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Development of Briquette-Powered Water Distiller

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Abstract

Human beings can survive for weeks without food but the possibility of man being able to live without water for a few numbers of days is slim. Hence, the need for potable water is of great importance to man as poor quality of water and unsatisfactory sanitation are seriously dangerous to man. Therefore, this study is aimed at developing a briquette-powered water distiller which will produce drinkable water for human consumption and hence reduce death occurrences due to poor water quality. The briquettes were made using carbonized sawdust and gelatinized starch mixed together uniformly in the proportion of 4479.2 cm^3 of the carbonized sawdust to 306.06 cm^3 of the gelatinized starch. Afterwards, the combustion chamber which consisted of the stove rest, ash filter, fuel rack and riser was fabricated. The stainless steel pot had a frustum shape with its height, larger and smaller diameters were 16.5 cm, 36.0 cm and 25.0 cm respectively. While the lengths were both 100 cm. The material for the inner pipe was stainless steel whereas that of the outer pipe was galvanized mild steel. It was observed that the gross calorific value of the briquettes produced was
20.3 kJ/kg while 4.91 litres of standard potable water was produced from 10 litres of feed water

Keywords: Biomass, briquettes distillers, energy, portable, water

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Introduction

Water is a chemical substance that is transparent, virtually colourless and has no taste and odour (Abduhamed *et al*., 2016). Potable water is important to human beings and other living things. In the past decades, accessibility to portable water has increased in virtually all over the world, even though about 1 billion people are yet to have access to potable water while more than 2.5 billion people do not have access to satisfactory sanitation (Alpesh *et al*., 2011; Roy and Corscadde, 2012; Alberta, 2016; Abduhamed *et al*., 2016). Bad quality of water and poor sanitation are very dangerous. Drinking of contaminated water has led to about 5 million death occurrences annually (Abduhamed *et al*., 2016). According to the World Health Organization (WHO), provision of potable water can stop 1.4 million deaths of children caused by diarrhoea every year (Asif, 2016; Azzeddine *et al*., 2017; Bates and Ghoniem, 2012; Eze *et al*., 2011). Therefore, for water to be safe for human consumption, it must undergo purification which will require the separation of undissolved particles, dissolved substances and dangerous microbial organisms. A water distiller is an effective treatment device used for producing potable water (Gangadhar *et al*., 2012; Kamran *et al*., 2013; Mathias, 2013; Manoj *et al*., 2015). It comprises majorly the heat source, boiling chamber, condensing and water storage units. Untreated water was boiled at 100°C by heating and then was allowed to condense back to its liquid form in the condensing unit. Majority of the impurities in the untreated water will remain in the boiling chamber after distillation, thus making the condensed water to be virtually free of impurities (Oyawale *et al*., 2010; Shashikanth *et al*., 2015; Sahoo *et al*., 2016). Shull (2012) reported that briquette is obtained by the compression of loose biomass materials and/or pulverized solid fuels into solid products of higher densities than those of the parent materials usually with the application of high pressure and heat. Some additives may be added to the raw materials to produce better briquette fuels. The various materials used for biomass briquette fuels are usually industrial organic wastes, forest products and residues, food crops, energy crops, sugar crops, aquatic plants, algae and mosses, kelps and lichens, bio renewable and agricultural wastes (Waterside and World Health Organization, 2008; Singh, 2011; Shull, 2012).

In addition, it should be noted that the use of electricity to power water distillers comes at a huge cost as it is an expensive source of energy, also using fossil fuels and firewood to power water distillers can lead to significant harmful effects on the climate system of the Earth and the ecosystems beside the huge cost of providing these fuels. Although solar energy serves as a cheaper means of powering water distillers when compared with these other sources already mentioned, the machines using this source of energy usually have low production rate of distilled water (Lee, 2007). The use of briquettes provides a cheaper means of powering water distillers in addition to its being environmentally friendly (Storlarski *et al*., 2013; Solano *et al*., 2016).

