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Density of Briquettes Produced from Bambara Groundnut Shells and It's Binary and Tertiary Combinations with Rice Husk and Peanut Shells

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Abstract
The density of briquettes produced from bambara groundnut shells and its binary and tertiary combinations with rice husk and peanut shells was investigated for its potentials in domestic cooking. The bambara groundnut shells, rice husk and peanut shells were collected from various locations in Benue State Nigeria, where the agro products are produced in large quantities. The briquetting process and assessment of compressed and relaxed densities were conducted in the Department of Forestry laboratory of the University of Agriculture Makurdi Nigeria. The experimental design was 4 x 2 x 3 factorial in Completely Randomized Design (CRD) with 4 replicates. There were 4 briquette types, 2 briquette shapes and 3 percentage starch binder levels. Bambara shells and its binary and tertiary combinations with Rice husk and Peanut shells were collected, dried, ground, sieved to uniform fraction of 1.17mm and used to produce donut and puck shaped briquettes at 15%, 25% and 35% of starch binder. The briquette combinations were Bambara (100:0), Bambara + Rice (50:50), Bambara + Peanut (50:50) and Bambara + Rice + Peanut (33:33:33). The results were analysed using ANOVA and LSD at $p \leq 0.05$ and descriptive statistics. The compressed densities of bambara briquettes and its binary and tertiary combination with rice husk and peanut shells were significant. Bambara briquettes recorded the highest compressed density of 1.0g/cm3, while the relaxed densities of the briquettes were not significant. Bambara briquettes produced the lowest relaxed density of 0.55 g/cm^3 while bambara + rice briquettes had the highest relaxed density of 0.87 g/cm^3.The effect of percentage starch binder was significant on compressed density of bambara briquettes and its combinations but the relaxed density was not significant. The effect of briquette shape was significant on compressed and relaxed densities of the briquettes. Puck shaped bambara briquettes and its combinations recorded higher compressed and relaxed densities than donut shaped briquettes. Bambara briquettes showed favourable physical and combustion properties that are suitable for utilization as alternative fuel energy. Bambara shells and its binary and tertiary combinations with rice husk and peanut shells are therefore, recommended for production of briquettes as alternative fuel for domestic cooking due to the high energy composition of the briquette.
Keywords: Compressed density, Relaxed Density, Briquette type, Percentage binder, Briquette shape.

1.Introduction

The need for renewable and sustainable alternative energy sources is growing due to the rapid depletion of fuelwood and the environmental impacts of over its exploitation (FAO, 2007). Biomass resources are of great interest as briquette materials because of associated miscellaneous advantages such as abundance, low price and very high worldwide potential (Yahaya and Ibrahim 2012). Biomass materials according to United States Agency for International Development (USAID), (2010) include all renewable organic materials that contain energy in a chemical form that can be converted to fuel through briquetting. Biomass comprises the residues from agricultural operations, food processing, forest residues, municipal solid wastes and energy plantations.

Advances have been made in briquette production from various biomass materials and bambara groundnut shells offer full potentials for briquette production due to its priceless abundance. Bambara groundnut is the third most important grain legume after peanut and cowpea in Sub-Sahara Africa (Rachie & Silvestre, 1977). The annual world production is 330,000 tons, 45-50% of which are produced in West Africa (Nigeria, Niger, Burkina Faso, Chad, Cote d'Ivoire, Ghana & Mali) (PROTA, 2006). Bambara groundnut is cultivated primarily for its subterranean pods rich in protein which helps to alleviate nutritional disorders in humans and livestock (Massawe *et al*. 2002). The seeds of bambara groundnuts are used in cooking moi moi which is eaten by people in urban and rural areas of Benue state, while its shells are simply discarded indiscriminately as agricultural waste causing environmental degradation. Producing briquettes from bambara nut shells will increase the pool of raw materials for briquetting, reduce the over dependence on wood fuel for domestic cooking and reduce the impact of environmental degradation associated with wanton disposal of bambara groundnut shells.

