Comparative energy study of biogas with firewood and charcoal

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ABSTRACT

This study focused on the energy comparison of biogas with firewood and charcoal. It consisted of evaporating 0.5 liters of mineral water with three types of fuel (biogas, firewood and charcoal). The quantities of fuels used are: 283.33 liters of biogas; 240 g of charcoal and 726.67 g of firewood. This corresponds to the following energy equivalences: 1453.483 kcal for biogas; 1584 kcal for charcoal and 3124.681 kcal for firewood. The average evaporation times of 0.5 liters are respectively: 97 minutes with biogas; 135 minutes with charcoal and 185 minutes with firewood. These results show that the use of biogas is always advantageous compared to the other two fuels (firewood and charcoal). With a time saving of 38 minutes compared to charcoal; 88 minutes compared to firewood. Energy losses compared to biogas are: 1671.198 kcal for firewood and 130.517 kcal for charcoal.

Keywords: *Biogas, firewood, coal, study, energy*.

1. Introduction

The fight against global warming involves the development of renewable energies such as wind, solar, biomass, etc., according to the objectives set within the framework of Renewable Energies for All [1]. The development of renewable energies is essential insofar as fossil energies, non-renewable, are becoming scarce but also and above all because of the growing demand for energy. These fossil fuels have a negative impact on our environment. It is also worth remembering the enormous positive impact that agriculture plays in the reduction of carbon dioxide in the ecosystem, through the phenomenon of photosynthesis [2]. This is why developing and promoting renewable energies in general, and that of biomass in particular, is becoming a priority for their many environmental and energy benefits. Modern biomass remains little used in Africa, due to the lack of reliable data on its availability and its methods of recovery. About 85.7% of the population of member states of the Economic Community of West African States use solid fuels (mainly wood and charcoal) for cooking [3]. However, Africa has a huge amount of previously unused agricultural biomass. Indeed, most African economies are based on agriculture. This generates a huge amount of non-recovered agricultural biomass based on the inventory of agro-industrial by-products in West Africa [4].

This form of energy source can play a major role in improving the rate of rural electrification from the moment the raw material is available, nearby and low cost. Sub-Saharan Africa stands out from other regions for the inequality between population growth and access to electrical energy.

In 2010, the share of traditional biomass in total energy consumption was 42.9%; 84.1%; 85.4%; 65.7%; 64.3%; 90% and even 92.5% respectively in Benin, Burkina-Faso, Mali, Côte d'Ivoire, Togo, Guinea and Liberia [5]. Today, there is a significant number of households that use improved cookers with biomass base, to the detriment of wood or charcoal.

Today, we see that renewable energy technology plays an important role in increasing thermal and electrical production in Africa in general and in West Africa in particular. Despite the ever-increasing involvement of renewable energies in the management of the energy crisis, there are in sub-Saharan Africa, in 2011, 599 million souls who are still deprived of electricity, i.e. 47.6%. In 2011, there were generally low electrification rates, especially in rural areas within the Economic Community of West African States: 6% in Benin; 4% in Burkina Faso; 1% in Guinea; 1% in Niger; 4% in Liberia and 2% in Guinea Bissau. However, Cape Verde and Ghana come out on top with rates of 70% and 52% respectively [6].

The fermentation process in a digester is a natural process of degradation of organic matter which takes place in the absence of oxygen (anaerobiosis) and which is accompanied by the production of a combustible gas, "biogas", essentially composed methane which is a flammable gas with a calorific value of 9.94kWh/m3.

Methane burns with a blue flame when its combustion is complete. This is accompanied by a strong release of heat [7, 8]. Thus, the present study is based on the energy comparison of biogas with firewood and charcoal.

2. Material and method

2.1 Hardware

The experimental device consists of: biodigester, biogas, mineral water, stove, scale, pot and stopwatch.

2.2 Method

2.2.1 Experimental devices

The methodology focused on determining the average quantity of each fuel (biogas, firewood and charcoal) needed to evaporate 0.5 liters of water. The energy equivalents of each fuel and finally evaluate the energy gain achieved by biogas. The photos in Figure 1 show the experiment steps.

