 6 depicts smoking of fish using the Chorkor and Morrison stoves 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.

Figure 4 Weighing of fuels. Wood

Figure 5 Charcoal

Figure 6 Weighing of fish before…

Figure 7 …and after smoking

Figure 8 Smoking of fish on various stoves using IAP meter. Clockwise from top left: Morrison; Chorkor-Ada; Chorkor-Otuam; TULLOW Oven; FTT; Chorkor-KOSMOS; KOSMOS Oven; AWEP

4.0 RESULTS AND DISCUSSION

The constructed stoves were carried out under Controlled Cooking Test (CCT) protocol and each stove test was repeated twice with a quantity of fish. Although the tray sizes were not the same, the cook was supplied with the same weight of fish and woodfuel but weight varies per testing location for each process. Comparison was determined between the stoves performance at various locations.

The statistically significant analyses (t-test) and summary among the stoves results per location have been presented at a confidence level of 95%.

4.1 Controlled Cooking Test (CCT)

Table 1 Controlled Cooking Test Statistical Results for the cookstoves at Ada-Foah (Chorkor Ada and Morrison)

1. CCT results: Chorkor-Ada	units	Test 1	Test 2	Mean	St Dev
Total weight of food cooked	g	67017	48496	57756.5	13096.3
Weight of char remaining	g	0	0	0	0
Equivalent dry wood consumed	g	33984.6	56927.1	45455.9	16222.8
Specific fuel consumption	g/kg	507.1	480.9	494	18.5
Total cooking time	min	306	318	312	8.5
2. CCT results: Morrison	units	Test 1	Test 2	Mean	St. Dev
Total weight of food cooked	g	64019	44496	54257.5	13804.9
Weight of char remaining	g	0	0	0	0
Equivalent dry wood consumed	g	19685.8	32934.4	26310.1	9368.2
Specific fuel consumption	g/kg	307.5	318.9	313.2	8.1
Total cooking time	min	270	300	285	21.2
Comparison of Stove 1 and Stove 2		% difference	T-Test		Sig @ 95%?
Specific fuel consumption	g/kg	0.365995	12.65381		YES
Total cooking time	min	0.056604	1.67		NO
		Chorkor	**Morrison**		
Processing rate	g/min	185.1	190.4		
% Yield				2.763044	

Table 2 Controlled Cooking Test statistical results (t-test) for the cookstoves (@ α = 0.05) at Otuam (Chorkor Otuam and AWEP)

1. CCT results: Chorkor-Otuam	units	Test 1	Test 2	Mean	St Dev
Total weight of food cooked	g	19239	18978	19108.5	184.6
Weight of char remaining	g	354	370	362	11.3
Equivalent dry wood consumed	g	32139.9	37471.6	34805.8	3770.1
Specific fuel consumption	g/kg	1670.6	1974.5	1822.5	214.9
Total cooking time	min	592	938	765	244.7
2. CCT results: AWEP	units	Test 1	Test 2	Mean	St. Dev
Total weight of food cooked	g	21080	17888	19484	2257.1
Weight of char remaining	g	148	0	74	104.7
Equivalent dry wood consumed	g	29599.3	27178.7	28389	1711.6
Specific fuel consumption	g/kg	1404.1	1519.4	1461.8	81.5
Total cooking time	min	554	865	709.5	219.9
Comparison of Stove 1 and Stove 2		% difference		T-test	Sig @ 95%?
Specific fuel consumption	g/kg	0.197944		2.718746	NO
Total cooking time	min	0.072549		0.292215	NO
		Chorkor-Otuam	**AWEP**		
Processing rate	g/min	24.97843	27.46159		
% Yield				9.042306	

Table 3 Controlled Cooking Test statistical results (t-test) for the cookstoves (@ α = 0.05) at Ankobra (Chorkor-KOSMOS and KOSMOS Oven).

1. CCT results: Chorkor-KOSMOS	units	Test 1	Test 2	Mean	St Dev
Total weight of food cooked	g	19944	20354	20149	289.9
Weight of char remaining	g	1105	577	841	373.4
Equivalent dry wood consumed	g	55745.5	26642.7	41194.1	20578.8
Specific fuel consumption	g/kg	2595.1	2013.0	2304.1	411.6
Total cooking time	min	434	302	368	93.3
2. CCT results: KOSMOS Oven	units	Test 1	Test 2	Mean	St. Dev
Total weight of food cooked	g	21114	21385	21249.5	191.6
Weight of char remaining	g	757	1222	989.5	328.8
Equivalent dry wood consumed	g	25128.1	27300	26214.0	1535.7
Specific fuel consumption	g/kg	2856	2784	2820	50.9
Total cooking time	min	450	480	465	21.2
Comparison of Stove 1 and Stove 2		% difference		T-test	Sig @ 95%?
Specific fuel consumption	g/kg	-0.22393		-1.75931	NO
Total cooking time	min	-0.26359		-1.43315	NO
		Chorkor-KOSMOS	**KOSMOS Oven**		
Processing Rate	g/min	54.75272	45.69785		
Yield	%			16.53775	

Table 4 Controlled Cooking Test statistical results (t-test) for the cookstoves (@ α = 0.05) at Ankobra (Chorkor-KOSMOS and TULLOW Oven).

1. CCT results: Chorkor-KOSMOS	units	Test 1	Test 2	Mean	St Dev
Total weight of food cooked	g	19944	20354	20149	289.9
Weight of char remaining	g	1105	577	841	373.4
Equivalent dry wood consumed	g	55745.5	26642.7	41194.1	20578.8
Specific fuel consumption	g/kg	2595.1	2013.0	2304.1	411.6
Total cooking time	min	434	302	368	93.3
2. CCT results: TULLOW Oven	units	Test 1	Test 2	Mean	St. Dev
Total weight of food cooked	g	18953	18475	18714	338.0
Weight of char remaining	g	2297	756	1526.5	1089.7
Equivalent dry wood consumed	g	66413.5	81877	74145.3	10934.4
Specific fuel consumption	g/kg	3304.1	4031.8	3667.9	514.5
Total cooking time	min	662	560	611	72.1
Comparison of Stove 1 and Stove 2		% difference		T-test	Sig @ 95%?
Specific fuel consumption	g/kg	-0.592		-2.9273	YES
Total cooking time	min	-0.66033		-2.91337	YES
		Chorkor-KOSMOS	**TULLOW Oven**		
Processing Rate	g/min	54.75272	30.62848		
Yield	%			44.06035	

Table 5 Controlled Cooking Test statistical results (t-test) for the cookstoves (@ α = 0.05) at Ankobra (KOSMOS Oven and TULLOW Oven).

1. CCT results: KOSMOS Oven	units	Test 1	Test 2	Mean	St Dev
Total weight of food cooked	g	21114	21385	21249.5	191.6
Weight of char remaining	g	757	1222	989.5	328.8
Equivalent dry wood consumed	g	25128.1	27300	26214.0	1535.7
Specific fuel consumption	g/kg	2856	2784	2820	50.9
Total cooking time	min	450	480	465	21.2
2. CCT results: TULLOW Oven	units	Test 1	Test 2	Mean	St. Dev
Total weight of food cooked	g	18953	18475	18714	338.0
Weight of char remaining	g	2297	756	1526.5	1089.7
Equivalent dry wood consumed	g	66413.5	81877	74145.3	10934.4
Specific fuel consumption	g/kg	3304.1	4031.8	3667.9	514.5
Total cooking time	min	662	560	611	72.1
Comparison of Stove 1 and Stove 2		% difference		T-test	Sig @ 95%?
Specific fuel consumption	g/kg	-0.300689		-2.31929	NO
Total cooking time	min	-0.313978		-2.74642	NO
Processing Rate	g/min	**KOSMOS Oven**	**TULLOW Oven**		
Yield	%	45.697849	30.628478		
				32.97611	

Table 6 Controlled Cooking Test statistical results (t-test) for the cookstoves (@ α = 0.05) at Ghana Standards Authority (Chorkor-KOSMOS and FTT).