Materials and methods

Materials

The briquette-powered water distiller consisted of heating stove fed with sawdust briquettes. The stove was positioned in the combustion chamber. This distiller also had the boiling unit which comprised a skirt and a covered pot whose capacity is about 12.2 litres, the condenser with the ability to produce potable water from steam generated, the tank for storing the distilled water produced, the reservoir for the coolant and the chimney to aid convection. The capacity of water to be distilled was 10 litres which was equivalent to 10 kg of water.

The briquette-powered water distiller consisted of heating stove fed with sawdust briquettes. Other materials utilized for construction include, 0.5 mm thick stainless steel sheets used for constructing the combustion chamber and the boiling unit, stainless steel and mild steel pipes used for making the condenser, 0.8 mm thick mild steel sheets for making both the chimney and the outer cover for the combustion chamber, hoses and pipes, insulator used for lagging the riser (a mixture of gypsum and sawdust), water used as coolant in the condenser, plastic containers for storing the distillate and coolant, ingredients for making the sawdust briquettes, consumables and machines used. The sawdust was obtained from the mixture of *Gmelina (Gmelina arborea Roxb) and Teak (Tectona grandis*) timbers at the Sango Sawmill in Minna, Nigeria and was dried in the sun for a period of seven days after which it was made to undergo Torre faction in order to drive off moisture and other unnecessary volatiles present in the sawdust thereby producing a carbonized substance called bio coal. The starch obtained from cassava tubers was bought from the Kure Ultra-Modern Market in Minna, Nigeria.

Methods

Briquette-powered distiller

The stove was positioned in the combustion chamber. This distiller also had the boiling unit which comprised a skirt and a covered. The capacity of water to be distilled was 10 litres which was equivalent to 10 kg of water.

Production of Briquettes

The ingredients for the sawdust briquettes were sawdust, starch and water. About 4479.2 cm^3 (680.39 g) of the carbonized sawdust was measured and poured into an empty bowl. This was then properly mixed with 306.06 cm^3 (992.25 g) of the gelatinized starch to give a uniform mixture. This mixture was then poured into the mould of the briquetting machine after which the die of the machine was used to manually compress the mixture into briquettes. The moulded briquettes were then removed and dried in the sun for three days. Afterwards, they were kept in a cool place and exposed to draught within the place. The diameter of the briquettes produced was 3.33 cm and the average height of each briquette was 3.41 cm and the average mass of each briquette was 30.86 g.

Construction of water-distilling Machine

The construction of the machine took about three months and was carried at the Hamstring Engineering Workshop located within the Technology Incubation Centre, Minna-Nigeria. The various units of the water-distilling machine produced at this stage include combustion chamber, the boiling unit, the condensing unit and the chimney indicated in Fig. 1.

The combustion chamber contained the removable stove which consisted of the stove rest whose length, breadth and height were respectively 39 cm x 23 cm x 5 cm; the fuel rack whose length, width and height were respectively 22 cm x 22 cm x 8 cm. Directly below the fuel rack was the ash filter with a respective length and breadth of 19.5 cm and18.3 cm. The riser was directly placed above the rack and its height and diameter were 20 cm and 17 cm respectively. It was lagged round about by a mixture of gypsum and sawdust with the thickness of insulation being 22.5 cm. Also, the boiling unit consisted of the stainless steel pot skirt whose diameter was 39 cm while its depth was 18 cm. The pot itself which was positioned inside the skirt had larger and smaller diameters of 36 cm and 25 cm respectively. Its depth was 16.5 cm while its material was also stainless steel. The mass of the pot was around 765g and was covered with a lid whose diameter was 38 cm. The lid had two openings. From the first opening comes a stainless steel pipe which is to channel the steam from the pot to the condenser while the other opening had a PVC pipe which is to help in directing the cooling water from the exit of the condenser to the inside of the pot. The diameters of the stainless steel and PVC pipes were 25 mm and 15 mm respectively. In addition, the condensing unit consisted of the condenser, the tank for storing the coolant and the container for storing the distilled water produced. The condenser was an indirect-contact heat exchanger in which heat was transferred through the wall which separated the steam from the cooling water. This was a counter-flow heat exchanger where the cooling water flow in opposite direction to that of the steam. The condenser had two pipes which are concentric with the steam flowing in the inner pipe while the coolant flowed in the outer pipe. The pipe for the steam was made of stainless steel having a diameter and length of 25 mm and 1 m respectively. The pipe for the cooling water was made of galvanized steel having a respective diameter and length of 60 mm and 1 m. Furthermore, the chimney was used to aid convection of the heated air in the system. It is made of mild steel material. Its length and diameter were 2 m and 12 cm respectively. Finally, the various parts of the water-distilling machine were assembled together to form the water distiller. Fig. 1 shows the set-up arrived at after the various parts of the water distiller had been assembled together.

