Production of Fuel Briquettes from Waste Paper and Coconut Husk Admixtures

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ABSTRACT

Nigeria has abundant supplies of biomass resources, particularly agro-forestry residues and municipal solid waste, whose potentials are yet to be fully tapped for energy generation. The study was undertaken to investigate the properties of fuel briquettes produced from a mixture of a municipal solid waste and an agricultural residue, i.e., shredded waste paper and hammer-milled coconut husk particles. Briquettes were manufactured using a manually-operated closed – end die piston press at an average pressure of 1.2 x 10^3 N/m^2 using four coconut husk: waste paper mixing ratios (by weight), i.e., 0:100; 5: 95; 15: 85; and 25: 75. Results obtained showed that briquettes produced using 100% waste paper and 5:95 waste paper-coconut husk ratios respectively exhibited the largest (though minimal) linear expansion on drying. While the equilibrium moisture content of the briquettes ranged between 5.4 % and 13.3%, there was no clearly discernible pattern in e.m.c variation with increase in coconut husk content. A reciprocal relationship was observed between compressed/relaxed density and relaxation ratio of the briquettes. The mean durability rating of all the briquettes exceeded 95%. It was concluded that stable briquettes could be formed from waste paper mixed with coconut husk particles.

Key Words: Waste paper, coconut husk, briquettes, density, relaxation, durability

1. INTRODUCTION

Traditionally, wood in form of fuel wood, twigs and charcoal has been the major source of renewable energy in Nigeria, accounting for about 51% of the total annual energy consumption. The other sources of energy include natural gas (5.2%), hydroelectricity (3.1%), and petroleum products (41.3%) (Akinbami, 2001). The demand for fuel wood is expected to have risen to about 213.4 x10^3 metric tones, while the supply would have decreased to about 28.4 x10^3 metric tones by the year 2030 (Adegbulugbe, 1994).

The decreasing availability of fuel wood, coupled with the ever-rising prices of kerosene and cooking gas in Nigeria, draw attention to the need to consider alternative sources of energy for domestic and cottage level industrial use in the country. Such energy sources should be renewable and should be accessible to poor. As rightly noted by Stout and Best (2001), a transition to a sustainable energy system is urgently needed in the developing countries such as Nigeria. This should, of necessity, be characterized by a departure from the present subsistence – level energy usage levels based on decreasing firewood resources, to a situation where human and farming activities would be based on sustainable and diversified energy forms.

An energy source that meets such sustainability requirements is fuel briquette. If produced at low cost and made conveniently accessible to consumers, briquettes could serve as complements to firewood and charcoal for domestic cooking and agro-industrial operations, thereby reducing the high demand for both. Besides, briquettes have advantages over fuel wood in terms of greater heat intensity, cleanliness, convenience in use, and relatively smaller space requirement for storage (Singh and Singh, 1982; Wamukonya and Jenkins 1995; Yaman *et al.* 2000; Olorunnisola, 2004).

Briquetting can be done with or without a binder. Doing without the binder is more convenient but it requires sophisticated and costly presses and drying equipment which makes such processes unsuitable in a developing country like Nigeria (Janczak, 1980). As observed by Wamukonya and Jenkins (1995), for the briquetting industry to be successful in the less industrialized countries, the equipment should consist of locally designed simple, low-cost machines.

In Nigeria, large quantities of agricultural and forestry residues produced annually are vastly under-utilized. The common practice is to burn these residues or leave them to decompose (Olorunnisola 1998, Jekayinfa and Omisakin 1995). However, previous studies have shown that these residues could be processed into upgraded liquid fuel products such as briquettes. A number of such locally available materials briquetted for fuel energy production include sawdust, cowpea chaffs, corncobs, and water hyacinth (Faborode 1988, Adekoya 1989, Ajayi and Lawal 1995, Olorunnisola 1998, 1999). However, in many of the foregoing studies, the briquettes were produced with the aid of binders such as cassava starch and palm oil sludge which tend to produce smoky briquettes.

As an alternative, waste paper appears to be a viable candidate for binding the agricultural residues for binder-less and perhaps smokeless briquette production. Approximately 25 to 40% of the municipal solid waste each year world wide consists of paper and paper products (Grigorion, 2003). While the prevailing practice worldwide is to recycle these products in the paper industry, the process could be expensive in view of its requirements for resorting, de-inking and decontamination. Also, re-use of recovered waste paper tends to reduce the quality of paper produced (Groom *et* al., 1994). Besides, the present level of waste paper recycling technology is such that a certain percentage of waste paper cannot be recycled for technical and economic reasons (Grigorion, 2003).