This study determines the density of bambara groundnut shells and its binary and tertiary combination with rice husk and peanut shells, as the major index of assessing the amount of matter and energy contained in briquette samples. Density also determines the combustion and handling characteristics of briquettes. The higher the density values for any briquette samples the higher the corresponding energy and strength qualities of the briquettes (Sotannde *et al*. 2010). Briquette density was determined in form of compressed density which was measured immediately after briquettes were produced (0minutes) and relaxed density which was measured after briquettes had dried (Sotannde *et al*. 2010).

2.Materials and Methods

2.1 Study Area

Bambara groundnut shells, peanut shells and rice husk were collected in farming communities around Makurdi town in Makurdi LGA of Benue state Nigeria, where the nuts are produced in large quantities. The briquettes were produced and analysed for density in the Laboratory of Department of Forest Production and Products, University of Agriculture Makurdi, Benue State Nigeria.

2.2 Briquetting Process

Bambara groundnut shells, peanut shells and rice husk were air dried to reduce moisture content to between 8-12% which is within the acceptable operating limit for briquetting (Eriksson and Prior, 1990) and (Maninder *et al*. 2012). A grinding machine was used to grind the samples while a sieve of 1.17mm as used by Harrell *et al.* (2010), was used to obtain uniform grain size distribution for the samples. The ground particles were weighed, labeled and stored ready for briquetting. The ratios of the briquette types (combinations) were: Bambara (100:0), Bambara + Rice (50:50), Bambara + Peanut (50:50), Bambara + Rice + Peanut (33.33:33.33:33.33). A briquetting steel mould (die), a hydraulic press and weighing balance were used in briquetting the samples. Two shapes of briquettes: Donut and Puck shaped briquettes, as used by Harrell *et al.* (2010) in producing peanut briquettes were used for the study. For either donut or puck shaped briquettes, 100g of dried ground and uniformly sieved samples were mixed with cassava starch binder until a uniform mixture was obtained. The proportion of starch binder was 15%, 25% and 35% of the dry weight of samples. Thus, the component ratio (sample: binder) in each charge for briquetting was 100:15, 100:25 and 100:35 (Sotannde *et al.* 2010). The briquetting die (mould) was made of cylindrical steel die 10mm high and 6.4mm in diameter with a rod in the centre and a 2mm hollow diameter screw plate to accept the rod. The steel cylindrical die was hand-filled with 100g weight of sample-binder mixture, covered with a top plate and compressed manually using a hydraulic press at a pressure of 19.62KN/m^2 .The compressed briquettes were kept under pressure for a dwell time of 90 seconds. The same die used for producing donut shaped briquettes was also used in producing puck shaped briquettes but the hollow screw plate was replaced with a compact screw plate without hole.

2.3 Determination of Density

The weights, heights and diameters of 4 representative briquettes were measured at 0, 30, 60 and 1440 (24hrs) and 10,080 minutes (7days) intervals to obtain the relaxed densities of the briquettes in the dry condition. The compressed densities (density immediately after compression) of the briquettes was determined immediately after extrusion from the die as the ratio of measured weight to the calculated volume (Olorunnisola, 2007). The weights of produced briquettes were determined using digital weighing balance, while the average diameters and heights of the briquettes were taken at 2 different positions using calipers to determine the volume. For the donut shaped briquettes, the outer volume was subtracted from the inner volume to obtain the actual volume of the briquettes. The initial, maximum and the relaxed densities of the briquettes were determined using the die dimensions and ASAE (2004) standard method of determining densities.

Density was determined for each briquette as ratio of briquette weight to volume.

$$\text{Density} = \frac{\text{Weight of Briquette}}{\text{Volume of briquette}}$$

The relaxed densities (density determined when dried) of the briquettes were determined in the dry condition at 30, 60 and 1440 (24hrs) and 10,080 (7days) minutes of the briquette after sun drying to a constant weight at an ambient temperature of 33 ± 2^{o}C and relative humidity of 58 ± 2% respectively (Obi *et al.* 2013).