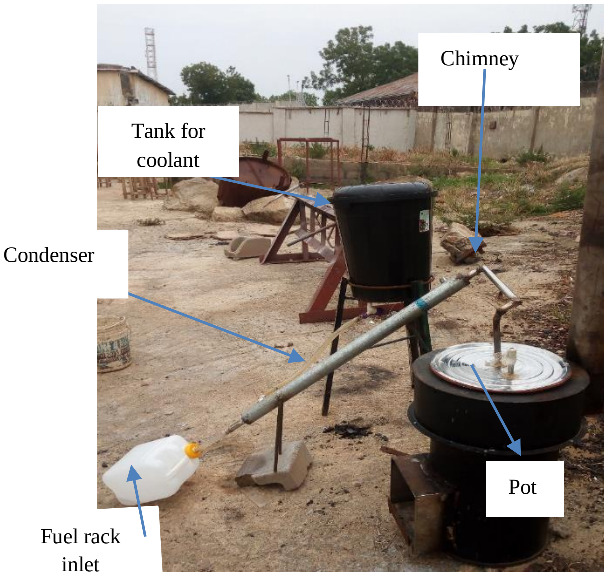

Fig.1**:** The set-up of the water distiller from various parts.

Testing water-distilling Machine

With the water-distilling machine fully set, it was tested within the compound of the Technology Incubation Centre, Minna, Nigeria. On this day, the pot in the boiling unit was filled with 10 litres of feed water (well water). Forty-two pieces of briquettes, which were capable of turning this feed water to steam, were then put into the fuel rack of the combustion chamber. These briquettes were ignited with the aid of kerosene. Once the fuel was ignited, the timing of the process began. The test began at 12:45 pm and ended at 1:55 pm. By 1:55 pm, all the briquettes were completely burnt and 4.91 litres of distilled water were produced. Four samples of the briquettes were taken to the National Cereals Research Institute, Badeggi- Nigeria with the aim of carrying out proximate and ultimate analyses on them. In the same vein, two samples of the briquettes were also taken to the Department of Chemical Engineering, University of Ilorin, Nigeria; in order to determine the calorific value of the briquettes. Some of the distilled water produced was taken for various tests of purity at the Centre for Genetic Engineering and Biotechnology of Federal University of Technology, Minna, Nigeria; to determine how portable the distilled water produced was, the various results obtained from these tests were presented as follows as indicated Tables 1-2:

Results and Discussion

Ultimate and Proximate analysis of the briquettes produced

The results of proximate analysis of the briquettes produced are shown in Table 1 while the results of the ultimate analysis of the briquettes produced are shown in Table 2.

Table 1: Proximate analysis of the briquettes produced.

S/N	Component composition	Percentage (%)
1	Mixed content	31.53
2	Volatile Matter	50.00
3	Moisture content	4.30
4	Ash content	14.17

Table 2: Ultimate analysis of the briquettes produced.

S/N	Component composition	Percentage (%)
1	Carbon	62.20
2	Nitrogen	2.01
3	Oxygen	18.91
4	Sulpur	0.35
5	Ash content	11.81

From Table 1, the briquettes produced had a moisture content of about 4.30 %. This value was low and so its effect on the calorific value of the fuel was minimal. This therefore made the heating value of the briquettes produced to be high which agreed with the earlier work of Solano *et al*. (2016). Also, the ultimate analysis of the produced briquettes shown in Table 2 indicates that the Carbon (62.2%) constitute the highest percentage content while sulphur (0.35 %) present the least amount in the produced briquette.

