



CHAPTER 4

Adoption and Economic Impact of Briquettes as Cooking Fuel: The Case of Women Fish Smokers in Ghana

Solomie Gebrezgabher,^{1*} Sena Amewu¹ and Mary Njenga^{2,3}

¹ International Water Management Institute (IWMI), PMB CT 112, Accra, Ghana

² World Agroforestry Centre (ICRAF), P.O. Box 30677-00100, Nairobi, Kenya.

³ Wangari Maathai Institute for Peace and Environmental Studies, University of Nairobi, Kenya, P.O. Box 30197-00100, Nairobi, Kenya

* Corresponding author, e-mail: S.Gebrezgabher@cgiar.org

4.1 Introduction

In Ghana, much of the population relies on traditional biomass such as firewood and charcoal. Referred to as woodfuel, they are considered the primary source of energy for heating and cooking. In rural Ghana, 73.4% of the households use firewood as the main source of fuel while charcoal is the most common energy source for cooking in urban areas (GSS 2013). The use of firewood is not only limited to rural households as it is also predominant in commercial activities in urban settings. Firewood is used in commercial activities such as smoking fish, bakeries, batik (traditional clothing) making and by street food vendors. A number of negative socio-economic and environmental effects result from the use of woodfuel due to the unsustainable nature of production and use. Deforestation and climate change effects are some examples of the effects on the environment while incomplete combustion and smoke have important health implications for the primary users, who are mainly women and children (UNDP 2014). With projected urban population growth, the use of charcoal for instance will continue to increase as the

main source of fuel for cooking among urban households in Ghana. The main reasons for the continued dependence on firewood and charcoal are their affordability, availability and lack of affordable and reliable alternative energy sources. The popularity of charcoal and firewood may also be attributed to their capacity to meet cooking and heating needs as well as local communities' preferences (Mendum and Njenga 2018).

The opportunity to utilize organic wastes more efficiently such as municipal solid waste and agricultural residues has in recent years aroused the interest of developing countries in briquetting technologies. Briquettes are a form of solid fuel produced by compacting dry loose biomass residues into solid blocks that provide energy and are used like firewood and charcoal (Njenga et al. 2013). They can serve as substitutes for traditional biomass energy sources for domestic and institutional cooking such as cooking in schools, hospitals and prisons as well as for industrial processes. Briquettes have the potential to counteract many adverse health and environmental impacts associated with traditional biomass energy (Njenga et al. 2013).

In spite of the advantages of briquettes, their uptake as a substitute for firewood and charcoal in Ghana remains very limited. Furthermore, despite the growing interest in briquettes and their potential for improving the living standards of the poor, there have been limited studies focusing on their adoption potential by end users. The primary objective of this study is to assess the likelihood of adoption of briquettes by women fish smokers and to explore the resulting economic impact on the women. Smoking fish is a commercial activity, predominantly undertaken by women. It is carried out using traditionally-designed stoves with firewood as the main source of fuel. This study explores fish smokers' willingness to adopt briquettes through application of the binary choice probit model using data collected from women fish smokers in the Greater Accra region (Maddala 1992). Respondents for the study came from major fishing communities in three districts. A total of 130 respondents were interviewed using a structured questionnaire in 2016.

4.2 Characteristics of the Fish Smokers

4.2.1 Sociodemographic characteristics of the fish smokers

All of the respondents in our sample were female (Table 4.1). The fish smokers buy their firewood on a daily, weekly and monthly basis depending on the scale of the business. The size of the fish-smoking business measured by the amount of fish smoked per month determines the frequency of firewood purchase. Small businesses tend to buy their firewood on a daily basis while medium and large businesses buy their firewood on a weekly or monthly basis. In our survey, 56, 27 and 17% of the fish smokers bought their firewood on a daily, weekly and monthly basis respectively. The businesses were categorized into three

groups based on their frequency of firewood purchase: (1) small (buying firewood on a daily basis), (2) medium (buying firewood on a weekly basis) and (3) large (buying firewood on a monthly basis). Data are presented across the three categories. The small-scale traders comprised young people in and around 35 years of age and the majority (65%) had some form of formal education; medium- and large-scale traders comprised women above 40 years of age with the majority (55%) having attended school.

