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RESEARCH ARTICLE

Poverty sequestration using Sawdust biomass energy in Nigeria

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Abstract

The commensurate increase in the price of kerosene and gas created fear in the minds of many Nigerians, which force them to think of the future and show much concern about the security of energy needed for survival and economic sustainability. The growing demand in energy coupled with the population increase places more demand on agricultural biomass such as sawdust to be used for heating processes. A large quantity of sawdust is produced on daily basis in most Nigerian cities and can be utilize for domestic heating. The potential of this biomass to serve as an alternative energy source is explored in this work. About 1500 gram of sieved sawdust mixed with 150 gram of starch binder were prepared into a moderate size briquette. Study on combustion performances was conducted using constructed sawdust stove. Analysis of the experimental data indicates that the sawdust stove performances in terms of combustion rate and efficiency are comparable to that of kerosene stove and surpass ordinary fire-wood stoves. The advantage of using sawdust for heating applications are its domestic origin and help in waste management.

***Keywords*:** Poverty, biomass, sawdust

INTRODUCTION

By performing a large number of measurements of the under-utilized sawdust waste in Nigeria, whereby, the population energy need to individual source income ratio is around one to thirty-two (1: 32). Most of the Nigerian citizens are struggling for daily survival, just to have what to eat and what to use in cooking it. More especially, when look at the national minimum wage for salary earners and how local the business is. Therefore, it is obvious, whenever there is a sharp increase in population growth, there will be a serious challenge on energy sources such as nuclear power, solar, fossil, hydro-power, electricity, biogas, wind-power, biomass. This paper focused on mitigating the excess waste of the sawdust material by some of the wood and timbre industries and by the local carpentry workshops. In order to sequestrate poverty among the lowest economic class in Nigeria, by supplying them with a simple sawdust stove other than cooking fuels like kerosene which is now very costly making it unaffordable to most Nigerians including 60 % of the civil servants and business class. Nigeria is a blessed and endowed country with abundant of different energy resources, both conventional and renewable that can potentially provide sufficient energy capacity for both urban and rural communities of [11]. Nigeria can generate enery from four different sources that include oil, coal, natural gas and hydro. Although Nigeria has an abundant coal reserve to the tune of 40 billion tons, but this coal deposit is not used for energy generation as attention is only on petroleum products [4]. Globally, it is said that 15% energy is renewable energy, and the major part is biomass wood fuel and hydropower [4, 27]. This is then followed by wind power, which is predicted to provide the highest renewable energy generation [4, 27]. Given the neglect of coal in the energy generation mix, petroleum has contributed over 70% of the commercial primary energy in Nigeria [4,25]. Unfortunately, the fossil fuel energy cannot solve Nigeria's energy problems, due to the fact that the approximate magnitude of Nigerian population as per last census is about 180 million, among which only 11% are civil servants, 14% business men, 7% industrial workers, 36% students, 5 % retirees, 27% juvenile delinquencies. Over 50% of the population are dependents leading to high level of poverty in Nigeria [2]. Yet, Nigeria has poor provision in term of energy for the teeming population resultinh in the lowest energy consumption rates per capita in Africa[11]. Remember that, the most populous country in Africa is Nigeria, which has over 180 million people [4, 21], and more than 85 % of the citizens are living below $1 per day [4, 22]. Moreover, more than 60% of Nigeria's population have no access to the national electricity grid; and only 18% can afford a generator [4, 20, 23]. From the year 2009, the energy crisis is has crippled individual businesses and many industries which requires about 2000 MW for continues operation. The Manufacturers Association of Nigeria (MAN) spend more than US $11 million, in Naira equivalence is ₦1.8 billion weekly for running power generators and its maintenance [4,24]. This figure has skyrocketed due to the worsening economic conditions which eventually increase the cost of production [4]. Therefore, this paper presents an overview of Nigeria electricity crisis, policy issues and environmental ramifications that is causing poverty, and also deliberate on how to sequestrate the poverty level using sawdust, a biomass energy for heating and cooking. Within the context of this paper, the technological means of using sawdust as biomass energy is by constructing a sawdust stove [4, 26, 27]. Because

it is the most favored strategy for the sustainable development of any nation [3]. Similarly, the study will emphasize on waste management in Nigeria, this include all aspects of handling, treatment, conditioning, transportint, storage and finally disposal of these biomass wastes. To keep in mind, the main objective of the current research is to investigate the suitability and compatibility of sawdust performance in producing sustainable or good energy.

