A study of fuel consumption of three types of household charcoal stoves in Ghana

W. QUAYE & L. STOSCH
(W. Q.: CSIR-Food Research Institute, P. O. Box M20, Accra, Ghana; L. S.: Enterprise Works Worldwide, 1828L Street, NW Suite 1000 Washington, DC 20036, USA)

ABSTRACT

The purpose of this study was to find out the amounts of charcoal consumed using the traditional Ghanaian coalpot in contrast with two improved stoves, "Ahinbenso" and "Gyapa" stoves. The study covered 80 purposively selected charcoal-consuming households in the Greater Accra Region of Ghana. Each household was allowed a 1-week measurement of charcoal consumption for each of the three stoves and data were analyzed with Excel. The study results showed fuel (charcoal) efficiency of 31 and 23 per cent for "Gyapa" and "Ahinbenso" over the traditional coalpot, respectively. The "Gyapa" stove saves 0.51 kg of charcoal per day or 186 kg of charcoal annually, which translates into about US$25.00 per year per household. For every 1,000 "Gyapa" stoves in use, the savings would be 186 tons of charcoal per year, equal to 1,488 tons of wood and 31.83 ha of forestland. It is, therefore, recommended that promotional activities on the use of "Gyapa" stove among charcoal-consuming households in Ghana should be strengthened.

Original scientific paper. Received 30 Jun 05; revised 06 Aug 07.

RÉSUMÉ

QUAYE, W. & STOSCH, L.: *Une étude de la consommation d' énergie de trois types de réchaud à charbon de bois pour le ménage au Ghana.* Le but de cette étude était de déterminer les quantités de charbon consommées en utilisant le poêle à charbon ghanéen traditionnel par contraste avec deux poêles améliorés–Les poêles "Ahinbenso" et "Gyapa". Cette étude englobe 80 ménages utilisant le charbon, qui étaient délibérément sélectionnés dans Greater Accra Region du Ghana. Chaque ménage était permis de mésurer le charbon á utiliser pour une semaine pour chacun de trois poêles et les données analysées avec Excel. Les résultats de l' étude montraient l'efficacité de charbon de bois de 31 et 23% respectivement pour "Ahinbenso" et "Gyapa" au-dessus de fourneau traditionnel. Le fourneau "Gyapa" fait d'économie d'énergie de 0.51 kg de charbon par jour ou de 186 kg de charbon anneullement. Ceci se traduit en presque US$25.00 par an par un ménage. Pour tous les 1,000 fourneaux de "Gyapa" utilisé on fait l'économie de 186 tons de charbon par an, équivalent à 1,488 tons de bois et à 31.83 hectares de terres boisées. Il est recommandé par conséquent que les activités de promotion sur l'utilisation de fourneau "Gyapa" parmi les ménages de consommation de charbon au Ghana doit être renforcé.

Introduction

Wood fuel, comprising charcoal and firewood, dominates the list of options of household energy in Ghana at 62.5 per cent; liquid petroleum gas, 4.1 per cent; crop residues, 1.2 per cent; kerosene, 1.1 per cent; and electricity at 0.4 per cent (MOE, 2002). About 1.29 million households use charcoal as their main source of fuel for cooking, 31 per cent of the total number of households in Ghana (Togobo, 2002). The charcoal-using households are mostly lower- and middle-income, urban households. The low-income, rural population normally cooks with firewood, while the higher-income, urban households typically cook with LPG or electricity. Wood fuel is the predominant domestic fuel for 70 per cent of urban households in Ghana. In Accra alone, about 70 per cent of households use charcoal as their main fuel for

cooking (Energy Commission, 2002). It is estimated that about US $70 million is spent on wood fuels per year, the high level of consumption reflecting the fact that most Ghanaians cannot afford alternative fuel sources.