1. CCT results: Chorkor-KOSMOS	units	Test 1	Test 2	Mean	St Dev
Total weight of food cooked	g	19944	20354	20149	289.9
Weight of char remaining	g	1105	577	841	373.4
Equivalent dry wood consumed	g	55745.5	26642.7	41194.1	20578.8
Specific fuel consumption	g/kg	2595.1	2013.0	2304.1	411.6
Total cooking time	min	434	302	368	93.3
2. CCT results: FTT	units	Test 1	Test 2	Mean	St. Dev
Total weight of food cooked	g	17913	16894	17403.5	720.5
Weight of char remaining	g	400	500	450	70.7
Equivalent dry wood consumed	g	29345	17174	23259.5	8606.2
Specific fuel consumption	g/kg	1438.2	1016.6	1227.4	298.1
Total cooking time	min	385	402	393.5	12.0
Comparison of Stove 1 and Stove 2		% difference		T-test	Sig @ 95%?
Specific fuel consumption	g/kg	0.4672974		2.995927	YES
Total cooking time	min	-0.0692935		-0.3832	NO
		Chorkor-KOSMOS	**FTT**		
Processing rate	g/min	54.752717	44.22745		
% Yield				19.22329	

4.1.1 Total Weight of Food Cooked

Total weight of food cooked for the various stoves were determined to be 57756.5 and 54257.5 g for Chorkor-Ada and Morrison stoves respectively and 19484 and 19108.5 g for Chorkor-Otuam and AWEP respectively. The analysis showed no significant difference between the means at a particular location.

Total weights of food cooked were determined to be 20149 and 21249.5 g for Chorkor-KOSMOS and KOSMOS Oven stoves respectively. There was no significant difference between the means.

Total weights of food cooked were determined to be 20149, 21249.5 and 18714 g for Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. There was no significant difference between the means.

The total weight of food cooked using the FTT was determined to be 17403.5 g. There was no significant difference between the means (Chorkor-KOSMOS and FTT).

4.1.2 Equivalent Dry Wood Consumed

Equivalent dry wood consumed for the various stoves were determined to be 45455.9, 26310.1, 34805.8 and 28389 g for Chorkor, Morrison, AWEP and Chorkor-Otuam stoves respectively. The analysis showed that there was a significant difference between the means.

Equivalent dry wood consumed were determined to be 41194.1, 26214 and 74145.3 g for Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. The analysis showed that there was a significant difference between the means.

Equivalent dry wood consumed for the FTT stove was determined to be 23259.5 g and compared to Chorkor-Ada. The analysis showed a significant difference between the means.

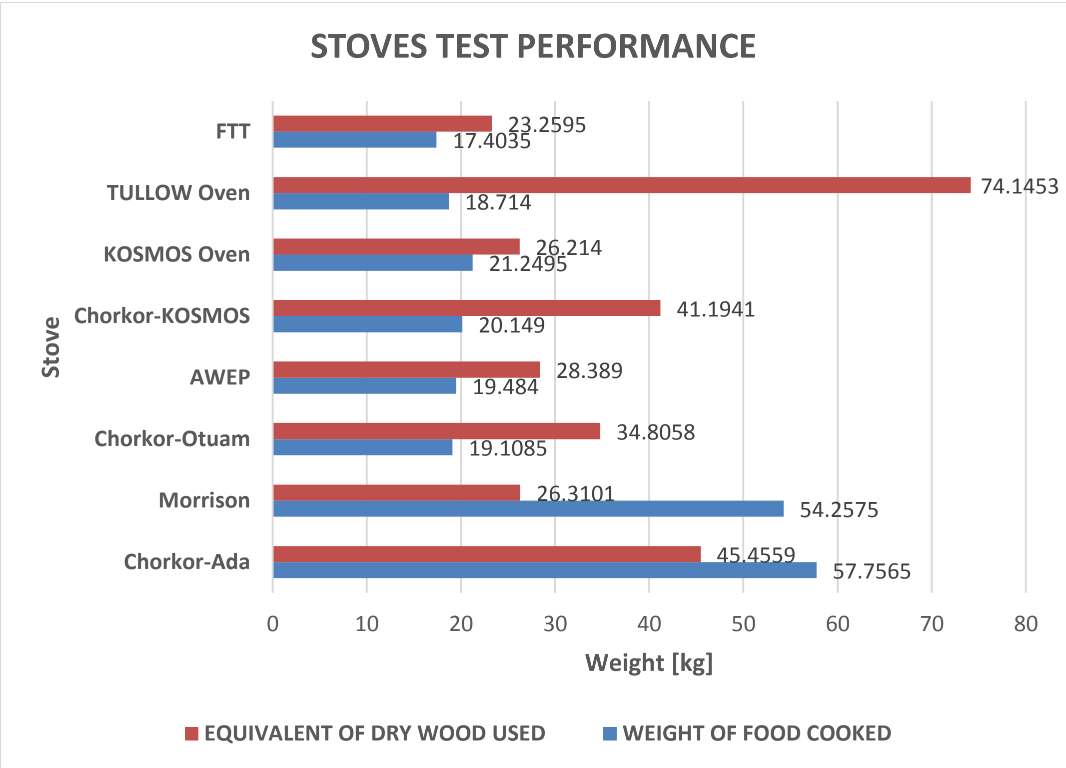


Figure 7 Shows that the TULLOW Oven used more dry wood than any of the stoves. The weight of raw fish used on the Chorkor-Ada and Morrison were more than the other test locations.

4.1.3 Specific Fuel Consumption

The specific fuel consumption were determined to be 494 and 313.2 g/kg for Chorkor-Ada and Morrison stoves respectively. The analysis shows that there was a significant difference between the means @ 95% confidence level and determined to be 36.6% - YES (i.e. fuel saving of 36.6%) but does not meet the EnDev requirement of 40%.

The specific fuel consumption were determined to be 1822.5 and 1461.8 g/kg for Chorkor-Otuam and AWEP respectively. The analysis showed that there was no significant difference between the means and was determined to be 19.8% - NO; Sig. @ 95% confidence level (i.e. fuel saving of 19.8%) which does not meet the EnDev requirement of 40%.

The specific fuel consumption was determined to be 2304.1 and 2820 g/kg for Chorkor-KOSMOS and KOSMOS Oven respectively. The analysis shows that there was no significant difference between the means and was determined to be -22.4% @ 95% confidence level (i.e. fuel loss of 22.4%) and therefore does not meet the EnDev requirement of 40%. When compared the Chorkor-KOSMOS to TULLOW Oven (3667.9 g/kg), the analysis showed that there was a significant difference between the means (-59.2%) @ 95% confidence level (i.e. fuel loss of 59.2%). By comparing the KOSMOS and TULLOW Oven, it was realised that there was a significant difference between the means (-30%) @ 95% confidence level (i.e. fuel loss of 30%).

