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Research Paper

Characterization of Briquette Produced from Tannery Solid Waste

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ABSTRACT

Skin processing produces large volumes of wastes, much of which are not utilized but disposed in the landfill. This study explored the possibility of producing briquettes from tannery waste that could be used for heating purposes for cottage factories and domestic cooking. Wastes studied are buffing dust, chrome shavings, fleshing, and hair. The briquette properties tested were moisture content, volatile matter, ash content, fixed carbon content, calorific value, compressive strength, density and durability. The moisture content of the raw materials ranged between 2.04 and 8.37% while the moisture content of the produced briquettes after 19 days of drying ranges between 1.17 and 4.13%. The volatile matter also decreases while the ash content increases after briquetting. The fixed carbon content ranges 73.79 and 93.23%. The heating values of the briquettes also showed a great increased after briquetting of between 19.82 and 21.86 MJ/kg. The compressive strength ranges between 0.17 and 0.21 kN/cm^2, the durability ranges between 97.83 and 99.54%. The maximum densities of the briquettes also meet the required specifications of minimum value of 600 kg/m^3. The briquettes produced also possess good qualities that make tannery solid waste a materials for production of briquettes for heating and in cottage industries

1 Introduction

The global energy consumption increased sharply and is predicted to continuously boost for the next 50 years, caused by the industrialization growth both in developed and developing countries [1]. Nigeria, as a developing country, has vast potential resources for renewable energy, of which only a small portion has been utilized. For example, agricultural and agro-industrial waste which is gradually increasing due to more agricultural production. Currently, biomass is the only clean renewable energy source that can help to significantly diversify fuels throughout the world. The search and development of alternative renewable energy continues to grow in recent times due to the fear of energy insecurity in the near future, environmental and sociopolitical issues connected with the use of fossil fuels. The demand for fuel wood is expected to rise to about 213.4x10^3 metric tonnes, while the supply is expected to decreased to about 28.4x10^3 metric tonnes by the year 2030 [2]. The demand for traditional energy in Nigeria mostly fuel wood and charcoal is 39 million tons

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per annum and about 37.4% of the total energy demand and the highest single share of all the energy forms [3, 4]. This is projected to increase to 91 million tonnes by 2030. The deforestation and desertification rate will continue to increase if nothing is done to discourage the use of fuel wood and promote the use of alternative energy sources.

The growing demand for alternative energy sources apart from charcoal and petroleum products in addition to waste disposal challenges have brought about increased interest in the production of briquettes. Since the raw materials for briquettes are loose and low density, the production of briquettes will be profitable and economical if situated close to sources of raw materials. The briquettes should be able to withstand long distance transportation, multiple handling and long time storage. Leather is used to produce a variety of finished goods ranging from belts, shoes, bags, clothing, footballs, wrist watch furniture, stuffed animals, puffs, straps, mats, wallets, accessories etc. The process of converting hides and skin which are by - products of meat industry to leather is referred to as tannery. The conventional leather tanning technology generates large amount of organic and chemical pollutants. Worldwide, it is estimated that the industry is responsible for dumping 300-400 million tons of heavy metals, solvents, toxic sludge, and other wastes into waters each year [5]. Thus, the environment is under increasing pressure from wastes emanating from such industrial activities. According to Salman, [6] about 600,000 tons per year of solid waste are generated worldwide by leather industries. Out of 1000 kg of raw hide, nearly,730 kg is generated as a solid waste in leather processing, only 270 kg of the raw material is converted into a usable product [7]. The generated solid waste in leather industry are mainly skin trimmings, fleshings, shavings, buffing dust and keratin waste. All tanning process step, with the exception of finishing operations, produces wastewater. Producing an average of 35 m^3 per ton of raw hide. The wastewater is made up of high concentration of salts, chromium, ammonia, dye and solvent chemicals etc. [8]. In most tanneries, it is the foul smell which emanate from some of these putrescible solid wastes is responsible for much of the smell traditionally associated with tannery wastes. Some of the bio-degradable tannery solid wastes are causes of pathogenic bacteria and volatile organic compounds emission. As leather industries mostly use chrome sulphate for leather manufacturing process, some of the solid wastes generated from the industry contain chromium (Cr) which is one of the toxic heavy metals and known for contaminating ground water, soil, plants and causing carcinogenic effect on human health. The standard safe limit for chromium metal in the soil is 150ppm [9]. The main components of the waste are organics comprising mainly of proteins and fat, up to 10.5% (w/w) for both groups. Water content is high: moisture amounts to 60%. These wastes contain small amounts of mineral substances, 2-6% (w/w). Chromium compounds are not present in the material [10].