2.4 Data Analysis

The data collected for sample tests were subjected to analysis of variance using the 4x2x3 factorial design in Completely Randomized Design (CRD). Statistical analyses were conducted using GenStat Discovery Edition Release 7.2 DE at 5% significant levels and where significant differences were identified, the difference between the mean values were tested using the Fisher's Least Significance Difference (LSD).

3. Results and Discussion

3.1Effect of Briquette Type on Density of Bambara Briquettes and Its' Combinations

The result of analysis of densities of bambara briquettes (Table 1) showed that briquette type had significant effect ($p<0.05$) on the compressed density (density at 0 minutes) and relaxed densities of Bambara briquettes at

30 minutes and 1 hour. Bambara briquettes recorded the highest compressed and relaxed densities within the drying time of 0 minutes to 1 hour, followed by Bambara + Rice briquettes (Table 1). This could be attributed to the moisture retention capacity of Bambara and Bambara + Rice briquettes which increased the mass per unit volume of the briquettes as observed by Bamgboye and Bolufawi (2009). The compressed and relaxed densities of briquettes in Table 1 showed a progressive decline in values from 0 minutes to 7 days. The compressed densities were higher than the relaxed densities at 30 minutes, 1 hour, 24 hours and 7 days (Table 1). The higher results for compressed density could be related to the effect of moisture contained in the starch binder which increased the mass per unit volume of the briquettes immediately after removal from the die. The moisture loss due to drying of the briquettes from 30 minutes to 7 days resulted in reduction in density values as drying progressed (Maninder *et al*. 2012). High quality briquettes are obtained at reduced moisture content levels as too much moisture causes steam formation and could affect heating characteristics or even cause explosion (Maninder *et al*. 2012). In 24 hours and 7 days of drying the relaxed densities of bambara briquettes were not significant ($p<0.05$) indicating that all the briquettes types had lost sufficient moisture and could serve as efficient briquette materials Obi *et al*. (2013). The relaxed densities ranged from 0.55 g/cm^3 -0.87g/cm^3 in 7 days with Bambara + Rice briquettes recording the highest relaxed density of 0.87 g/cm^3. The relaxed density of 0.87 g/cm^3 for Bambara + Rice briquettes was higher than 0.15 g/cm^3 obtained by Adetogun, *et al*. (2013) in their work on briquettes from maize cob, 0.7269 g/cm^3 obtained by Obi *et al*. (2013) in their work on sawdust briquettes, 0.75g/cm^3, 0.69g/cm^3, 0.81 g/cm^3 and 0.65 g/cm^3 respectively for rice husk, maize cob, groundnut shells and sugar cane baggasse respectively as reported by Idah and Mopah (2013).

Table 1: Means of Briquette Type and Density of Bambara Briquettes

Bambara + Combinations	Density (g/cm^3)				
	0mins	30mins	1hr	24hr	7days
Bambara	1.00^a	0.92^a	0.90^a	0.76^a	0.57^a
Bambara + Peanut	0.81^b	0.78^b	0.78^b	0.67^a	0.57^a
Bambara + Rice	0.86^b	0.86^c	0.82^c	1.11^a	0.87^a
Bambara + Rice + Peanut	0.81^b	0.78^b	0.75^d	0.66^a	0.55^a

