Cooking Ghanaian Dishes with Biogas

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Abstract

Food is cooked to make it more palatable or easier to eat and in some cases more digestible. There are different types of food which are used by the human body for various purposes and most food are sources to more than one nutrient essential for man to stay healthy. Biogas is one source of energy used for cooking food in the household. One major advantage of biogas over other fuels is that it can be generated from waste organic material produced in the household. The design of biogas plants for use in cooking in household depends on the types of dishes being cooked. The quantity of biogas needed for the preparation of the popular fufu and palm nut soup in Ghana is about 440 litres.

Keywords: *Cooking; Biogas; Palm nut Soup; Food; Yam; Plantain; Ghanaian Dishes*

1 Introduction

Eating a nutritious diet is easy to do in most regions of Ghana. The four main groups of foods are Protein, Fats and Oils, Carbohydrates and Starches, and Vitamins and Minerals. Most foods contain substances from each of these groups. Eating a variety of foods from each group every day will provide all the nutrients you need to stay healthy (Schroeder, 2003).

Sources of animal proteins common in Ghana are meat, poultry, fish, eggs, milk, cheese, yoghurt, snails and sea-food. Plant proteins are mainly legumes such as beans and lentils (soya, bambara, cow pea), melon seeds (*agushie*), and groundnuts (*Dietary and Physical Activity Guidelines for Ghana*, 2009).

Dietary fat is found in foods derived from both plants and animals. It is divided into saturated, unsaturated (mono- and poly-unsaturated), trans-fats and cholesterol. Saturated fats are heavier, denser and usually solid at room temperature. They are mostly of animal origin, e.g. fat in dairy products (milk, cream, ice-cream, butter and cheese), in red meat (veal, beef, pork, lamb), in poultry, eggs, and in some plants such as palm, palm kernel and coconut oils.(*Dietary and Physical Activity Guidelines for Ghana*, 2009). Butter, margarine, red palm oil (which is very rich in vitamin A), groundnut oil (composed of 50 percent fat and 27 percent protein), coconut oil and shea butter are all important ingredients in Ghanaian food and are sources of fats and oils . It is best to use unsaturated fats and oils such as corn, safflower and sunflower oil. Red palm oil is also unsaturated and is different from the clear palm kernel oil which is saturated (Schroeder, 2003).

Carbohydrates in the form of cereal grains and root vegetables, are the major energy sources in Ghana. Other examples of cereal grains are rice, millet, guinea corn and maize. Roots and tubers such as cassava, yam, cocoyam, and sweet potato are also important staples but they do not contain as much protein as cereal grains. Carbohydrates can be polished (refined) or unpolished. Whole meal cereals and their products such as corn, *Ga* or *Fanti kenkey*, brown rice, millet, *fula*, sorghum, Tubers and their products such as yam, cassava, *gari*, cocoyam, water yam and potatoes, starchy fruit such as plantain are all examples of unpolished carbohydrates. Examples of polished carbohydrates on the other hand are polished white rice, polished breakfast cereals such as *oblayoo*, *ekuegbemin*, and white flour, white *kenkey* (*nsiho*), *abodoo*, osino *kenkey*. Examples of refined starches are custard powder and tapioca(*Dietary and Physical Activity Guidelines for Ghana*, 2009).Fruit such as oranges, pineapple, bananas, pawpaw and mangoes are rich sources of vitamins and minerals. Other sources of vitamins and minerals are green leafy vegetables such as spinach and Kontomire (cocoyam leaves), bitter leaf, cassava leaves, baobab leaves and Guinea sorrel. Other vegetables found in Ghana are peppers, onions, tomatoes, cucumber, eggplant and okro(Schroeder, 2003).

Most Ghanaian foods are made into sauces, stews or soups. They usually contain tomatoes, palm oil, okra, garden eggs and groundnuts. Also included are meat, chicken or fish. These sauces, soups and stews are usually eaten with starchy staples. The staples range from cereals such as maize, sorghum, millet, rice and wheat to the roots and tubers such as yams, cassava, cocoyam, plantain and sweet potatoes (Schroeder, 2003).