One of the problems faced by the world today is management of all types of waste and energy crises. The chemical composition of untreated hide or skin waste (fleshing, trimmings, splits, scouring) depends mainly on the kind and the quality of raw material, treatment type and process conditions. It constitutes protein as the main component. High moisture, up to 80% of water is characteristic of these materials. The amounts of fat and protein are relatively high and require to 10.5% (w/w) and up 2.5 to 10.5% (w/w), respectively. The tanned leather wastes are mainly useless splits, chrome shavings and trimmings. The chemical compositions of the waste do not differ substantially among themselves, because they come from the same chemical processing. The size and shape of individual elements are different. The problem for tanners is to find an economic use for collagen and by-products not sold as leather. In order to overcome these problems, there is a need to explore more on the utilization of the waste into heat and power generation. Enormous quantity of solid waste such as trimmings of finished leather, shaving dusts, hair, fleshing, trimming of raw hides and skins, are being produced from the industries daily. Chromium, chlorine, sulphur, oils and noxious gas (methane, ammonia, and hydrogen sulphide) are the elements of liquid, gaseous and solid waste of tannery industries [8]. In order to eliminate or reduced some of the problems posed by the tannery industries conversion of the solid waste to briquettes for energy production was considered in this work.

2 Experimental Work

2.1 Sample collection and preparation

Solid waste samples from pre-fleshing, lime fleshing, shaving, buffing and trimming, randomly selected among piles from the various leather operation units in a Company in Challawa Industrial estate, Kano, Nigeria were examined. The feedstock were sorted manually to remove impurities such as pieces of wood, bone, metal and any other unwanted material. Hair (HR), Pre-fleshing and lime fleshing (FS), wastes from the were air dried to reduce the moisture content (up to 10% moisture content) and were evenly mixed and oven dried at 50°C. While the Chrome shavings (CS), and buffing dust (BD), from tanned leather wastes were oven dried at 105°C according to [11]. The local starch used as binder was obtained from local market in Kano. The feedstock was then reduced in size by milling until it could pass through a screen of 1mm. sieve mesh while the hair waste was reduced to 0.5mm since it is very light. 500g of each of the dried samples were put in a crucible and placed in an oven at a temperature of 450ºC for 30 min. The calcined samples were then transferred into a silver plate to reduce the temperature and avoid further combustion. The waste was macerated to provide uniform consistency (slurry). Maceration of the carbonized BD, CS, FS and HR samples was done by mixing equal amount of each sample with cassava starch binder and water at the ratio of 4:5:1 as used by [12]. The starch was mixed to form slurry before adding the feeds so as to facilitate flow of lignin present in the biomass which acts as a natural binder to increase adhesion between intermolecular particles. In each case, a fixed quantity of the feedstock was hand-fed into the design and produced press and compacted. The dwell time was 5 minutes as suggested by Oyelaran [13]. The machine is a motorized briquetting machine, according to the design of the moulds, twelve (12) rectangular briquettes of 25 mm by 20 mm and 80 mm length were produced per batch.

