BRIQUETTE PRODUCTION, INGREDIENTS AND BINDING MATERIALS

BY

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CERTIFICATION PAGE

This is to certify that this project work has been read and approved as meeting part of the requirement for the award of National Diploma in Agricultural technology, Department of Agricultural Technology, Kwara State Polytechnic, Ilorin

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Abstract

An experiment was conducted using different waste materials to make Briquqette a biofuel substance that will reduce the environment harzards, like carbon dioxide and carbon monoxide to goes to the atmosphere to destroy the Ozone layer, that is cheap and then make use of our waste that would have caused nuisance. The briquette was made in different shapes and using different materials, the ingredients used include Rice bran, wood shaving, charcoal waste powder, Maize cob while two binding materials used were cement and starch. It was discovered that sawdust was strike out that is not good for making briquette because of the smoke produced while rice bran was the best because of its efficiency and heat control others like Maize shaft and Maize cob were also good for briquette but not as good as Rice bran

DEDICATION

I dedicate the project work to God Almighty who is my creator, my guard and my guidance, to him I praise and worship for the rest of my life.

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CHAPTER ONE

Introduction

Farmers for a very long time prefer carrying out their activities at a very low cost, so that they can maximize profit without changing anything in terms of nutrients of both the inputs and the produce of the farm Lawal et. al., (2024)

Briquette is a compressed block of coal dust or other combustible biomass material used for fuel and kindling to start a fire. The term is a diminutive derived from the French word brique, meaning brick. Briquette can be made from various agricultural waste including rice husk, soybean shaft, maize shaft, maize cob and sugar cane shaft etc and binded by substance that support combustion like starch or cement in a quantity that is moderate because too much of it may not give a desired result.

Every year, millions of tons of agricultural waste are generated, which is either destroyed or burned inefficiently, causing air pollution. This waste can be recycled to provide a renewable source of energy by converting biomass fuel into high-density fuel briquettes (Garrido *et al.,* 2017). The current energy poverty in Nigeria, occasioned by increasing energy demand, insufficient grid electricity supply, increasing costs, and shortage of fossil fuel resources, are topical issues that require intervention. This is because the attendant effects on the environment in the form of pollution, greenhouse gas emissions, and general environmental imbalances are issues that still remain unresolved. The concern that fossil fuel resources tend to be exhausted requires concerted efforts by stakeholders to identify new, sustainable, and alternative energy sources (Ayuk *et al.,* 2020).

Biomass fuel briquettes have received global acceptance as a better replacement for fuelwood (firewood) and charcoal for heating, cooking, and other industrial applications in urban and rural areas (Mwamlima *et al.,* 2023). Biomass briquettes are considered superior alternatives to traditional fuels due to their higher energy efficiency, lower emissions, and

sustainability. They have higher energy density, resulting in longer burn times and greater heat output per unit compared to raw biomass or traditional wood fuels. Additionally, biomass briquettes produce fewer emissions, including lower levels of particulate matter, sulfur oxides, and nitrogen oxides, contributing to improved air quality and reduced health risks. Furthermore, the use of agricultural waste for briquetting promotes environmental sustainability by reducing deforestation and managing waste effectively.

The Nigerian Conservation Foundation (NCF) reported that Nigeria lost almost all of its original forest due to deforestation, which is partly attributed to the use of fuel wood and charcoal for energy (Mong *et al.,* 2022). Most rural dwellers (about 70% of people in Nigeria) and almost all farmers heavily depend on wood fuel for all their domestic and other commercial activities that require heat (Mohammed *et al.,* 2018). The energy crisis in Nigeria is exacerbated by the overreliance on traditional energy sources like firewood and fossil fuels, which are increasingly unsustainable and environmentally harmful. Biomass briquettes offer a viable solution to this problem by providing an alternative, renewable source of energy that can alleviate the pressure on existing resources and reduce environmental degradation.

