https://doi.org/10.33263/Materials22.111116

ISSN: 2668-5728 https://materials.international

Materials International

Volume 2, Issue 2, Pages 0111-0116
2020

Review

Received: 06.03.2020
Accepted: 08.04.2020
Published: 13.04.2020

Biomass to Biochar Conversion for Agricultural and Environmental Applications in Nigeria: Challenges, Peculiarities and Prospects

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Abstract: Agriculture is an important aspect of the lifestyle in rural areas and the role of agricultural resources in sustainable development in Nigeria has been positively established. Due to the availability of a rich tropical rainforest in Nigeria, biomass resources are abundant. These biomasses have been evaluated for the production of biochar for agricultural and environmental protection applications. In this mini-review, the authors discuss the recent research effort that has been conducted on the conversion of biomass to biochar in the Nigerian context in the past 2 years. This focus was based on location as the nature and type of biomass available for conversion would be inherently different than for other locations. Furthermore, the nature of agricultural practice is also different hence there will be peculiarities in the way the biochar can be utilized. The challenges and peculiarities are due to a general lack of investment and neglect by stakeholders, and un-empowered youthful population and a lack of awareness of research findings by potential investors and farmers. Modern agricultural practice like mechanization and the use of agrochemicals is still not quite popular in remote locations. This suggests that biochar technologies suitable for such locations would need to be developed to help improve productivity. This discussion is quite important as it comes at a time when a concerted effort is being made by the country to achieve sustainable development through agriculture and reduce reliance on oil revenue.

Keywords: Agriculture; Biochar; Biomass; Environment; Nigeria.

1. Introduction

Agriculture is an important aspect of the lifestyle in rural areas and the role of agricultural resources in sustainable development in Nigeria has been positively established. Due to the availability of a rich tropical rainforest in Nigeria, biomass resources are abundant [1]. Furthermore, the differences in the weather and climate in the northern and southern parts of the country ensure that a wide variety of crops can be cultivated.

Biomass is the oldest source of energy to humans and was once the global energy source before the advent of oil and electricity [2]. Biochar is the solid residue obtained from the thermochemical processing of biomass [3, 4].

Cite This Article: Ighalo, J.O.; Adeniyi, A.G. Biomass to Biochar Conversion for Agricultural and Environmental Applications in Nigeria: Challenges, Peculiarities and Prospects. Mat Int **2020**, 2, 0111-0116. https://doi.org/10.33263/Materials22.111116

Biochar is a carbon-rich (65–90%) material that possesses a porous structure of char particles [5]. This enhances its water-retaining capacity [6], nutrient retention of soil, as well in microbial accumulation. Biochar can be used for agricultural and environmental applications.

The use of fertilizer is deemed not too advantageous for tropical soils because it induces acidity and nutrient imbalance [7]. Biochar is favoured because besides stimulating soil fertility, it can assist in the stabilisation of nutrients in the soil to prevent leaching [7]. It also favours soil microbial activities. Besides its use for soil amendment and conditioning, biochar has other environmental applications. It can be used as a sequestrate of carbon in the soil for the mitigation of climate change [6]. It can also be used for water treatment applications as an adsorbent of pollutants [8, 9]. Attention must be paid to biochar as it has the potential of ameliorating food insecurity, environmental pollution and promoting sustainable development.

In this mini-review, the authors discuss the previous research effort that has been conducted on the conversion of biomass to biochar in the Nigerian context. This focus was based on location as the nature and type of biomass available for conversion would be inherently different than for other locations. Furthermore, the nature of agricultural practice is also different hence there will be peculiarities in the way the biochar can be utilised. The pool of literature was gotten from a google scholar search on only the key papers published on the subject in the last 2 years. This discussion is quite important as it comes at a time when a concerted effort is being made by the country to achieve sustainable development through agriculture and reduce reliance on oil revenue.

2. Recent Advances in Biochar Production in Nigeria

Some recent studies have investigated the conversion of biomass to biochar by thermochemical conversion processes. Adeniyi *et. al* [5] studied the conversion of elephant grass (*Pennisetum purpureum*) to biochar using a hybrid self-regulating biomass gasification process. The process involved the recycling of heat from biomass combustion for the gasification of the elephant grass. By the attainment of a peak temperature of 300^{o}C at an entire process time of 2 h, a yield of 14.29 wt% biochar was achieved. The biochar was mesoporous (specific surface area of 475.1 m^2/g), and very rich inorganic elements. Using a similar set-up, Adeniyi *et. al* [2] conducted the conversion of plantain fibers (*Musa paradisiaca*) yield of 6.98 wt% was achieved at a peak temperature of 220^{o}C and a processing time of 2.5 h. The biochar was mesoporous (specific surface area of 424.8 m^2/g), and rich inorganic elements.