Energy from electricity

In Nigeria, the right enerygy policy has always been the desire for its people. Nigeria has 12.5 GW of installed generation capacity but only 3500-5000 MW is available. By records it looks invariant since 2013, 2014, 2017, Nigeria operates on 6953MW, 7445MW, and 7200-7001MW respectively. This is a far cry compared to the country's energy need. Consequently, this has stunted the gowth of the local industires and prevent them from competing in the global arena. This also undermines industrialization and promote juvenile delinquencies in the future generations of this country [2]. Furthermore, the Nigerian energy consumption continue to increase on a daily basis, and it still depens on fossil fuels as the major enery source. Therefore, rising price of fossil fuel products and its future potential depletion lead to so many problems concerning security and poverty [9]. Moreover, according to the International Energy Agency (IEA), the global energy demand in the year 2030 will approximately increase by 65% in most of the developing countries [7–9]. Nowadays, limited energy is a critical issue in the world [10], [8], especially in Nigeria, where the population is rapidly increasing compared to other African countries. Thus, the Nigerian internal energy source and its distribution capacity across the nation is adequately insufficient to meet the growing demand [2]. For more than two decades, due to inadequate framework of Nigerian electricity generation, market, maintenance, high technical losses, vandalism, insufficient transmission, improper facilities, distribution and supply, these problems are still lingering resulting in a general despair on meeting their enery need [5, 28, 29]. For Nigeria to provide sufficient energy that can meet the needs of its growing population which would result in an improved living standards without exacerbating the already disquieting risks of poverty will be a daunting task [7]. By context analysis of the Nigerian electricity, since 1999, the average daily electricity generation was 1750MW and currently the situation has not changed because is still less than 2.5GW, which apparently, led the federal government embarking on reforms to decentralize operations in the power sector. In short, Nigeria seeks a better policy to promote least-cost electricity generation [5, 29]. The situational results is significantly deteriorating without any reasonable output on its productivity. The productivity can increase, perhaps by adopting a new practicable technology like that of Hicks [5, 30]. In recent years, there are multiple energy challenges that lead to agitations by the locals on why they were denied access to the forest trees in spite of the epileptic power supply. The power is most atimes supplied to the urban areas and even exported to neighboring countries since first generated Electricity in 1896. Although it has been generated for public use over a century but the electricity demand in Nigeria is by far higher than what it is supplying. Thereby affecting the Nigerian socio-economic and technological developments [3, 4].

Excessive mass spending that is still going on hydropower generation is highly devastating. Unfortunately, the government is not focusing on building a nuclear power plant that is safe, cheap in management and highest in energy supply. To buttress this point, we look back into the history of some developed countries. The X-10 Graphite Reactor was built in September 3, 1948, in Oak Ridge, Tennessee, United States is the first nuclear power plant that power a light bulb but still in operation with scientific and technological advancement. Nuclear power plant is a thermal station in which the heat source is a nuclear reactor with a fissionable fuel material, of great capacity of steam generation that can drive turbine connected to an electric generator before producing the electricity. The commonly used and most preferable fuels is uranium due its high melting point and radioactive half-life. However, Nigeria has only a research reactor producing 30Kw. We can go further as a country by educating and training young and promising Nigerian to take up the task of its nuclear power generation [2]. The performance model for Nigerian electricity production has to be reviwed to engineer higher efficiency and productivity in the sector [5].

Nigerian nuclear power plants

Going by the attitude of the current government, the Nigerian Nuclear power plants has a long way to go, therefore, it has become necessary for good hearted leaders to support and encourage all means of supplementing energy for survival **2p**. Even though, there has been numerous mass protests against the development of nuclear power plant in Nigeria long ago. The states and federal government of Nigeria has also refused permission to approve the proposal. Hence, a Public Interest Litigation (PIL) was filed against the government's civil nuclear programme at the Supreme Court [4,34]. Perhaps, the IAEA reports shown that there are in operations about 437 nuclear power reactors and 69 under construction for 31 countries for the past two decades, Nigeria is not among those [2, 31, 32, 33].