- The biogas meter and the pressure gauge respectively made it possible to determine the volume and the pressure of the biogas used;
- The masses of firewood and charcoal used were determined by the balance.
- The evaporation times were determined using a stopwatch.

Photo 1 : Mineral water

Photo 2 : Evaporation by the combustion of biogas

Photo 3 : Evaporation by burning charcoal

Photo 4 : Evaporation with burning firewood

Fig. 1: Stages of the experiments

2.2.2 Amount of fuel used and average evaporation time

In a series of experiments we evaporated 0.5 liters of water with biogas, firewood and charcoal respectively. For each fuel, the experiment was repeated three times under apparently identical conditions. The quantities of fuels used as well as the evaporation times are noted in tables 1, 2 and 3.

Table 1: Average amount of biogas and average evaporation time

Volume of water	Experience	Biogas (litre)	Duration (mn)
0,5 liters	1	292	94
	2	274	100
	3	284	96
Average		283,33	96,67

Table 2: Average amount of charcoal and average evaporation time

Volume of water	Experience	Charcoal (g)	Duration (mn)
0,5 liters	3	260	130
	4	200	140
	5	260	136
Average		240,00	135,33

Table 3: Average amount of firewood and average evaporation time

Volume of water	Experience	Firewood (g)	Duration (mn)
0,5 liters	6	780	180
	7	740	190
	8	660	186
Average		726,67	185,33

2.2.3 Equivalence in energy

The energy equivalents of the quantities of fuels used to evaporate 0.5 liters of water are determined as follows [9, 10].

a) Biogas

The lower calorific value of biogas is proportional to its methane content. As the biogas produced consists of 60% methane, its Lower Calorific Value (NCV) is:

$$\mathrm{PCI_{bigas}} = 60\% \times 9{,}94\ \mathrm{kWh/m^3} = 5{,}964\ \mathrm{kWh/m^3}$$

With: $1\ \mathrm{kWh} = 3{,}6 \times 10^6 \mathrm{j}$ et $1\ \mathrm{J} = \frac{1}{4184}\mathrm{kcal}$

We have :

$$\mathrm{PCI_{bigaz}} = 5{,}964 \times 3{,}6 \times 10^6 \mathrm{J/m^3} = \frac{21{,}4704 \times 10^6}{4184}\ \mathrm{kcal/m^3} = 5131{,}548757 \mathrm{kcal/m^3}$$

$$\mathrm{PCI_{bigaz}} = 5{,}13\ \mathrm{kcal/l}$$

Thus the energy equivalence of the quantity of biogas used to evaporate 0.5 liters of water is:

$$\mathrm{E_{biogas}} = 283{,}33\mathrm{l} \times \mathrm{PCI_{bigaz}} = 283{,}33\mathrm{l} \times 5{,}13\ \mathrm{kcal/l} = 1453{,}483\mathrm{kcal}$$

b) Charcoal

The lower calorific values of charcoal are:

$$\mathrm{PCI_{Charcoal}} = 6600\mathrm{kcal/kg} = 6{,}6\ \mathrm{kcal/g}.$$

The energy equivalent of charcoal to evaporate 0.5 liters is:

$$\mathrm{E_{Charcoal}} = 240\mathrm{g} \times \mathrm{PCI_{Charcoal}} = 240\mathrm{g} \times 6{,}6\ \mathrm{kcal/g} = 130{,}517\mathrm{kcal}$$

c) Firewood

The lower calorific values of firewood are:

$$PCI_{Firewood} = 4300 \text{ kcal/kg} = 4{,}3 \text{ kcal/g}$$

Its energy equivalent to evaporate 0.5 liters is:

$$E_{Firewood} = 726{,}67g \times PCI_{Firewood} = 726{,}67g \times 4{,}3kcal/g = 3124{,}681kcal$$

3. Results and discussion

3.1 Results

The results obtained are given in table 1. They are represented by the diagrams in figure 2.