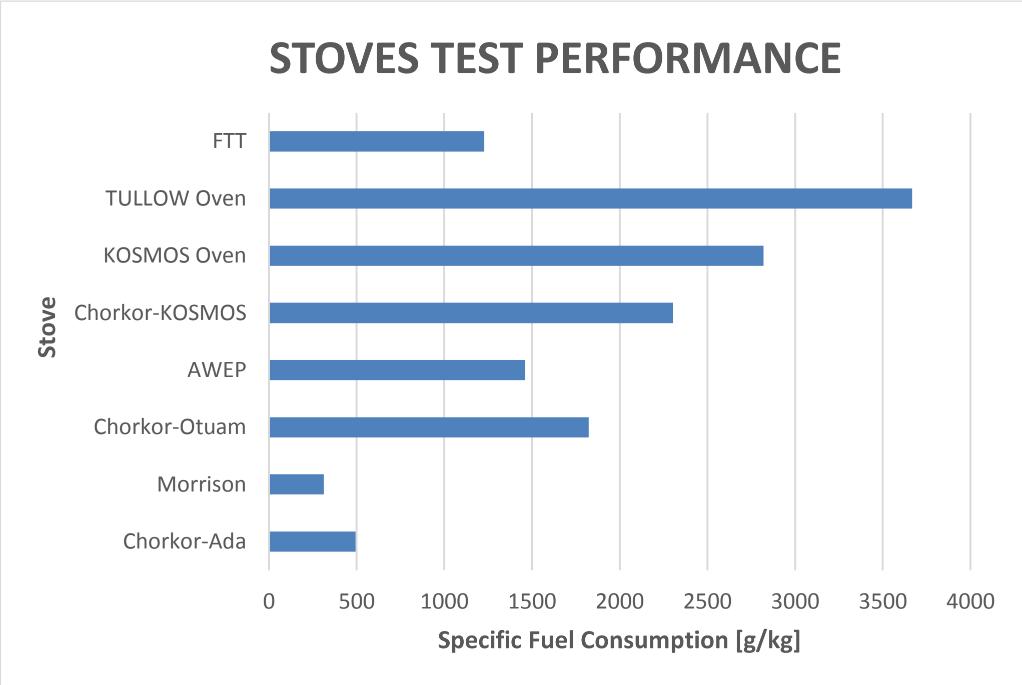


Figure 8 Summary of stoves test performance (specific fuel consumption).

The specific fuel consumption for the various stoves were determined to be 2820 and 1227.4 g/kg for Chorkor-KOSMOS and FTT respectively. The analysis shown that there was a significant difference between the means and was determined to be 46.7% @ 95% confidence level (i.e. fuel saving of 46.7%) and therefore met the EnDev requirement of 40%. Note that these particular two stoves used different fuels (firewood and charcoal respectively) and test was also performed under different environmental conditions.

The specific fuel consumption of the various stoves is presented in Figure 8. Among the stoves/ovens, the TULLOW Oven consumed most the fuel followed by the KOSMOS Oven and Chorkor-KOSMOS. This may be due to the oven design technology where the fire was not directly under the fish, sizing of the oven and firepot direction to the wind flow.

4.1.4 Total Cooked Time

Total cooked times for the stoves were determined to be 312, 285, 765 and 709 min for Chorkor-Ada, Morrison, Chorkor-Otuam and AWEP respectively. The analysis shown that there was no significant difference between the means and the difference was determined to be 5.7% for Chorkor-Ada and Morrison; and 7.2% for Chorkor-Otuam and AWEP @ 95% confidence level (i.e. time saving of 5.7% and 7.2% respectively). The trays were not of the same dimensions therefore only one firepot was used for the Morrison and Chorkor-Otuam.

At Ankobra, the total cooked times determined were 368, 465 and 611 min for Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. The analysis showed no significant difference between the means and was determined to be 26.4% and 31.4% for Chorkor-KOSMOS and KOSMOS Oven; KOSMOS Oven and TULLOW Oven respectively @ 95% confidence level (i.e. time saving of 26.4% and 31.4%). There was a time saving of 66% when using the Chorkor-KOSMOS relative to TULLOW Oven.

Total cooked times were determined to be 368 and 393.5 min for Chorkor-KOSMOS and FTT respectively. Analysis showed that there was no significant difference between the means and the difference was determined to be 6.9% @ 95% confidence level (i.e. time saving of 6.9%).

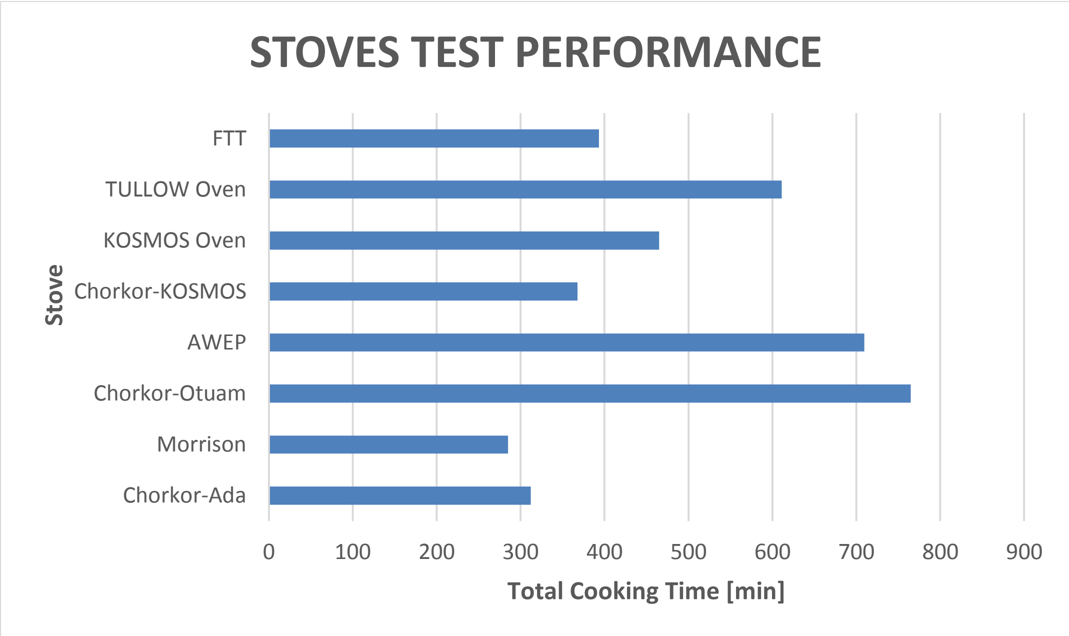


Figure 9 Summary of stoves test performance (total cooking time).

From Figure 9, it was observed that Chorkor-Otuam, AWEP, KOSMOS Oven and TULLOW Oven spent more than 400 min to cook the quantity of fish.

4.1.5 Processing Rate

It was determined that the processing rates were 185.1 and 190.4 g/min for the Chorkor-Ada and Morrison stoves respectively. This gave an increased in production by 2.8% when using the Morrison stove. In this test, only one side of the Morrison tray (one fire pot) was used.