Adeniyi *et. al* [10] compared the properties of biochar produced by the hybrid gasification of orange (*Citrus sinensis*) peel and albedo to evaluate the potential applications for the products. The products are shown in Figure 1. Both biochars were mesoporous and had specific surface areas of 352.5 and 356.3 m^2/g for the peels and albedo respectively. The key observation of the study was the suitability of the biochar for use as a soil amendment, as an adsorbent and as a catalyst.

Pyrolysis has also been conducted for maize cob [6], rice husk [8, 11] and sawdust [12].

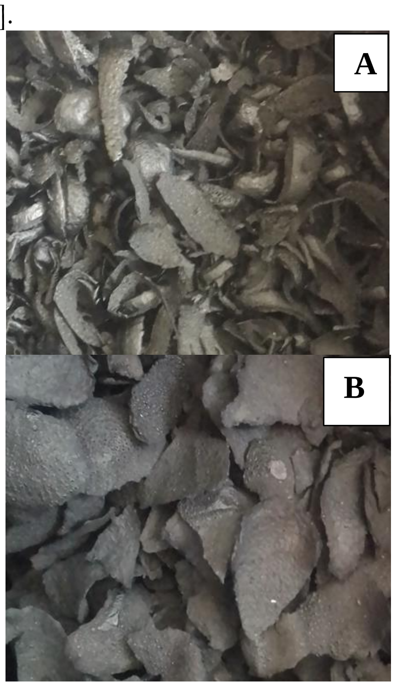

Figure 1. Camera images of biochar from orange peels (a) and albedo (b) [10].

Table 1 summarises the recent biochar production in Nigeria. It can be observed that the yield of biochar from pyrolysis is generally higher than for gasification (for studies where it was reported). Reduced yield from the hybrid gasification can be due to the presence of oxygen which oxidises the biomass to carbon dioxide thereby leading to less char [13]. Carbonisation was also observed to be conducted at a longer temperature than for pyrolysis and gasification.

Table 1. Recent biochar production in Nigeria

Biomass	Process	Time	Temperature	Biochar Yield	Ref
Unstated hardwoods	Carbonisation	24 h	540°C	-	[7]
Unstated hardwoods	Carbonisation	24 h	540°C	-	[14]
Unstated hardwoods	Carbonisation	12 h	500°C	-	[15]
Elephant grass	Hybrid gasification	2 h	300°C	14.29 wt%	[5]
Plantain fibers	Hybrid gasification	2.5 h	220°C	6.98 wt%	[2]
Orange peel	Hybrid gasification	2 h	300°C	-	[10]
Orange albedo	Hybrid gasification	2 h	300°C	-	[10]
Maize cob	Pyrolysis	-	-	26 wt%	[6]
Rice husk	Pyrolysis	2 h	550°C	-	[8]
Sawdust	Pyrolysis	-	400°C	-	[12]
Gliricidia	Pyrolysis	-	400°C	-	[12]
Rice husk	Pyrolysis	55 mins	350-400°C	51 wt%	[11]
Rice husk	Pyrolysis	1.25 h	350°C	-	[16]
Rice husk	Pyrolysis	55 mins	350°C	51 wt%	[17]
Rice husk	Pyrolysis	55 mins	350°C	51 wt%	[18]

3. Biochar Utilization in Agricultural and Environmental Applications

In recent times, several studies have evaluated the use of biochar for environmental and agricultural applications. These applications are summarised in Table 2. Adekiya *et. al* [7] utilised biochar for the amendment of soil in Omu-Aran, Kwara state given the cultivation of radish (*Raphanus sativus L.)*. The use of the biochar led to improved soil Physico-chemical properties, radish root length, leaf nutrient concentrations and yield of radish. Similar observations were also made by Adekiya *et. al* [14].

Table 2. Recent biochar utilisation in Nigeria

Biochar source	Application	Location	Results	Ref
Unspecified	Soil amendment	Omu-Aran, Kwara state	Improvement in soil properties and the yield of radish	[7]
Unspecified	Soil amendment	Omu-Aran, Kwara state	Improvement in soil properties and the yield of radish	[14]
Unspecified	Soil amendment	Owo, Ondo state	Improvement in soil properties and the yield of cocoyam	[15]
Maize cob	Soil amendment	Abeokuta, Ogun state	Increase in the yield of maize grains	[19]
Oil palm bunch	Soil remediation and amendment	Umudike, Abia state	Improvement in nutritional qualities of the leaves of *Telfairia occidentalis*	[20]
Oil palm bunch	Soil remediation and amendment	Egbema, Imo state	Improvement in nutritional qualities of the leaves of *Telfairia occidentalis*	[20]
Maize cob	Soil amendment	Akure, Ondo state	Improvement in soil fertility and maize yield	[6]
Cocoa pod husk	Soil amendment	Ibadan, Oyo state	Improvement in soil fertility and cashew yield	[23]
Rice husk	Water treatment	Abakaliki, Ebonyi state	Adsorption of methylene blue	[8]
Sawdust	Soil amendment	Iwo, Osun state	Improvement in maize yield and product quality	[12]
Gliricidia	Soil amendment	Iwo, Osun state	Improvement in maize yield and product quality	[12]
Rice husk	Soil amendment	Akure, Ondo state	Improvement in soil properties	[11]
Rice husk	Soil amendment	Akure, Ondo state	Improvement in soil properties and upland rice yield	[16]
Rice husk	Soil amendment	Akure, Ondo state	Improvement in soil properties and upland rice yield	[17]
Rice husk	Soil amendment	Akure, Ondo state	Improvement in soil properties and upland rice yield	[18]
Acacia	Soil Remediation	Ojota, Lagos state	Reduced heavy metals in the soil and Sorghum. Higher sorghum yield	[22]