About 67 per cent of the wood fuel supply is from non-forestland, mostly the transitional savannah zone. The total wood fuel consumption in 2000 was 18 to 20 million tons of solid wood equivalents, with annual charcoal consumption of 1.1 million tons and a carbonization ratio of 8 tons of wood to 1 ton of charcoal (FAO, 2002). It is also estimated that 50 per cent of the total wood consumption as fuel was used for charcoal production. Ghana has a forest cover of 9.6 million hectares, equal to 42 per cent of the land area. Some tree species preferred for charcoal production are *Anogeisus leiocarpus (*kane*)* and *Terminallia avicenioides (Ongo)* in the savannah zone, and *Lophira alata* (kaku) and *Piptadeniastrum africanum (Dahoma)* in the forest zones. Different types of charcoal found on the market include the hard, dense and sparkly type; the dense lustrous type; the very light and friable charcoal; and the medium-density charcoal that are preferred by most consumers (Nketiah, Hagan & Addo, 1998). However, not much variation is noted in pricing of charcoal regarding quality.

The rate of deforestation in Ghana was 1.72 per cent in 2000, which was among the highest in Africa; estimates for the rest of Africa were around 0.78 per cent for the period 1990-2000 (FAO, 2002). Several socio-economic and climatic factors are responsible for deforestation. These factors include exploitative fuel wood and charcoal collection, persistent bushfires, quarrying and mining, urban and industrial expansion, illegal timber and chainsawing operations; increasing demand for forest products in developed countries, unsatisfactory natural regeneration, and encroachment on the forest areas due to unsustainable agricultural practices. With the alarming rate of deforestation, the availability of wood fuels (including charcoal) is reaching a critical point. Besides the environmental consequences, a lot of studies have shown the causal association of particulate and carbon emissions from combustion of biomass with the incidence of respiratory and eye infections (Ezzati, Kammen & Mbinda, 2000; Ezzati, Kammen & Singer, 1999; Smith, 1993).

In a study by the UNDP and the National Energy Board of Ghana in 1988, it was estimated that charcoal expenditures were 10 per cent of the household expenditures on food. The cost of charcoal goes up in the rainy season and down in the dry season. The same group published an update to their report in 2002 and stated that the energy cost per household per year for charcoal is about 358,000.00 cedis or US $44.40 in a country with US$270.00 as the average per capita income. In an attempt to reduce charcoal consumption and expenditure on household energy, Enterprise Works Ghana, under its Household Energy project, introduced a charcoal-efficient stove called “Gyapa” in 2002, with funding from the United States Agency for International Development. EnterpriseWorks takes a commercial approach to development: identifying obstacles in key steps of the value-added chain and designing effective, appropriate technology solutions; establishing profit-driven manufacturing and distribution systems in cooperation with local entrepreneur partners; and building markets for the new products. As part of the monitoring and evaluation activities under the Household Energy Project, a baseline study of fuel consumption in three types of household charcoal stoves in Ghana was commissioned in August 2002.

The objectives of the study were to establish the charcoal savings of the improved stove over the traditional, and translate the charcoal savings into economic and environmental benefits.

Materials and methods

The target group for the Household Energy Project was typically the lower-middle class households living in urban settings. It was,

therefore, important to gauge any differences in charcoal consumption among differing income levels within the middle class category; so two income-level groups were chosen. The first group was named the "poor" and the second group "lower-middle income", to distinguish the two. The survey required a high degree of respondent cooperation and effort over a 3-week period. Forty respondents from each income-level group were selected randomly, giving a total of 80 respondents, allowing for a margin of unreliable surveys that could be discarded in the end. Surveys are excluded from the final analysis when respondents prove to be uncooperative or unreliable, or when the data are inconsistent or of poor quality. In the end, 10 samples were discarded.

The survey design included charcoal consumption testing for three stoves: the traditional stove (the coalpot), the "Ahinbenso" (promoted by the Ministry of Energy and the UNDP), and the "Gyapa" (the EnterpriseWorks ceramic-lined stove).