2.2 Proximate and Heating value

Proximate analyses (volatile matter, moisture content and ash content) of the solid tannery waste and the briquettes formed were conducted in accordance with American Society of Testing and Materials (ASTM) [14]. The fixed carbon(FC) was calculated by subtracting the sum of volatile matter, moisture content and ash from 100 [15]. The heating value (calorific value) of briquettes was determined according to NMDC manual, [16].

2.3 Preparation of the briquette samples

The four samples BD, CS, FS and HR were milled preparatory to briquetting and labeled. The samples were weighed using digital weighing balance with accuracy of 0.1 g. The different concentrations were loaded into the mould compartment of the motorized operated briquetting machine. A maximum of 16 briquettes were obtained at each operation of the machine. BD, CS, FS and HR briquettes were produced under this condition while maintaining the pressure at 9.00 MPa throughout production and a dwell time of 80 seconds. Proximate analysis of the briquette samples was carried out after 19 days of sun drying.

2.4 Mechanical Test of Briquettes Samples

2.4.1 Determination of compressive strength

It is the maximum crushing load a briquette can withstand before breaking or cracking. Compressive resistance was determined using compression test as performed by Kaliyan and Morey, [17], using a Universal Testing Machine. The briquettes were placed in-between two plates of the machine and pressure applied which pushed one of the plate upward as it compresses the materials against the second plate until the material starts to fail.Maximum force (N) and compressive stress (N/mm^2) were recorded before breaking and cracking of the briquettes.

2.4.2 Density

The compressed density also called maximum density is the density immediately after extrusion from the mould, the briquette length, breath and height were measured using vernier caliper. Briquette mass was also determined with a digital scale. The relaxed density (density determined when dried), relaxation ratio and density ratio were also determined using equations 1 – 5.

$$\text{Compressed density} = \frac{\text{Mass of Briquette}}{\text{Volume of Briquette}} \tag{1}$$

$$\text{Volume of Briquette} = L \times B \times T \text{ (of briquette)} \tag{2}$$

Where L = length, B = Breath and T = Thickness

$$\text{Relaxed density} = \frac{MassofBriquette}{NewVolume(relaxedvolume)} \tag{3}$$

Here the new volume is the volume of briquette after 19 days of production and sun drying.

$$\text{Density Ratio} = \frac{\text{Relaxed density}}{\text{maximum density}} \tag{4}$$

$$\text{Relaxation Ratio} = \frac{\text{Maximum density}}{\text{Relaxed density}} \quad (5)$$

2.4.3 Durability

The durability test was carried out according to Oyelaran et al., [13] method, where the briquettes were dropped from a height of 1.85 m on a flat steel plate four times. This gave an indication of the ability of the briquette to withstand mechanical handling,.

$$\text{Durability is equal to} = \frac{\text{Material weight in plate after 4 drops } (m_b)}{\text{Initial weight of materials } (m_a)} \times 100 \quad (6).$$

3 Results and Discussion

3.1 The results proximate analysis of the raw materials

The proximate analysis of the raw materials as shown in Table 1 shows that FS has the highest moisture content of 8.37%. This may be attributed to the presence of excess fat and collagen substances. CS followed with 6.93%. BD has the lowest moisture content of 2.04%. This is could also be attributed series of conditioning undergone to make it impermeable to moisture indicating a good leather quality. The next lowest in moisture content is HR having a moisture content of 6.02% obviously due to its fibrous and polymeric nature. Fuels with high volatile matter have low heating values from the results on Table 2 BD has the lowest volatile matter of 9.41% followed by HR and CS with 9.68 and 10.14 respectively with FS having the highest value of 14.38%. The ash content also showed a similar trend with BD having the lowest ash content of 2.37% while CS, FS, and HR have 2.51, 3.46 and 2.74% respectively.