Processing rates of 25 and 27.5 g/min were determined for Chorkor-Otuam and AWEP respectively which gave an increased in production by 9.0% when using the AWEP stove. In this test, only one side of the tray (one fire pot) of the Chorkor-Otuam was used.

It was determined that the processing rates of 54.8, 45.7 and 30.6 g/min for Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. Comparisons were made between Chorkor-KOSMOS and KOSMOS Oven; Chorkor-KOSMOS and TULLOW Oven; and KOSMOS Oven and TULLOW Oven. These gave an increased in production by 16.6%, 44.2% and 33% in favour of Chorkor-KOSMOS, Chorkor-KOSMOS and KOSMOS Oven respectively.

Processing rates were determined to be 54.8 and 44.2 g/min for Chorkor-KOSMOS and FTT stoves respectively. This gave an increased in production by 19.2% when using the Chorkor-KOSMOS stove.

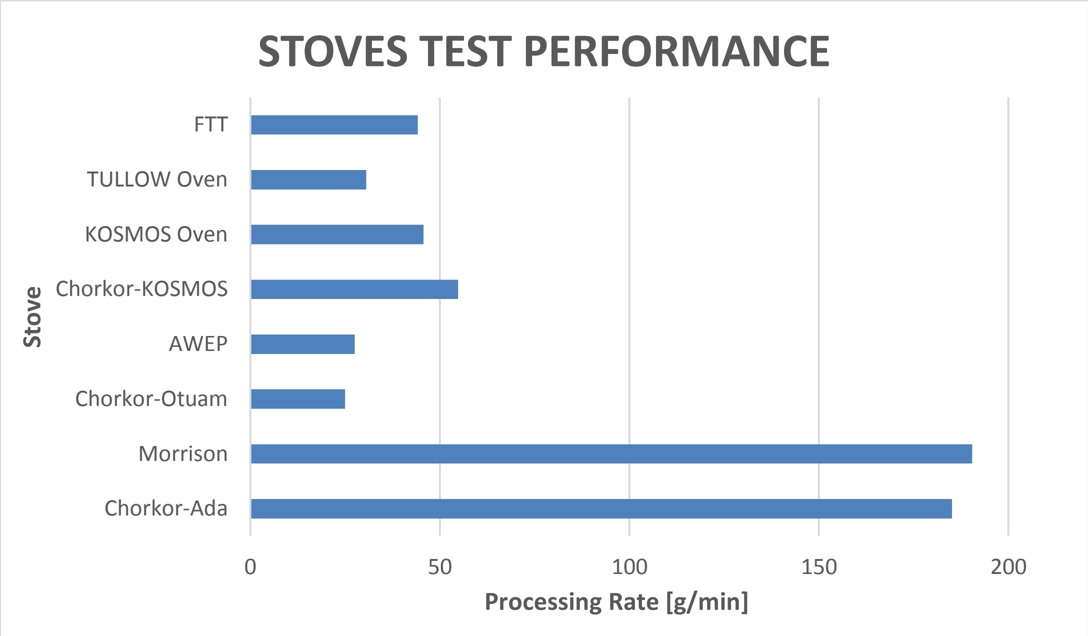


Figure 10 Summary of stoves test performance (processing rate).

In Figure 10, it was determined that Morrison and Chorkor-Ada processed more fish with a lesser time than rest of the stoves.

The bulk moisture contents of the smoked fish on the stoves at the various locations were determined to be as follows: Ada-Foah (Chorkor = 47.7% and Morrison = 39.4%); Otuam (Chorkor = 60.4% and AWEP = 58.3%); Ankobra (Chorkor-KOSMOS = 59.5%, KOSMOS Oven = 55% and TULLOW Oven = 59.2%) and GSA (FTT = 63.4%).

4.1.6 Emissions

In the test, emissions such as CO and $PM_{2.5}$ were measured using the Indoor Air Pollution (IAP) meter. The recorded values of Carbon monoxide (CO) and Particulate Matter ($PM_{2.5}$) emissions have been presented in Figure 11 through to Figure 14.

From Figure 11, the CO minimum values for the stoves were 5.3 and 5.1 g/min for Chorkor-Ada and Morrison stoves respectively. The maximum values recorded were 171 and 119.8 g/min with average values of 49.8 and 30.0 g/min for Chorkor-Ada and Morrison stoves respectively. With the time recorded, there was no significant difference between the means (39.6%) for the emissions.

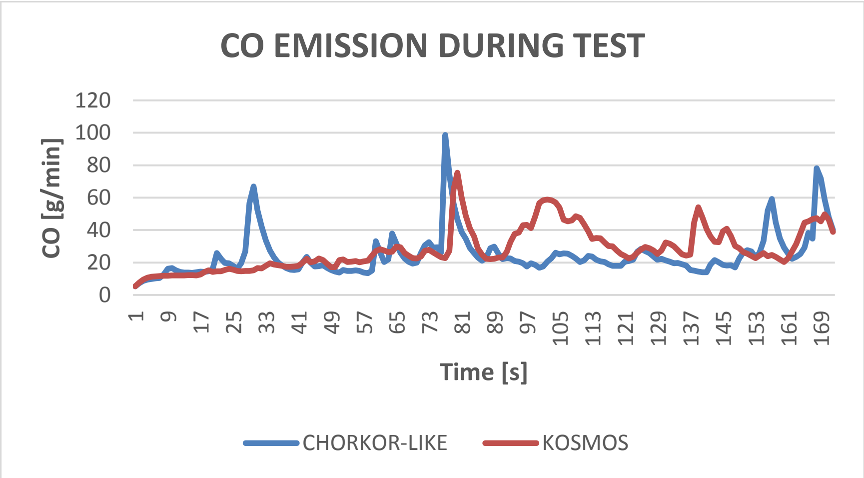
From Figure 11, the CO minimum values for the stoves were 5.5 and 6.1 g/min for Chorkor-Otuam and AWEP stoves respectively. The maximum values were 95.5 and 67.2 g/min with average values of 28.9 and 25.8 g/min for Chorkor-Otuam and AWEP stoves respectively. With the time recorded, there was no significant difference between the means (10.9%) for the emissions.

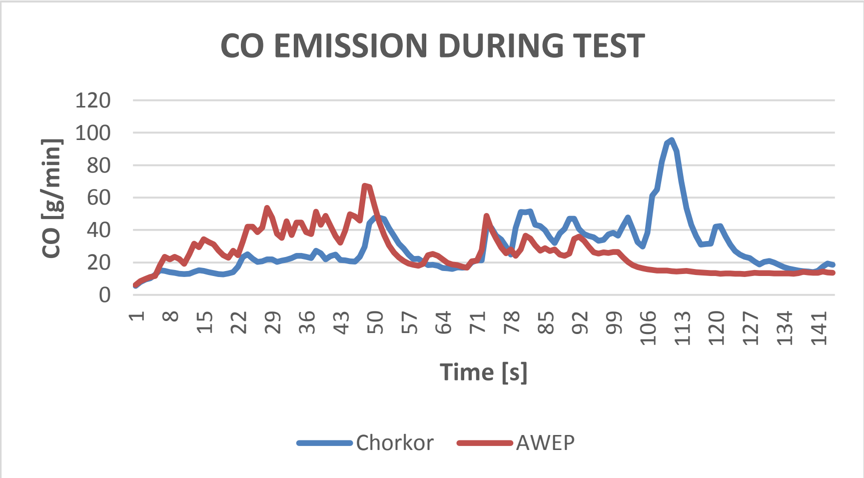
From Figure 11, the CO minimum values for Chorkor-KOSMOS and KOSMOS Oven were 5.3 g/min. The maximum values recorded were 98.7 and 75.4 g/min with average values of 24.6 and 28.1 g/min for Chorkor-KOSMOS and KOSMOS Oven respectively. With the time recorded, there was no significant difference between the means (14.2%) for the emissions.