4.2.2 Inputs and outputs in fish-smoking enterprises

The main inputs for the fish-smoking business are the fresh fish, labor and firewood (Table 4.2). The average monthly expenditure on fresh fish is GHS 10,510 (USD 2,872 month⁻¹) for small-scale businesses (most of the fish smokers) and GHS 35,691 (USD 9,751 month⁻¹) for large-scale businesses. The total monthly expenditure on labor varies across the different scales with an average monthly labor expenditure of GHS 261 (USD 71 month⁻¹), for small-scale businesses, GHS 454 (USD 124 month⁻¹) for medium-scale businesses and GHS 397 (USD 108 month⁻¹) for large-scale businesses. The proportion of expenditure on firewood in the total cost is similar across the businesses, accounting for on average 6% of the total input cost. The bulk of the cost is the purchase of fresh fish. The total monthly sales value is on average GHS 14,392 (USD 3,932) for small businesses with an average profit margin of 9%. The corresponding figures for the medium- and large-scale businesses are higher with each business reporting profit margins of 13 and 15% respectively. This implies that the profit margins vary across the three categories with medium- and large-scale businesses earning higher margins (they are mainly run by older women); young women, despite being more educated, earn less.

TABLE 4.1. SOCIODEMOGRAPHIC CHARACTERISTICS OF WOMEN FISH SMOKERS (n = 128).

Variable	Description	¹ Small scale (n=71)	² Medium scale (n=35)	³ Large scale (n=22)
Age	Age of respondents in years	35 (11) ^b	44 (12)	40 (9)
Gender	1= Female, 0= otherwise (%)	100	100	100
Education	Level of education (%)			
	1= never been to school	34	66	55
	2 = primary school	55	31	36
	3= secondary school	11	3	9
	4= undergraduate	0	0	0
	5 = graduate/professional	0	0	0

^a Scale is based on the frequency of purchase: 1=daily, 2=weekly, 3=monthly.

^b Standard deviation.

TABLE 4.2. INPUTS AND OUTPUTS IN FISH-SMOKING ENTERPRISES (MEAN VALUES) (n=128).

Description	Small scale	Medium scale	Large scale
Expenditure on fish (GHS month ⁻¹)	10,510 (11,015) ^a	32,894 (69,966)	35,691 (30,894)
Labor cost (GHS month ⁻¹)	261 (225)	394 (323)	397 (327)
Proportion of firewood expenditure (%)	6 (8)	7 (11)	5 (3)
Total value of fish sales (GHS month ⁻¹)	14,392 (14,682)	28,302 (35,026)	45,536 (38,767)
Profit margin (%)	9 (25)	13 (19)	15 (17)

^a Standard deviation. Exchange rate USD 1.00 = GHS 3.66.

4.2.3 Energy sources for smoking fish

The firewood is sourced from Kumasi in the Ashanti region. There are about 200 fish smokers in the three categories who obtain firewood in logs of about 45-50 kg (kilograms). The logs are split into smaller pieces, a process mainly undertaken by men because this requires intense physical energy (Figure 4.1a and 4.1b). Smoking of fish is carried out using traditionally-manufactured stoves with firewood as the only source of fuel (Figure 4.2a and 4.2b). The average monthly quantity of firewood used varies across the fish smokers from 1,354 kg month⁻¹ for small-scale businesses to 6,614 kg month⁻¹ for large-scale businesses. Similarly, the

price of firewood varies across the three categories with large fish smokers purchasing firewood at a lower price than the smaller fish smokers (Table 4.3). In addition, small business operators buy their firewood on a daily basis from retailers due to low income levels while large business operators buy on a weekly or monthly basis from wholesalers. This translates into a variation in the price of firewood purchased by the small and large businesses in favor of the latter. Buying firewood in bulk from wholesalers receives a price discount, hence the costs are reduced. This indicates that prices paid for inputs such as fish and firewood and the resulting profit margins vary among the three categories implying heterogeneity within the women’s group.

FIGURE 4.1A AND 4.1B. SPLITTING OF FIREWOOD TO BE USED FOR SMOKING FISH.



Source: Sena Amewu (IWM).

A



Source: Sena Amewu (IWM).