Energy for food

Heating or cooking is necessary in our day-to-day activities. Currently, the production cost in China despite the number of their population is nine time less than that of Nigerian [4,7.10]. The over-dependence of the energy sector on petroleum products has slowed down the development of alternative fuels especially biomass [28,29]. Therefore, energy diversification is necessary for real poverty mitigation and for greater energy security for the country [4, 10]. Energy for feeding is the most essential nationwide but it is unfortunate people are struggling for survival. The generation with a higher demand of energy has resulted in an inequitable access to rural communities buttressing the need for biomass. All these happenings are due to the political instability that stand against the effective implementation of the energy policy in Nigeria. Therefore, the inefficiencies that over shadowed the allocation of energy resources to prevent deforestation across the nation is unbelievable. Thereby, promoting the exploitation of its huge natural renewable energy resources. To avoid a worsening energy supply scenario and provide feasible means of cooking energy to our rural dwellers, the government needs to formulate a policy that supports the use of cheaper energy such as Sawdust stove as presented in this paper. Many renewable energy reviews in Nigeria have shown that, we have the ability to produce useful and uninterrupted electric energy supply.

Energy and food are very important and required at every facet of human life, such as health, education, political, industrial activities, economic, transportation, communication and social development of every nation. However, inadequate supply of energy will adversely affect the quality of life. For health, energy cannot be substituted and due to underperformance of Nigeria's power sector that has forced many scientist and technical personals to look for how to mitigate the terrible poverty level in Nigeria through urgent and proper research [2]. The only controversy that is facing this study is deforestation risks and uncertainties underlying the cost of biomass energy and ability to rekindle the old fears in the mind of Nigerians about this energy source [5]. In trying to make life easier and overcome the poverty level, we need to utilize our resources fully [9]. This will result in higher reduction in complain and migration from rural to urban areas for survival [3].

Government intervention

The government need to seriously consider biomass energy as a resource for supplementing the demand for electric power. Hence, energy diversification is critical to ensure that Nigeria does not solely depend on electric power. The rationale behind this policy initiative was to reduce Nigerian's over dependence on electric and fossil fuel in its overall energy consumption. Even though, the largest share of the Nigerian economy comes from fossil fuel [9]. Despite this opposition, the capacity factor of Nigerian biomass is insufficient to curtail the problems on ground [1,18 19].

The government intervention forum accepted the suggestion that the wood industrial companies should liaise with government sectors for better project and proper utilization of the sawdust for energy

purpose. A reliable and adequate biomass energy is an important catalyst for the peace and economic development of a country through which more job opportunities will be created [8]. Recently, the resurgence of interest in developing and expanding technical ways for good utilization of biomass energy in both rural and urban cities in Nigeria has emerged. Nevertheless, this paper described the current and future status plan for expansion and advancement of similar technology due its high performance impacts with minimal associated risks [8]. Despite that, Nigeria has drawn up an ambitious plan to promote biomass energy usage due to its abundance and to also minimize the effect of rising prices of petroleum products [1, 2, 7]. On the other hand, the fact that Nigeria seems keen to support this project on a large scale since the suggested cost is relatively cheap when compared to other local stoves. Moreover, this sawdust stove is a viable technology in which the wood disposed waste are reproduced back into biomass energy cycle in a more prominent way [3].Verily, our future policy plan is to integrate reprocessing the wood wastes for the best human resource management in Nigeria with a 'solid in and solid out' concept. Indeed, this will help in avoiding the legacy of unnecessary storage or rampant disposal of the sawdust.

Biomass as an alternative energy for heating and cooking

Organic plant matters energy produced by solar energy through photosynthesis is the basis of biomass energy. The biomass products can be in the form of gaseous, liquid or solid, which is our concern in this paper. Biomass energy depend on the conversion system of the dead organic matters [14, 15, 35]. The conversion process in which the biomass energy is obtained from anaerobic digestion that produces alcohol, pyrolysis then followed by some allied techniques and finally to the direct combustion. The direct combustion is by simple burning process whereby all burnt biomass energy will be collected and used as our energy input for reducing the poverty in most of the rural areas, where there is no energy source to take care of themselves. The solar energy radiation again has the significant important and contribution for drying the sawdust material even before making the sawdust stove. Environmentally, the biomass energy sources are very friendly in nature, for that everybody can access it unlike other source of energy like hydropower, solar, wind, tidal, hydrogen fuel cell and biofuel or biodiesel [9]. Therefore, Nigeria needs to improve efficiency in the energy perspective and reduce the biomass-energy waste and economical gamut [5]. The biomass have significant environmental impacts, even in countries like Malaysia, America, and China [1,2]. Though, it can cause ecological damage and affect human health as accordingly reported by World Health Organization (WHO) [2,3]