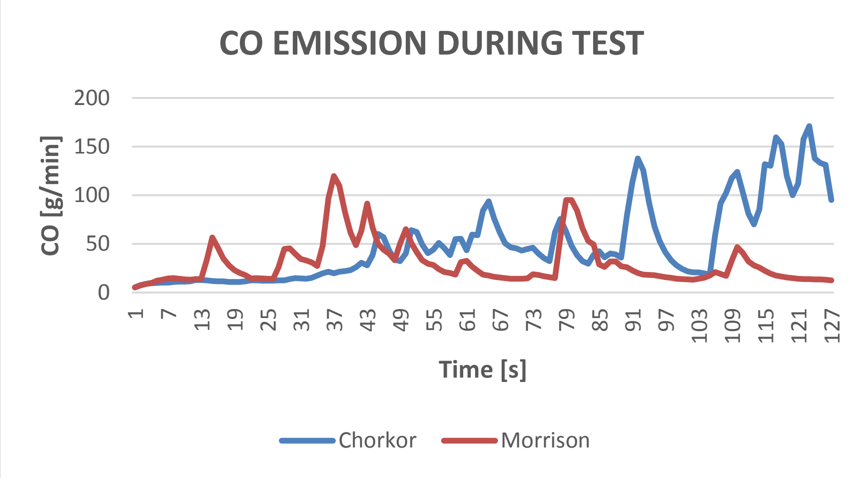
From Figure 11, the CO minimum values for the stoves were 5.3 and 10.7 g/min for Chorkor-KOSMOS and TULLOW Oven stoves respectively. The maximum values were 98.7 and 156.9 g/min with average values of 24.6 and 70.4 g/min for Chorkor-KOSMOS and TULLOW Oven stoves respectively. With the time recorded, there was a significant difference between the means (186.6%) for the emissions.

From Figure 11, the CO minimum values for the stoves were 5.4 and 10.7 g/min for KOSMOS Oven and TULLOW Oven respectively. The maximum values recorded were 75.4 and 156.9 g/min with average values of 28.1 and 70.4 g/min for KOSMOS and TULLOW Oven stoves respectively. With the time recorded, there was a significant difference between the means (151%) for the emissions.

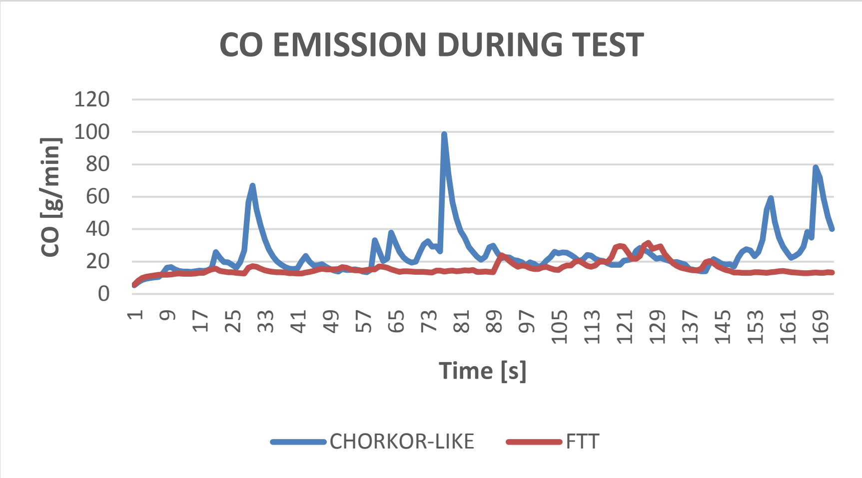
From Figure 11, the CO minimum values for the stoves were 5.3 and 5.8 g/min for Chorkor-KOSMOS and FTT stoves respectively. The maximum values were 98.7 and 31.5 g/min with average values of 24.6 and 15.7 g/min for Chorkor-KOSMOS and FTT stoves respectively. With the time recorded, there was no significant difference between the means (36%) for the emissions.



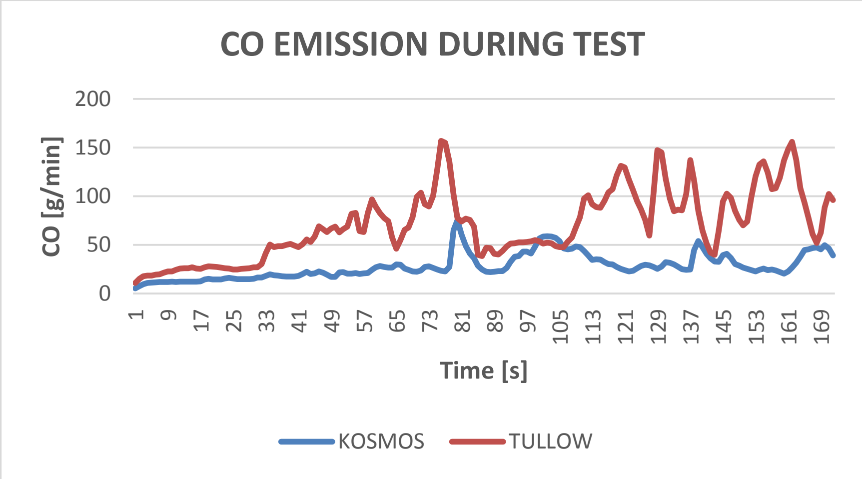




CO EMISSION DURING TEST
200
150
100
50
0
CO [g/min]
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
109
115
121
127
Time [s]
Chorkor
Morrison



CO EMISSION DURING TEST
120
100
80
60
40
20
0
CO [g/min]
1
9
17
25
33
41
49
57
65
73
81
89
97
105
113
121
129
137
145
153
161
169
Time [s]
CHORKOR-LIKE
FTT



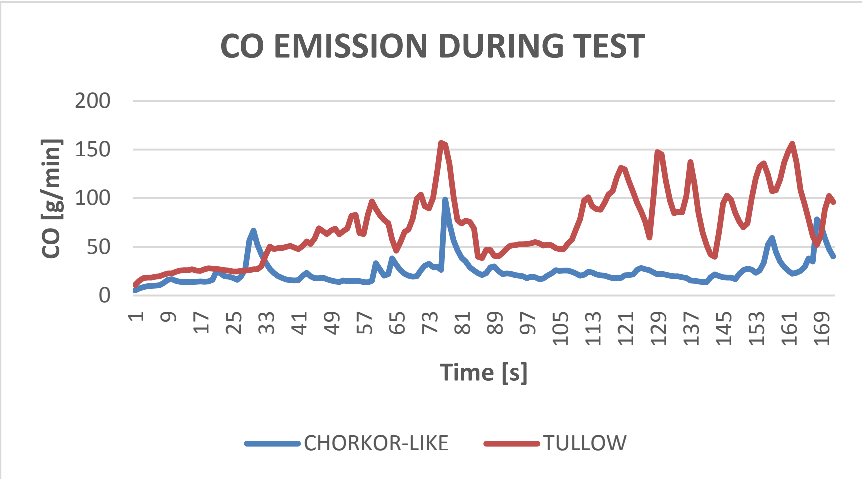


Figure 11 Sample of CO measured using the IAP meter for the various stoves.

