DESIGN, DEVELOPMENT AND TESTING OF A BIOCHAR MAKING MACHINE FOR RURAL FARMERS

Supported by tetfund

Ashiedu Festus Ifeanyi[1]* and [2]Popoola Eunice, O.
Mechanical Engineering Department, Federal University of Petroleum Resources Effurun, Delta State, Nigeria
Mechanical Engineering Department, Delta State Polytechnic Oghara, Nigeria
*Corresponding author: ashiedu.ifeanyi@fupre.edu.ng

Received: September 10, 2021 **Accepted:** November 07, 2021

Abstract: Biochar, a porous carbonaceous material, blessed with strong anti-decomposition characteristics and aromatization is made by subjecting Biomass to heating at a near zero air supply under controlled temperature of about 650°C and pressure. Biochar finds its applications in the areas of environmental remediation, agricultural practices, water treatment and Animal Production. However, the method of production of Biochar conventionally requires a large span of land which may no longer be useful after a prolonged thermal degradation of the soil. Again the level of pollution created during the burning of the Biomass affects the environment and the ozone layer thus affecting climate change negatively. As a result of these, this research work is therefore important and necessary in that it will address these shortcomings by designing and developing a machine for biochar production capable of eliminating these potential treats and dangers associated with crude methods of bio char production. A machine capable of producing biochar, mitigate air pollution, reduce land wastage as a result of burning and obeys the principle of pyrolysis has been designed developed and tested. The result of the test showed a remarkable departure from the old method of production by eliminating all potential shortcomings as listed above. We therefore recommend this device and its products to our rural farmers for increased agricultural produce all year round.
Keywords: Pyrolysis, biomass, biochar, feed stock pollution

Introduction

Majority of our farmers do not have idea of what biochar is and what advantages it can offer to both their crop fields and environment. Many of them often at times opt for the fertilizers to aid their crop production in spite of the chemicalised nature and harmful practices of fertilizers to the soil and the environment. It therefore becomes imperative to explain in details what biochar is and how to produce it from biomass. This forms the basis of this project. Biochar is a carbonaceous solid material that looks like charcoal but differ in both chemical and physical characteristics. It is very porous in nature; it equally has a high degree of aromatization and anti-decomposition ability when in the soil. Biochar is produced by the decomposition of biomass derived either from Plant or Animals under a controlled temperature and pressure in the absence of air. This process is referred to as Pyrolysis. Little has been said about biochar locally, but internationally, much has been done using biochar in the areas of crop field, environmental mitigation, water treatment and Animal Production. Notable research works that deals with biochar production and use include Dempster *et al*. (2012). The work pointed out that biochar is produced in an oxygen depleted environment which result in biochar having a physiochemical property suitable for safe and long storage of carbon in the environment. Thus carbon has a great potential for soil improvement. Bruun *et al*. (2012) compared the effects of Carbon and Nitrogen dynamics on slow pyrolysis and fast pyrolysis. The study observed that application of fast pyrolysis in the soil caused immobilization of soil Nitrogen while that of the slow pyrolysis of biochar does not immobilize the soil Nitrogen. The study added that with the slow pyrolysis of biomass the biochar obtained was fully pyrolized. Koide *et al*. (2011) developed a method for qualitative analysis of biochar in field soil. The paper added that the method developed was based on loss on ignition which requires no specialized equipment.

The extraction of phospholipids fatty acids from the soil before and after experiment that span for about four months was used by Steinbeiss *et al*. (2010) to quantify the changes that occurred in the microbial biomass and to identify, the microbial groups utilizing the biochar. Tawheed & Elhessien (2017) draw attention of farmers to the importance of using biochar which include improved crop field, creation of more yield on fewer land area, energy, environmental protection and additional area of interest. Bates, (2010) and Burges (2010) pointed out that biochar remain the major causes while some Terra Prata soil remain more fertile than the others over time, most especially where nutrients are rapidly filtered out of the soil and where organic materials decomposes rapidly. Lechman (2010) in his paper observed that standard, cleaner and better biochar are made when we have an incomplete supply of oxygen and the thermal decomposition process maintained at about 700°C and below.

