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Research Article

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Carbonized Briquettes from Chicken Litter as an Alternative Source of Fuel

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Abstract
Most families in Uganda are low income earners. The world bank classifies Uganda as a low income country. In 2022, the GNI per capita for Uganda was $840, which is below the world bank's threshold of $1,036 for lower-middle-income countries. The poverty headcount ratio in Uganda was 20.3% in 2019. this means that 20.3% of Ugandans lived below the national poverty line of $1.90 per day.

Billions of people especially in developing countries depend on biomass as a source of energy especially in cooking, heating, and basic energy needs. In Sub-Saharan Africa, 77.8% of the population depends on biomass for cooking. This means that more than 3 out of every 4 Africans cook with wood, charcoal.

This study aimed at producing carbonized briquettes from chicken litter as an alternative source of fuel. The study involved collection of chicken litter from the local community, drying it under the sun for 4 days at 25 ℃ and then performing the various tests, carbonizing the litter at 350 ℃ for 45 minutes, briquetting was done and the product measured 0.09 m in height and 0.03604 m in diameter. Then the drying process was done so that the briquette was 9.2% moisture content.

Various tests like thermal, physical and mechanical were performed on the obtained briquette.

It is recommended that farmers informed on the handling and storing of chicken. A more lengthy drying for about 8 days at 25 ℃ and bagasse mixture with the litter can boost the calorific value of the briquette.

Keywords Chicken Litter, Calorific Value, Wastes, Carbonization, Compaction, Energy.

1. Introduction
Most families in Uganda are low income earners [1].The world bank classifies Uganda as a low income country. In 2022, the GNI per capita for Uganda was $840, which is below the world bank's threshold of $1,036 for lower-middle-income countries (World Bank, 2022). The poverty headcount ratio in Uganda was 20.3% in 2019. this means that 20.3% of Ugandans lived below the national poverty line of $1.90 per day [2].

Billions of people especially in developing countries depend on biomass as a source of energy especially in cooking, heating, and basic energy needs [3]. In Sub-Saharan Africa, 77.8% of the population depends on biomass for cooking. This means that more than 3 out of every 4 Africans cook with wood, charcoal (World Bank, 2020).

The number of households in Sub-Saharan Africa using solid fuels has doubled over the past 30 years, reaching 730 million (International Energy agency [IEA], 2010). Among biomass fuels, wood charcoal is one of the most widely used resources across Africa [4]. East Africa produces 32,058,244 tons, representing 43.2% of the production while West Africa 23,831,683 tons, representing 32.1% [5]. Due to the growing population of Africa (rate of 2.6% per year) (World Bank, 2022), and increasing energy needs in Africa (rate of 4.6% per year) (International Energy Agency (IEA), (2021), the demand for charcoal is only expected to increase in the coming years [6].

Energy from biomass accounts for 9% of global energy consumption [7]. In Uganda, about 93% of the Ugandan population rely primarily on biomass fuel for cooking and heating [8]. Firewood (78.6%), charcoal (5.6%) and crop residues (4.7%) . Due to the high demand for wood fuel in Uganda, forests are depleting at an alarming rate [9].Therefore, there is need to do more exploration on the alternative sources of fuels that are dependable and clean.

Some of these sources may include but not limited to solar energy, hydro power, other biomass fuels, and even wind power [10] However, due to less information on these energies among the natives because of the way cultures and society view them, less has been done in pushing to the front hence hindering sustainability [11].

Briquettes are an alternative fuel source that is currently gaining popularity in Uganda [12]. Briquette technology has been put forward as one of the readily available alternatives to provide sustainable and clean fuels [13]. In Uganda, briquetting is mainly done from agricultural residues such as millet straw, rice husks, coffee husks and bagasse Though briquette fuels from various biomasses energy is now a common energy in Uganda, less has been done on the production of carbonized briquettes from chicken as an alternative energy source [14]. Uganda in 2021 produced 68,385 tons of poultry meat and in 2017, there were 5,852,000 exotic chicken in Uganda [15]. Each chicken produces approximately 59 Kg of litter per year [16]. This shows the potential of the chicken litter in becoming the next feedstock for the briquettes that is going into wastage through dumping into the communities.

2. Methods and Materials

The study was carried out at Ndejje University. Experiments were cariied out at Ndejje and Makerere University labs , which are both centers of Technology and innovation.

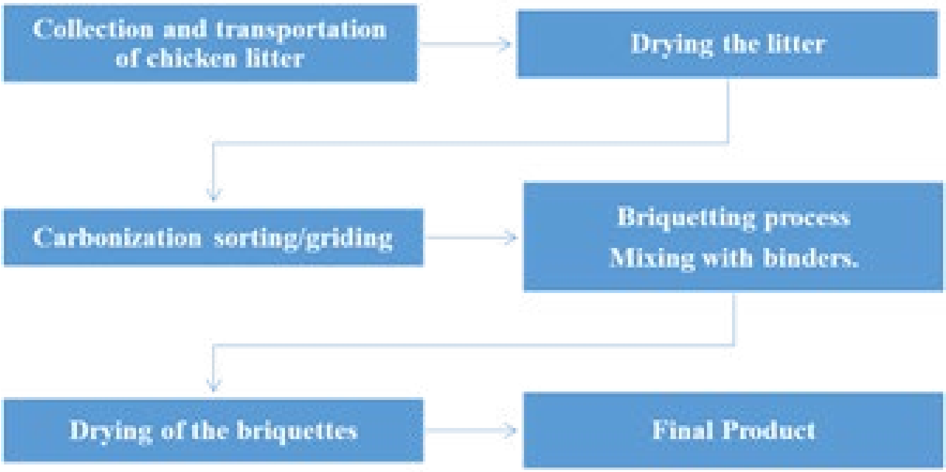

Figure 1: Activities flow-chart the litter

2.1 Sample Preparations

Chicken litter was collected from Ndeje community medium scale farmers in Luwero district. The sample was sun dried.