From Figure 12 it was observed that Chorkor-Ada and TULLOW Oven emitted the highest CO emissions greater than 30 g/min.

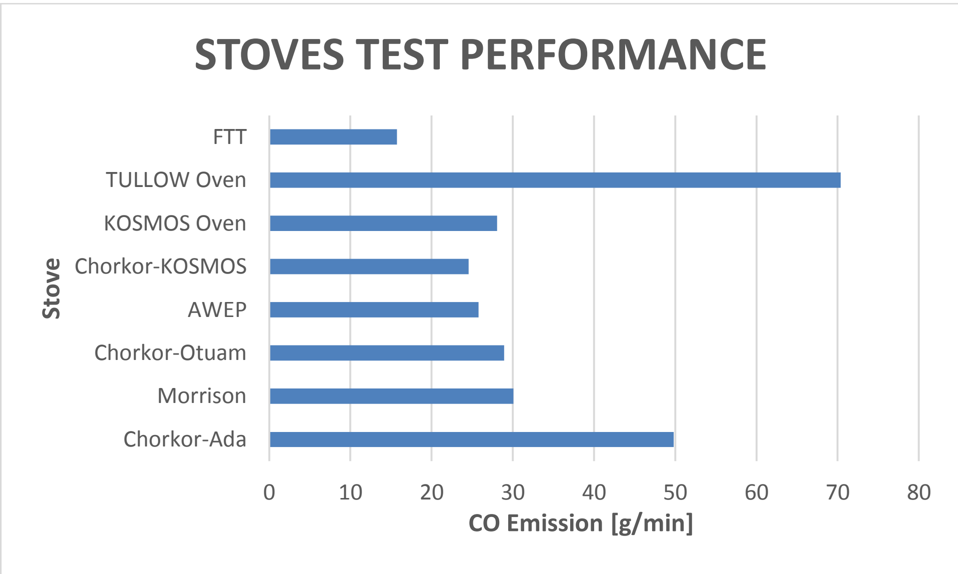


Figure 12 Summary of stoves test performance (CO emission).

Figure 13 depicts the recorded $PM_{2.5}$ for the stoves with minimum values of 856.9 and 841.5 mg/min for Chorkor-Ada and Morrison stoves respectively. The maximum values were

37098.5 and 20575.7 mg/min with average values of 5638.5 and 1922.2 mg/min for Chorkor-Ada and Morrison stoves respectively. With the time recorded, there was a significant difference between the means (65.9%) for the emissions.

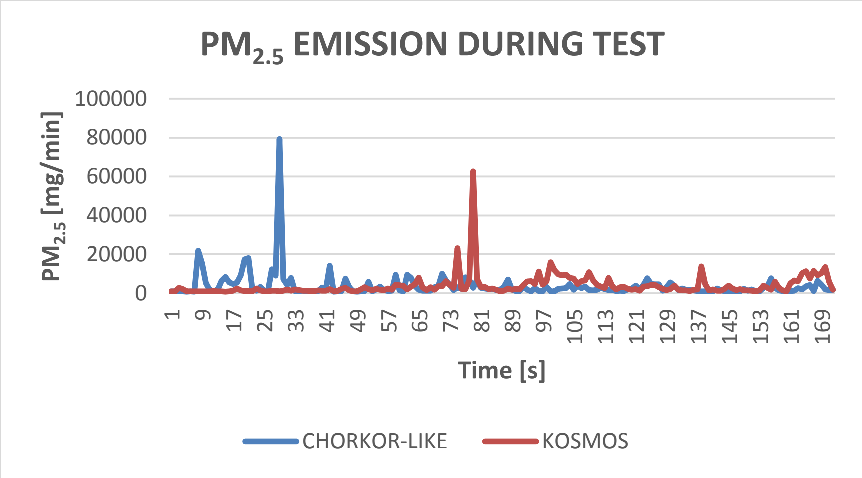
Figure 13 depicts the recorded $PM_{2.5}$ for the stoves with minimum values of 849.2 and 843.4 mg/min for Chorkor-Otuam and AWEP stoves respectively. The maximum values were 9015 and 8104 mg/min with an average values of 1585.7 and 1821.1 mg/min for Chorkor-Otuam and AWEP stoves respectively. There was no significant difference between the means (14.8%) for the emissions.

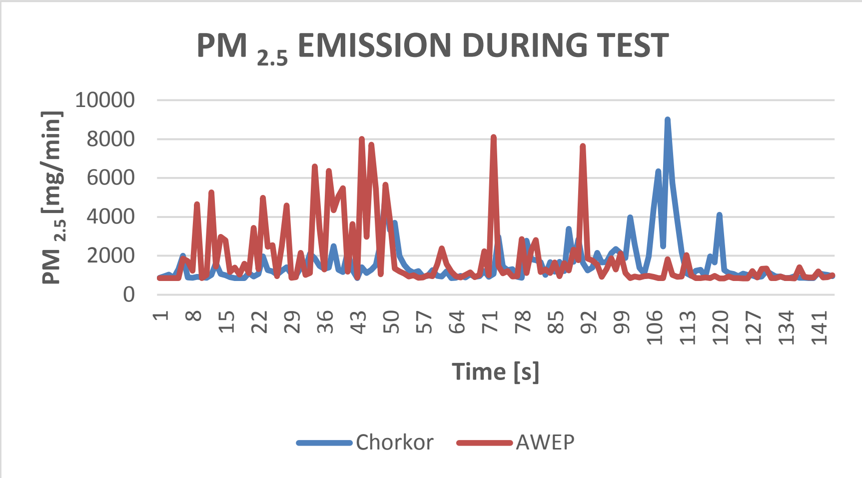
Figure 13 depicts the recorded $PM_{2.5}$ for the stoves with minimum values of 847.3 and 872.4 mg/min for Chorkor-KOSMOS and KOSMOS Oven respectively. The maximum values were 79334.6 and 62659.4 mg/min with average values of 3684.6 and 3836.9 mg/min for Chorkor-KOSMOS and KOSMOS Oven respectively. There was no significant difference between the means (4.1%) for the emissions.

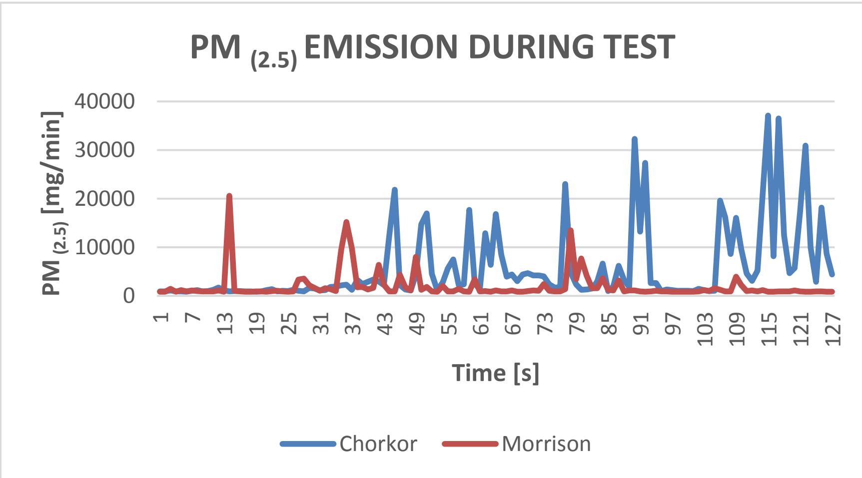
Figure 13 depicts the recorded $PM_{2.5}$ for the stoves with minimum values of 847.3 and 855 mg/min for Chorkor-KOSMOS and TULLOW Oven respectively. The maximum values were 79334.6 and 28807.2 mg/min with average values of 3684.6 and 6423 mg/min for Chorkor-KOSMOS and KOSMOS Oven stoves respectively. There was a significant difference between the means (74.3%) for the emissions.

