

Performance comparison of loose biomass briquettes produced using cow dung and cactus binders

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Abstract

In this work, loose biomass briquettes were produced using cow dung and cactus binders at various compaction pressures. Comparison is made of the briquettes produced using these binders with respect to their final bulk densities and moisture content. Yellow thatching grass, groundnut shells, sugar cane leaves, Mopani leaves and combinations recipe were used for briquetting. The objective was to identify a natural binder, which produces the best quality loose biomass briquettes. Results show alternating improvements between lower and higher compaction pressures on bulk densities. Briquettes with cow dung binder showed a good bulk density increment from low to high compaction pressures. At 6MPa, combined recipe had a density of 0.305 kg/m³, 0.333 kg/m³ at 12 MPa and 0.386 kg/m³ at 19 MPa. The lowest bulk density was for yellow thatching grass under 6 MPa compaction pressure but with a good increment on bulk density ranging from 0.236 kg/m³ at 6 MPa, 0.256 kg/m³ at 12 MPa and 0.285 kg/m³ at 19 MPa. Cactus briquettes were found to be insensitive to compaction pressure while pressure was found to be a critical parameter in producing quality briquettes when using cow dung binder. Cactus bonded briquettes achieved the highest bulk density of 0.375 kg/m³ on combination recipe and a maximum energy content of 16.49 MJ/kg.

Keywords

Biomass briquettes, density, moisture content, energy content

1. Introduction

Briquettes produced from agricultural and forestry residues present a good strategic waste management protocol, especially in sub-Saharan Africa. Conversion processes and methods deployed improve the energy supply, they are eco-friendly and protect the environment from pollution that result in adverse effect on climate change. Production processes do not involve chemicals for achieving good bonding. In many cases, lignin can act as natural binder (Khodiyar,1994). During briquetting, certain and process and technologies parameters must be controlled to achieve good quality briquettes. The technological parameters include particle size, moisture content, compaction pressure and pressing temperatures. In the work of (Krizan,2014), the effect of compaction pressure on briquetting of pine and oak sawdust was investigated. By varying pressure from a minimum of 31 MPa to a maximum of 254 MPa, they showed that briquette density depended on compaction pressure. Higher pressures resulted in improved briquette quality and density. This work highlighted the importance of particle size and compaction pressure on briquette quality and density. In this work, lignin in the process material was used as binder hence species type can affect briquetting quality (Mitchual, 2013).

In addition, some natural materials can also be blended with the process material to improve briquetting quality. Extensive investigations on blending materials and methods during the briquetting of various materials were conducted in India (Rajaseenivasan,2016). Neam powder was one such material that was blended with sawdust dust and briquetted at compaction pressures of 7 MPa for low compaction and 33 MPa at high compaction. The blending ratios in the range 100:0 to 0:100 by mass were considered. Briquettes with 100:0 blending yielded energy content of

3475 kJ/kg compared to 452 kJ/kg for blending ratio of 0: 100. Therefore, Neam powder is a good blending material for improved energy content. The size of the briquette also has an effect on briquette quality. Pressure decays significantly inside the briquette and optimum sizes have been suggested for given pressures (Karunanithy,2012). Furthermore, a noticeable effect resulting from moisture retention on briquettes was reported. Particle size was also highlighted as a factor on moisture content condition (Matus, 2015). Work on loose biomass briquette density improvement recommend working with small particle sizes for reduced moisture content (Krizan, 2011).