Biomass energy origin

Energy is generated from solid plant fuel matter that when burnt and converted to convenient gaseous or liquid biofuel. All these is originated when the green plants trapped and stored some energy from solar in the compounds of carbon through photosynthesis. The photosynthesis, chemical equation is summarize relation below:

$CO_2 + H_2O \rightarrow [CH_2O] + O_2$

The CH_2O group is the building block for plant material that are manufactured from carbon dioxide and water in the presence of sunlight. The plant material consists mainly of carbohydrate in the form of storage substances, from where the energy is confined and later released by combustion. Most of the direct combustion material with less than 20% dry water is insufficient, and further processing to a more useful fuel is necessary, in order to mitigate the effects of utilizing excess or unprocessed biomass energy [14, 15, 17, 35]. The major problems includes: Ecological, in which the excessive utilization of the biomass energy may lead to erosion, desertification and other ecological degradation. Technical, in this case, the development of stove and other cooking materials is being hindered by either lack of enough construction materials not the technical expertise or the lack of political will of the country as whole. Financial, this is due the insufficient capital or the lack of funds towards this kind of innovation, and of course, is a great set back in the national economic development. Thus, affecting the biomass energy production. Temporal, this problem tells more about lack of proper maintenance of the abundant sawdust material that we have in Nigeria. Therefore, in a nut-shell, the optimum level of plant utilization is almost 10% compared to its availability. Geographical, unnecessary quantities of woodcut to feed wasteful cooking fire contribute to serious geographical set back. Socio-culture, harvesting and burning wood fuel releases carbon monoxide, which is harmful to living organisms.

Finally, this research aims to identify usability of sawdust energy for poverty alleviation amongst Nigerians. Hence, the volatility of fuel prices brought a lot of insecurity, indirect global climate changes and economic crisis [20, 21].

Management of biomass wastes

Management of biomass wastes from the back end of the wood industries now can be recycled for successful deployment of feeding energy. The safe management of biomass waste include reprocessing, reuse and disposal. The waste treatment have the basic objective of achieving poverty sequestrating in Nigeria indigenously [3]. The best sawdust stove is the one with best sieving technology of the sawdust from the sand particle that weakens adhesion binding energy during the compaction of the sawdust [3]. Therefore, the implementation of a safe and sustainable sawdust technology to address, optimize waste management could have been the best and essential for the success and sustainability of our ambitious biomass energy program [3]. Yes, is the only nearby solution for achieving a quality and continuous well-functioning cooking energy in the country. Even though the infrastructural development is the main factor for economic growth and sustainable development, but with a skyrockeing poverty level in the nation, this sounds like a mirage. Life standard can only be improved when feeding and food production is made available. This is reasonably enough to suggest steps for eradicating poverty through educative and easy scientific research that can provide ways of sustenance. Therefore, this study is very vital and an essential requirement for development [2]. The underlying objective governing the management of sawdust waste is the protection of man and his environment presently and later in future. Philosophically, the utmost emphasis in biomass-waste management is the minimization and good usability of it through stages of reprocessing, designing, construction, operation and maintenance with effective confinement and safety [3, 14, 16].

Biomass energy utilization

The investigations on sawdust biomass-fuel performance is often by determining its relative utilization efficiency and the fuel-burnup combustion time. The study examined the potential and harnessing ability of biomass resources in Nigeria toward life sustainability. The biomass energy can contribute toward poverty mitigation amongst Nigerians by securing and sustaining non-polluting ways of using sawdust waste as biomass energy source. In addition, is to make use of biomass energy as the best alternative to electric energy consumption demand especially where there is no electric and utility grids [9, 16]. Man's biomass energy utilization started since life began on earth. People depend on biomass energy utilization in cooking, pressing clothes and for heating their body and rooms by charcoal or fire wood in rural areas where there is shortage or limited electricity and in rare cases the urban areas at the time of power failure. Even the source of petrol is originally from the biomass energy, since is one of the product of the decomposed organic matter after it undergo an underground process of one million years [17, 19].

Utilization of the biomass energy help to improve energy efficiency as a way to reduce unnecessary energy waste. The biomass energy can be used in heating our buildings, water and for transportation like train (biofuel). It can be used to produce alcohol, which is an excellent substitute for kerosene for cooking purposes. Even after combustion of wood, there will be a useful potash fertilizer produced by the ash of biomass plant material. Biomass organic materials are used in building many different types of stoves that are gas effluent with no pollution effects. In addition, the biomass (organic waste) carbonized to produce a good, durable and cheap charcoal for that matter. Generally, by so doing, this will promote and stimulate the economic growth of our nation. So, in this paper, the technological and innovative details of the above aspects are presented [14, 15, 18, 35].