Figure 13 depicts the recorded $PM_{2.5}$ for the stoves with minimum values of 872.4 and 855 mg/min for KOSMOS Oven and TULLOW Oven respectively. The maximum values were62659.4 and 28807.2 mg/min with average values of 3836.9 and 6423 mg/min for KOSMOS and TULLOW Oven respectively. With the time recorded, there was a significant difference between the means (67.4%) for the emissions.

Figure 13 depicts the recorded $PM_{2.5}$ for the stoves with minimum values of 847.3 and 847.3 mg/min for Chorkor-KOSMOS and FTT stoves respectively. The maximum values were 79334.6 and 41669 mg/min with average values of 3684.6 and 910.8 mg/min for Chorkor-KOSMOS and FTT stoves respectively. With the time recorded, there was no significant difference between the means (75.3%) for the emissions.


PM2.5 EMISSION DURING TEST
PM2.5 [mg/min]
100000
80000
60000
40000
20000
0
1 9 17 25 33 41 49 57 65 73 81 89 97 105 113 121 129 137 145 153 161 169
Time [s]
CHORKOR-LIKE
KOSMOS


PM 2.5 EMISSION DURING TEST
PM 2.5 [mg/min]
10000
8000
6000
4000
2000
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141
Time [s]
Chorkor
AWEP


PM (2.5) EMISSION DURING TEST
PM (2.5) [mg/min]
40000
30000
20000
10000
0
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97 103 109 115 121 127
Time [s]
Chorkor
Morrison

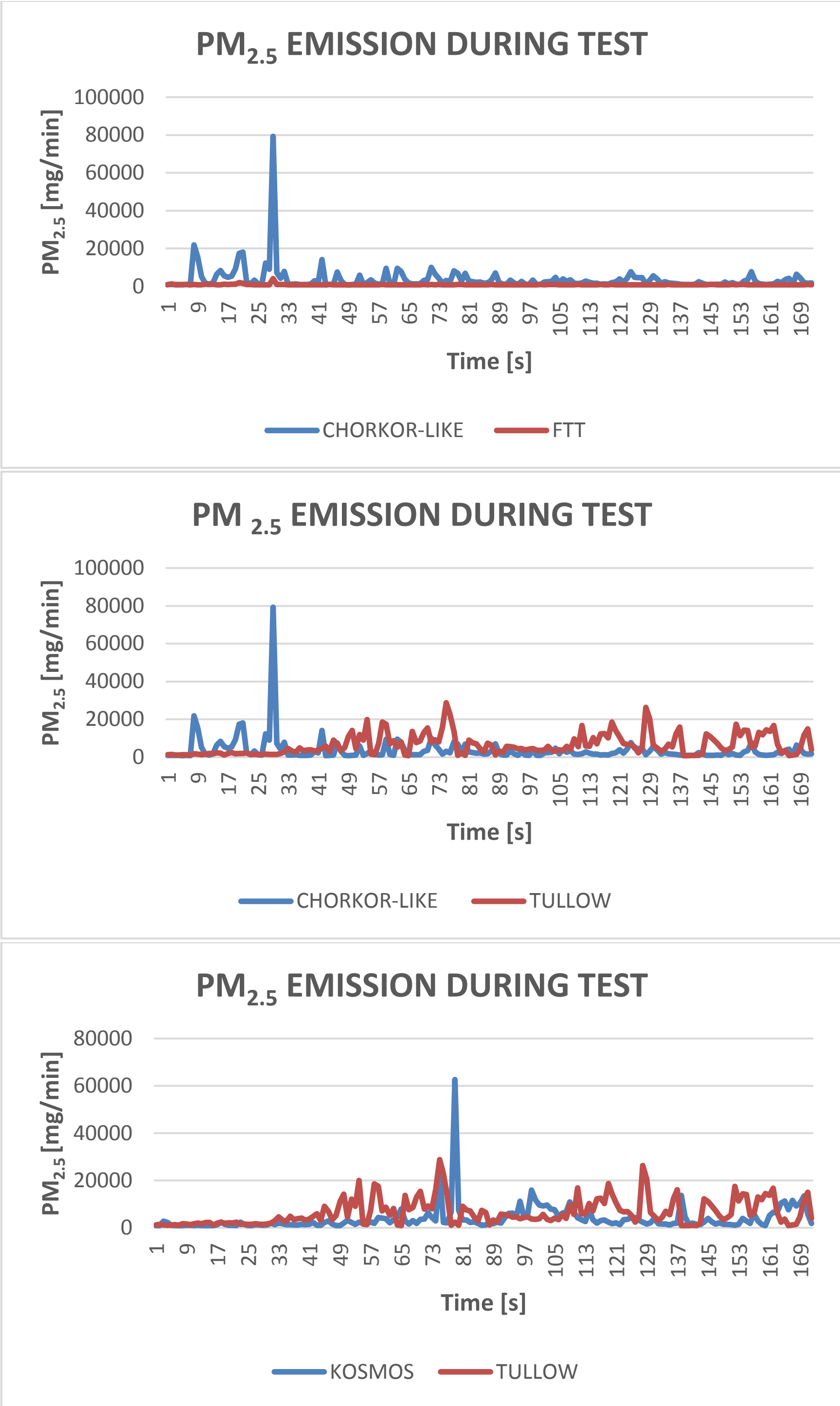


Figure 13: Sample of $PM_{2.5}$ measured using the IAP meter for the various stoves

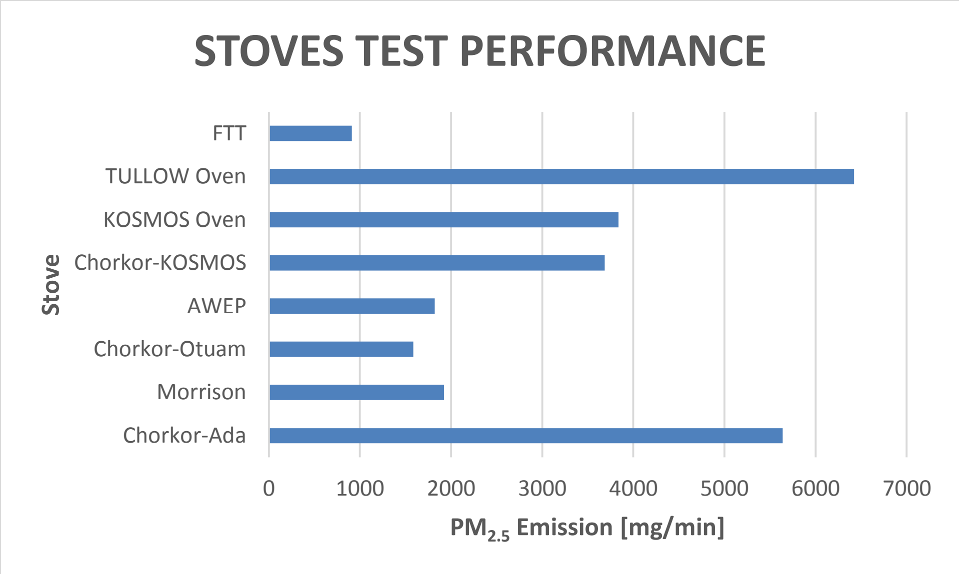


Figure 14 Summary of stoves test performance ($PM_{2.5}$ emission).