All the communities are in the Greater Accra Region of Ghana, except Kasoa in the Central Region and Nsawam in the Eastern Region. The survey was launched on 15th August 2002 and lasted for 6 weeks. There were two 3-week sessions. Each session allowed for a 1-week measurement of charcoal consumption for each of the three stoves. Each household was visited nine times over a 3-week period. The visits were made every 2 or 3 days, excluding Sundays. During the first week, charcoal consumption was tracked using the traditional stove, which was already present in each of the households. During the second week, half of the households were introduced to the "Ahinbenso" stove and the others introduced to the "Gyapa". The stoves were interchanged for the households during the third week. Table 1 presents an example of the schedule for a household.

In the initial visit, background information about the family was collected: number of meals cooked with charcoal in a typical week; number of people consuming food in the household; amounts of charcoal purchases; and other kinds of stoves used.

Charcoal consumption calculations

In the eight subsequent visits, the main purpose was to determine the amount of charcoal consumed and to examine the respondents' reaction to the stove. On the first day of each new week, a new stove was introduced. The nine visits to a household were all around the same

Traditional stove

"Gyapa"

"Ahinbenso"

Four zones were chosen as follows:
ZONE 1: La, Teshie Nungua, Nima, and Madina
ZONE 2: James Town, Korle Gonno, Mamprobi, and Abossey Okai
ZONE 3: Mallam-Gbawe, Alajo, Kasoa, and Odorkor
ZONE 4: Pokuase, Nsawam, and Dome-Taifa

TABLE 1

A Typical Household Visit Schedule

Week One Household 1	Monday Traditional stove	Wednesday Traditional stove	Friday Traditional stove
Week Two Household 1	Monday "Ahinbenso" stove	Wednesday "Ahinbenso" stove	Friday "Ahinbenso" stove
Week Three Household 1	Monday "Gyapa" stove	Wednesday "Gyapa" stove	Friday "Gyapa" stove

time of the day to help with consistent comparisons of charcoal consumption. Each respondent was provided with a bucket and instructed to use only charcoal for cooking from the bucket. Data collected were tabulated in a designed template in Excel.

Measurement of Charcoal Consumption:

Weight of charcoal added to the supply bucket between visits

Plus

Weight of charcoal in the supply bucket at the end of the last visit

Minus

Weight of charcoal in the supply bucket at the start of current visit

Results and discussion

Meal consumption

To establish a standard measurement for a consumer, it was determined that all children aged 12 and under would be considered one-half of an adult. The total number of adults plus one-half the number of children, results in a total called "adult-equivalents". Table 2 shows estimates of people consuming meals prepared in the households provided at the beginning of the survey period.

The estimates provided at the beginning of the survey period on meals consumed per day did not differ substantially from the data gathered during the survey period (Table 3). The average adult-equivalent eating each meal was 3.4. The total meals consumed per day by the adult-equivalents were estimated to be 11.1 and the survey results were 10.14.

The minimum adult-equivalents consuming meals was sometimes zero, suggesting that no meal was prepared in the households. This observation was very common among households with busy working mothers. For example, the children could eat breakfast from food provided by a local vendor, and their school might supply lunch. The maximum number of adult-equivalents consuming meals prepared in the household was 16.2, which could be explained by the extended family system in which other relatives outside the

TABLE 2

Estimates of Average Adult-equivalents Consuming Meals Prepared in the Household Per Day

	Breakfast	*Lunch*	*Dinner*	*Total meals per day*	*Average per meal*
People older than 12 years of age	2.9	1.8	4.6	9.3	3.1
Children 12 years of age or younger	1.2	0.6	1.7	3.5	1.2
Total adult-equivalents	3.6	2.0	5.5	11.1	3.7

Source: Authors' compilation, August 2002

TABLE 3

Actual Average Adult-equivalents Consuming Meals During the Survey

	Between 1st and 2nd visit	*Between 2nd and 3rd visit*	*Between 4th and 5th visit*	*Between 5th and 6th visit*	*Between 7th and 8th visit*	*Between 8th and 9th visit*	*Mean*
Total adult-equivalents	2.9	2.85	2.76	2.87	2.95	2.54	2.81
Total meals	25.35	25.68	23.66	26.66	25.04	23.61	25
Total meals per day per A-E	10	10.44	9.94	10.93	9.78	9.5975	10.14
Average A-E per meal	3.33	3.48	3.31	3.64	3.26	3.19	3.37

Source: Authors' compilation, August 2002

nuclear family share the same budget, especially in a typical family house or compound house in which other tenants may be invited to dine. The sample included relatively large family sizes in James Town and Korle Gonno, which are traditional Ga communities in Accra.