Table 1: Average quantities, energy equivalences and average durations of experiments

Fuel	Quantity	Equivalence in energy (kcal)	Average evaporation time (mn)
Biogas	283,33 *l*	1453,483	97
Charcoal	240 g	1584	135
Firewood	726,67 g	3124,681	185

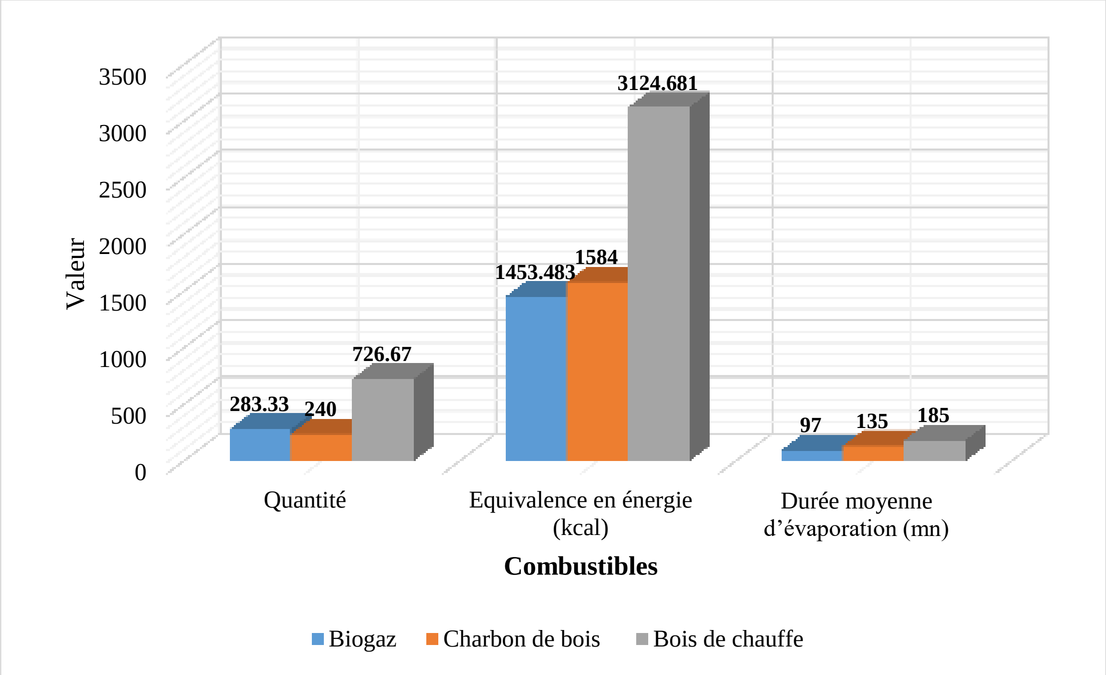

Figure 2: Diagrams of fuel quantity, heat energy equivalence and evaporation time

3.2 Discussion

The diagrams in Figure 2 show that, to evaporate 0.5 liters of mineral water, the quantities of fuels used are: 283.33 liters of biogas; 240 g of charcoal and 726.67 g of firewood. These values correspond to the following energy equivalences: 1453.483 kcal for biogas; 1584 kcal for charcoal and 3124.681 kcal for firewood. The average evaporation times of 0.5 liters are respectively: 97 minutes with biogas; 135 minutes with charcoal and 185 minutes with firewood.

These results show that the use of biogas is always advantageous compared to the other two fuels (firewood and charcoal). With a time saving of 38 minutes compared to charcoal; 88 minutes compared to firewood. The energy losses compared to biogas are: 1671.198 kcal for firewood and 130.517 kcal for charcoal.

Similarly, on the environmental level, the use of biogas makes it possible to limit deforestation locally and to limit climate change globally [11]. Its use also allows better waste management, preservation of the environment as well as diversification of energy resources (alternative energies) with lower costs [12].

4. Conclusion

This research is a continuation of our work in the context of energy recovery from biomass. In order to considerably reduce the exploitation of natural resources and its harmful effects on our environment, it seems important us to demonstrate the advantage of continuing to popularize the use of biogas compared to firewood and charcoal. This would reduce logging

This experimental study focused on the energy comparison of biogas with firewood and charcoal. It consisted of evaporating 0.5 liters of mineral water with three types of fuel (biogas, firewood and charcoal). The results related to the average quantifications of the types of fuels used, the energy equivalences and the average evaporation times. The energy losses of firewood and charcoal compared to biogas were evaluated. These results show that the use of biogas for cooking is always advantageous compared to the other two fuels (firewood and charcoal).

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