Rice husks (RH) are the protective outer coating surrounding rice grains that are separated during milling. In rice-producing countries such as Nigeria, rice husk is a waste material containing 30-50 % organic carbon and 17–23 % ash (Masilan *et al.,* 2023). Included in this composition are cellulose (50 %), lignin (30 %), silica (SiO3) 16-20 % and moisture, 10-15 % (Pharm *et al.,* 2019). Palm kernel shells (PKS), also known as palm kernel expeller (PKE), are the hard endocarp of the palm kernel fruit that surrounds the palm kernel seed of the oil palm tree (Elaeis guineensis). PKS is a by-product produced when the kernel is crushed to remove palm seeds after the production of palm kernel oil. PKS is rich in proteins and fibers. It has high energy value, low ash content, and low water content, making it suitable for energy purposes (Kahar *et al.,* 2022).

Biomass briquetting is the densification of loose biomass materials to produce compact solid composites of different sizes under the application of pressure (Sa'ad and Bugaje 2016). The process of converting rice husks and palm kernel shells into briquettes not only addresses waste management issues but also provides a sustainable energy source that can contribute to alleviating Nigeria's energy crisis. The advantages of biomass briquettes, such as improved combustion efficiency, reduced emissions, and utilization of agricultural waste, underscore their potential impact.

A review of existing literature reveals a range of studies focused on the production and evaluation of biomass briquettes from various agricultural residues. For instance, Tembe *et al.,* (2014) explored the use of groundnut shells, rice husks, and sawdust for briquetting, achieving favorable density and combustion properties. Ibitoye *et al.,* (2023) investigated corncob and rice husk briquettes, reporting results comparable to the present study in terms of density and heating value. These studies highlight the potential of different agricultural residues for briquetting but indicate a gap in comprehensive evaluations involving rice husks and palm kernel shells combined with cassava starch as a binder.

In this research work, the evaluation of the physicochemical properties of briquettes from rice husk and palm kernel shells was carried out using cassava starch as a binder with the application of pressure, to determine the compressed and relaxed density, proximate analysis, and calorific value of the briquettes. The study aims to address Nigeria's energy challenges by providing an affordable alternative fuel for households and industries. By focusing on the combination of rice husks and palm kernel shells, this research seeks to fill the gap in literature and demonstrate the potential of these materials in producing high-quality biomass briquettes.

Despite the promising benefits, producing and using biomass briquettes also present certain challenges. Issues such as material handling, binder efficiency, and market acceptance need to be addressed to ensure the widespread adoption of briquettes. Additionally, the variability in the quality of agricultural residues and the consistency of briquette production are potential limitations that require attention. Acknowledging these challenges provides a balanced view and sets realistic expectations for the study's contributions.

The scope of this research includes investigating specific research questions related to the physicochemical properties of the briquettes: What are the compressed and relaxed densities of the briquettes produced from rice husks and palm kernel shells? How do the moisture content, volatile matter, ash content, and fixed carbon vary among different briquette compositions? What is the higher heating value of the briquettes, and how does it compare to conventional fuels? By addressing these questions, the study aims to provide valuable insights into the potential of biomass briquettes as an alternative energy source in Nigeria.

Sugar development sector is one of enormous projects which enables industry take a leading role in the nation’s economy. Ethiopia has huge human as well as natural resources which enable the nation to broaden this export oriented manufacturing industry sector and its productivity. The nation has suitable climate, wide and proved irrigable agricultural land (more than 500 thousand hectares) as well as abundant resource of water to use through canal schemes. The government in its effort to ensure equitable share of the nation’s resource among its peoples, has started broadening the sugar development sector.

The industrial strategic development plan of Ethiopia gives great emphasis to improve export-led products to join the international market in large-scale such as sugar factory. Sugar sector plays a unlimited role in the socio-economy of Ethiopia since it produces sugar for household and industrial consumptions, provides great job opportunity for the nationals, serves as source of energy and co-products are used for miscellaneous purposes. However, the liquid, gaseous and solid effluents produced from sugar industry have adverse impact on ecosystem and environment due to their high BOD load and toxicity. Bagasse is a main byproduct of sugar industry which finds a useful utilization in the same industry as an energy source. Sugarcane consists of 25 to 30% bagasse whereas sugar recovered by the industry is about 10% (Maung et al., 2015). Bagasse has high calorific value and hence it is usually used as a fuel in boilers in the sugar mills to generate steam and electricity. Each ton of sugarcane generates approximately 26% of bagasse (at a moisture content of 50%) and 0.62% of residual ash (Maung et al., 2015). However, currently, not all bagasse produced is used in the factories for the generation of heat and power. It is difficult to handle, transport and where storage facilities are lacking, and hence the surplus is dumped in compounds around the factory posing serious environmental problems, including fire hazards.