(Sivakumar, 2012) used wood waste to maximise the briquetting conditions with various particle sizes ranging from course to fine particles. Results also identified significant influence of particle size on final briquettes performance. When working with course particle sizes, compaction pressure must be elevated for improved performance. In Thailand (Sen, 2016), binder influence towards fuel briquettes physical properties was investigated using Casanova rhizome waste and five different binders. Comparison was made considering the final briquettes physical properties versus density, compressive strength and impact resistance shatter index. The binder used are molasses, starch gel, concentrated slop, cassava pulp and soya residue with mixing ratios of 6:4, 7:3, 8:2, 9:1 and 10:0. Results shows gradual improvement on briquettes with high amount of binders, on 6:4 and 7:3 mixing ratios yielded highest densities ranging from 0.69 g/cm³ to 0.91 g/cm³ and highest energy content ranging from 21.670 kJ/kg to 24.367 kJ/kg. (Tabout, 2015), looked at the effect of applied pressures and binder proportion during the production of holly bio-briquettes using bamboo saw dust. Palm fibres and molasses was used as binders with varying pressures of 40 kg/cm², 50 kg/cm², 60 kg/cm² and 70 kg/cm². Binder mixing ratios was 20 % by weight. Increased density was found to be at the range of 260 kg/m³ to 416 kg/m³ at the highest compaction pressures. Compaction pressure of 70 kg/cm² briquette reached the improved energy content of 21.26 MJ/kg. Primary aim of briquettes production includes achieving good combustion parameter with maximum energy extraction. (Handra,2017). Investigated the effect of binder with respect to combustion quality using bio-briquettes produced from empty fruit bunch (EFB) waste. Pine sap and starch flour was used as binders at 40 %, 50% and 60% mixing ratios. Results shows an increased energy content at 50% mixing ratio with the maximum energy content of 6331.7 cal/g. Binder percentage during briquetting reported to influence the final briquettes quality. Evaluation of different binding materials in forming biomass saw dust briquettes was conducted in Sri Lanka (Shyamalee, 2015). Dry cow dung, wheat flour and paper pulp were used as binders with binder percentage of 30%, 40 % and 50 %. Results shows that binder percentages influence the production, with 30% briquettes produced from dry cow dung was reported to have failed during mould detaching. Wheat flour and paper pulp briquettes yielded improved bulk densities to 373.7 kg/m³ and 289.8 kg/m³ respectively. (Wakchaure, 2009), investigated the effect of binders on biomass briquettes quality focusing on binder performance evaluation. The binder ratio was 3:1 with concentration of 5,10.15 and 20% on briquettes produced from mustard stalk, mixed waste of three leaves and grass bonded with press mud, distiller dry grain and molasses with varying compaction pressure of 112.34 MPa, 117.68 MPa and 123.42 MPa. Better quality briquettes were found on press mud binder at the highest compaction pressure of 123.42 MPa. Binders with good viscosity influences good quality on final briquette quality (Bhattacharya, 2002). Furthermore, a good binder improves lignin formation during compaction at high pressures of 100 MPa (Kaliyan, 2010).

2. Experimental Methodology

2.1 Aim of the investigation

The aim of this investigation is to compare the performance of loose biomass briquettes produced with cow dung and cactus binders respectively.

2.2 Materials

Five loose biomass materials were used in the investigation. These were yellow thatching grass, sugar cane leaves, ground nut shells, Mopani leaves and combine recipe (mixture of the four in equal proportion). The materials were collected from the Maphophe Village in the northern part of the Limpopo province.

2.3 Sample preparation

Prior to briquetting, the loose biomass was cut down to 20 mm sizes and mixed in various proportions with the binder i.e. cow dung or crushed cactus. The various briquette samples were produced at compaction pressures of 6 MPa, 12 MPa and 19 MPa.

2.4 Descriptions of equipment

2.4.1 Briquettes production

Briquettes were produced using a standard 30-ton workshop hydraulic press for compaction per figure 1 (a), briquettes mould set consisting of three components (base plate, compaction shaft and moulding cylinder) was used for briquettes moulding per figure 1 (b).



Figure 1. Loose biomass briquetting equipment and moulding (a) 30 Ton hydraulic press and (b) briquetting mould set

2.4.2 Density

Density of loose biomass briquettes was measured for all binder's types. Mass of briquettes were measured in millimetres using LBK-30 digital Adam scale with readability of 5g, repeatability (S.D) of 5g and linearity (+-) 10g, volume was calculated by measuring the briquette radius and height using a scale ruler in millimetres per the below figure 2 and the measure values used to calculate volume per equation 1 below, density in kg/m³ was calculated using the measure values.

$$V = \pi r^2 h \text{ (M}^3\text{)} \dots\dots\dots (1)$$

Where V is the volume of briquettes, r is the radius of briquettes, h is the height of briquettes and π is the constant part of the equation