The Physico-chemical properties of the alfisol soil in Owo, Ondo state was found to be improved by the application of biochar [15]. Furthermore, the yield of cocoyam was improved and soil loss was reduced. The yield of maize grains in Abeokuta, Ogun state was improved by the application of corn cob biochar in the soil [19]. The optimum yield was observed at a 20 t/ha biochar application. Qualities such as moisture ash, crude fibre, fat content, vitamins and minerals were improved in *Telfairia occidentalis* leaves at Umudike, Abia state and Egbema, Imo state when the soil was amended with biochar from oil palm bunch [20]. The biochar was used for remediation because the soil in those locations was earlier polluted by gas flaring from the exploration activities in the region.

Faloye et. al [6] established that biochar was a statistically significant factor in maize production albeit to a lesser extent than irrigation. Positive results of biochar application in Nigeria have also been observed for cashew [21], maize [12] and upland rice [16, 17]. Nworie et. al [8] studied the adsorption of methylene blue from aqueous media using biochar prepared from the pyrolysis of rice husk. The biochar was suitable for the intended application and the pollutant sorption was according to the Hill isotherm and intra-particle diffusion kinetic models. Oziegbe et. al [22] utilised biochar from acacia wood for the remediation of heavy metal pollution in landfill soil. The soils and sorghum (planted on the soil) were found to have less heavy metal content. Furthermore, the yield of the sorghum was improved. Application of 10-15 t/ha was observed to be optimal.

4. Peculiarities and Challenges in Local Biochar Production and Utilization

Adeniyi *et. al* [10] discussed some of the peculiar challenges of biochar production in Nigeria. A thermal process without any power requirement will inadvertently gain more acceptance due to the epileptic power supply in the country and its non-availability in remote/rural locations. Agriculture in Nigeria is usually practised in the rural areas hence such technologies would be relevant. Modern agricultural practice like mechanisation and the use of agrochemicals is still not quite popular in remote locations as a farming practice is still done by hand in the interior villages. This suggests that biochar technologies suitable for such locations would need to be developed to help improve productivity. The onus falls on agricultural extension workers to help give proper orientation to the local farmers on the use of biochar to farming. Only the effort of these agricultural extension workers can help bridge the gap between research findings and actual implementation/utilisation of these results by farmers

5. Prospects and Future Perspectives

Biochar production from biomass is one that has a bright future in Africa in general and Nigeria in particular. Considering that the nation possesses a tropical rainforest, a southern guinea savannah, a northern Guinea savannah, a Sudan savannah and a Sahel savannah, a variety of different biomass types is available to be harnessed. Furthermore, agriculture is still an important aspect of the Nigerian way of life hence any technology in that domain will be impactful in the long run. There future perspectives that can be investigated in the research area. Most studies on soil amendment have investigated soils in the southern part of the country (that is predominantly tropical). Soils in the drier northern part have scarcely been reported on in recent times. This is a quite interesting area of research to work on. Also, the interest in the environmental application of biochar is comparatively lesser when compared to agricultural applications. This also is an area that can be looked at in future studies.

6. Conclusions

In this mini-review, previous research effort that has been conducted on the conversion of biomass to biochar in the Nigerian context was discussed. It was observed that the yield of biochar from pyrolysis was generally higher than for gasification (for studies where it was reported). Carbonisation was also observed to be conducted at a longer temperature than for pyrolysis and gasification. It was observed that biochar is quite popular with agricultural researchers in recent times as they have extensively investigated it for the amendment and conditioning of soil. It was fairly less popular with environmental engineers as less interest is paid on its use for the remediation of soil pollution and for water treatment applications (at least in recent times). The challenges and peculiarities are due to a general lack of investment and neglect by stakeholders, and un-empowered youthful population and a lack of awareness of research findings by potential investors and farmers. Modern agricultural practice like mechanisation and the use of agrochemicals is still not quite popular in remote locations. This suggests that biochar technologies suitable for such locations would need to be developed to help improve productivity. Most studies on soil amendment have investigated soils in the southern part of the country (that is predominantly tropical). Soils in the drier northern part have scarcely been reported on in recent times. This also is an area that can be looked at in future studies.

Funding

This research received no external funding.

Acknowledgements

The authors wish to acknowledge the academic staff of the Department of Chemical Engineering, University of Ilorin, Nigeria.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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