Huge amount of bagasse are produced annually by the sugar factories in Ethiopia constituting about 4.6% of the total bagasse production (Thinda et al., 2012). Disposal of bagasse has become a serious problem and large quantities of bagasse are regularly accumulated on open spaces around sugar factory thereby endangering fragile ecosystem. To reduce pollution hazards, industry should implement environment management system to advance economic and environmental performance of sugar processing unit.

In the search for new alternative sources of ecologically friendly energy, the utilization of Bagasse for the production of briquettes has become a good alternative. A briquette is biochar in a particular shape, made by using pressing techniques and adhesives (Fikri and Sartika, 2018). Bagasse carbonization process is environmentally friendly, energy self-providing continuous flow technology. Thus, the objective of the research was to use bagasse for the production of energy (high caloric value briquette) and ultimately safeguard the environment from pollution.

Justification

i-Briquette production saves us from using our tress for charcoal or firewood

ii-Both charcoal and firewood produces smokes but briquette did not

iii-Since no smoke is produced that is why briquette is used brooding of chicks

iv-Briquette is used in the brooding again because the amount of the amount of heat produced can be control or regulated

v-Briquette is made from waste materials thereby removing the waste and dirts that would have constitute nuisance in our environment

Aim and objectives of the study are :

i-Prepare briquette from different waste materials

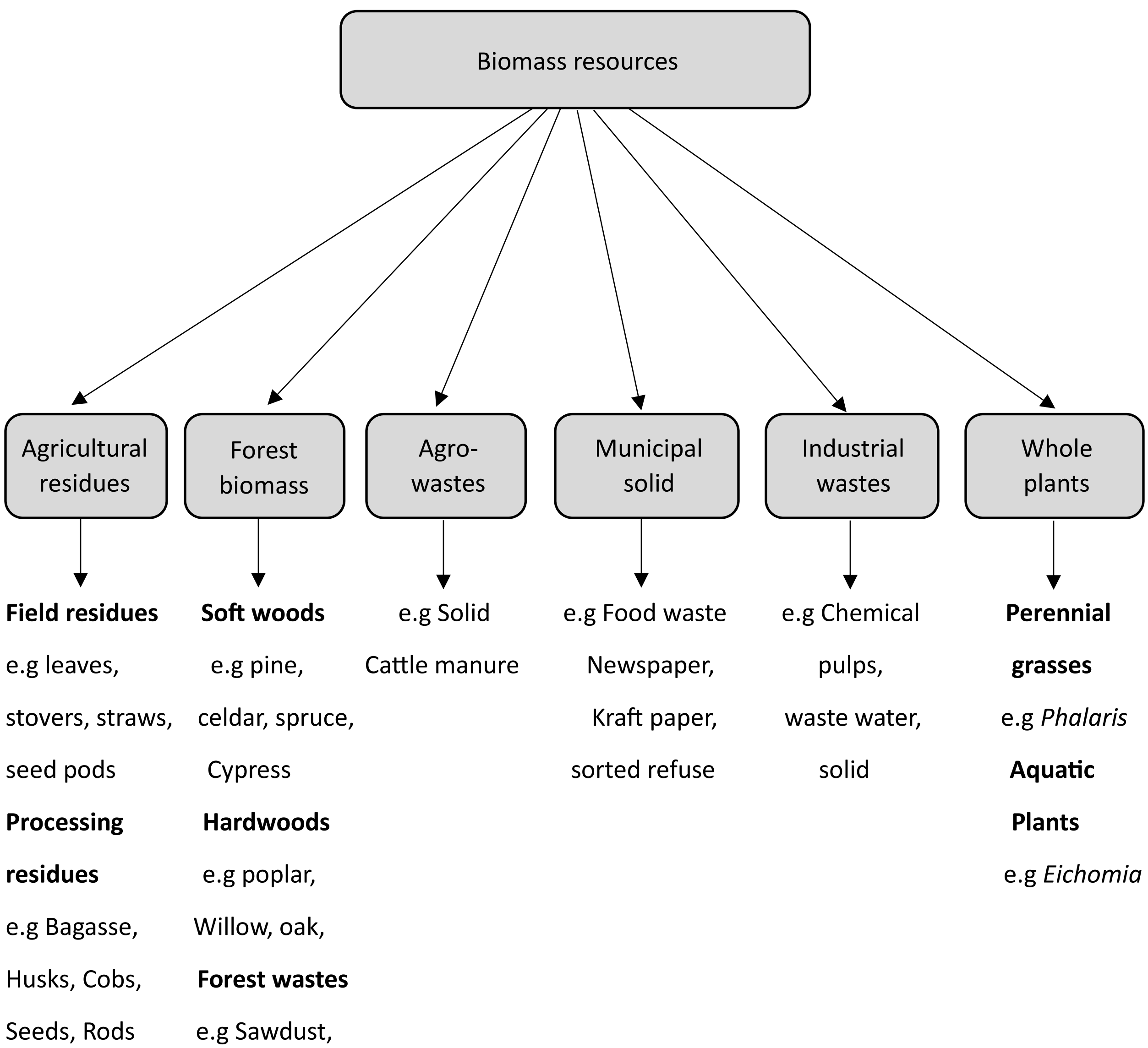
ii- Use different binding materials in the production of briquette