Previous studies have shown that waste paper could be mixed with other biomass materials to produce relatively cheap and durable binder-less briquettes Demirbas and Sahin, 1998; Yaman *et al.* 2000) Attempts have also been made in the past to create fuel from newspaper by rolling them up into ‘logs’. However, it was found that the product did not burn well (Arnold 1998). Coconut husk, on the other hand, has a relatively high calorific value (between 18.1 and 20.8 MJ/Kg) coupled with relative low ash content (3.5 - 6%) (Barnard 1985, Jekayinfa and Omisakin 2005).

In the present study, efforts were made to produce binder-less briquettes from a mixture of waste paper and coconut husk particles at low pressure (< 0.20 MPa) using a locally fabricated manual briqutting machine. Selected physical properties of these briquettes were also determined.

2. MATERIALS AND METHODS

2.1 Raw Material Preparation

Waste paper in form of disused typing sheets, photocopying and printing paper (excluding cardboard papers) was obtained from an office waste paper bin on the University of Ibadan campus, Ibadan, Nigeria. The papers were manually shredded into small bits, mixed together, and soaked in cold water at room temperature (22 ± 3^{0}C) for a period of three days. Thereafter, the water was drained off and the paper was converted into pulp by manual pounding with a pestle and a mortal. Coconut husks were obtained from a local coconut processor. The husks were hammer- milled and sieved. Particles that passed through the 850μm sieves and were retained on the 600μm sieves were used. The average moisture content of the coconut husk, determined by the oven dry method, was 26.4 % (dry basis).

2.2 Briquette Production and Quality Evaluation

The digested waste paper and coconut husk were thoroughly mixed by hand until a uniformly blended mixture was obtained. Mixtures were prepared at the following four coconut husk: waste paper weight ratios, i.e., 0:100; 5: 95; 15: 85; and 25: 75. In each case, a fixed quantity of the coconut husk-waste paper mixture was hand-fed into a manually operated closed-end piston press (Figure 1) and compacted at an average pressure of 1.2 x 10^3 N/m^2. The dwell time (i.e., duration of load application) was 5 minutes as in Olorunnisola (2004). Thirty replicate briquette samples were produced per batch.

After ejection, the weight, length and diameter were determined. Three to five briquettes were randomly selected from each production batch for further evaluation. First,

Figure 1: The manually operated briquetting machine

the mean compressed density of the briquettes was determined immediately after removal from the briquetting machine as a ratio of measured weight over calculated volume. To determine dimensional stability, the length of five representative briquettes from each production batch was measured at 0, 30, 60 and 1440 and 10,080 minute intervals. Equilibrium Moisture content (e.m.c.)

of the briquettes after 19 days of sun-drying at an ambient temperature and relative humidity of 22 $\pm 3^0$C and 75 ± 5% respectively were determined. The relaxed density of the briquettes was also determined in the dry condition after 19 days.

The durability of the dry briquettes was determined with the aid of a durability tester, i.e., a dust-tight 300 mm x 300mm x 475 mm enclosed box using the ASAE standard method, S269.3. Test sample of three briquettes (approximately 100g) was tumbled for 10 minutes at 50rev/min. The weight of the solid briquettes remaining was then determined. The durability rating for each type of briquette was expressed as a percentage of the initial mass of the material remaining in the box.

The water resistance of the dry briquettes was determined by immersing five samples each in a glass container filled with distilled water at room temperature 72 hours and measuring the changes in length and diameter of each briquette. Each experiment was replicated thrice.

3.0 RESULTS AND DISCUSSION

3.1 Physical Characteristics of the Briquettes

Samples of the sun-dried briquettes produced are shown in Figures 2 and 3. Each briquette weighed approximately 35 grams. The average length of the briquettes was 37 mm, while the average diameter was 73 mm. Briquettes produced using 100% waste paper assumed a whitish colour, while those produced using different proportions of waste paper and coconut husk assumed different shades of brown coloration, depending on the quantity of coconut husk included. The more the waste paper content, the more attractive were the briquettes.