Charcoal purchases

Most households in the study buy charcoal in tins, which meets their charcoal needs for a day. Thus, most households do not have large cash balances to buy and store larger amounts of charcoal, although cost-efficiencies are associated with the purchase of maxi sacks. This fact was confirmed during the survey. Households that had the means purchased the larger sacks. In addition, the survey showed consistent results for the prices for heaps and tins, but a wide range for mini sacks (US$2.50 to US$3.75) and maxi sacks (US$2.75 to US$5.63) (Table 4).

Most households in Accra purchased their charcoal from a neighbourhood vendor daily, which was convenient for transporting the charcoal to their homes (Table 5). The 17 per cent that went to a more formal, neighbourhood market also enjoyed the convenience of its closeness to their homes. Only 3 per cent of the surveyed respondents said they purchased their charcoal from a location outside the city, and only 1 per cent actually paid additional costs for transportation to obtain the charcoal.

The study showed that most respondents used the stove principally for household cooking. Only 10 per cent of the surveyed respondents used the charcoal stove for commercial business, and 3 per cent for ironing (Table 6). If the respondent used the stove to heat water to make some kind of meal (for example, oatmeal), then that use was counted in the data collection.

Table 7 depicts fuel types used for the various meals prepared in the households. The survey results showed that dinner was the most common

TABLE 4

Characteristics of Charcoal Purchases

Unit of purchase (size)	*Number of households*	*Percent of households (%)*	*Estimate of how long the amount lasts (days)*	*Price of unit[1] (US$)*
Heaps	5	7	0.75	0.05
Tins	63	89	1	0.13
Mini sacks	7	10	24	2.66
Maxi sacks	11	15	26	4.17

Source: Authors' compilation, 2002

[1] Exchange rate used is 7,800 cedis to one US dollar

TABLE 5

Types of Charcoal Vendors

Kind of charcoal vendor	*Number of households*	*Percent of households (%)*	*Transportation cost*
Travelling seller	2	3	None
Neighbourhood market	12	17	None
Market in another part of the city	1	1	None
Around the neighbourhood	53	75	None
Outside the city	2	3	US$0.13 for 1 % of households surveyed
Self-seller	1	1	None

Source: Authors' compilation, August 2002

TABLE 6

Non-cooking Uses of the Charcoal Stove

Use	*Number of households*	*Percent of households (%)*
Ironing	2	3
Commercial business – food vending	7	10

Source: Authors' compilation, August 2002

meal prepared by the households, followed by breakfast. Both meals were prepared mainly with charcoal and, to a limited extent, LPG. Preparation of lunch at the household level was rather unusual. For all meals, any fuel other than charcoal and LPG were scarcely used. These findings compared favourably with household fuel consumption patterns reported by the Energy Commission (2002). Some people who could afford, used LPG to cook breakfast because it was faster; however, most target respondents used charcoal for all three meals. None of the participants were accustomed to making and consuming tea in the afternoons.

TABLE 7

Fuel Used for Particular Meals

Fuel	*Breakfast (%)*	*Lunch (%)*	*Tea or snack*	*Dinner (%)*
Charcoal	76	31	-	100
LPG	9	1	-	6
Kerosene	0	0	-	0
Wood	0	0	-	3
Other	1.25	0	-	0

Source: Authors' compilation, August 2002

Types of stoves

The medium-sized ¼-in traditional coalpot is a typical charcoal stove used in Accra households. The survey results showed that 83 per cent of the respondents used the medium-sized traditional coalpot, with an average number owned per household of more than one stove and a maximum of three stoves (Table 8). The average expected useful life of a typical traditional medium-sized coalpot is estimated at 40 months (based on user perceptions, which may or may not be accurate). Only a few respondents, about 7 per cent of the sample size, used small and large-sized traditional coalpots. The "Ahinbenso" stove was rarely found among the poor and low-income class households. The use of the traditional tin coalpot was also limited, with only 3, 7 and 1 per cent of the sample size interviewed using small, medium and large sizes, respectively.