Other local fire wood stoves

Previously, the majority of our poor rural population and as well many inhabitants of areas on the peripheries of cities and towns, used very simple open fires for their cooking purposes. Even though, different arrangements on how to set the open-fire stove were made depending on the materials available around people of the community that inhabit the areas. In some areas where rocks are available, three rocks are arranged in a triangular shape in which the cooking utensils or clay mud pot will be rest upon, while in places where rocks are scarce, a mound of clay is used in placed of rocks. In addition to this arrangement, some used an inverted clay pots that are filled with special charms, combination of stones and pots, stones and hot pot combination, five rocks for two pots and or wall with three rocks for two pots [14, 16]. Secondly, a DOLO stove was invented for an alcoholic beverage that is made from fermented millet. It is common throughout Burkina Faso and it is made in three or four large earthen pots as big as 1m in height and 50cm in diameter. The alcohol is processed through boiling and simmering for three consecutive days, in which the entire process consume enormous quantity of firewood. This stove is restricted to areas of clay soil and the pot making is seasonal with serious labour force. Moreover, it will lead to an acute shortage of firewood that result in devaluation of the economy of such area [14, 15, 35]. Thirdly, BOBO stove also named U-shaped mud wall. The bobo constructed with two mud filled discarded pots connected by a mud of wall in the form of "U". This stove use to enclosed a fire while on it a large metal pot simmered, which results in heavy smoke, especially when built indoor, not moveable and of doubtful durability [14, 15, 16, 35]. The fourth stove is BANFORA, which is made with mud, as are all the dwellings,and it is built indoors without chimney. Therefore, with no chimney, the smoke goes up behind the pot, finding its way out of the kitchen through openings in the roof and walls as well. Therefore, Banfora is good because of its wind protection that increases cook pot stability and some heat retention in mud wall. The fifth in chain is the MALIAN stove, which is made of clay soil, transportable, easy to use and it is self-feeding because the fuel falls into the fire as it burns. The CANARIS-KILNS is another stove used for cooking and in its traditional method of firing the clay pots uses no kiln. Unfired pots are stacked on a layer of straw on the ground or in a depression in the earth, covered with layer of straw, bark, firewood and or cow dung and the pile is then set on fire. Instead of this, a special stove for firing canaris were made of approximate dimension of 2m in diameter and height of 1.5m. Nevertheless, the LORENA stove emerged and it is most important and economical local mud stove made so far. It has 3 to 4 opening for a single cooking pot but having only one inlet for which fuels to be supplied. Moreover, there so many other stove with different design at different location of the world but it is not the right avenue to mention all. While our major mission concerned is to sequestrate the poverty with a sawdust stove, being that it is available across the country and misused. Reliably, to date, most Nigerians lack the needed energy for cooking such as cooking gas, kerosene, electricity (hydro, biogas, petrol-generator, charcoal and firewood). All are now problem due the economic situation and social stability [14, 17, 19]

Why this works

The sawdust stove project is in the interest of government because all the material are available and are not valuable in eyes of the majority of the citizens. Therefore, the improvisation and fabrication of the sawdust stove is to minimize the energy problem that is currently faced by Nigerians due to the rising cost of petroleum products through proper and tangential implementation of technologies for the exploitation of renewable energy sources. The mitigation of poverty is not by supplying can-food, money-gift or cooked food to alleviate the terrible situation of those in the poverty line, but through an elaborate scientific and technological approach. Proper measurement in weighing, timing, testing, synthesis and analysis was taken into consideration. Special emphasis is on supplying those parts of the population, which have been the most severely affected by energy shortage particularly in the rural areas after ensuring of its performance and efficiency. The sawdust stove is designed to be an up draft, to allow air to enter through the inlet and pass out through the outlet, which is at the top. The stove is made up of compacted sawdust, which is ignited by means of other fuels such as dried small sticks or barks immersed in small kerosene or none, where small sheet of papers are used. The surface of the compacted material contributes more to the efficiency of the stove; hence, fuel supplied is not enough to make it efficient. Drawing from above, the study analyses the overall performance of the sawdust as a means of disquieting poverty among the Nigerian citizen. Therefore, biomass energy can play an important role in human life [2].