3.2 Briquette Stability (Length Expansion)

It is a well established fact that briquettes and/or pellets compressed in a closed cylinder have a tendency to expand as the pressure is released. The expansion takes place primarily in the direction in which the load is applied, i.e., longitudinal direction. Figure 4 shows the increase in length with time of briquettes from the various waste paper-coconut husk mixtures.

Figure 2: Samples briquettes produced with 100% wastepaper

Figure 3: Samples of wastepaper-coconut husk briquettes

The observed linear expansions were generally minimal. Briquettes produced using 100% waste paper and 5:95 waste paper-coconut husk ratio respectively exhibited the largest linear expansion (about 9%), while those manufactured at 15:95 and 25:75 ratios exhibited the least expansion (about 3%). What this finding seems to suggest is that the coconut husk perhaps had some stabilizing effects on the briquettes. Bruhn *et al* (1959) had observed that the type of material briquetted is one of the factors that have appreciable effects on product expansion.

3.3 Equilibrium Moisture Content

As shown in Table 1, the equilibrium moisture content (e.m.c.) of the briquettes ranged between 5.4 % and 13.3%. There was no clearly discernible pattern in e.m.c variation with increase in coconut husk content. However, the observed values fall within the range of values (7.7 – 15.1%, wet basis) reported by Wamukonya and Jenkins (1995) for sawdust and wheat-straw briquettes, and the range of values (12 -20 %, wet basis)

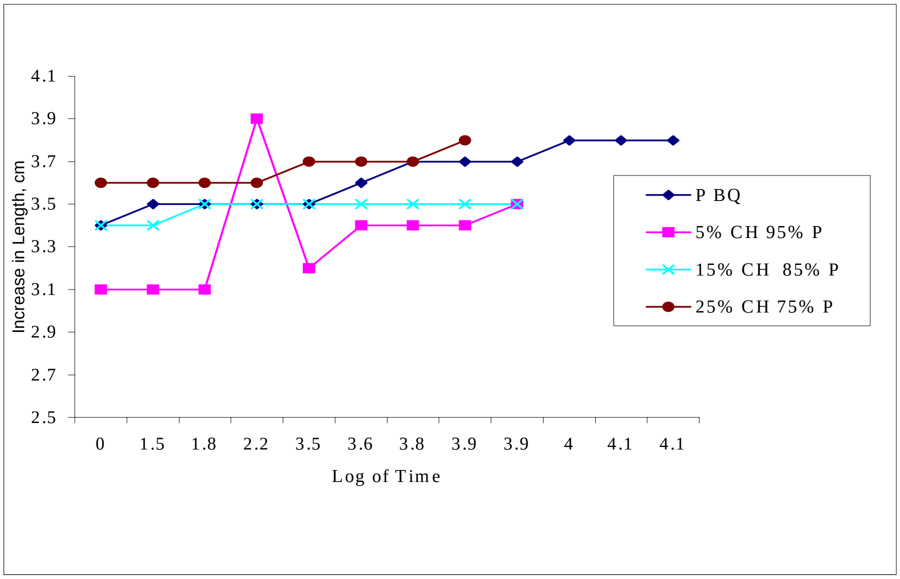

Figure 4: Length increase with time.

Note that the length at time zero is the length of the briquettes immediately upon removal from the die. 'PBQ' stands for 100% waste paper briquette; 'CH' stands for coconut husk, while 'P' stands for waste paper

recommended for good storability and combustibility of briquettes (Carre *et al.* 1988). An e.m.c. in excess of 20% would result in considerable loss of energy required for water evaporation during combustion at the expense of the calorific value of the fuel. Such a briquette may also not be stable in storage.

3.4 Compressed and Relaxed Density

One of the parameters used to characterize briquettes is relaxed density, i.e., the density of briquette after removal from the press. As shown in Table 1, the average compressed density of the briquettes (i.e., density determined immediately after compression) ranged from 8.1g/cm^3 to 11.2g/cm^3, while the average dry density ranged from 3.7g/cm^3 to 6.3g/cm^3. These values give a relaxation ratio (i.e., ratio of compressed density to relaxed density) of between 1.8 and 2.5. O'Dogherty (1989) reported a comparable relaxation ratio in the range of 1.65 to 1.80 for briquetted hay materials.

Briquettes produced with 100% waste paper had the highest compressed and relaxed density, as well as the lowest relaxation ratio, while there was a slight increase in relaxed density and a fairly constant relaxation ratio with increase in coconut husk content. The general decrease in compressed density with increase in coconut husk content may be due to the relatively low bulk density of coconut husk as reported by Olorunnisola (2006).