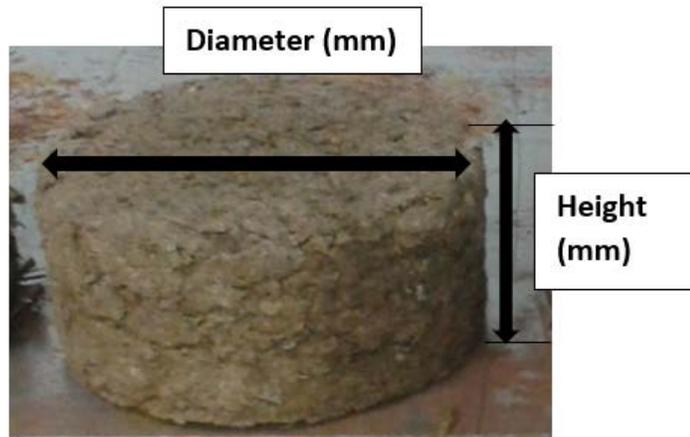


Figure 2. loose biomass briquette sample used to measure the densities

2.4.3 Moisture content

Moisture content of briquettes produced from loose agricultural and forestry residues was measured using a laboratory oven with automatic temperature control fitted with type K thermocouple and a heating maximum temperature of 800 °C as shown by figure 3 (a). Steel oven rack built with steel fine grid as sample tray for oven inside heating unit as unit per figure 3 (b).



Figure 3. Loose biomass briquettes moisture content analysis equipment (a) laboratory oven and (b) briquettes moisture content analysis tray

2.5 Experimental procedure

2.5.1 Densities

The dimensions of the loose briquettes produced were measured and recorded (diameter and height). Volume of each briquette was then calculated in m³. The mass of each briquettes was also measured, and the densities determined in kg/m³ using equation 1.

$$\text{Density (}\rho\text{)} = \text{Mass of briquettes (kg)} / \text{Volume of briquettes (M}^3\text{)} \dots\dots\dots 2)$$

2.5.2 Moisture content

Prepared briquettes were dried in an oven at 60 °C while their weight was monitored after every two hours until the mass was constant. Final moisture content of each briquette was then determined using equation 2.

$$\text{Moisture content (\%)} = \frac{W_{\text{initial}} - W_{\text{final}}}{W_{\text{final}}} \dots\dots\dots(3)$$

Where W_{initial} is the initial mass of the briquette prior to drying and W_{final} was the final mass of the briquette after trying.

3. Discussion of results

3.1 Density

Comparison on densities was made for both briquettes binders. Cow dung binds briquettes found to have more densities on all pressures. Cow dung binds briquettes pressures were measured against the constant cactus binds briquettes of 19 MPa since Cactus binds found to be insensitive to compaction pressures, the results are shown by Table 1. Table 1. Loose biomass briquettes densities for varying pressures with cow dung binds and 19 MPa for cactus binds

| DENSITIES BRIQUETTE TYPE | 6MPa density (kg/m ³) | 12MPa density (kg/m ³) | 19MPa density (kg/m ³) | 19 MPa Cactus density (kg/m ³) |
|-----------------------------|--------------------------------------|---------------------------------------|---------------------------------------|---|
| Yellow thatching grass | 0.236 | 0.256 | 0.285 | 0.274 |
| Ground nut shell | 0.392 | 0.326 | 0.446 | 0.330 |
| Sugarcane leaves | 0.289 | 0.317 | 0.336 | 0.276 |
| Mopani leaves | 0.349 | 0.315 | 0.363 | 0.351 |
| Combination recipe | 0.305 | 0.333 | 0.386 | 0.375 |

6 MPa Cow dung – 19 MPa Cactus

Cow dung found to have the highest bulk density on ground nut shell at 0.392 kg/m³, where cactus found to be at 0.375 kg/m³ for combined recipe. In principle, the highest bulk density should be expected from the highest compaction pressures. Results are shown by figure 4