From Figure 14 it was observed that Chrokor-Ada, Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven emitted more $PM_{2.5}$ at a rate greater than 2000 mg/min

5.0 CONCLUSIONS

Controlled Cooking Tests (CCT) were performed at Ada-Foah, Otuam, Ankobra and Accra for fish smoking and compared the fuel efficiencies and emissions of the constructed stoves at various locations.

For total weight of food cooked for the various stoves, the analyses showed that there were no significant differences between the means at various locations.

There were no char remaining after cooking using Chorkor-Ada and Morrison stoves as fuels were allowed to burn completely which had been the normal practice in the community.

Weight of char remaining after cooking for the various stoves was determined to be 362 and 74 g for Chorkor-Otuam and AWEP respectively, 841, 989.5 and 1526.5 g for Chorkor-KOSMOS, KOSMOS-Oven and TULLOW Oven respectively. There was no significant difference between the means (Chorkor-KOSMOS and KOSMOS Oven) but a significant difference between the means (Chorkor-KOSMOS, KOSMOS Oven against TULLOW Oven).

Weight of char remaining after cooking for the various stoves was determined to be 841 and 450 g for the Chorkor-KOSMOS and FTT stoves respectively. There was a significant difference between the means.

Equivalent dry wood consumed for the various stoves was determined to be 45455.9 and 26310.1 g for Chorkor and Morrison stoves respectively; 34805.8 and 28389 g for AWEP and Chorkor-Otuam respectively; 41194.1, 26214, 74145.3 and 23259.5 g for Chorkor-KOSMOS, KOSMOS Oven, TULLOW Oven and FTT respectively. All the analyses showed a significant difference between the means.

The specific fuel consumption was determined to be 494 and 313.2 g/kg for Chorkor-Ada and Morrison stoves respectively and 1822.5 and 1461.8 g/kg for Chorkor-Otuam and AWEP respectively. There was a fuel savings of 36.6% for Morrison and 19.8 for AWEP but does not meet the EnDev requirement of 40%.

The specific fuel consumption were determined to be 2304.1, 2820 and 3667.9 g/kg for Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. There was a fuel loses of 22.4% by using the KOSMOS Oven and 59.2% when using the TULLOW Oven. Between KOSMOS Oven and TULLOW Oven there was 30% fuel loss when using the TULLOW Oven.

The specific fuel consumption were determined to be 2304.1and 1227.4 g/kg for Chorkor-KOSMOS and FTT respectively. There was a fuel saving of 46.7% for the FTT which met the EnDev requirement of 40% but note that the test was performed under different environmental conditions as well as fuel used.

Total cooked times for the various stoves were determined to be 312 and 285 min for Chorkor-Ada and Morrison respectively. There was a time saving of 5.7% for the Morrison stove.

Total cooked times were determined to be 765 and 709 min for Chorkor-Otuam and AWEP respectively. There was a time saving of 7.3%. The trays are larger than that of the AWEP and only one firepot was used for the Chorkor-Otuam stove.

Total cooked times were determined to be 368, 465 and 611 min for Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. There was no significant difference between the means and time loss of 26.4% (Chorkor-KOSMOS and KOSMOS Oven) but a significant difference between the means and a time saving of 66% (Chorkor-KOSMOS and TULLOW Oven) and a time saving of a time saving of 31.4 % (KOSMOS Oven and TULLOW Oven).

Total cooked times were 368 and 393.5 min for Chorkor-KOSMOS and FTT respectively. There was a time saving of 6.9%.

It was determined that the processing rates were 185.1 and 190.4 g/min for the Chorkor-Ada and Morrison stoves respectively which gave an increased in production by 2.8% when using the Morrison stove.

Processing rates of 25 and 27.5 g/min for Chorkor-Otuam and AWEP respectively which gave an increased by 9.0% when using the AWEP stove.

Processing rates of 54.8, 45.7 and 30.6 g/min were determined for the Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. This gave a decreased in production by 16.5% and 44% when using the KOSMOS Oven and TULLOW Oven respectively and an increase of 33% when compared KOSMOS Oven and TULLOW Oven. Processing rate of 44.2 g/min was determined for the FTT stove when compared to Chorkor-KOSMOS it gave a decreased by 19.2%.

The bulk moisture contents of the smoked fish on the stoves at the various locations were determined to be as follows: Ada-Foah (Chorkor = 47.7% and Morrison = 39.4%); Otuam (Chorkor = 60.4% and AWEP = 58.3%); Ankobra (Chorkor-KOSMOS = 59.5%, KOSMOS Oven = 55% and TULLOW Oven = 59.2%) and GSA (FTT = 63.4%).

Carbon Monoxide (CO) average values of 49.8 and 30.0 g/min were determined for Chorkor-Ada and Morrison stoves respectively and 28.9 and 25.8 g/min for Chorkor-Otuam and AWEP stoves respectively. There was no significant difference between the means for the emissions.

Carbon Monoxide (CO) average values of 24.6, 28.1and 70.4 g/min were determined for Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. There was no significant difference between the means (Chorkor-KOSMOS and KOSMOS Oven) and a significant difference between the means (Chorkor-KOSMOS and TULLOW Oven; KOSMOS Oven and TULLOW Oven) for the emissions.

The average values of CO were 24.6 and 15.7 g/min for Chorkor-KOSMOS and FTT stoves respectively and no significant difference between the means for the emissions.

The average $PM_{2.5}$ values of 5638.5 and 1922.2 mg/min were determined for Chorkor-Ada and Morrison stoves respectively. There was a significant difference between the means for the emissions and 1585.7 and 1821.1 mg/min for Chorkor-Otuam and AWEP stoves respectively. There was no significant difference between the means for the emissions.

The average $PM_{2.5}$ values recorded were 3684.6, 3836.9 and 6423 mg/min for Chorkor-KOSMOS, KOSMOS Oven and TULLOW Oven respectively. There was no significant difference between the means (Chorkor-KOSMOS, KOSMOS Oven) but a significant difference between the means (Chorkor-KOSMOS and TULLOW Oven; KOSMOS Oven and TULLOW Oven) for the emissions.

The average $PM_{2.5}$ values recorded were 3684.6 and 910.8 mg/min for Chorkor-KOSMOS and FTT stoves respectively. There was a significant difference between the means for the emissions.

It can be concluded that almost all the stoves do not meet the EnDev requirements but the Morrison could be considered for promotion.

REFERENCES

Rob Bailis, 2004. The Household Energy and Health Programme, Shell Foundation, August 2004.