Calorific value test result of the briquettes produced

The calorific value of the briquettes produced was 20.30 MJ/kg. Table 3 shows the data obtained from the calorific value test done using the bomb calorimeter at the Department of Chemical Engineering in University of Ilorin, Nigeria. The parameters utilized in this study were: fuel mas sample was 1.0 g; Energy equivalent of the bomb calorimeter was 2330 Cal/^{o}C and amount of water used in the bomb calorimeter was 1500 ml respectively.

Furthermore, Nichrome fuse wire used was 15 cm/0.018 g and cotton thread used was 5 cm/0.040 g respectively.

The experimental results obtained from the calorific value test done using bomb calorimeter are shown in Table 3 while the characteristic temperature-time curves of a bomb calorimeter is shown in Fig, 2.

Table 3: Result obtained from the calorific value test done using bomb calorimeter.

Period	**Temp. (^{0}C)**	Time (min.)	Period	Temp. (^{0}C)	Time (mins)
Initial	**27.00**				
A	0.00	1:00	07	2.31	10.00
B	0.00	2:00	08	2.35	11.00
C	0.00	3.00	09	2.39	12.00
D	0.00	4.00	010	2.43	13.00
E	0.00	5.00	011	2.45	14.00
12	2.48	15.00			
01	0.00	6.00	13	2.51	16.00
02	0.17	6.15	14	2.53	17.00
03	1.15	6.45	15	2.55	18.00
04	1.43	7.00	16	2.57	19.00
05	2.04	8.00	17	2.59	20.00
06	2.23	9.00	18	2,60	21.00

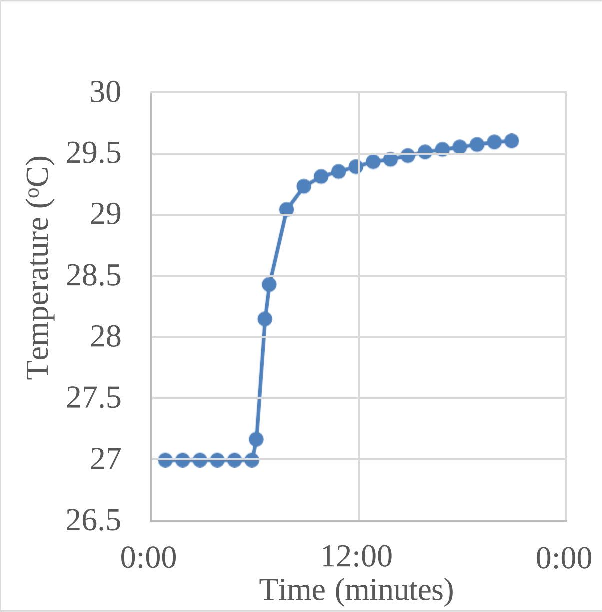

Fig. 2: The characteristic temperature-time curve of a bomb calorimeter.

The gross calorific value of the briquettes made shown in Table 3 and represented in Fig. 2 was 20.30 MJ/kg. This indicates that the briquettes could sustain combustion since its heating value was more than the 11.66 MJ/kg required by solid fuels like briquettes to sustain combustion (Mathias, 2013; Stolarski *et al*., 2013). In addition, this heating value was also close to those values stated for briquettes made from sawdust in the literatures reviewed. According to Roy and Corscadden (2012), the heating value of briquettes from sawdust was around 17.93 MJ/kg while (Lee, 2007) stated that the value was about 19.52 MJ/kg. Also, as shown in Fig. 2, it can be seen that the temperature was steady for the first five minutes with it being at 27 °C. This occurred before the fuel sample in the bomb calorimeter was ignited. At this stage, the water in the calorimeter was continuously stirred for about five minutes to obtain a uniform temperature. Immediately after the five minutes elapsed, ignition of the fuel sample took place and there was a sharp increase in the temperature of the water in the calorimeter for up to the ninth minute of the test in which the temperature rose to about 29.2°C. After this stage, the increase in temperature became gradual until it rose to about 29.6°C where it became steady again and the test was stopped. Afterwards, the gross calorific value of the fuel sample was determined.