The calorific value determines the amount of heat energy present in a material. From Table 2, FS has the highest calorific value of 14.61 MJ/kg followed by BD, CS and HR with 11.78, 10.71 and 10.12 MJ/kg respectively. The pH of HR and FS is basic of 9.47 and 11.42 respectively. This is attributed to the presence of salt and lime used for preservation. The lower pH of HR to that of FS is as a result lost of some salt as salt dust during the process of handling. It should be noted that HR and FS are waste from pretanning operations and before tanning, the pelt is made acidic by adding ethanoic acid, hydrochloric acid, or ammonium chloride, which is responsible for the pH of CS being 4.21. After tanning and ageing, the wet blue is neutralized to a pH 6.5-11 before finally processing it into leather. This accounts for the pH of BD from the buffed finished leather being 5.42.

Table 1 Proximate Analysis of Raw Samples

SAMPLES	MC (w%)	VM (w%)	AC (w%)	FC (w%)	CV (MJ/kg)	pH
BD	2.04	9.41	2.37	86.18	11.78	5.42
CS	6.93	10.14	2.51	80.42	10.71	4.21
FS	8.37	14.38	3.46	73.79	14.61	11.42
HR	6.02	9.68	2.74	81.54	10.12	9.29

As shown in Table 2 BD briquettes have the lowest moisture content of 1.17% .This is anticipated as it is from the finished leather which has undergone different processes to make it impermeable to moisture making it quality leather. The next lowest in moisture content is HR briquettes having a moisture content of 2.25%. This is observably due to its polymeric and fibrous nature. FS briquettes have the highest moisture content of 4.13%. This may be due to the presence of excess fat and collagen substances. The tolerance level of moisture content for briquette is between 8-12% depending on the nature of the feed [18]. Moisture content of briquette above tolerance level lowers its thermal efficiency as well as its burning rate. Consequently, more energy will be used to exhume the moisture. In a furnace a damp fuel will lead to excessive emission of fumes. Briquettes with high moisture content favour the growth of fungi and other micros. From the above statement it can therefore means the four samples meets the moisture requirement of a good briquette.

From Table 2, FS briquettes have the least volatile matter of 2.98% followed by BD briquettes with 2.26% while CS briquettes have the highest value of 2.81%. This implies that more energy will be required to burn off the volatile matter in CS briquettes before the release of heat energy. HR briquettes as seen in Table 3, has the lowest ash content of 3.18%

followed by BD briquettes with a value of 3.34%. The highest ash content was observed in FS briquettes with 4.25% and CS briquettes with 4.03%. Ash content is an important factor in the burning rate and ignition time of briquettes. The tolerance level of ash content for fuel is below 4% [19]. From the above it implies that HR and BD briquettes have better qualities in terms of the ash content. As shown in Table 2, BD briquettes have the highest percentage of fixed carbon of 93.23%, followed by and HR and CS briquettes with 92.26% and 90.77% respectively. FS briquettes have the least with 88.84%.

From Table 2, FS briquettes were observed to have the highest calorific value of 21.86 MJ/kg which is probably due to the lower volatile content. BD and HR briquettes are next having 20.17 and 20.02 MJ/kg respectively, this could probably be due to their high carbon content. CS briquettes have the least calorific value of 18.84 MJ/kg, this could be as a result of its higher volatile matter compared to the other three briquettes since sample with the least volatile matter is expected to have the highest energy value vice visa. According to Vassiley and Vassileva, [20], the heating value of bituminous and lignite coals are 28.33 and 20.07 kJ/kg respectively. This indicates that all the briquettes except CS compare favourably with coal. This energy value is sufficient enough to produce heat required for household cooking and small scale industrial cottage applications. It also compares well with most biomass energy like groundnut shell briquette cowpea 14,372.93 kJ/kg and soy-beans 12,953 kJ/kg, [21].The picture of the briquettes produced is shown in Figure 1.