iii-Use the briquette in brooding or cooking so as to know the effect of different waste materials used in making briquette iv-Use the briquette in cooking or brooding to know the effect of different biding materials used in making the briquette

CHAPTER TWO

Literature Review

2.1. Biomass resource The organic polymers originally produced by sunlight is called biomass. It is a dry matter which is an abundant and very cheap source of renewable energy and can be referred to as lignocellulosic biomass (Dhyani & Bhaskar, 2018; Park et al., 2014). The categories of typical lignocellulose biomass sources are shown in Figure 2.1.



woodchip

2.1.1. Agricultural residues The world's total biomass is made up of agricultural residues obtained from crops which are wheat, rice, sugarcane, and corn (Zabed et al., 2016; Biswas et al., 2017). Apart from being environmentally friendly, agricultural residues are considered as short-harvest ration which makes them more readily available than forest residues and reduces the reliance on woody biomass which causes deforestation (Limayem and Rickle, 2012). Therefore, different highvalue products such as biofuels and added fine chemicals can be produced from the hugely available amount of agricultural residues. Agricultural residues possess high energy content in the form of cellulose, hemicellulose, and lignin (Biswas et al., 2017). According to Limayem and Rickle (2012), they are 25-35% more hemicellulosic than forest biomass. Potential agricultural lignocellulosic feedstocks and their composition are described in Table 2.1. Table 2.1: Potential agricultural lignocellulosic feedstocks and their composition. Agricultural residue's high levels of hemicellulose (24-32%) and low levels of lignin (3-13%) makes them advantageous over woody biomass because they do not require as much energy during pre-treatment such as size reduction of their a less resistant texture (Limayem and Rickle, 2012).

