A CRITICAL COMPARISON OF THE QUALITY OF BIOCHAR SUITABLE FOR PYROMETALLURGICAL PROCESSES

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Abstract

Carbon footprint has, for decades, become a centre of research regarding environmental threats that the world still faces. The impact of pyrometallurgical processes on the environment has played and still plays a role in the climate change. This is observed through different events that affect nature and the universe. Reduction processes have largely contributed to carbon emissions; hence researchers have embarked on researching new reductants. Biomass has recently been the centre of numerous tests. Many biochars have shown potential to replace the generic coke used for centuries. It is therefore of great importance to categorise biomass that might be used for reduction, adsorption, or energy generation. This paper develops a critical comparison of different biomass for pyrometallurgical use and essentially for reduction. Amongst the prospective biochars compared in this paper are namely Palm Kernel Shells biochar, coconut biochar, sugarcane biochar, macadamia biochar and malt waste biochar. All biochars were produced through pyrolysis in an alumina tube furnace under argon. Ultimate and proximate analyses were used to characterise the raw biomass and the generated biochars. Results have shown that although all biochars show high fixed carbon content, some may require reconditioning to be usable in furnaces through agglomeration.

Keywords: Pyrometallurgy, Biochar, environment, critical comparison

1. INTRODUCTION

The environmental threat caused by the use of fossil fuels has reached a worrying level. Carbon footprint becomes a topic of the day for which a sustainable solution is required. In pyrometallurgy coke, anthracite and different types of coal have been used for years in different production units namely sintering, matte production when a reverberatory furnace is used, and reduction in different processes. Climate change and other impacts depicted in different spheres in the world and other effects have led to finding a replacement for generic carbonaceous materials. Biomass remains the track to solving the major problem the world is facing. Biochar is defined by the United Nations as a carbon-like containing high carbon obtained after burning in neutral atmosphere agricultural materials [1] and used as fertilizers in the farming industry [2-5]. The emission of carbon dioxide has been identified as the main source of air pollution [6,7]. The characterisation and the selection of reductants are based on their chemical properties [8,9]. Because the metallurgical industry is amongst the biggest fossil fuel consumers, therefore one of the major contributors to the high CO_2 gas emission, accounting for approximately 10% of the total CO_2 gas emitted. Serious actions must be taken by the industry to reduce their carbon footprint [9].

The replacement of generic reductants by biomass should therefore be based on their chemical and physical properties. The current paper compared different biochars as prospect-efficient substitutes for generic reductants in the pyrometallurgical industry. Results have shown that some biochars would require to be conditioned to sustain the hardship imposed on them in furnaces.

2. METHODOLOGY

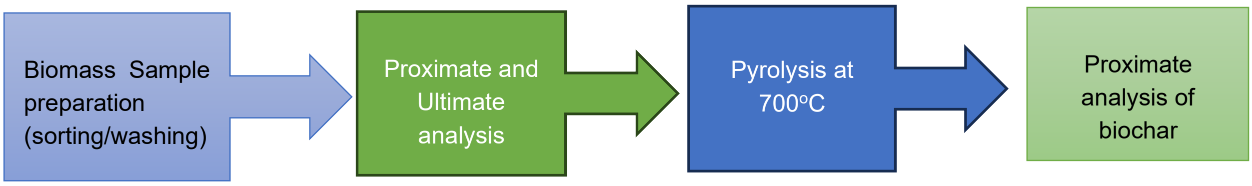
2.1 Materials and Equipment

Different biomasses were used: Macadamia nutshell, Palm Nutshell, coconut nutshell and Sugarcane bagasse. All the biomasses were sourced in South Africa from different regions. Argon of 99.98 percent, sourced from Afrox, was used to maintain the neutral atmosphere to avoid any combustion reaction that would disturb carbon content. Different equipment was used to conduct proximate and ultimate analysis.

An alumina tube furnace was used to conduct pyrolysis with a heating rate of 7°C/min.

2.2 Experimental procedure

The experimental procedure is summarized in the flow sheet below:



The as received biomass sample was cleaned by sorting when required or washing the outside of the shell followed by drying for palm kernel shells and coconut shells to avoid contamination from the shell hair and the humidity brought in through washing. The drying was done using a muffle furnace at 50°C for eight hours. The biomass was then characterized to compare to the final product which is the biochar obtained after pyrolysis conducted in a neutral atmosphere in the presence of argon at 700°C for 90 minutes.

2.3 Experimental setup

Figure 1 depicts the experimental setup used for the pyrolysis tests conducted in this project for all the biomasses used to produce all the biochar.