Biomass energy concept

The biomass energy is a clean and safe alternative to fossil fuels. The general idea of biomass energy originates from hydrocarbon compound of an organic matter that is responsible for generating heat, which served as fuel. The energy released from the hydrocarbon compound of the organic matter mainly depend on the kind of conversion method suitable in processing it. The methods include carbonization, gasification, pyrolysis and direct heat utilization. Hence, the organic plant matters energy is produced by solar energy through photosynthesis. Photosynthesis is a process of synthesizing and manufacturing carbohydrate from water and carbon dioxide in a achlorophyllous (green) leaves and stems using solar energy and oxygen, received by the plant organic matter. The green cells contained chloroplasts that are essential for the food synthesis. The plant obtained the carbon dioxide from atmospheric air and raw materials such as water, salt and minerals from soil. Thereafter, all the raw material are transported to the chlophyllous cells which are the most abundant in leaves mesophyll cell. While the tiny pores or stomata are found in great numbers on the lower surfaces of most leaves that allowed some atmospheric gases to pass into the main plant tissues. The stoma is an oval shaped pore situated between two green kidney-shape like epidermal cells known as guard cell. Each stoma is an aperture of sub-stomata air chamber, which is the largest intercellular air space, lying adjacent to the stoma and it contained other intercellular air spaces found within the leaves [14, 15, 16, 35].

The general chemical equation is as shown below:

$$CO_2 + H_2O \rightarrow CH_2O + O_2 \quad (2)$$

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \quad (3)$$

The hydrocarbon compound ($C_6H_{12}O_6$) is the responsible part for generating heat during direct heating of a woody material as fuel or in the organic matter used for biomass energy generation.

EXPERIMENTAL ANALYSIS

Methodology

In this study, four different types of stoves are used and their efficiencies compared by time taken to boil the same quantity of water and other liquid. This help in the calculation of the performance of the sawdust that proved enough to disquieting the poverty amongst the large portion of Nigeria population. The stoves used are open-fire, kerosene, electric hot plate and the Sawdust stoves. The open-fire has three supporting stands on which the pot will rest upon. The arrangement of this stove allows the air to circulate, from all directions; hence, the cooking utensils are lifted up small above the ground level. The eleven yarns kerosene stove used kerosene as fuel. The 1000kW Stuart hot plate that used an electric power as the energy source or fuel. The stove of our concerned, sawdust stove which uses briquetted sawdust with starch as a binder for the compaction process and used small dried sticks or barks as ignition fuel or with little kerosene especially during wet season. The four stoves were set to heat water volumes of 250 cm^3 and 500 cm^3 with initial temperature of 34 ^oC and 37 ^oC respectively to its boiling point (100 ^oC) and then the time taken to heat the water through the following temperatures (50, 60, 70 80 90 and 100) ^oC is recorded. The efficiency of each stove was calculated based on the measured time and the performance of the sawdust based on the rate of combustion of the sawdust particles via the computations of weight, volume, density, heat capacity, area and mass of the water,

can, bottle and sawdust. The physical equations used for the study are as listed below:

a) Specific heat capacity, $H = mc\vartheta$
b) Volume of compacted sawdust in Can (A), $V_{cs} = V_{sd} - V_b - V_{sc}$
c) Volume of the saw dust without bottle and Can (B), $V_{sd} = \pi R^2 h$
d) Volume occupied by bottle used for heat outlet, $V_b = \pi r_1^2 h$
e) Volume of occupied by small-Can (B) for fuel inlet, $V_{sc} = \pi r_2^2 l$
f) Area of outlet hole after removal of the bottle, $A_1 = 2\pi r_1(h + r_1)$
g) Sawdust area with respect to Can (A) center, $A_2 = 2\pi R(h + R)$
h) Area of the compacted saw dust, $A_{cs} = A_2 - A_1$
i) Heat effeciency of the sawdust, $H_{sd} = Ka(\vartheta_2 - \vartheta_1)/(r_2 - r_1)$
j) Density of water, $\rho_w = M/V$
k) Bottle diameter measured with Vanier calipers, $C = 2\pi r = \pi d$

Construction

The equipment and solutions used for constructing the saw dust stove are waste-can of paint (A), small sized can (B), bottle, pestle, sawdust, binder (starch), scissors, compass, set of sieves, containers (4), measuring cylinders, thermometer, vanier caliper, ruler of 30 cm, plastic bags, belt, beam balance and water.