Fuel consumption and savings

About 70 out of 80 households involved in the study provided good-quality data and were retained in the sample. The

TABLE 8

Kinds of Stoves Used at the Household Level

Type and size of stove	*Percent of households using it (%)*	*Average number owned*	*Average expected useful life (in months)*
Traditional coalpot			
- Small	7	1	30
- Medium	83	1.3	40
- Large	7	1	47
Ahinbenso			
- Small	0	-	-
- Medium	3	-	78
- Large	0	-	-
Tin coalpot			
- Small	3	1	9
- Medium	7	1	16
- Large	1	1	12

Source: Authors' compilation, August 2002

respondents perceived that the "Ahinbenso" and "Gyapa" stoves saved fuel compared to the traditional stove. Table 9 presents the actual daily charcoal consumption in the households used for the study, while Table 10 shows the actual measured fuel savings of the improved stoves over the traditional. The "Gyapa" and "Ahinbenso" stoves save households 31 and 23 per cent per day in charcoal consumption or expenditure compared with the traditional stove, respectively.

Economic and environmental benefits

The "Gyapa" stove saves 0.51 kg of charcoal per day per household or 186 kg of charcoal annually. The percentage savings translate into about US$25.00 per year per home (using 365 days per year and charcoal cost of US$0.13 kg^{-1}). The savings in charcoal do not only result in economic benefits, but also result in reducing the number of trees felled for charcoal production. Determining the number of hectares of forest saved depends on how the wood is grown and harvested. For the natural forest, if it were clear-cut then it would yield 8.625 metric tons of charcoal. This equals 1,445.03 ha of natural forest. The "Gyapa" stove saves 0.51 kg of charcoal per day or 186 kg of charcoal annually. For every 1,000 improved stoves in use, the savings would be 186 tons of charcoal per year, equal to 1,488 tons of wood and 31.83 ha of forestland; using the natural forest-stocking rate of 46.75 MT ha^{-1} and 8 kg of wood to 1 kg of charcoal conversion rate from Ghana (MOE, 2002).

Conclusion

The results of the study showed fuel (charcoal) efficiency of 31 and 23 per cent for "Gyapa" and "Ahinbenso" over the traditional coalpot, respectively. Thus, among the three stoves used in the study, "Gyapa" is the most charcoal-efficient. For a household switching from traditional coalpot to "Gyapa" stove, charcoal savings amounting to 186 kg are recorded annually; which translates into US$25.00 per year per home. For every 1,000 "Gyapa" stoves in use, the savings would be 186 tons of charcoal per year, equal to 1,488 tons of wood and 31.83 ha of forestland. It is, therefore, recommended that promotional activities on the use of "Gyapa" stove

TABLE 9

Fuel Consumption at the Household Level (kg)