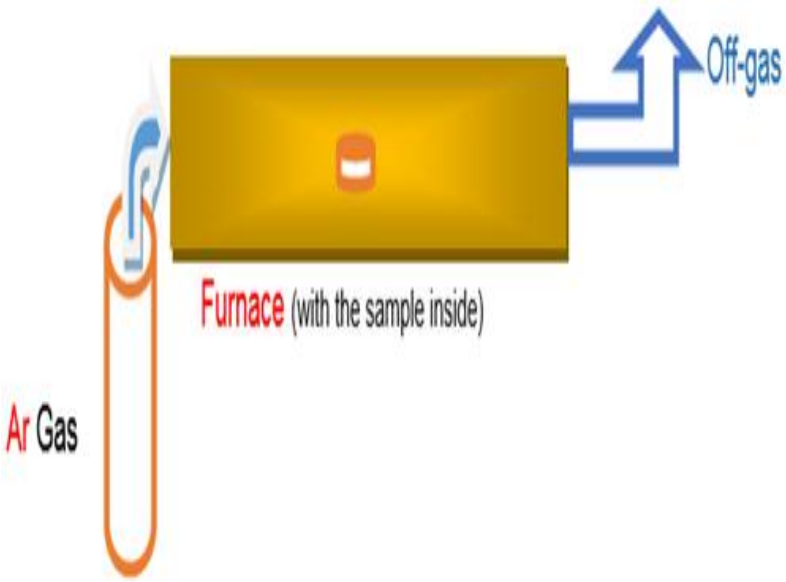


Figure 1 Experimental setup

3. RESULTS AND DISCUSSION

Table 1 presents the proximate and ultimate analysis of different biomasses used in this project. Fixed carbon, volatile matters, ash content, moisture and calorific values for all the biomasses were generated.

Table 1 Proximate and ultimate analysis of the raw macadamia nutshells

	Proximate analysis				
	Fixed C	**Volatile matters**	**Ash**	**Moisture**	**CV(MJ/kg)**
Macadamia Nutshells	19.2	72.6	0.7	7.5	19.5
Palm Kernel Shell	15.78	79.21	0.16	4.85	17.8
Coconut Nutshell	18.4	74.6	1.3	5.7	18.8
Sugarcane bagasse	10.4	65.09	14.66	10.05	10.39

From **Table 1** it is observed that amongst the raw biomass analyzed macadamia nutshells have the highest fixed carbon followed by coconut nutshells amounting to 19.2 and 18.4 %, respectively. Sugarcane bagasse is the biomass that is of poor quality with low fixed carbon of 10.4 %while palm kernel shells contain 15.78%. From the chemical potential, it transpires that macadamia nutshells have a better profile for the generic reductant currently used. It remains to be confirmed whether physical properties are good enough for the biochar to sustain the rough environment in the furnace due to some degradation that might be caused by temperature change, friction abrasion and other factors. Regarding the calorific value (CV), macadamia nutshells are the best with a CV of 19.5 followed by coconut nutshells with 18.8. Sugarcane bagasse remains the lowest CV amongst the biomasses used in this study.

Table 2 Proximate and ultimate analysis of the raw macadamia nutshells

Type	**Proximate analysis (wt%)**				**CV(MJ/kg)**
	Fixed C	**Volatile matters**	**Ash**	**Moisture**	
Macadamia Biochar	92.9	6.24	0.8	0	32.96
Palm Kernel Shell Biochar	84	7.5	5	2.3	32
Coconut shell biochar	88,52	7.28	1.93	2.28	32.95
Sugarcane bagasse biochar	67.5	13.99	15.96	2.55	25.69

Results in **Table 2** show that although the figures presented are not from an optimised pyrolysis process, the quality of most biochar is acceptable to be used as a substitute for generic fossil reductants. The fixed carbon is above 80%, indicating that biochars are true competitors of metallurgical coke based on their chemical potential. The best biochar remains the macadamia biochar followed by coconut biochar. From their calorific values it can be stated that in addition to their good reductant properties they can be used as fuel. The only noted exception is the sugarcane bagasse which has both the lowest fixed carbon and caloric value of 67%

and 25.69 respectively. It is important to mention that although biochars have a high potential to efficiently replace the generic reductants currently used in pyrometallurgy, it remains to be seen whether they may have an impact on the slag structures and slag properties thereof. The structure of slag is key in metal recovery because the viscosity of the slag is generally a result of the slag structure, platelike, treelike, long thin plates are to be investigated when any biochar is used as a reductant. Previous works have demonstrated that the use of macadamia nutshells as a possible replacement for generic coke has demonstrated that reducing manganese ore using raw macadamia nutshells had led to a slag that was platelike as opposed to the needlelike slag produced when coke was used. This led to a slag of high viscosity which made the separation of metal-slag difficult [10].

4. CONCLUSION

In this project, four different biomasses were used as possible substitutes for current generic reductants namely coke, anthracite and coal. The biamasses investigated were Palm nutshells also known as palm kernel shells, macadamia nutshells, coconut shells and sugarcane bagasse. The four biomasses and their biochars were compared. It was found that raw macadamia nutshells and their biochar presented the best chemical potential in terms of fixed-carbon 19.2% and 92.9% respectively for reduction and high calorific values of 19.5 and 32.95 respectively, that could serve for energy generation. Raw coconut nutshells and their biochar had fixed-carbon of 18.4% and 88.52% respectively and calorific values of 18.8 and 32.95 respectively. Palm kernel shells came third with fixed-carbon and calorific values close to coconut shells with sugarcane bagasse having the lowest chemical potential. Although all the biochars present a great potential of being used as coke replacements for reduction processes, it remains important to investigate thoroughly their impact on the produced slag to ensure a good slag-metal separation and the viscosity of the slag thereof.

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