Note: Means with the same alphabets are not significantly different

3.2 Effect of Percentage Binder on Density of Bambara Briquettes and Its' Combinations

Analysis of variance result showed that percentage binder had significant effect ($p<0.05$) on compressed and relaxed densities of bambara briquettes at 30 minutes and 1 hour of drying (Table 2). In 24 hours and 7 days of drying the percentage binder concentration had no significant effect ($p>0.05$) on relaxed densities of bambara briquettes. The maximum compressed density of 0.93 g/cm^{3}was observed at 35% binder levels, this was significantly higher than 15% and 25% binder levels with 0.88 g/cm^3 and 0.80 g/cm^3 respectively (Table 2). In 7 days of drying, briquettes with 35% percentage binder still recorded the highest relaxed density of 0.84 g/cm^3 which was higher than 0.50g/cm^3 and 0.58g/cm^3 for 15% and 25% binder levels respectively (Table 2). This implies that compressed and relaxed densities of briquettes increased with increase in percentage binder level. This could be related to the fact that binder increases the bonding capacity and compactness of the briquette materials on drying, therefore the higher the binder level the higher the expected increase in the mass per unit volume of briquettes. This similar trend was reported by Bambgoye and Bolufawi (2009) in their work on guinea corn briquettes.

Table 2: Means of Percentage Binder and Density of Bambara Briquettes

Percentage Binder	Density (g/cm^3)				
	0mins	30mins	1hr	24hr	7days
15 percent	0.80^c	0.75^c	0.73^{ac}	0.62^a	0.50^a
25 percent	0.88^b	0.85^b	0.84^b	0.72^a	0.58^a
35 percent	0.93^a	0.91^a	0.87^a	1.00^a	0.84^a

Note: Means with the same alphabets are not significantly different

3.3 Effect Shape on Density of Bambara Briquettes and Its' Combinations

The result of effect of briquette shape on density of bambara briquettes is shown in Table 3. The result show that briquette shape had significant effect ($p<0.05$) on compressed density and relaxed densities at 30 minutes, 1 hour, 24 hours and 7 days of briquette drying. Puck-shaped briquettes had significantly higher ($p<0.05$) compressed density of 0.97g/cm^3 than donut shaped briquettes with compressed density of 0.77 g/cm^3 (Table 3). The relaxed density of puck shaped briquettes reduced from 30minutes to 1 hour at 0.92 g/cm^3 to 0.88 g/cm^3 and finally to 0.84g/cm^3 in 7 days while the relaxed density of donut shaped briquettes was 0.44g/cm^3 in 7 days (Table 3). In general, puck shaped briquettes had higher compressed and relaxed densities than donut shaped briquettes (Table 3). Higher compressed and relaxed densities of puck shaped briquettes may be related to the possible compactness of the particles since the steel mould (die) for producing puck shaped briquettes. Puck shaped briquettes had a flat compact base and the hydraulic press could more effectively compress the particles together unlike the donut shaped die which had an extruded iron rod in the middle which may reduce the impact of compression, a similar trend was reported by Bamgboye and Bolufawi (2009). This result agrees with Harrell *et al*.(2010) in their work on peanut shell briquettes that Puck shaped briquettes produce higher briquette densities.

Table 3: Means of Briquette Shape and Density of Bambara Briquettes

Briquette shape	Density (g/cm^3)				
	0mins	30mins	1hr	24hr	7days
Donut	0.77^b	0.75^b	0.74^b	0.61^b	0.44^b
Puck	0.97^a	0.92^a	0.88^a	0.97^a	0.84^a

Note: Means with the same alphabets are not significantly different

4. Conclusion and Recommendations

Briquette type, Percentage binder and Briquette shape had significant effect on compressed density (density at 0 minutes) of bambara briquettes. At 30 minutes and 1 hour, briquette type, percentage binder and briquette shape and its binary combinations had significant effect on relaxed density of bambara briquettes. The tertiary combinations had no significant effect on relaxed density on Bambara briquettes at 30 minutes and 1 hour. At 24 hours and 7 days only briquette shape had significant effect on relaxed densities of bambara briquettes.

Bambara shells, rice husk and peanut shells are suitable briquette materials and should be used in producing briquettes at binary and tertiary combination due to the high briquette potentials obtained from the briquettes.

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