2.1.2. Lignocellulose biomass physicochemical characteristics Approximately 70% of the total biomass is made up of cellulose and hemicellulose. Due to covalent and hydrogen bonds, they are directly linked to the lignin component which makes the structure highly robust and resistant to any treatment (Limayem and Rickle, 2012; Viikari et al., 2012). According to Zabed et al. (2016), the recalcitrance is attributable to the crystallinity of cellulose, accessible surface area, and protection by lignin, and heterogeneous character of the biomass particle. As shown in Table 2.1 cellulose, hemicellulose and lignin proportions of lignocellulosic biomass components differ according to biomass types which gives variation in the digestibility

2.1.2.1. Cellulose is an organic polymer that contributes approximately 30% of the plant composition (Limayem and Rickle, 2012). The polymer is joined with linear chains up to 12 000 residues containing glucose and it is largely composed of (1,4)-D-glucopyranose units with an average molecular weight of around 100 000 which are connected by β-1,4 linkages (Anwar et al., 2014). This cross-link between numerous hydroxyl groups creates extensive hydrogen bonds among the cellulose molecules forming microfibrils that result in a crystalline matrix structure which makes molecules more rigid and water-insoluble and resistant to depolymerisation (Zabed et al., 2016).

2.1.2.2. Hemicelluloseis a heterogeneous group of branched polysaccharides surrounding the cellulose fibres which is a connecting link to cellulose and lignin and its structure element contains various monomers such as glucose, galactose, mannose, xylose, arabinose, and glucuronic acid (Dhyani and Bhaskar, 2018). The β-1, 4 linkages that include approximately 90% D–xylose and 10% L–arabinose are made up of xylan which is the backbone chain of the polymer (Zabed et al., 2016). Comparing hemicellulose to cellulose, the degree of polymerisation is much lower by 50-200 monomers. Also, hemicellulose is 9 amorphous and has lower physical strength which makes it susceptible to hydrolysis by dilute acids, alkalis, and enzymes (Dhyani and Bhaskar, 2018)

2.1.2.3. Lignin is a heterogeneous polymer that contributes approximately 10-25% of the biomass by weight and is largely composed of long-chain phenyl-propane units that are commonly linked by ether bonds (Anwar et al., 2014). It is present in all lignocellulosic biomass, and it binds cell walls component together by filling the gab around and between the cellulose and hemicellulose polymers (Dhyani and Bhaskar, 2018; Anwar et al., 2014). There is approximately 3-15% of lignin in agricultural residues (Zabed et al., 2016).

2.1.3. Corn residues As mentioned earlier, agricultural residues make up a huge amount of the total biomass and its utilisation for bioenergy production is common for many countries but there is little experience in energy conversion for other agricultural residues (corn residues) for solid fuels production (Batidzarai et al., 2016). Thus, this study focuses on the use of South Africa's staple food maize, where the interest is the corn-stover (CS) for bio-briquettes production.

2.1.3.1. Description of corn-stover Corn-stover is usually left in the field after the harvest of maize. Its structural components comprise the leaves, stalks, husks and stem without the grain, accounting for 80% of the corn residue in agricultural crop production (Barten, 2013). According to Danje (2011), CS contains 32.4% cellulose, 40.8% hemicellulose and 25% lignin. This composition illustrates that CS has a great potential as renewable raw material just like corn cobs. Due to the abundance of CS, it attracts interest in the energy sector to be used as a raw material to produce solid composite fuel known as briquettes for industrial and domestic uses (Klingenfeld et al., 2008).

2.1.3.2. Characterisation Agricultural Biomass feedstocks have a variety of characteristics that are essential when considering their potential use (Milhollin et al., 2011). The key chemical characteristics in terms of HHV, ultimate and proximate analyses of various agricultural feedstocks are detailed in Table 2.2

According to Capunitan (2012) for biomass to render as suitable biofuel, the oxygen content must be reduced to improve its heating value. The authors further mentioned that it is desirable to have biomass with relatively low ash content and high volatile matter as a feedstock during any conversion process, because it readily releases a lot of volatile compounds while leaving the solid product with less ash and high fixed carbon content. Hence, improving its heating value and rendering it a valuable solid fuel CS is desirable as a potential feedstock for biofuel production as not only does it have lower ash contents and high volatile matter and it also has lower sulphur contents as well as being carbon

neutral. Also, although materials burn better than others, the easy access and availability of biomass is usually the determining factor for raw material selection (Sani, 2008).