The experimental results of the microbial analysis of the feed water used and distilled water produced in this study are shown in Table 4 and 5 respectively while the results of the physicochemical analysis of both the feed and distilled water is shown in Table 6.

Table 4: Results of the microbial analysis of the feed water used.

Test	Count (cfu/ml)	Limit
Total coliform count	5.78 x 10^6	0
Total faecal coliform count	0	0
Total aerobic mesophilic bacteria count	5.78 x 10^6	1.0 x 10^2
Total Salmonella species	0	0
Total Pseudomonas aeruginosa count	0	0
Total Staphylococcus aureus count	0	0
Total Yeast/Mould count	0	1.0 x 10^2

Table 5: Result of the microbial analysis of the distilled water produced.

Test	Count (cfu/ml)	Limit
Total coliform count	0	0
Total faecal coliform count	0	0
Total aerobic mesophilic bacteria count	0	1.0×10^2
Total Salmonella species	0	0
Total Pseudomonas aeruginosa count	0	0
Total Staphylococcus aureus count	0	0
Total Yeast/Mould count	0	1.0×10^2

Table 6: Result of the physicochemical analysis of both the feed and distilled water.

Ample conductivity (µS/cm)	Conductivity	pH value (mg/l)	Total hardness (mg/l)	TDS (mg/l)	Calcium (mg/l)	Magnesium
Feed water	1411	6.11	236.0	903.04	84.0	5.82
Distilled water	41	6.50	3.0	26.24	0.16	0.09

Presented in Table 4 is the result obtained from the microbial analysis of the feed water before it was distilled off by the water distiller constructed. The water was found to contain E. Coli, the microorganisms which are pathogenic bacteria and are also called indicator organisms for water pollution. The water was therefore not good for human consumption. Similarly, from Table 5, it can be seen that these E. Coli microorganisms were no longer present in the water after distillation had taken place which made it to be good for human consumption.

In addition, as shown in Table 6, it can be seen that the conductivity of the water distilled off reduced significantly from 1411 µS/cm before distillation to 41 µS/cm after distillation, its pH value changed from 6.11 before distillation to 6.50 after distillation. Similarly, its total hardness also decreased considerably from 236.0 mg/l before distillation to 3.0 mg/l after distillation while the total dissolved solids (TDS) of the water before and after distillation were respectively 903.04 mg/l and 26.24 mg/l thereby resulting in a great reduction of the TDS present in the water after distillation. In the same vein, the amount of calcium available in the water changed greatly from 84.0 mg/l before distillation to 0.16 mg/l after distillation just as the amount of magnesium present in it also changed from 5.82 mg/l before distillation to 0.09 mg/l after distillation. The various values obtained for all these tested parameters after distillation were well below the safe limit for portability which made the water obtained after distillation to be good for human consumption.

Conclusion

In this study, the development of briquette- powered water distiller had been carried out by designing and fabricating a water distiller which made use of briquettes as its source of energy. The fabricated water distiller was used to purify untreated water and, in the process, 4.91 litres of portable water was produced from 10 litres of feed water. From the result obtained, it can be concluded that;

i. Carbon content constitutes the highest percentage content in the production of briquette which also recorded a moisture content of about 4.30 %.

ii. The gross calorific value of the briquettes made was 20.30 MJ/kg. This indicates that the briquettes could sustain combustion since its heating value was more than the 11.66 MJ/kg required by solid fuels like briquettes to sustain combustion.

iii. The gross calorific value of the briquettes made was 20.30 MJ/kg, which indicates that the briquettes can sustain combustion since its heating value was more than the recommended value of 11.66 MJ/kg required by solid fuels like briquettes to sustain combustion (Bates and Ghoniem, 2012).

iv. Finally, the various values obtained after distillation were far below the safe limit for portability reported in literatures. This made the water obtained after distillation to be suitable for human consumption.

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