Fig. 1 – An illustration of samples produced

Table 2: Average Results of Proximate Analysis of Briquette Samples

SAMPLES	MC (w%)	VM (w%)	AC (w%)	FC (w%)	CV (MJ/kg)
BD	1.17	2.26	3.34	93.23	20.17
CS	2.29	2.81	4.03	90.77	19.82
FS	4.13	2.08	4.25	88.84	21.86
HR	2.25	2.31	3.18	92.26	20.02

3.2 Mechanical Properties of Briquette Samples

3.2.1 Compressive strength

Compressive strength is one of the most important characteristics of a briquette that determines the stability and durability of the briquette [22]. From Table 4, the average compressive strength of the briquettes ranged from 0.134 to 0.192 kN/cm². FS briquettes have higher compressive strength of 0.192kN/cm² due to its elastic nature influenced by the presence of gelatine collagen fibre. HR briquettes are brittle and have the lowest compressive strength of 0.134 kN/cm², due to the particle size being larger. Larger particle size causes cracks and fracture of briquette. HR could not be reduced to the recommended size range because it of its agility.

3.2.2 Durability

Durability is a measure of the briquettes ability to withstand destructive forces such as compression, impact, and shear during handling and transportation [23]. The production of fines or dust during handling, transport, and storage would create health hazard and inconvenient environment for the workers [24]. There is no limit for the production of fines in place. However, Karunanithy et al., [25] wrote that that fines up to 5% (by weight) would be an acceptable level and greater than 5% would reduce storage capacity and create problems in flow characteristics. Depending upon the values researchers has classified the durability into high (> 0.8), medium (0.7-0.8), and low (< 0.7) [26]. From Table 3, the durability of the briquettes varied between 97.83 and 99.54 %. it is observed that FS briquettes is the most durable by 99.54% , followed by CS and BD briquettes with durability of 98.71 and 98.62 respectively. However, HR has the least value of 97.83%. Minimum durability rating obtained was 97.83%, which is higher than 84.4% reported by Wamukonya and Jenkins, [27] for sawdust and wheat straw briquettes. On the basis of durability the four materials meets the requirement for a good briquette.

Table 3: Mechanical Properties of Briquette Samples

SAMPLES	Compressive Strength (kN/cm²)	Durability (%)	Maximum Density (Kg/m²)	Relax Density (Kg/m²)
BD	0.185	98.62	701.43	413.84
CS	0.183	98.71	669.73	375.09
FS	0.192	99.54	648.36	369.57
HR	0.134	97.83	639.84	365.55

3.2.3 Density

None of the parameters used to characterize briquettes is their densities, i.e., the density of briquette after removal from the press term compressed density (maximum density) and relaxed density which is the dry density. As shown in Table 4, the average maximum density of the briquettes (density determined immediately after compression) ranged from 639.82 kg/m^3 to 701.43 kg/m^3, with BD having the highest value of 701.43 kg/m^3, followed by CS and FS briquettes with 669.73 and 648.36 kg/m^3 respectively. HR briquettes have the least value of 639.82 kg/m^3which could be as result of its larger grain size. The density obtained in this work compares well with densities of notable biomass fuels such as coconut husk briquette-630 kg/m^3, banana peel-600 kg/m, groundnut shell briquette-524 kg/m^3 and melon shell briquette-561 kg/m^3[28]. The value of minimum densities obtained is greater than the minimum value of 600 kg$m$recommended by Mani et al., [29] and Gilbert etal., [30] for efficient transportation and safe storage. The implication of this is that using any of the four materials will results in briquettes of good quality in term of density. Relaxed density is the dry density (density determined after 19 days of sun drying) as shown in Table 4, the average relaxed density of the briquettes ranged from 351.90 kg/m^3 to 413.84 kg/m^3.

The density obtained in this study compares well with relaxed densities of notable biomass fuels such as the values of 385 kg/m^3, 236.0kg/m^3 and 286.42 kg/m^3 386.4 kg/m^3 and 512.54 kg/m^3 relaxed density obtained for briquette produced from corncob, groundnut shell, melon shell, cassava and yam peels respectively [31]. Relaxation ratio is the ratio of the maximum (compressed) density to the relaxed density of the briquette. As shown in Figure 2, BD briquettes had the lowest relaxation ratio of 1.69, while HR briquettes have the highest with 1.82, with FS having 1.75 and CS 1.79. This Relaxation ratio translated into a volume reduction, which provides technological benefits and a desirable situation for material storage, packaging and transportation.