B

FIGURE 4.2A AND 4.2B. TRADITIONAL STOVE USED FOR SMOKING FISH (L) AND TRADITIONAL STOVES (R).



Source: Sena Amewu (IWM).

A



Source: Sena Amewu (IWM).

B

TABLE 4.3. SOURCE, AMOUNT AND PRICE OF ENERGY FOR SMOKING FISH (n=128).

	Description	Small	Medium	Large
Quantity of firewood	Monthly firewood quantity used (kg month ⁻¹)	1,354	4,353	6,614
Price of firewood	Price of firewood purchased (GHS kg ⁻¹)	0.363	0.292	0.285
Place of purchase	Place of firewood purchase (%)			
	1= source of production			
Firewood supply	2= retailer	99	51	5
	3= wholesaler	1	49	95
	4= obtained freely			
	Rating of fuel supply throughout the year (%)			
	1= adequate, 0= otherwise	77	77	82
Credit access	Mode of payment for purchase of firewood (%)			
	1= if fish smoker buys firewood on credit	30	34	36
	0= if fish smoker buys only on a cash basis			
Future price	Perception of trends in future price of firewood (%)			
	1= will remain constant	7	6	23
	2= will decrease in future	3	0	14
	3= will increase significantly but will continue to buy it	69	51	36
	4= will increase significantly so will switch to another source	21	43	27

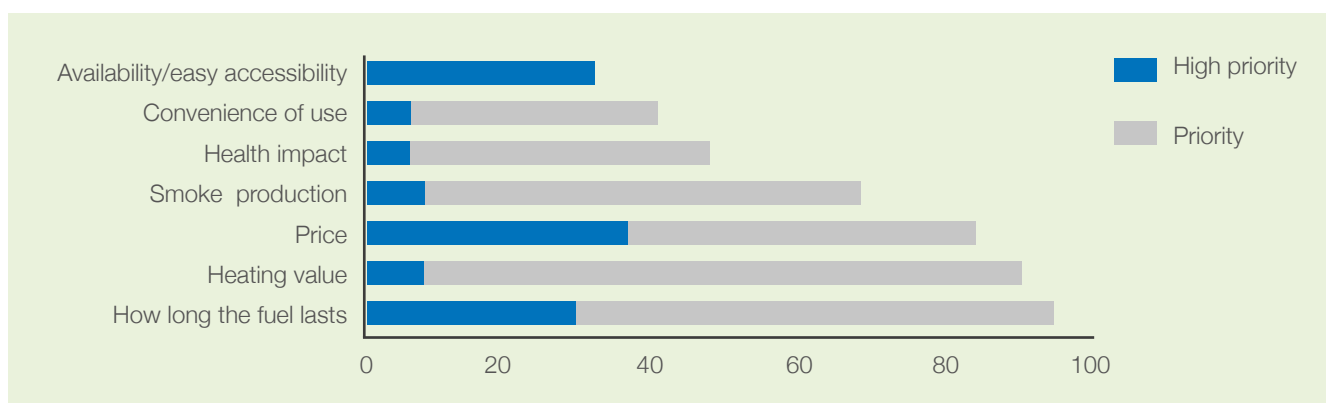
The survey collected information on respondents' perceptions about the supply of firewood throughout the year and the future price trends. The response across the three categories was uniform for firewood supplies and most fish smokers believed that their firewood supply was adequate throughout the year. However, perceptions on the trend in future prices of firewood varied across the three categories. More than 90% of the small and medium businesses believed that the price of firewood would increase significantly while the proportion among the large-scale businesses who believed the same was lower (63%). This also indicates that more than one-third of the large-scale businesses believed that the price of firewood would either remain constant or would decrease in the future. Of those who believed that the price of firewood would increase, 69% of the small, 51% of the medium and 36% of the large businesses stated that they would continue buying it while the remainder wished to switch to another alternative fuel source. It is possible that the small and medium businesses who believed that the price of firewood would increase significantly were more likely to switch to alternative sources of cooking fuel. Moreover, there are also business traders who are spending more on firewood and need cheaper fuel to increase their profit margins.