The world population is rapidly increasing without a corresponding increase in land required for agricultural and environmental purposes. In order to sustain the activities of man on planet earth, food must be readily available and all variables needed for the production of these agricultural products must be optimized so as to guarantee food security. One of the variables highly relevant in food production is land, while the other is environment. Excessive use of soil causes depletion of the organic matter and the soil nutrients. As a result of the decrease in soil nutrients and organic matters, production of agricultural produce drops drastically. Over the years, inorganic fertilizers are been used to improve on soil fertility and quality, however, the observable effects of the excessive use of fertilizers on our soil include, leaching of the soil, mineralization of organic matter and deterioration of our environment which most times leads to global warming among others. Most recently, the use of biochar, organic manure specially made from biomass has been found to mitigate in the areas of improving the soil fertility and quality of yield and at the same time assist in controlling the quantity of carbon (iv) oxide (CO_2) released into our surrounding and its ability to absorb some poisonous gases in our surroundings.

Evidentially, studies carried out on the use of biochar in improving soil quality revealed that there exist a significant difference between the use of chemical fertilizers and that of the organic fertilizers obtained from prepared biomass otherwise referred to as biochar. Some of these works includes, Atkinson *et al*. (2010), the paper established and x-rayed the capacity of Biochar to absorbing soil water and releasing same, in times of need. Again, Rahman and Razzaq (2017) pointed out that Biochar is gifted with the ability of absorbing carbon iv oxide (CO_2) from the atmosphere, store it for a considerable length of time and release same to the soil for increased fertility over time. Sohi *et al*. (2010) observed that the use of Biochar in promoting soil fertility also assist in reducing the quantity of methane, Nitrogen iv oxide and other poisonous gases in the soil released to the immediate environment. These gases are responsible for the abnormal increase in the environmental temperature responsible for climate change. The paper further stated that Biochar has the potential of storing about 50% of the carbon iv oxide released during the burning and decomposition of biomass. In a similar work, Laird *et al*. (2010) highlighted some of the benefits derived from the use of Biochar to include, increase in cation exchange capacity, binding of required cations and anions for future use and providing enough space for microorganism to carry out its task.

Again, Lehmann (2007) argued that the cation exchange capacity (CEC) is directly proportional to the temperature at which the biochar is produced. Rondon *et al*. (2006) noted that the inclusion of 20 g of biochar in 1 kg of soil has the ability to retard the emission of nitrogen iv oxide into the atmosphere by 80% in a grass pot while that for soya bean pot can be reduced to about 50%. Accordingly, global warming gases from soil decreases by the inclusion of biochar in the soil for agricultural purposes, Sohi *et al*. (2009). The production of biochar using plantain fiber was carried out by Adewale *et al*. (2019). The paper reported that the biochar produced was highly porous with a surface area of 424.8 m^2/g and find relevance in multiple applications. Qambrani *et al*. (2017) described biochar as a porous carbon rich product of biomass pyrolysis. The paper added that the porous nature of bio char enabled it to retain water, nutrients, microbial accumulations and absorption of carbon iv oxide from the atmosphere. An overview production of bio char production properties and potential benefits was carried out by Rumi *et al*. (2015). Among the interesting discoveries of the paper is the use of bio oil produced for energy generation and making of chemicals for industrial and agricultural applications. Keiluwiet *et al*. (2010), Garcia-Perez *et al*. (2008) and Desisto *et al*. (2010) pointed out in their various studies that increase in temperature lead to a decrease in the yield and quality of bio char produced. The paper added that the decrease in yield was as a result of de polymerization of organic compound such as cellulose, hemicelluloses as well as the combustion of other organic materials.

Materials and Methods

Production of bio char requires the use of any kind of organic materials such as woods, maize husk, rice husk and others. For the purpose of this research work, Coco Nut husk was considered. The choice of Coco-Nut husk arose because of its availability, spread and popularity in the south - south region of Nigeria. Again, the dried Coco Nut husk constitutes environmental hazards by blocking water channels around the city. This in turn causes flooding in our major streets and highways. Apart from blocking water channels, it floats on our water ways thus preventing accessibility some critical water ways infrastructures.