The result obtained also compares well with the values of 1.69, 2.20, 1.95, 1.92 and 1.78 obtained for relaxation ratio for briquette produced from corncob, groundnut shell, melon shell, cassava and yam peels respectively [29]. Pellets or briquettes with higher density ratio are preferred as fuel because of their high energy content per unit volume and slow burning property [32]. Figure 2 shows the comparative result of density ratio of the briquettes. BD briquettes have the highest density ratio and therefore a better material for briquette. The greater density ratio and smaller relaxation ratio as observed in the BD briquettes showed it’s denser and more stable nature during compaction.

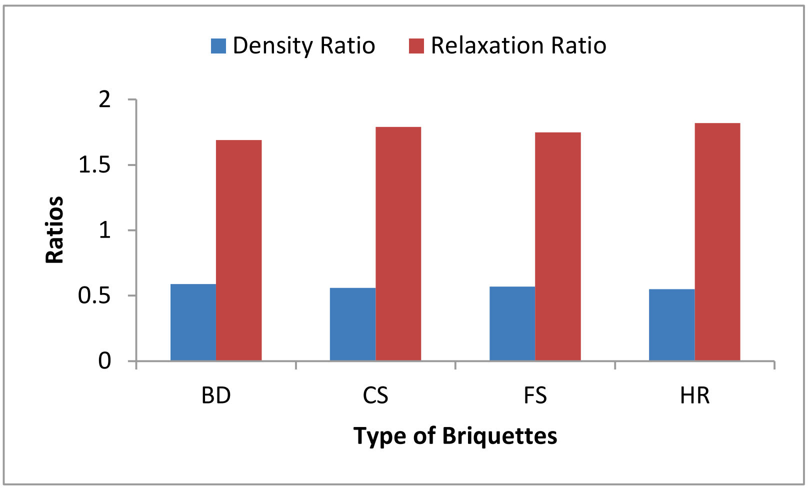

Fig. 2 – Comparative results of Density and Relaxation Ratios

4 CONCLUSION

This study involves conversion of tannery solid wastes to char, by an environment friendly, process and briquetting of the char into a solid fuel form for efficient, clean and user friendly fuel. The proximate and mechanical properties of the briquettes produced from tannery solid waste were investigated. The following results were obtained. The moisture content of the raw materials ranged between 2.04% (BD) and 8.37% (FS) while the moisture content of the produced briquettes after 19 days of drying ranges between 1.17% (BD) and 4.13% (FS). The volatile matter also decreases from the raw material to the briquettes. However, there is an increased in the ash content after briquetting. The fixed carbon content of the raw materials ranges 73.79% (FS) and 86.18% (BD) while that of the briquettes ranges between 88.84% (FS) and 93.23% (BD). The heating values of the briquettes also showed a great increased after briquetting of between 19.82 MJ/kg (CS) and 21.86 MJ/kg (FS) from the results obtained it shows that fixed carbon content is not the only property that determine the caloric value of a material. The briquettes produced also possess good qualities that make tannery solid waste as materials for production of briquettes for heating and in cottage industries. The compressive strength ranges between 0.17 kN/cm^2 (HR) and 0.21 kN/cm^2 (FS), the durability ranges between 97.83% (HR) and 99.54% (FS). The maximum densities of the briquettes also meet the required specifications of minimum value of 600 kg/m^3 recommended by [29] and [30] for efficient transportation and safe storage. The briquettes produced from the tannery solid waste also possesses good relax densities, density ratio and relaxation briquette form, will ratio. The converting of this waste to briquette for use as fuel will greatly help in solving the disposal problems; it will also provide an alternative to fossil fuel and also assist in reducing desertification and deforestation.

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