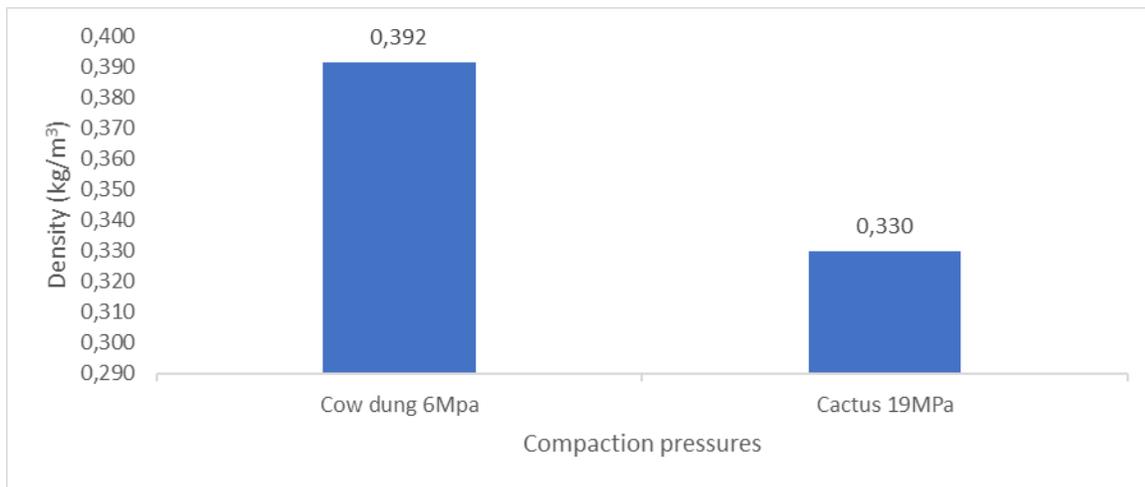


Figure 4. loose biomass briquettes compaction pressure comparison from low compaction pressures of 6 MPa briquettes with cow dung binder and high compaction pressures of 19 MPa with cactus binder.

12MPa Cow dung – 19 MPa Cactus

Cactus bind found to be relatively performing better on 19 MPa under combination recipe with bulk density of 0.375 kg/m³. When combination recipe has 0.333 kg/m³. The lowest bulk density was found on yellow thatching grass at 0.256 kg/m³ hence improved bulk density was notice on cactus binder at 0.274 kg/m³. Results are shown by figure 5.

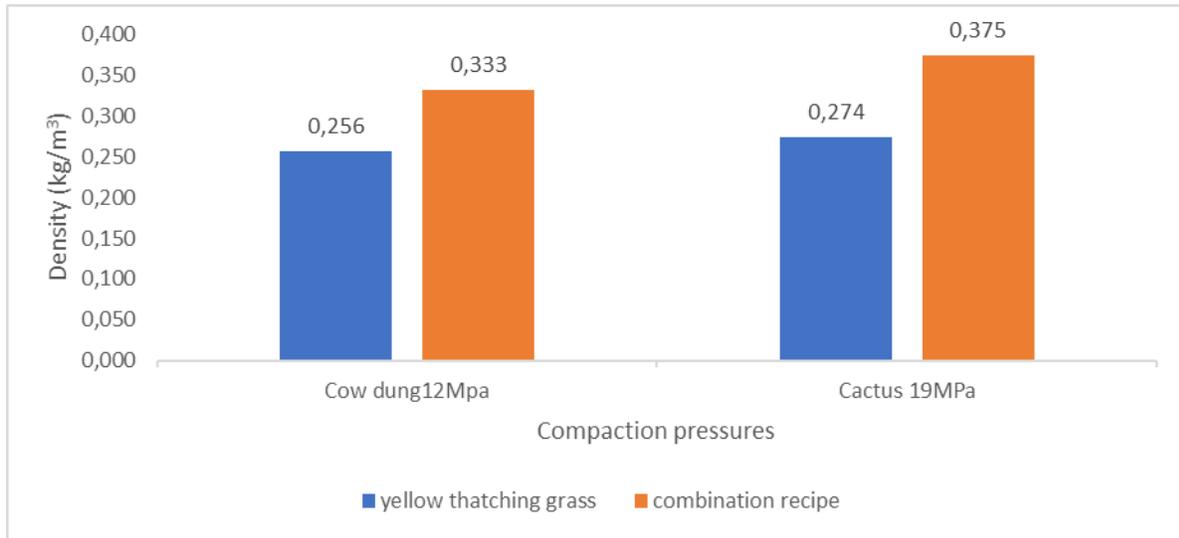


Figure 5. loose biomass briquettes compaction pressure comparison from low compaction pressures of 12 MPa briquettes with cow dung binder and high compaction pressures of 19 MPa with cactus binder.