The International Energy Agency ,IEA, in a World Energy Outlook report in 2006 estimated that household energy use in developing countries totalled 1,090 Mtoe[1] in 2004, almost 10% of world primary energy demand(IEA, 2006). The report also established that household use of biomass in developing countries alone accounts for almost 7% of world primary energy demand(IEA, 2006). The main use of energy in households in developing countries is for cooking, followed by heating and lighting(IEA, 2006). Households generally use a combination of energy sources for cooking that can be categorised as traditional (such as dung, agricultural residues and fuelwood), intermediate (such as charcoal and kerosene) or modern (such as LPG, biogas, ethanol gel, plant oils, dimethyl ether (DME) and electricity) (IEA, 2006).

Cooking is more than the combination of food in an appliance using energy(Balmer, 2007). Cooking is linked to cultural, religious and societal beliefs, it is the lubricant of family and community life and it is associated with well-being, mothering, safety and nourishment(Balmer, 2007). Cooking also provides cooked food necessary for human survival. Lack of food can seriously jeopardise human health and well-being, while lack of fuel for cooking energy can also be threatening to human survival(Balmer, 2007).

Cooking foods makes them more palatable or easier to eat. For instance, the flavour of meat is enhanced by cooking it, and the flavour and consistency of most cereal grains are improved by heating, which gelatinizes their starch content and makes carbohydrates more digestible(Pimentel & Pimentel, 1985). Although not all vegetables are cooked, heating them, if carefully done, makes them more tender while preserving their natural flavours and colours. Certainly, cooking foods and mixtures of foods also increases the variety of food available at mealtime(Pimentel & Pimentel, 1985).

Biogas is a mixture of mainly methane and carbon dioxide produced during the digestion of organic matter such as animal and kitchen waste as well as crop residues, in the absence of oxygen in vessels known as biogas digesters(Sasse, Kellner, & Kimaro, 1991). Anaerobic bacteria ferment biodegradable matter into methane (40-70%), carbon dioxide (30-60%), hydrogen (0-1%) and hydrogen sulphide (0-3%)(Sasse et al., 1991). The ideal process temperature for the fermentation process is about 35^{o}C, which might require additional heat or insulation of the digester in regions with daily or seasonal temperature fluctuations(Sasse et al., 1991).

A typical calculation to size household biogas digesters for various purposes such as cooking and lighting depends on the number of people who will use the facility. A close look at the calculation reveals that this is based on the type of food which will be prepared and the type of appliances to be used for the coking and lighting. A search in literature gives only general values for biogas consumption based on tests conducted in India and China.

To make the sizing of plants in Ghana more realistic, there is the need to come up with figures on the consumption of biogas when cooking Ghanaian local dishes.This study was therefore conducted using stoves manufactured at IRI.

2 Experimentation

Four dishes were prepared in the laboratory simulating the preparation methods used in the household. The dishes were Palmnut Soup, Rice, Yam and Plantain. The pots used were aluminium saucepans.
The stoves used were:

2.1 Gesellschaft fur Technische Zusammernarbeit (G.T.Z.) Table Top Stove (GTZTTS)

This comprises a circular burner with 222 holes each 2.5 mm. in diameter. This burner was fabricated based on the design by Sasse, L. *et al*(Sasse et al., 1991). This is fitted into a rectangular table-top stove structure (figure 1). The height of the base of the saucepan above the burner was 2.5 cm.

[1]The**tonne of oil equivalent** (**toe**) is a unit of energy defined as the amount of energy released by burning onetonneofcrude oil. It is approximately 42gigajoulesor 11,630kilowatt hours. (Mtoe,Mega-toe one million toe)

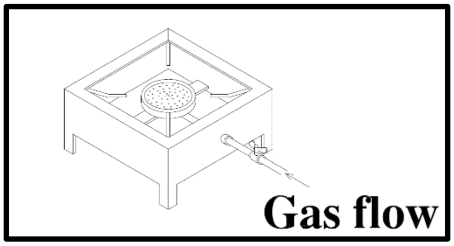

Figure 1: GTZTTS burner installed in stove

2.2 Gesellschaft fur Technische Zusammernarbeit(G.T.Z.) Coal Pot (GTZCP). This comprises a circular gas burner with 219 holes, each of diameter 2 mm. This burner was fabricated from a design suggested by Sasse, L *et al.*(Sasse et al., 1991) (figure 2). This is installed in a traditional Ghanaian stove (figure 4). The height of the base of the saucepan above the burner was 2.1 cm.