The husks are cut down, chopped into the desired sizes as to fit into the 30 liters drum selected for the study. The chopped pieces of husk are dried so as to aid combustion in a controlled air medium. The already dried particles were then carefully stacked to completely fill the steel made container to the brim as seen in Fig. 1(a – e). The filled container

Design calculations

Mass of feed stock in consideration

Mass Balance (law of conservation of mass apply)

Therefore, mass of husk – mass of char = mass of pyro gas + mass of bulk water

Volume of the conversion chamber (V)

$(V) = \pi r^2 h$

Where r = 200 mm = 0.2 m

h= 560 mm = 0.56 m

Therefore $V = 3.14 \times 0.2^2 \times 0.56 = 0.0704\ m^2$

Maximum loading capacity should be 70% of the volume of the conversion chamber to allow effective conversion process.

Maximum loading capacity = $^{70}/_{100}\ x\ 0.0704\ mm^2 = 0.04928 m^2$

Thermal Efficiency

Heat Lost to the environment = Temperature inside the conversion chamber registered by the thermometer – Temperature of the outer steel shell registered by a standby thermometer

∵ Heat lost = 310 – 128°C = 182°C

Efficiency of lagging material = $\frac{Heat\ Lost}{Temp\ inside\ Conversion\ chamber}\ x\ 100 = \frac{182}{310}\ x\ 100 = 58.71\%$

Mass of Biochar produced = Mass of Coconut Husk ÷ 4

Amount of Gas used per $7.0 \times 107\ kg^3$ of Husk = 2.5 kg

Y Biochar = (M Biochar ÷ M raw) × 100%

Where Y biochar = mass yield of biochar, %;

Biochar = mass of biochar, kg; m raw = mass of raw biomass, kg.

In consideration of the thermal conductivity of the system,

The thermal expansion of mild steel $\Delta L = \alpha L\ (T_{hot} - T_{cold})$

Where ΔL = change in length

L = particular length measurement

α = coefficient of linear expansion

$T_{hot} - T_{cold}$ = change in Temperature

L= 560 mm = 0.56 m (using height of the conversion chamber)

$\alpha = 1.2\ x\ 10^{-5}$

$T_{hot} - T_{cold=}$ 300-0 = 300°C

ΔL= 0.000012 x 0.56 x 300 = 0.002016 m

Rate of heat transfer through conduction is giving by

Q/t = {kA [T hot- T cold]} ÷ d

Where: Q = Heat transferred, k = Thermal Conductivity of mild steel, A = Area of Surface, t = Time, d = the thickness of the material, T hot = Hot temperature, T cold = Cold temperature.

Given the values A = 0.69 m², t = 45 min = 45x60 sec = 2700 sec, d = 2 mm\1000= 0.002 m,

T cold = 0°C, T hot = 300°C, k = 50 w.m -1K -1 (Watts per meter Kelvin)

Rate of heat transfer Q = {0.69 x 50 x [300 - 0] × 2700} ÷ 0.002

=

Rate of heat transfer Q =13,972 MJ (Joules).

Clay conducts heat at a rate of 1.5- 1.8 watts for each meter of thickness in the material

$\Delta t = (T_1 - T_2)$°C.