2.2. Corn-stover availability and its current use The agricultural sector generates corn residues every year particularly corn-stover (Salema et al., 2017). Power plants, cellulosic ethanol plants, and biomass densification businesses would be interested in potentially using this feedstock (Milhollin et al., 2011). It is estimated that a total amount of 16 million tonnes of CS biomass is generated per year in South Africa. This total includes the below and above ground biomass at 6.3 million and 9.7 million tonnes, respectively. CS is potentially available in different provinces across South Africa, with significant amounts in Mpumalanga (31%), Free State (32%) and Northern Cape (26%) (Batidzirai et al., 2016). Conventionally, CS is used for animal bedding and feed and as well as a soil amendment. (Klingenfeld, 2008; Salema et al., 2017). However, excess biomass remains, and the need to safely dispose of it is still a challenge (Huang et al., 2013). It is important to note that the below-ground biomass is not available for removal and can only be used for soil organic control maintenance. Therefore, the required CS for soil erosion control is about 4.2 million tonnes and about 9.3 million tonnes for soil organic carbon (SOC) maintenance. For districts that have excess residue, it is estimated that about 260 thousand tonnes of CS account for animal feed. This results in about 5.1 million tonnes of total CS that remains and is available in excess per year after the combined estimated required 9.5 million tonnes for soil amendment and animal feed (Batidzirai et al., 2016). This motivates the use of the most abundant agricultural biomass CS as the feedstock in this study.

2.3. Limitations Despite CS being a potential renewable energy source, it has a very low bulk density, irregular shapes, and sizes, has high moisture content making it to be difficult to handle, transport and store (Wang et al., 2011). CS has a potential challenge such as high alkaline content in the stover ash when directly combusted. This usually causes slagging and fouling during burning in boilers etc (Milhollin et al., 2011). Also, CS as loose biomass tends to retain the moisture content of about 33% and high moisture content affects its higher heating value. The heating values of CS and various other solid where CS has the lowest HHV value in comparison to conventional fuels due to the characteristics it possesses.

CHAPTER THREE

Materials and Methods

Site of the experiment: The experiment was carried out in the Agricultural garden of Agricultural department of Kwara State Polytechnic, Ilorin.

Material for making Briquette: The materials include waste farm materials, like Rice bran, Maize cob, Maize shaft while binding materials are starch (strong one made from cassava) or Cement (used in ratio 3:1)

Briquette Production

i-From powdered charcoal

Ruminant of full bag of charcoal bag which is the powered ones after the real charcoal has been exhausted are collected and recleaned to remove the real charcoal so that you can have even and fin3 powdered charcoal, this is then mix with either starch or cement, if starch is to be used, it is mixed thoroughly so that all parts have fair share of the starch, it mixed about three or four times

But if cement is to be used ratio 3:1 of charcoal to cement are used and water is then added in a way to foam a paste after which the paste of either charcoal and starch or charcoal and cement is made then, a plastic moulde is then used to mould it into blocks by compressing it very well and then make a hole at the Centre so that we can have proper combustion and it is then sundry properly after which it is used ii-Sample then, the collected samples of bagasse were chopped into suitable size, and then dried in oven dryer at a temperature of 500°C for 24 h. All physical and chemical analyses of the sample were done at Ethiopian Rural Energy Development and Dissemination Center The bagasse sample was allowed to dry in oven for 24 h before carbonization to remove the moisture and facilitate the carbonization process. The bagasse sample was carbonized separately in an oxygen scarce environment using metal barrel-kiln carbonization machine. The process of carbonization was carried out in oxygen limited condition in barrel kiln with long chimney; which was used to control the proper air for carbonization process. Then, the carbonized material was removed immediately from the metal barrel-kiln carbonization machine and cooled using water. The cooled charcoal was dried in a naturally ventilated room at temperature of 25 to 30°C for two days. After being cooled and dried, the carbonized bagasse was ground using a milling machine (hammer mill) and sieved with a mesh size of 3 mm to obtain particles in the size range from 1 to 3 mm.