A compass is used to draw a circle of 7.6cm diameter, tangential to the bottom edge of the waste-can of paint (A) for a fuel inlet and cut out with scissors until it remain a small portion that can serve as a hinge to the cover lid of the inlet opening. In addition, at the top most of the can (A) small holes are perforated to serve as air inlet, for better air radiation cycle. Therefore, a bottle of approximate external diameter of 7.6cm rapped with plastic bag, fully inserted at the central inner part of the waste-can of paint (A) and rapped small can (B) placed horizontally through the fuel inlet opening. Thereby, making the bottle and small can form L-like shape within the paint can (A) and remaining surface was filled up with the mixture of sieved and briquetted sawdust and starch (binder), and then compacted with pestle while the waste can of the paint (A) is belted, to avoid expansion of the can or spillage of the sawdust. Sawdust of 510.4 g mixed with 150 g of starch in 1500 cm^3 boiled water. While after three days, the compacted sawdust is dried, the bottle and can (A) then removed and re-measured the inlet and topmost outlet of the compacted sawdust to ensure its diameter. The removed sawdust was measured in a measuring cylinder to know its exact volume for error calculations. Then, the lid-cover hinge is removed after unbolting the can (A). Another set of sawdust stove without air holes and leaving the inlet cover tested and proved that it cannot operate on air tied, rather, it produced much carbon monoxide.

Efficiency of the sawdust stove

The measure of effectiveness of the bind briquetted sawdust stove bio-energy supplied and utilized in performing the required assignment or task of boiling a specified quantity of a solution is termed efficiency. Generally, efficiency is the ratio of output to the input or resource utilization. The 4 different stoves; open-fire, kerosene, 1000kW hot plate and sawdust, used in this study use different source of energy, therefore, it will be difficult to compare their efficiencies based on the input resource. Therefore, the efficiency will either be determined on the index of cost and value or energy and time content of each. Moreover, the study used the latter option, which seem more scientific because the first option which is cost, is what the research wanted to mitigate. Verily, the efficiencies are based on time taken vis-à-vis the amount of an input required to perform the task. Of course, this is a more appropriate means of comparing the efficiencies in this paper.

Performance criteria for wood or sawdust stove

The performance of open fire wood stove was satisfactory but used excess fuel with little or no control, therefore, it waste enormous resource. Since, the high energy or degree of hotness is due toexcessiveness of the wood utilized during the heating process, which hasten the cooking in a short period. The wood stoves designed with provision or ability to restrict or restrain the air in circulation or other means of controlling the fuel combustion such as Lorena, Malian, Bonfora, Bobo, and Dolo stoves would be devoid of wastage of the fuel. However, the views on biomass energy and its potential role or performance in meeting the energy demand for heating and cooking, while at the same time mitigating the risks of serious damage caused by hunger is justified [5, 14, 15, 16, 35].

RESULTS AND DISCUSSION

Discussion

At the first four minutes, the temperature of the four stoves: Stuart hot plate, open fire, Sawdust and kerosene, measured are 38.5, 52.0, 52.0 and 75.0^{o}C respectively. The time taken by the above listed four experimental stoves to boil 250ml of water is 1800sec, 900sec, 540sec and 350sec respectively. The process and measurement repeated with 500 ml of water is as presented in the results. Graphically, the nature of the curves show that, the Stuart hot plate and kerosene follow almost the same pattern, only the time taken to boil the water varies. In this case, the energy is directly proportional to time after room temperature as according to time spaces. While, the nature of sawdust graph is slightly bended and its efficiency is by far better than the open fire and Stuart hot plate on comparison.

Results

Table 1: Measurement of mass and volume of water using beam balance.

Volume of water (ml)	250.00	500.00
Weight of the can (g)	111.70	111.70
Weight of can and water (g)	358.00	611.70
Weight of water (g)	246.30	500.00

Table 2: Measured Temperature for boiling 250 ml water of initial temperature of 34 ^{o}C.

Temperature (^{o}C)	50.00	60.00	70.00	80.00	90.00	100.00
Time for kerosene stove (s)	1.4	2.4	3.2	4.2	5.2	6.0
Time for Sawdust stove (s)	3.6	5.4	6.8	7.4	8.2	9.0
Time for open fire stove (s)	3.6	6.4	9.0	11.0	13.0	15.0
Time for Stuart hot plate (s)	14.6	17.6	20.8	24.0	27.0	30.0

Table 3: Measured Temperature for boiling 500 ml water of initial temperature of 37 ^{o}C.