19 MPa Cow dung - 19 MPa Cactus

The highest bulk density was found to be with cow dung binds briquettes at 0.446 kg/m³ on ground nut shell, followed by Mopani leaves at 0.363 kg/m³ and the lowest bulk density found to be yellow thatching grass at 0.285 kg/m³. On Cactus binds briquettes found to performed exceptionally well at 0.351 kg/m³ for Mopani leaves, followed by Ground nut shell at 0.330 kg/m³. Results are shown by figure 6.

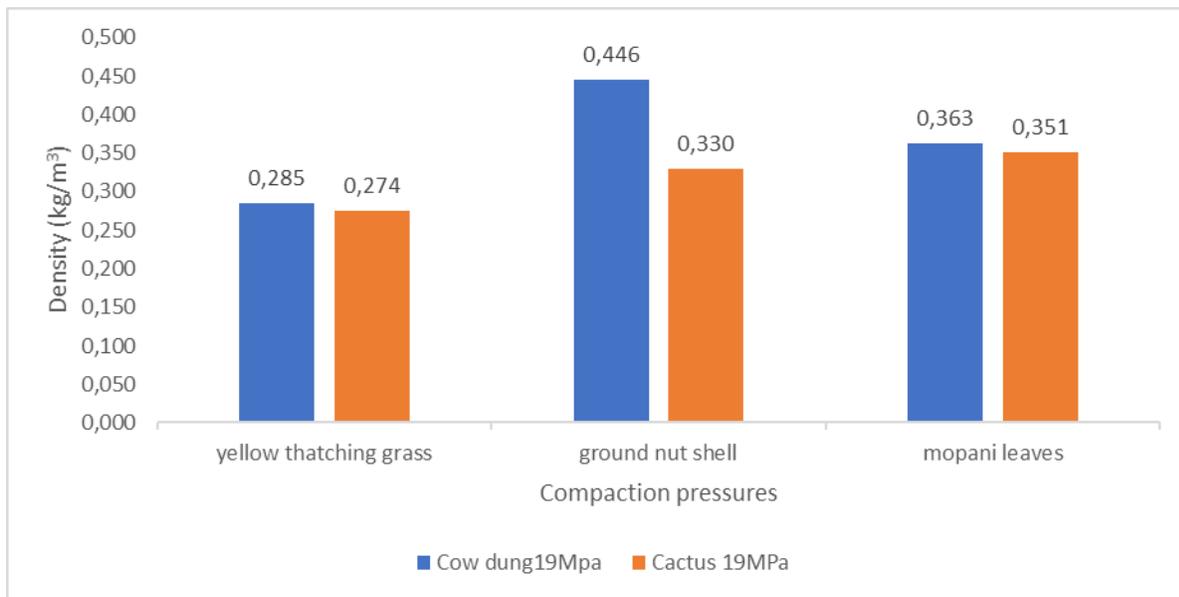


Figure 6: loose biomass briquettes compaction pressure comparison from low compaction pressures of 19 MPa briquettes with cow dung binder and high compaction pressures of 19 MPa with cactus binder.

3.2 Moisture content

Moisture content found to be relatively high on all briquettes for cow dung and cactus binds from production phase. The recommended good moisture content should be at 10 %. Cow dung briquettes made of yellow thatching grass loses moisture content quicker at 22.9 % per day, followed by groundnut shell at 12 % during drying. Mopani leaves was found to dry slowly at 4.6 %, and combination receipt at 5.6 %. Sugarcane has ability of retaining moisture content and drying process is slow at 6.8%. The quantified drying process per day is shown by table 2

Table 2. Loose biomass briquettes moisture content loss rate during drying process on cow dung bonded briquettes.