ID of respondent	*Traditional*	*"Ahinbenso"*	*"Gyapa"*	*ID of respondent*	*Traditional*	*"Ahinbenso"*	*"Gyapa"*
1	2.58	1.43	1.78	41	1.28	0.88	0.78
2	1.73	1.63	1.35	43	1.37	1.23	1.40
3	1.78	1.00	0.98	44	1.50	0.82	0.80
4	0.74	0.53	0.52	45	0.88	0.92	0.85
6	2.68	0.20	1.19	46	1.35	1.08	0.97
7	1.82	1.40	0.80	47	1.53	1.35	1.10
8	2.17	2.10	2.00	48	2.25	2.00	1.50
9	2.07	1.82	1.38	49	2.30	1.23	1.13
10	1.02	0.43	0.35	51	1.88	1.23	0.90
11	1.60	1.65	0.73	52	1.59	1.03	0.95
12	2.15	1.55	1.48	54	1.07	0.92	0.83
13	2.56	2.50	2.33	55	2.10	2.00	1.72
14	1.18	1.15	0.80	56	1.13	1.10	0.88
15	1.78	1.50	1.08	57	1.77	0.95	0.98
16	0.63	0.32	0.22	58	0.73	0.53	0.48
17	1.67	1.50	1.02	59	2.20	1.55	1.08
18	2.55	1.45	1.65	60	1.95	1.58	1.30
19	1.75	1.73	1.32	61	1.90	1.40	1.35
21	2.68	2.45	2.95	62	1.76	1.13	0.93
22	2.58	2.45	2.08	63	1.80	1.33	1.50
25	1.93	2.13	2.90	64	2.93	2.43	2.50
26	1.43	1.35	0.67	65	2.03	1.73	1.43
27	0.93	1.02	0.80	66	0.75	0.52	0.45
28	2.15	1.77	1.65	67	2.70	2.13	2.20
29	1.47	0.87	0.33	68	2.10	1.78	1.50
30	2.56	1.70	2.10	69	2.45	1.98	1.80
31	1.82	1.15	1.58	70	3.58	2.03	0.86
32	2.01	1.77	0.78	71	1.38	1.10	1.00
34	1.43	0.57	1.42	72	1.58	1.00	0.60
35	1.92	0.97	1.18	73	1.38	0.95	0.85
36	0.95	0.50	0.68	74	0.53	0.36	0.37
37	1.18	1.55	1.50	75	1.82	1.53	1.50
38	0.38	0.38	0.36	76	1.13	1.05	0.72
39	1.25	1.00	1.23	77	1.00	0.97	0.60
40	0.88	0.56	0.57	80	1.00	0.92	0.60

Source: Authors' compilation, August 2002

TABLE 10

Average Fuel Consumption and Percentage Savings of Improved Stoves Over the Traditional

	Traditional stove (kg)	*"Ahinbenso" stove*	*"Gyapa" stove*
Average consumption per day	1.69	1.3 kg	1.18 kg
Average consumption per day per adult-equivalent	0.78	0.59 kg	0.53 kg
Savings over traditional coalpot	-	23 %	31 %

Source: Authors' compilation, August 2002

among charcoal-consuming households in Ghana should be strengthened.

REFERENCES

Energy Commission (2002) *Official Journal of Energy Commission of Ghana*, August 2002. Energy Commission of Ghana.

Ezzati, M., Kammen, D. M. & **Mbinda, B. M.** (2000) *Comparison of traditional and improved cookstoves: A health-focused analysis*. Environmental International (submitted).

Ezzati, M., Kammen, D. M. & **Singer, B. H.** (1999) The health impacts of exposure to indoor air pollution from biofuel stoves in rural Kenya. *Proceedings of Indoor Air 99: The 8th International Conference on Indoor Air Quality and Climate*, Edinburgh, Scotland, August 1999. **3**, 130-135.

FAO (2002) *Forestry Information Systems Country Profiles.* Food and Agriculture Organization of the UN.

FAO (2002) *Wood Energy Planning and Policy Development Programme for Ghana.* Food and Agriculture Organization of the UN.

MOE (2002) *Wood fuels use in Ghana.* Traditional Energy Unit, Ministry of Energy, Technical Report.

Nketiah, K. S. , Hagan, E. B. & **Addo, S. T.** (1998) *The charcoal cycle in Ghana*. United Nations Development Programme and National Energy Board Project.GHA/82/020. Technical Report.

Smith, K. R. (1993) The health impact of cookstove smoke in Africa. In *African Development Perspectives Yearbook*, 3 (ed. P. Oester-diekhoff).

Togobo, W. A. (2002) *The household energy for cooking in Ghana.* Technical Report. Ministry of Energy, Ghana.