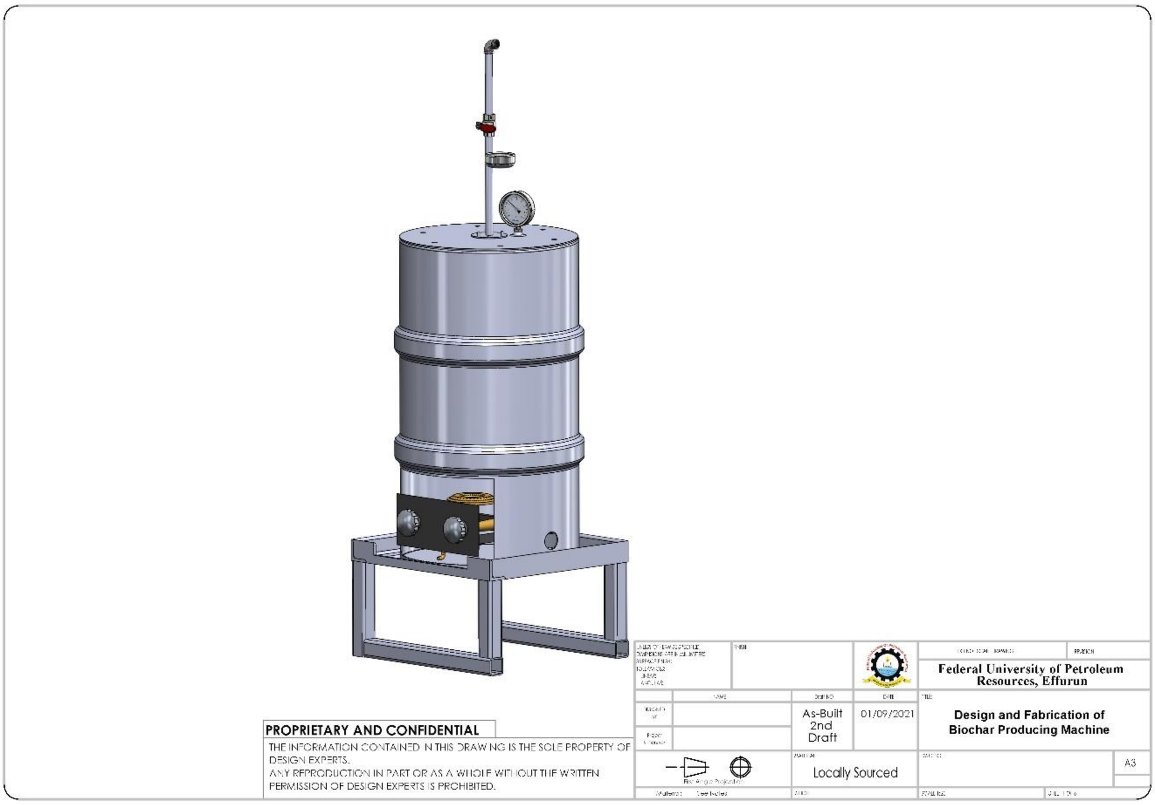

Fig. 1(a): Biochar making machine

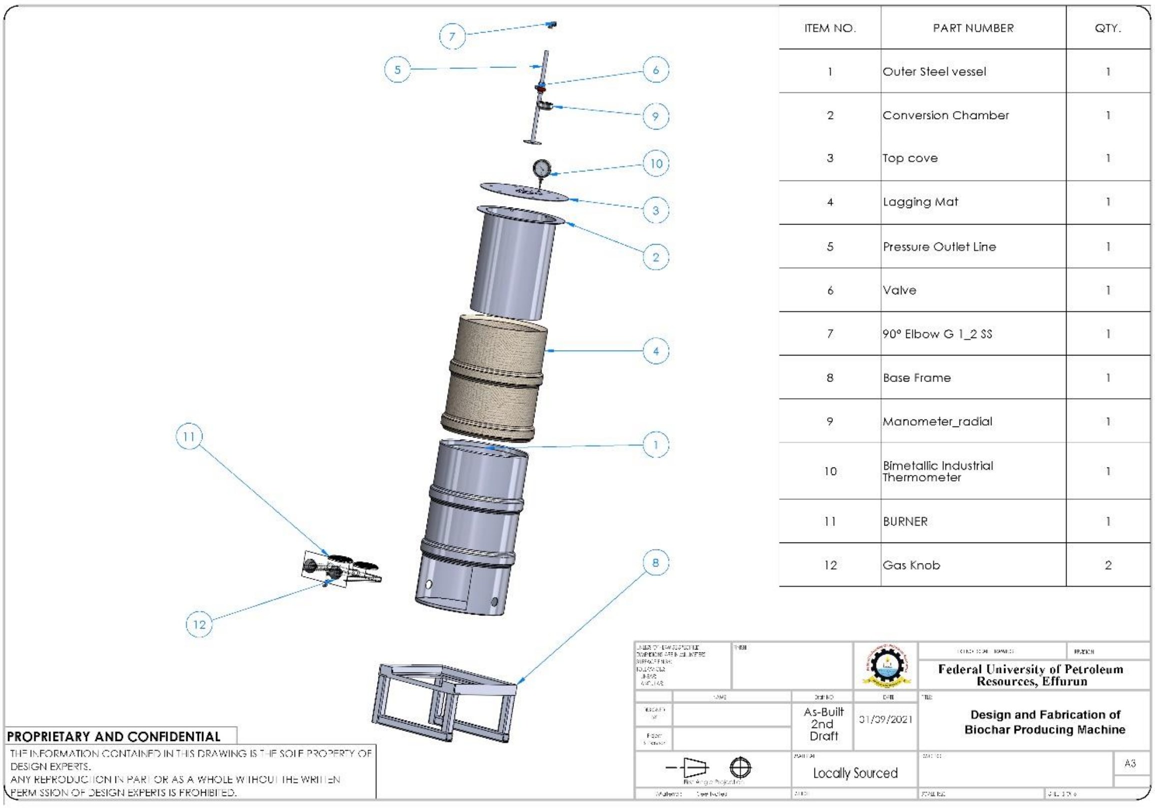

Fig. 1(b): Isometric projection of various components used

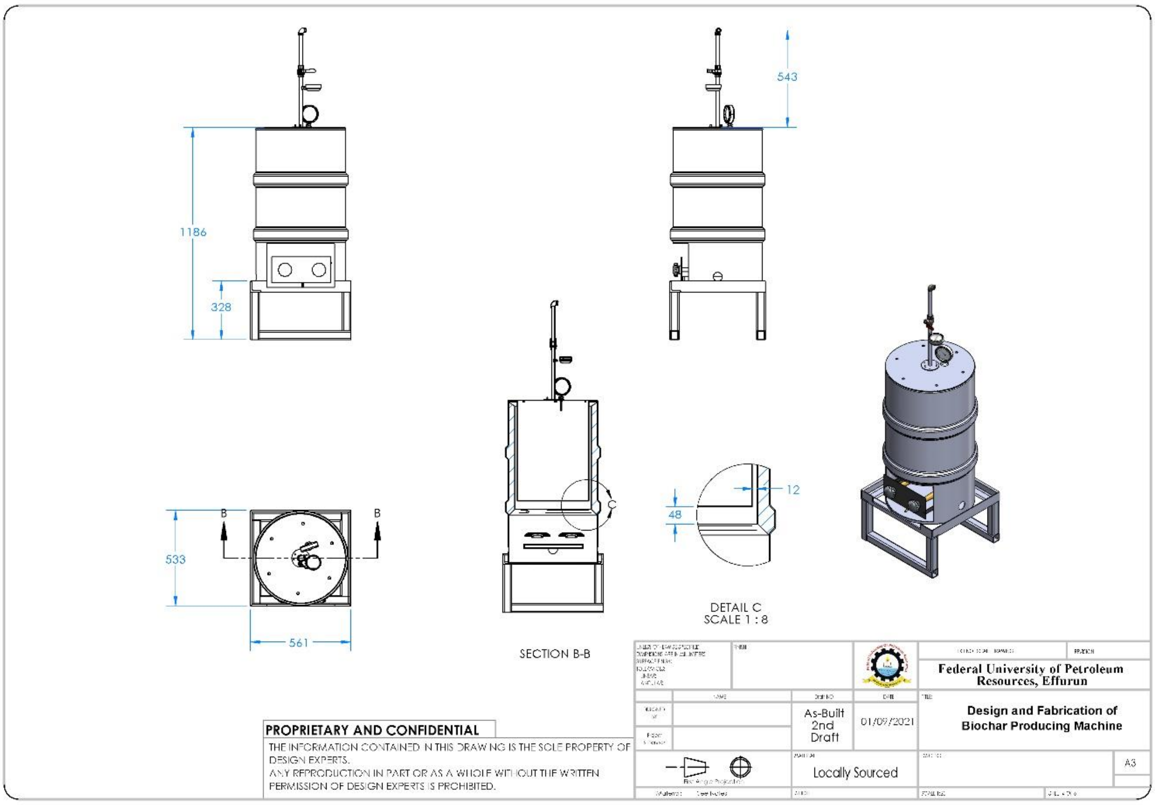

Fig. 1(c): schematic representation of biochar plant

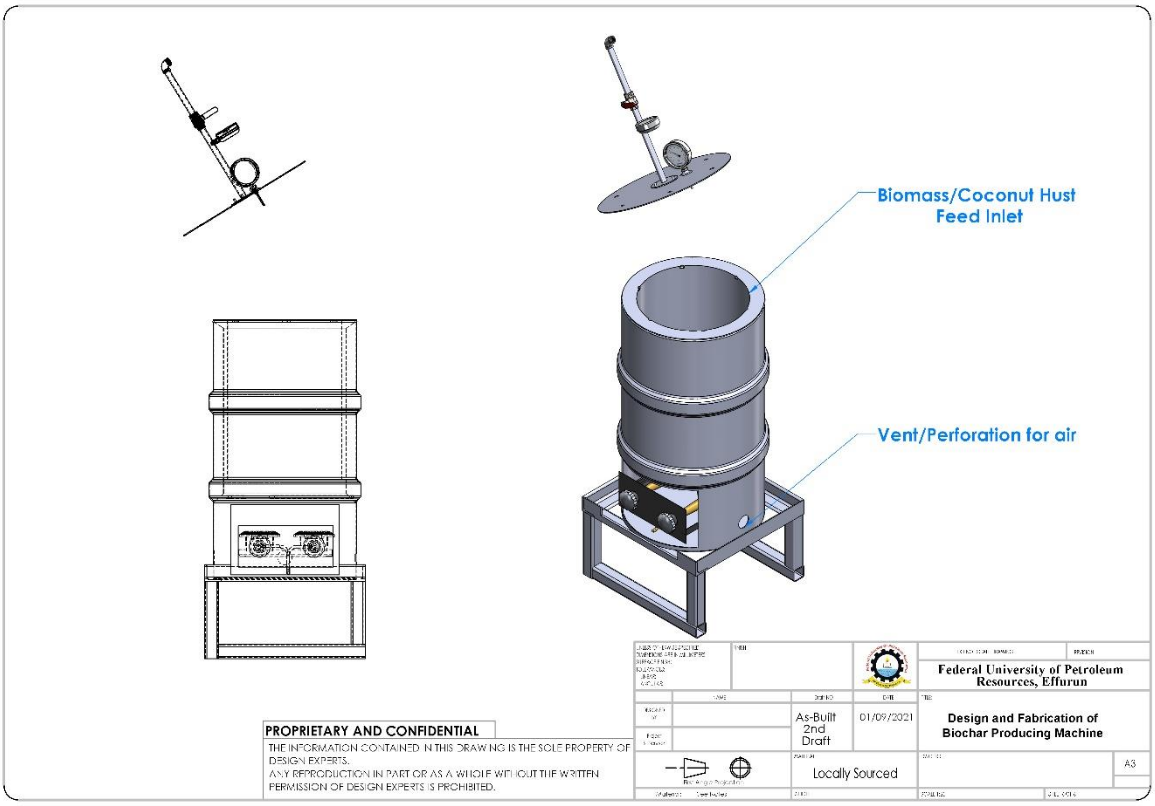

Fig. 1(d): front view of the biochar machine

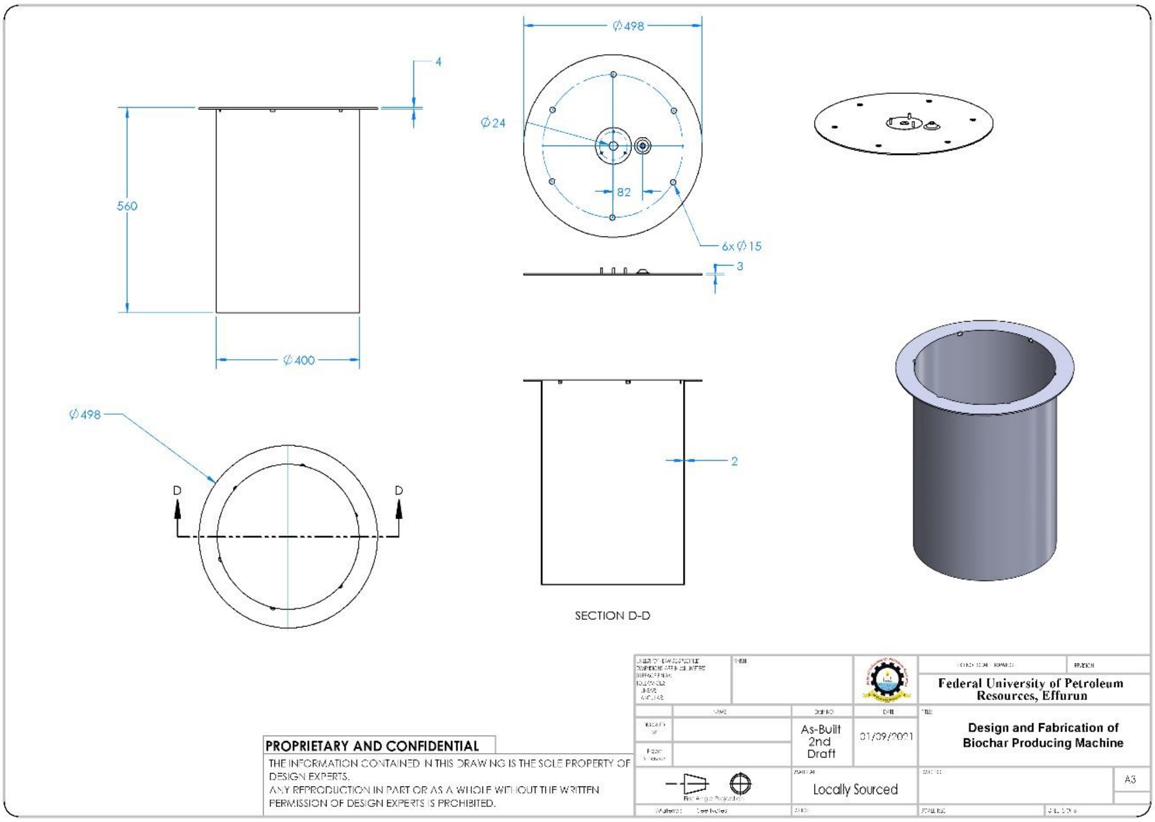

Fig. 1(e): Biochar production plant

Alcohol was then sprinkled on the prepared biomass to aid combustion at a controlled temperature of 90 degree centigrade. The system was then ignited and allowed to burn for about one (1) h in an air tight medium.

Results and Discussion

Bio char production plant capable of making bio char for rural farmers in agrarian communities in Nigeria has been conceived, designed, fabricated (Fig. 1a – e) and tested using dried Coco nut husk which is readily available in the Niger Delta region of the country. The bio char produced was found to have enough capacity to retain soil moisture, increase in carbon retention capacity and efficient in aerating qualities to the soil.

In comparing the bio char produced using this developed machine and the locally produced in the open farm land; it was observed that not much changed in terms of their physical characteristics. However, the attendant consequences derived in the use of open farm land for production was reduced to the minimum, this again corroborates the findings of Adewale *et al*. (2019).

Materials for the development of the bio char making machine was carefully selected from the available local materials. This was achieved after a critical mathematical analysis of each component used for the design in line with the required task to be performed.

Conclusion

The project work was designed to assist farmers in producing cash crops such as fruits, vegetables, tubers and other food items. However, it is our view that Governments at all levels, Nongovernmental Organizations, public spirited individuals, Philanthropist and Churches assist these peasant farmers in forming and organizing Bio mass production clones to ease and encourage the use of the natural crop growth enhancer in their region. If this is done effectively, bush burning which causes environmental pollutions will be reduced to the barest minimum, if not eliminated totally.

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