Temperature (^{o}C)	50.00	60.00	70.00	80.00	90.00	100.00
Time for kerosene stove (s)	2.8	4.8	6.4	8.4	10.4	12.2
Time for Sawdust stove (s)	7.2	10.8	13.6	14.8	16.6	18.4
Time for open fire stove (s)	7.2	12.8	18.0	22.0	26.0	30.0
Time for Stuart hot plate (s)	25.2	35.2	41.6	48.0	54.0	60.0

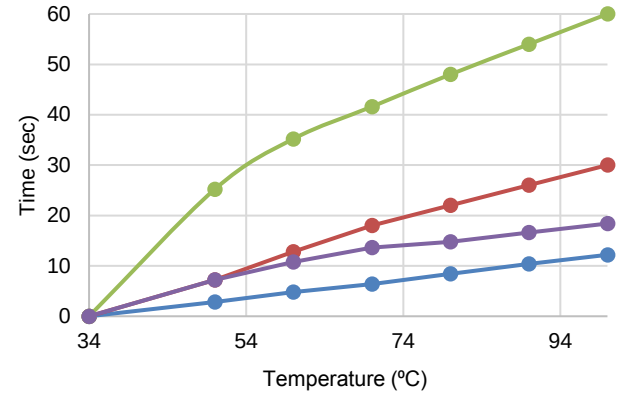

Fig: 1 Performance efficiency of Stove over other heating stoves using 250ml 0f water

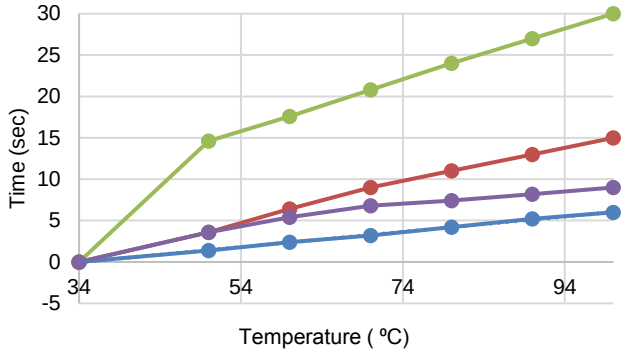

Fig: 2 Performance efficiency of Sawdust Stove over other heating stoves using 500ml of water

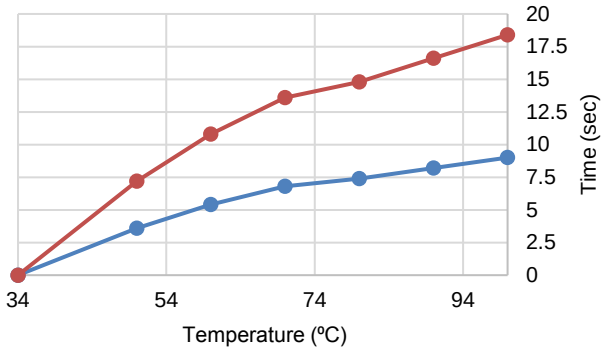

Fig: 3 Consistancy in the Sawdust performance efficiency inrespect of the substance volume on heat.

CONCLUSION

The designed and constructed sawdust stove was accepted and recommended for use in our local communities based on its high efficiency that is enough to sequestrate the engulfed poverty among Nigerians and drastically reduce the excessive biomass energy wastage in cooking. The study provide a clearly define guide in making the best used or utilization of the waste product of sawdust that is commonly disposed. The major problems accounted in meeting the objective as expected is the misappropriate maintenance of the sawdust by the carpenters and the wood industries as a whole. Some of the sawdust used contained little sand-gravel particles after all the filtration and sieving process. The presence of the gravel effected the binding ability of the sawdust compaction during the construction process and perhaps affect the efficiency of the stove under study. Previously, different types of stove were designed in different areas with less efficiency and cost, but with some associated predicaments on how to get the materials available for constructing them. Indeed, the stove is the best among the designed stoves ever in our community and has many advantages over the rest of the stoves because of its heat retention, material availability, material cost affordability, high efficiency, good wind protection, portability, easy to use, no skill required for its construction and marketing. Generally, the extent of biomass energy resources as described, gives the government the chance to create policies for its sustainable and efficient use as an alternative energy source. Even though, various polices that possibly incentivize the realization of wider biomass energy applications in rural areas are proposed, the challenges and future prospects of biomass energy in Nigeria is still a daunting one for researchers. Improving and disseminating this sawdust stove of unwanted biomass energy resources will not only improve the well being of the rural communities, but also enhance energy and economic prospects of Nigeria for potential global investment and production.

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