| PRODUCTION DATE | | 18 /11/2015 | | | | Moisture loss % |
|------------------------|---------------------------------|-------------|-----------------------------|-------|------|--------------------|
| Sampling Interval | 09h00 Briquettes Mass (g) | 11h0 | 13h30 Cow dung binder | 16h00 | | |
| Yellow thatching grass | 247 | 240 | 231.5 | 190.5 | 22.9 | |
| Groundnut shells | 250 | 247. 5 | 238 | 220 | 12.0 | |
| Sugarcane leaves | 249 | 240 | 237.5 | 232 | 6.8 | |
| Mopani leaves | 249 | 243 | 240.5 | 237.5 | 4.6 | |
| Combination recipe | 251 | 248. 5 | 240 | 238 | 5.2 | |

Loose biomass briquettes with cactus binder was analysed of their moisture content using oven drying technique. During drying, cactus bonded briquettes demonstrated high moisture retention on all samples with a slow drying pattern. Sugarcane leaves dry faster at 11.5% followed by mopani leaves and the combination recipe at 5.1 %. These drying rates is relatively slow, a faster drying response from the briquettes requires to be investigated. Yellow thatching grass and groundnut shells dry slowly at 6.2%, this is due to reception and retention of moisture content ability. The results are shown by table 3

Table 3. Loose biomass briquettes moisture content loss rate during drying process on cactus bonded briquettes

| PRODUCTION DATE | | 18 /11/2015 | | | | Moisture loss % |
|------------------------|------------------------------|-------------|---------------------------|-------|------|--------------------|
| Sampling Interval | 09h00 Briquettes Mass (g) | 11h00 | 13h30 Cactus binder | 16h00 | | |
| Yellow thatching grass | 250 | 243 | 240 | 234.5 | 6.2 | |
| Groundnut shells | 249 | 247 | 240 | 233.5 | 6.2 | |
| sugarcane leaves | 247.5 | 230 | 226.5 | 219 | 11.5 | |
| Mopani leaves | 248 | 240 | 236 | 229.5 | 7.5 | |
| Combination recipe | 247 | 238 | 230 | 234.5 | 5.1 | |

3.3 Briquettes quality

Loose biomass briquettes produced from cactus bind and cow dung binds were assessed for the quality during and after production. Yellow thatching grass, groundnut shell, sugarcane leaves, Mopani leaves and combination recipe were used under production visual inspection and technical performance assessment.

During production, briquettes with cow dung binder were found to have a solid geometry without slump and respond to compaction pressures, changes in moisture loss during compaction was noticed. At low moisture content range of 6 -12 MPa, briquettes weighed slightly higher and at highest compaction pressures of 19 MPa briquettes weighed less than the lower compaction pressures. The final surface finish was smooth, solid, does not stick to the mould and does not change shape after production or during drying. The samples of produced briquettes are shown by figure 7.



Figure 7. Loose biomass briquettes produced from cow dung binder

Cactus bonded briquettes were identified to be insensitive to briquetting pressures. Compaction on all pressures of 6, 12 and 19 MPa briquettes were found to be watery, sticky on moulds and deformed during mould release. An extra caution briquettes realising from mould showed a bit of achievement, but briquettes still deformed on releasing and on drying. This is due to a lot of retained moisture was extracted, the briquettes are very light in weight with a bit of honey comb characteristics on some briquettes such as yellow thatching grass. The final produced briquettes are shown by figure 8



Figure 8. Loose biomass briquettes produced from cactus binder

Briquettes binder must be able maintain consistency during moisture and density analysis process. Cow dung briquettes were exceptionally able to maintain consistency during density measurement, volume measurement was maintained without height or width changes. Geometry forms a critical parameter during density measurement.

4. Conclusion

Two types of briquettes produced using cow dung and cactus binders were compared for their performance. Factors such as density, moisture content, were monitored and compared. Briquettes made with cow dung binder found to perform better in all criteria with longer combustion time compared to cactus binders. Compaction pressure was found to be a key parameter in the performance of cow dung briquettes. When the pressure increased, an improvement with respect to bulk density, energy content was achieved. During combustion, briquettes with highest improved bulk density and energy content combusted the longest at average of 200 minute with average burn rate of 0.5 g/min. ground nut shells, Mopani leaves and combined recipe with cow dung as a binder performed better that cactus bonded briquettes. Briquettes with cactus binder exhibited lowest bulk density. Lower bulk density on cactus briquettes might have influenced the final lower bulk density and calorific values.

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