4.3 Preferred Energy Attributes and Fish Smokers' Purchasing Behavior

To determine the most important factors that influence their energy source choices, respondents were asked to rate seven attributes. These attributes were rated based on their level of importance prior to purchasing fuel (Figure 4.3). Burning time (how long the fuel lasts) (95%) and heating value (91%) were ranked as the most important product attributes. Price was ranked third (84%) followed by smoke production (68%). Thus burning time, heating value and price are the most important attributes that influence fish smokers' choice of fuel. Health impacts and accessibility modes were ranked as the least important factors in making fuel purchase decisions. This implies that, although fish smokers are aware of health implications associated with burning fuel, they do not consider them to be an important factor when choosing their fuel, possibly because of related economic benefits and their purchasing power. Therefore, more affordable, good quality and cleaner sources of cooking fuel are needed.

4.4 Estimating Likelihood of Adoption

Respondents were asked if they would be willing to adopt briquettes as an energy source for smoking fish and 77%

FIGURE 4.3. FACTORS INFLUENCING FISH SMOKERS' PURCHASE OF FUEL.


agreed. However, when their willingness to pay for the briquettes was raised, most (more than 90%) of those willing to adopt replied negatively until they could assess the performance of the briquettes and compare it to their current source.

Table 4.4 shows that neither age nor education influenced fish smokers' willingness to adopt briquettes. Notably, the price and total monthly quantity of firewood negatively influence fish smokers' willingness to adopt briquettes. This implies that large-scale fish smokers using large quantities of firewood per month are less likely to adopt briquettes as they purchase firewood in bulk and get a discounted price. On the other hand, small-scale fish smokers buying firewood more frequently from retailers are more likely to adopt briquettes as they get no discounts and make their purchases in small quantities on a daily basis which is costly. Moreover, income from smoking fish has a positive and significant effect on fish smokers' willingness to adopt briquettes. This indicates that as income from smoking fish increases, the likelihood of briquette adoption increases.

TABLE 4.4. FACTORS EXPLAINING WILLINGNESS TO ADOPT BRIQUETTES.

Variable	Coefficient	Z-value
Age	0.011	0.78
Education	-0.027	-0.11
Firewood price	-1.417	-3.98***
Firewood quantity	-0.0008	-1.74**
Income from smoking fish	0.847	1.63*
Credit access	-0.162	-0.49
Future price	0.561	3.00**
Source - frequency	0.686	2.37*
Constant	-1.726	-1.85*
Log likelihood	-43.54	
LR Chi2	47.14	
Prob > Chi2	0.000	
Pseudo R2	0.35	

* Significant at 0.10 level; **Significant at 0.05 level; ***Significant at 0.001 level.

Table 4.5 shows that the impact of a change in firewood price would have a greater effect on the likelihood of adoption than a change in quantity of firewood used. Furthermore, a change in income from smoking fish has a larger impact on the likelihood of adoption after the price of firewood. For instance, an increase in the firewood price by one unit decreases the likelihood of adoption by 0.366 which seems counterintuitive and difficult to explain. However an increase in income from smoking fish by USD 1.00 increases the likelihood of adoption by 0.219. Furthermore, trends in the future price of firewood show that a higher score in the perception variable increases the likelihood of briquette adoption. This indicates that fish smokers who believe that the future price of firewood may increase are more likely to adopt briquettes.

TABLE 4.5. MARGINAL EFFECTS OF FACTORS INFLUENCING LIKELIHOOD OF ADOPTION.

Variable	Coefficient
Age	0.003
Education	-0.007
Firewood price	-0.366
Firewood quantity	-0.0002
Income from smoking fish	0.219
Credit access	-0.042
Future price	0.145
Source - frequency	0.177

4.5 Economic Impact of Briquette Use

4.5.1 Savings from reduced expenditure on energy

Replacing firewood with briquettes has the potential to minimize costs on energy incurred by fish smokers (Table 4.6). The energy content in 1 kg of briquette is 16.8 MJ (megajoule) while the energy content in 1 kg of firewood is 13.8 MJ (Hu et al. 2014). Thus, less briquette by weight is required for the same amount of heat compared to firewood. In addition to the calorific value of the energy sources, the