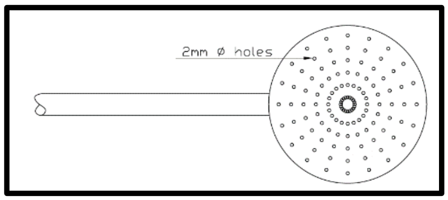

Figure 2: GTZCP Burner

2.3Industrial Research Institute Coal Pot (IRICP). This comprises a rectangular gas burner with 443 holes, each 1.5 mm in diameter. This burner (figure 3) was designed and built at the Institute of Industrial Research. This is installed in a traditional Ghanaian stove (commonly called Coal Pot) (figure 4). The height of the base of the saucepan above the burner was 1.4 cm.

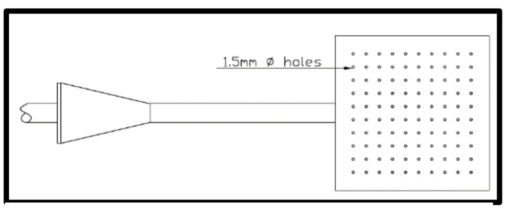

Figure 3: IRICP burner

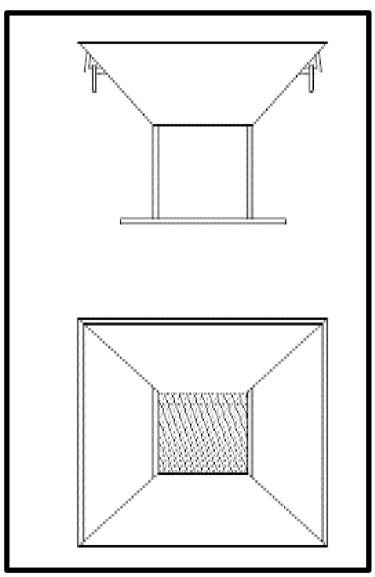

Figure 4: Traditional Ghanaian Stove ('Coal Pot')(elevation above and plan below)

2.4 Quantity of Foodstuffs used

2.4.1 Yam: About 0.5 kg of peeled yam slices were put in an aluminium saucepan. Approximately 0.65 g (0.65 litres) of water were added into the saucepan. The saucepan and contents were placed on the appliances. The initial biogas pressure was noted as well as the reading on the gas meter. The initial temperature of the contents was also noted. The stove was then lighted. After the foodstuff was cooked, the final biogas pressure, the final reading on the gas meter and the final temperature of the cooked foodstuff were noted.

2.4.2 Rice: About 0.5 kg of white polished rice was put in an aluminium saucepan. Approximately 0.90 g (0.90 litres) of water were added into the saucepan. The saucepan and contents were placed on the appliances. The initial biogas pressure was noted as well as the reading on the gas meter. The initial temperature of the contents was also noted. The stove was then lighted. After the foodstuff was cooked, the final biogas pressure, the final reading on the gas meter and the final temperature of the cooked foodstuff were noted.

2.4.3 Plantain: About 0.4 kg of peeled semi-ripe plantain fingers were put in an aluminium saucepan. Approximately 0.60 g (0.60 litres) of water were added into the saucepan. The saucepan and contents were placed on the appliances. The initial biogas pressure was noted as well as the reading on the gas meter. The initial temperature of the contents was also noted. The stove was then lighted. After the foodstuff was cooked, the final biogas pressure, the final reading on the gas meter and the final temperature of the cooked foodstuff were noted.

2.4.4 Palm-nuts: About 0.9 kg of palm-nuts were put in an aluminium saucepan. Approximately 0.7 g (0.7 litres) of water were added into the saucepan. The saucepan and contents were placed on the appliances. The initial biogas pressure was noted as well as the reading on the gas meter. The initial temperature of the contents was also noted. The stove was then lighted. After the foodstuff was cooked, the final biogas pressure, the final reading on the gas meter and the final temperature of the cooked foodstuff were noted.

2.4.5 Palm-nut Soup: This soup is prepared in two stages:- In the first stage, the palm fruits are cooked and the fibre removed from the nuts by pounding the cooked fruits. The nutrients and fat are extracted from the fibre using hot water to give a ‘cream’. In the second stage, the mixture of fat and nutrients (‘cream’) is added to other ingredients such as tomato paste, spices, fish and/or meat, etc. to prepare the soup. By the time the soup is cooked, the excess water from the extraction process is reduced to acceptable levels.