The prepared carbonized materials/charcoal powder was mixed with a binder to produce a briquette. Clay and molasses were used as a binder in different ratio for making briquette during the experiment. Based on the experiment design the binder was manually mixed in different concentration with the prepared carbonized materials/charcoal. Then the mixture was converted into briquettes by using a briquette extruder machine. Finally, the briquettes were placed on a suitable material for drying under the sun.

iii- Rice husk and Palm kernel shell

The handpicking technique was employed for the initial removal of unwanted materials from raw rice husk and palm kernel shell samples. The leftovers were ground into smaller particles and sun-dried in an open place for 7 days to remove their extrinsic moisture content. The rice husk and palm kernel shells were ground into a powder and sieved using a 1 mm sieve. The particle size before grinding was approximately 2-3 mm. The drying environment maintained an average temperature of 35 °C and relative humidity of 25%. The samples were prepared, weighed, and mixed for characterization and briquette production.

One liter of water was put into a pot and brought to a boil using a local charcoal stove; 400 g of starch was mixed with cold water (0.5 L) in a separate container to form a paste, making it easier to incorporate into hot water. Once the water boiled, the paste was poured into the boiling water and continuously stirred for approximately 15-20 minutes until it became thick and cloudy. The starch solution was allowed to cool to room temperature for 2-3 hours before use. The mixture was then gradually poured into a binder-to-raw-material ratio of 25:75 wt of 300 g.

The briquettes were produced at the Physics Department, Federal University of Technology, Minna, Niger State, Nigeria. Samples of rice husk (RH) and palm kernel shell (PKS) were thoroughly mixed to obtain a uniform and homogeneous mixture. The mixtures were prepared at the following weight ratios of rice husk to palm kernel shell: 90:10, 80:20, 70:30, 60:40, 50:50, 100:0 and 0:100, with the addition of 25% cassava starch gel as the binder. The mass of water mixed with the raw material was 400 ml while the mixing time of the composite materials (rice husk, palm kernel shell, and binder) was 10 minutes. In each case, the mixture was hand-fed into a briquette machine and compacted using a manually operated 20-ton air hydraulic piston press with a pressure gauge to obtain the compressive pressure at room temperature and relative humidity. The compressive pressure used in this study was 110 bar. A dwell time of 1-2 minutes was used for each bio-residue consolidated in the mold after loading and compaction to prevent spring-back. Twelve (12) briquettes were produced per batch. The average time taken by two people to produce 12 briquettes from loading to removal was 18 minutes. The briquettes were cylindrical with a 1.0 cm diameter placed in the center to create a hole in the middle of the briquette. The holes help to increase the porosity and oxygen supply, thereby improving briquette combustion

CHAPTER FOUR

Results and Discussion

Briquette are found very useful, it produces steady heat, that is controllable with no smoke when made with normal or common materials like waste charcoal powder, rice bran and very thick starch made from cassava as binding material.

While briquette is made from same materials above with cement as binding materials are stronger they don't break easily like that made with cassava but it takes more time before it catches fire, we all know briquette is lighted with charcoal picked from already burning fire and it burn a little bit slowly when compared with the one made from starch.

When briquette is made sawdust it produces a lot of smoke and is considered not appropriate for brooding chicks

Limitations to use of Briquette

i-It is critical to water and losses its compactness when wet and becomes useless
ii-Store in large space and dry condition
iii-Initial burning is stressful and becomes a problem in raining and winter season
iv-Ash disposal is also hurdle
v-Required to be pieces before use, this is another problem because Briquette is a very hard substance
vi- Special stove is required

Reasons for acceptability

i-Availability

ii-Economical to use

iii-Good fuel property

iv- Low moisture and high burning efficiency

v- Easy to store

vi- All the ingredients required are waste not useful elsewhere, this makes it cheaper

vii- Produces noo smoke and odour

viii- Good physical properties

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Briquette is a very good biofuel because of its efficiency, readily available and is cost effective, the material and ingredients used in making briquette maters as this contributes to its performance. It catches fire easily when starch is used as binder than when cement is used as binder. The performance is very high if Rice husk is used than other ingredients.

Recommendations

Briquette is recommended for use by everyone because it is environmental friendly, it reduces deforestations, it is cheap and the ingredients are available everywhere

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