Table 1: Equilibrium moisture content and density of the briquette

% inclusion of Coconut Husk in briquette	Equilibrium Moisture Content (Wet Basis, %)*	Compressed Density (g/cm^3)*	Relaxed Density (g/cm^3)*	Relaxation Ratio
0	6.9	11.2 ± 2.3	6.3 ± 1.3	1.8
5	9.4	8.1 ± 1.1	3.7 ± 0.6	2.2
15	5.4	9.5 ± 0.7	3.8 ± 0.3	2.5
25	14.3	9.5 ± 0.9	3.9 ± 0.4	2.4

*Mean and standard deviation of 5 replicate samples

The greater density and smaller relaxation ratio observed in the 100% waste paper briquettes may, perhaps, also be due to its homogenous nature, which may have enabled the material to form a stronger bond, hence a denser and more stable product during compaction, than the waste paper-coconut husk mixture.

3.4 Durability Rating

Durability is a measure of the ability of a briquette to withstand mechanical handling. As shown in Table 2, the durability rating of the different briquette composition ranged from 93.3% to 98.5 %. These are relatively high values, higher than between 46.5 and 88.4% reported by Wamukonya and Jenkins (1995) for sawdust and wheat straw briquettes.

Table 2: Durability rating of the briquettes

% inclusion of Coconut Husk in briquette Composition	Mean Durability Rating (%)*	Standard Deviation
0	98.5	1.7
5	97.9	0.1
15	97.9	1.9
25	96.3	1.1

*Mean of 3 replicates.

The highest durability rating was observed in briquettes produced with 100% waste paper. As observed by Husain *et al.* (2002), the durability of briquettes is a function of the moisture content and density. While the presence of moisture tends to reduce durability, density tends to enhance it. It stands to reason, therefore, that the waste paper briquettes that had the lowest moisture content and the highest density also had the highest durability rating. Durability of briquettes is also a function of the bond strength between the constituent parts. The observed decline in briquette durability with decrease in waste paper content could also be attributed to the adhesive role the waste paper played in the briquettes. Cellulose, the main constituent of paper, is known to contain proteinaceous materials which tend to have excellent adhesive properties (Immergut 1975).

3.5 Water Resistance

The results of the simple immersion test are presented in Table 3. The post-immersion linear expansion of the briquettes ranged between 0 and 10%. It could be inferred, therefore, that the briquettes had a relatively low water absorption characteristic. Briquette samples produced from the 5:95 coconut husk: waste paper mixing ratio in particular did not exhibit any linear expansion after 72 –hour immersion in water, indicating the least absorption quality.

Table 3: Dimensional changes in briquettes after 3-day immersion in water

% inclusion of Coconut Husk in briquette	Initial Length (mm)*	Final Length (mm)*	% Length Expansion*
0	34	35	10
5	36	36	0
15	35	36	10
25	39	36	10

Mean of 3 replicates

Coconut husk, on its own, is known for its relatively high affinity for water. Savastano (1990) noted that the water absorption rate of coconut husk usually tend to be high, sometimes reaching over 100% in only one hour of immersion in water. Filho *et al.* (1990) also reported that the water absorption capacity of naturally dried coconut husk fibres during the first 96 hours was about 120%**.** The relatively high resistance of the briquettes to water may therefore be attributed to the waste paper inclusion. Paper is composed mainly of cellulose fibres which at the microscopic level contains waxes (water repellants), among other noncellulosic substances (Immergut 1975). What this finding suggests, however, is that a mild exposure of the briquettes to moisture would not have any serious deleterious (disintegrating) effect on them.

4. CONCLUSIONS

The conclusions drawn from this study are as follows-:

i. Good quality and highly storable/durable briquettes can be produced from a mixture of coconut husk and waste paper and also from waste paper only.

ii. The generally high durability rating of the briquettes suggests that they could be transported over a long distance without disintegrating.

Based on the foregoing conclusions, further investigations shall be conducted on the combustion characteristics of waste paper and coconut husk briquettes. This is necessary to enable a pronouncement on their utility as a fuel product. In addition it is also desirable to produce briquettes by blending paper with other types of agricultural residues such as bagasse, rice husk, and groundnut shells and test same.

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