About 1.7 litres of palm ‘cream’ extracted from cooked palm fruits were put in an aluminium saucepan. Approximately 0.35 g of ingredients made up of fish, meat, tomatoes, pepper, salt and onions were added into the saucepan. The saucepan and contents were placed on the appliances. The initial biogas pressure was noted as well as the reading on the gas meter. The initial temperature of the contents was also noted. The stove was then lighted. After the foodstuff was cooked, the final biogas pressure, the final reading on the gas meter and the final temperature of the cooked foodstuff were noted.

3 Results and Discussions

Yam cooked between 17 minutes to 20 minutes. The fastest cooking was by the I.R.I Coal Pot with a time of 17 minutes and 12 seconds. This was done with the lowest amount of biogas consumption, 70.3 litres (Table 1).

Table 1: Biogas Consumption in cooking Yam

Cooking of Yam				
Stove	**Mass of foodstuff (kg)**	**Mass of water (kg)**	**Cooking time (GMT)**	**Quantity of Biogas (litres)**
G.T.Z. Table Top Stove (GTZTTS)	0.5	0.65	00:17:40	112.4
G.T.Z. Coal Pot (GTZCP)	0.45	0.65	00:20:12	95.9
I.R.I Coal Pot (IRICP)	0.45	0.65	00:17:12	70.3

The rice was cooked between 18 minutes and 29 minutes. The fastest cooking was when using the G.T.Z. Coal Pot (18 minutes) but this also used the highest amount of biogas (140 litres) (Table 2). The big difference between cooking times is due to the different rates of heat delivery by the stoves.

Table 2: Biogas Consumption in cooking Rice

Cooking of Rice				
Stove	**Mass of foodstuff (kg)**	**Mass of water (kg)**	**Cooking time (GMT)**	**Quantity of Biogas (litres)**
G.T.Z. Table Top Stove (GTZTTS)	0.5	0.9	00:28:41	102.3
G.T.Z. Coal Pot (GTZCP)	0.5	0.9	00:18:00	140
I.R.I Coal Pot (IRICP)	0.5	0.9	00:24:30	85.1

Plantain was cooked between 14 minutes and 24 minutes. The G.T.Z. Table Top Stove was the fastest in cooking plantain with a time of 14 minutes and 10 seconds. This stove also used the smallest amount of biogas, 97.9 litres (Table 3).

Table 3: Biogas Consumption in cooking Plantain

Cooking of Plantain				
Stove	**Mass of foodstuff (kg)**	**Mass of water (kg)**	**Cooking time (GMT)**	**Quantity of Biogas (litres)**
G.T.Z. Table Top Stove (GTZTTS)	0.4	0.55	00:14:10	97.9
G.T.Z. Coal Pot (GTZCP)	0.3	0.6	00:23:50	149.4
I.R.I Coal Pot (IRICP)	0.4	0.55	00:20:56	116

The time for cooking palm nuts varied from19 minutes to 24 minutes with the fastest cooking being done by the G.T.Z. Table Top Stove in 19 minutes and 34 seconds. In this instance, however, this stove consumed the highest volume of biogas, 115.6 litres (Table 4).

Table 4: Biogas Consumption in cooking Palm nuts

Cooking of Palm nuts				
Stove	**Mass of foodstuff (kg)**	**Mass of water (kg)**	**Cooking time (GMT)**	**Quantity of Biogas (litres)**
G.T.Z. Table Top Stove (GTZTTS)	0.9	0.65	00:19:34	115.6
G.T.Z. Coal Pot (GTZCP)	0.8	0.7	00:23:31	94.1
I.R.I Coal Pot (IRICP)	0.8	0.7	00:23:02	63.9

Preparation of Palm nut Soup took between 33 minutes and 1 hour. This was after the palm fruits had been cooked. The longest time was used by the G.T.Z. Coal Pot, 1 hour and 11 minutes, which incidentally also used the highest volume of biogas, 296.7 litres (Table 5).

Table 5: Biogas Consumption in preparing Palm nut Soup

Cooking of Palmnut Soup				
Stove	**Mass of ingredients (kg)**	**Mass of palm 'cream' (kg)**	**Cooking time (GMT)**	**Quantity of Biogas (litres)**
G.T.Z. Table Top Stove (GTZTTS)	0.35	1.7	00:40:11	221.9
G.T.Z. Coal Pot (GTZCP)	0.35	1.7	01:11:15	296.7
I.R.I Coal Pot (IRICP)	0.35	1.7	00:33:50	163.4

On the average, the given mass of foodstuff is equivalent to one servings of each dish(Schroeder, 2003). The biogas consumption for the preparation of palm nut soup is the highest as expected since it is arguably one of the most heat-consuming dishes prepared in Ghana. This study shows it consumes about 320 litres of biogas (i.e. adding the cooking of the palm nuts to the preparation of the soup) (Table 6). The time for preparing palm nut soup is also very high, 48 minutes as determined in this study.The dish using the least amount of time to cook is yam, 18 minutes (Table 6) and it has a corresponding lowest biogas consumption, 92 litres (Table 6).