replacement value of briquettes to firewood depends on the efficiency of cookstoves used (Roy and Corscadden 2012). The stoves that the women fish smokers use are made from metal containers fitted with iron rods and with an opening to provide oxygen helping ventilation to light the firewood. These stoves are assumed to have an efficiency of 45% when firewood is used compared to 50% when briquettes are used (Young and Khennas 2003). Based on these assumptions, the actual price per MJ of useful energy is GHS 0.051 (USD 0.014) in firewood equivalent and GHS 0.047 (USD 0.013) in briquette equivalent. Switching from firewood at GHS 0.33 kg⁻¹ (USD 0.09 kg⁻¹) to briquettes at GHS 0.44 kg⁻¹ (USD 0.12 kg⁻¹) has the potential to reduce the cost of energy for fish smokers by 10% as fewer briquettes are required for the same amount of heat compared to firewood. The saved income could be used for other purposes including expanding the business and improving livelihoods for women and their families.

4.5.2 Saving income from reduced cost of labor in splitting firewood

In addition to reduced expenditure on energy, switching to briquettes would enable the women fish smokers to save income spent on paying for labor to split firewood. Based on our survey results, the average cost of labor for splitting firewood is GHS 0.11 kg⁻¹ (USD 0.03 kg⁻¹) which could be avoided if briquettes are used. The average quantity of firewood used by one fish smoker is 36 tons per annum at an average purchasing cost of USD 0.09 kg⁻¹ and splitting cost of USD 0.03 kg⁻¹ or a total cost of USD 0.12 kg⁻¹ (USD 4,320 year⁻¹). On the other hand, the average quantity of briquettes used by one fish smoker to replace the same amount of firewood per annum would be 26.6 tons at a cost of USD 0.12 kg⁻¹ (USD 3,192 year⁻¹) resulting in a 26% reduction on energy expenditure for the fish smoker.

4.5.3 Health and climate change impacts

Burning biomass energy produces pollutants that have negative impacts on human health and the environment, a situation exacerbated when inefficient cooking appliances are used. Coughing, sneezing and headaches are common among women who work in smoky kitchens, while bronchitis, lung cancer, asthma and tuberculosis have also been linked to smoke from indoor combustion (WHO 2006). Smoke from burning biomass for energy is a serious concern as globally, over 4 million deaths occur annually from illnesses related to the smoke generated by indoor combustion, which mainly affects women and children (Lim and Vos 2012). Methane (CH₄), carbon dioxide (CO₂) and nitrous oxide (NO₂) among other gases emitted when burning biomass energy cause air pollution that contribute to climate change (FAO 2017). However, briquettes produce lower emissions owing to the raw materials and processing techniques used (Njenga et al. 2013). Using briquettes addresses health risks faced by the fish smokers and reduces demand for firewood hence saving trees and reducing air pollution. Better results will be achieved from a combination of using briquettes in more efficient cookstoves.

4.6 Conclusions

Technologies for briquetting are well researched and ready for use in practice. However, the use of briquettes as a source of cooking fuel is not common in Ghana. This study assessed the likelihood of adoption of briquettes by women fish smokers in Ghana. The results of this study are useful for policy-makers, technology developers and distributors in identifying what determines the decision-making behavior of potential end users, specifically women fish smokers. Moreover, it can contribute to identifying key technology attributes that need to be targeted for improvement if adoption is to be achieved at scale.

TABLE 4.6. POTENTIAL SAVINGS FOR FISH SMOKERS BY SWITCHING FROM FIREWOOD TO BRIQUETTES.

Item	Firewood	Briquette
Firewood replaced by briquettes (ton) (A)	1	1
Heating value (MJ kg ⁻¹) (B)	13.8	16.8
Price (USD kg ⁻¹) (C)	0.09	0.12
Efficiency of stoves (%) (D)	45%	50%
Actual price per useful energy (USD MJ ⁻¹) (E= C/(B*D))	0.014	0.013
<i>Saving from shifting to briquettes:</i>		
Average annual quantity used per fish smoker (ton year ⁻¹)	36	26.6
Price of fuel (USD ton ⁻¹)	90	120
Labor cost (USD ton ⁻¹)	30	0
Total cost of fuel per annum (USD year ⁻¹)	4,320	3,192
Total annual savings from briquette use instead of firewood (%)	26%	

The main conclusions from the study are:

- Small-scale enterprises were run by younger women with higher education but earning less than counterpart older women with low education as the latter run medium- to large-scale enterprises purchasing inputs in large quantities and at lower cost. There is a need for entrepreneurship support to increase the purchasing power of the former.
- Most of the women surveyed lack awareness and knowledge about briquettes. Thus, an awareness campaign program needs to be carried out to familiarize the target end users on the benefits of using fuel briquettes including a demonstration of the performance of briquettes in comparison to alternative cooking fuels.
- The quality of the product as measured by how long the fuel lasts and heating value are the most important product attributes influencing fish smokers' choices when purchasing fuels. The health impact of fuel was among the factors ranked as the least important, implying that despite fish smokers' awareness of health implications associated with burning firewood, economic-related factors are more important in making decisions on the type of fuels to use in their enterprises. This emphasizes the need for briquettes as they save on fuel consumption and are cleaner than firewood.
- Most of the fish smokers were willing to adopt briquettes. However, switching from firewood to the new type of energy would be informed by practical experience on how the briquettes work in comparison to what they are used to, i.e. firewood. The main factors that influence the adoption of briquettes are quality, income from smoking fish and trends in future prices of firewood; hence, briquettes need to have a competitive or lower price or high reduction in consumption level. Briquette adoption by fish smokers is more likely to occur among small-scale fish smokers rather than among large-scale fish smokers as the latter buy firewood in bulk and get a discounted price.
- The economic analysis of shifting to briquettes showed that at the current price of firewood (USD 0.09 kg⁻¹), using briquettes priced at USD 0.12 kg⁻¹ has a potential cost saving of 10% compared to firewood used by the fish smokers. When the cost of buying the firewood and labor for splitting firewood is considered, the total saving by switching to briquettes is estimated to be 26%.

4.7 References

- FAO (Food and Agriculture Organization of the United Nations). 2017. *The charcoal transition. Greening the charcoal value chain to mitigate climate change and improve local livelihoods*. Rome, Italy: FAO.
- GSS (Ghana Statistical Service). 2013. *Population and housing census*. Accra, Ghana: GSS. (National analytical report).
- Hu, J.; Lei, Z.; Wang, Z.; Yan, X.; Shi, X.; Li, Z.; He, X.; Zhang, Q. 2014. Economic, environmental and social assessment of briquette fuel from agricultural residues in China - a study on flat die briquetting using corn stalk. *Energy* 64: 557–566.
- Lim, S.S.; Vos, T. 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: A systematic analysis for the global burden of disease study 2010. *Lancet* 380: 2224–2260.
- Maddala, G.S. 1992. *Limited dependent and qualitative variables in econometrics*. Cambridge, United Kingdom: Cambridge University Press.
- Mendum, R.; Njenga, M. 2018. Integrating woodfuels into agriculture and food security agendas and research in sub-Saharan Africa. *FACETS* 3: 1–11.
- Njenga, M.; Karanja, N.; Jamnadass, R.; Kithinji, J.; Sundberg, C.; Jirjis, R. 2013. Quality of briquettes produced locally from charcoal dust and sawdust in Kenya. *Journal of Biobased Materials and Bioenergy* 7: 1–8.
- Roy, M.M.; Corscadden, K.W. 2012. An experimental study of combustion and emissions of biomass briquettes in a domestic wood stove. *Applied Energy* 99: 206–212.
- UNDP (United Nations Development Programme). 2014. *Nama study for a sustainable charcoal value chain in Ghana*. New York, USA: UNDP.
- WHO (World Health Organization). 2006. *Fuel for life, household energy and health*. Geneva, Switzerland: WHO.
- Young, P.; Khennas, S. 2003. *Feasibility and impact assessment of a proposed project to briquette municipal solid waste for use as a cooking fuel in Rwanda – consultants report*. Available at: http://cleancookstoves.org/resources_files/feasibility-and-impact.pdf (accessed on September 18, 2018).

Acknowledgments

This research presented in this chapter was carried out with funding by the Ghana Netherlands WASH Window – Sustainable Water Fund (GWW-FDW), BMBF-BMZ via Urban FoodPlus and as part of the CGIAR Research Program on Water, Land and Ecosystems (WLE), supported by Funders contributing to the CGIAR Trust Fund (<https://www.cgiar.org/funders/>).