Table 6: Average Biogas Consumption for preparing various dishes

FoodStuff	**Mass of Foodstuff (kg)**	**Cooking Time (GMT)**	**Biogas Consumption (litres)**
Yam	**0.65**	00:18:21	92.87
Rice	**0.50**	00:23:44	109.13
Plantain	**0.57**	00:19:39	121.10
Palm Nuts	**0.68**	00:22:02	91.20
Palm nut Soup	**1.03**	00:48:25	227.33

All staples cook between 18 minutes to 23 minutes (Table 6). This means that for effective cooking, the preparation of soup should begin before the cooking of the staples so that both can be served hot right after preparation. The plantain and yam could also be used to prepare yam fufu (similar to cassava fufu)(Wikipedia contributors, 2017), a common and favourite Ghanaian dish which is usually served with palm nut soup.

4 Conclusion

The consumption of biogas while preparing any dish depends on the design of the stove. The time used while preparing the dish on the other hand does not correlate directly with the biogas consumed. Cooking of Ghanaian dishes with biogas is economically feasible with consumption for one serving of a typical Ghanaian dish of fufu and palm nut soup approximately 440 litres.

References

Balmer, M. (2007). Energy poverty and cooking energy requirements: The forgotten issue in South African energy policy? Journal of Energy in Southern Africa, 18(3), 4–9. Retrieved from https://www.google.com.gh/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwip0OXTh4XXAhXCC8AKHYU2A30QFggkMAA&url=http%3A%2F%2Fwww.erc.uct.ac.za%2Fsites%2Fdefault%2Ffiles%2Fimage_tool%2Fimages%2F119%2Fjesa%2F18-3jesa-balmer.pdf&usg=AOvVaw

Dietary and Physical Activity Guidelines for Ghana. (2009). Ministry of Health, Ghana. Retrieved from https://www.google.com.gh/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0ahUKEwim1vj-5YTXAhUEiRoKHQ0YDbQQFggzMAI&url=http%253A%252F%252Frhnp. gov.gh%252Fadmindox%252FDIETARY%252520AND%252520PHYSICAL%252520ACTIVITY%252520GUIDELINES%252520FOR%252520GHANA%252520Final%252

IEA. (2006). Energy for Cooking in Developing Countries. In International_Energy_Agency (Ed.), World Energy Outlook 2006- Focus on Key Topics (p. i-599). OECD - Organisation for Economic Co-operation and Development,. Retrieved from http://www.ingentaconnect.com/content/oecd/16832345/2006/00002006/00000023/6106232e

Pimentel, D., & Pimentel, M. (1985). Energy use in food processing for nutrition and development. Food and Nutrition Bulletin (USA), 13. Retrieved from https://www.google.com.gh/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjrxqK7lIXXAhXLCMAKHRihBL8QFggkMAA&url=http%3A%2F%2Farchive.unu.edu%2Funupress%2Ffood%2F8F072e%2F8F072E06.htm&usg=AOvVaw2_1K93ZdIRkUDOE4K2V0I1

Sasse, L., Kellner, C., & Kimaro, A. (1991). Improved Biogas Unit for Developing Countries. Eschborn, Germany: Deutsches Zentrum fur Entwicklungstechnologien (GATE) & Deutsches Gesellschaft fur Technische Zusammernarbeit (GTZ) GmbH; Friedr. Vieweg & Sohn Verlagsgesellschaft mbH, Braunschweig.

Schroeder, D. (2003). The Dawn of Cooking (2nd ed.). Accra: Peace Corps, Ghana. Retrieved from http://www.friendsofghana.org/forms/Dawn_Of_Cooking.pdf

Wikipedia contributors. (2017). Ghanaian cuisine. In Wikipedia. Wikipedia, The Free Encyclopedia. Retrieved from https://en.wikipedia.org/wiki/Ghanaian_cuisine