2.2 TGA Analysis

The final moisture content was obtained using Thermogravimetric analysis (TGA) model ELTRA THERMOSTEP at Makerere university labs.

The base measurements of the TGA were mass, temperature and time. The TGA analyzed properties like;
moisture content of the litter, volatile matter, ash content and fixed carbon

2.3 Carbonization of the Litter

The Chicken litter biomass was placed in a drum carbonizer by slow pyrolysis. The char was allowed to cool by sprinkling with water on it so that it doesn't burn to ash.

2.4 Making the Briquettes

Molasses was used as a binder and was obtained from the retailers in Matuga town. The 10.3 Kg of char was mixed with 2 litters of molasses to get a better mixture. Two liters of molasses were mixed with 10.3 kg of carbon. The mixer was then poured into the small scale briquette press of height 9 cm and diameter 4 cm to produce cylindrical briquettes

2.5 Storage and Drying of the Briquettes

Briquettes were dried in a solar drier for 4 days to obtain 11% moisture content as measured by an Extech MO550 moisture meter at Ndejje University labs.

3. Results

50 kg of chicken litter was obtained from one of the community farms for use. The sample was sun dried at 25 ℃ for four days to obtain a 13.% moisture content before being carbonized. Carbonization of the dried matter was done in the drum for 45 minutes at a temperature of 350 ℃ to obtain the carbon. Briquetting was done after the binder had been applied and the obtained briquette was 3.604 cm diameter as measured by a vernier calipers and 9 cm in height.

3.1 Physical Properties of Briquettes.

3.1.1 Bulk Density

A cylindrical container weighting 0.110 kg was used in this experiment. Chicken litter was filled in the container and the total weight of the container with the litter was determined as 1.120 kg. The volume of the container was also determined by filling it with water and then transferring the water to a beaker. The readings on the beaker was 0.0015 m^3

The bulk density of the chicken litter is:

– 0.110 kg) / 0.0015 m^3 = 673.33 kg/m^3

3.1.2 Mass of the Briquette

Mass of the briquette = ρV

V = $\pi r^2 h$ = 3.14 x 0.01802^2 x 0.09

V = 0.000092 m^3

Mass = 0.117 kg

3.1.3 Shatter Resistance

This was obtained by dropping the briquette from a height of one meter and taking the percentage decrease in weight.

Shatter resistance = impact force x distance of fall (Fadele et al., 2021)

Impact force = mg

Impact force = 0.117 x 9.81 = 1.148 N

Therefore, Shatter resistance = 1.148 x 1 m = 1.148 J

Percentage shatter resistance

Weight loss, w = w_b-w_a/w_a ×100

Shatter resistance = 100 - w

w_b – Weight before dropping, w_a – Weight after dropping

Weight loss, w = w_b-w_a/w_a ×100 = (230.50-222.40)/230.50 x 100

W = 3.514%

Shatter resistance = 100 - w

Shatter resistance = 100 – 3.514

Therefore, shatter resistance is 96.486%

The shatter resistance of the developed briquettes was 96.486%.

3.1.5 Resistance of Water Penetration

A weighed briquette was immersed in tap water contained in a beaker at room temperature for 30 min as recommended by It was then withdrawn, wiped to remove surface moisture, and reweighed [17].

% water absorbed = w_2-w_1/w_1 ×100

Resistance of water penetration = 100 – water absorbed

Where w_1- weight of briquette before immersion (g), w_2 - weight of briquette after immersion (g)

Percentage of water absorbed = (6.2-4.66)/4.66 x 100 = 0.33 x 100%

= 33%

Therefore, the resistance to water pentration = 77%

3.1.6 Degree of Densification

This was obtained by determining the corresponding decrease in biomass due to briquetting.

Degree of densification = D_r-D_D/D_r

D = m/v

D_r – Density of raw materials, D_b – Density of briquettes.

As quoted by chicken litter has a density of 543.8 kg/m^3, molasses has a density of 1400 kg/m^3 [18-19].

Density of a Mixture =

Mass of Component A × Density of Component A + Mass of Component B × Density of Component B/Total Mass of the Mixture ***Chicken litter***

Mass = 0.475 kg

Density = 543.8 kg/m^3

Molasses

Density = 1400 kg/m^3

Volume = 4 litters

Mass = ρV = 1400 x (2 L ≈ 0.002 m^3)

Mass = 2.8 kg

Density of a Mixture = ((0.475 × 543.8 + 2.8 × 1400))/3.275

Density of a Mixture = 1275.8 kg/m^3

So, Density of a Mixture of chicken litter and molasses =

Degree of densification = 1275.8-673.33/1275.8 x 100 = 47.22%

Therefore, Degree of densification of the obtained briquette in this study = 47.22%

3.2 Thermal Properties of the Briquettes

TGA version : 1.4.3.2a3							
Date of Analysis: : 05.06.2023 2:53							
Operator: Administrator							
Application: Thermal properties of chicken litter biomass							
Id	**Weight (g)**	**% moisture content**	**% Volatile matter**	**% Analytical ash**	**% Volatile dry basis**	**% Ash dry basis**	**% Fixed Carbon**
Chicken litter	1.1328	13.5593	61.6078	11.4319	69.9614	12.9819	13.4010
Chicken litter	1.1146	12.9105	65.1258	10.9905	73.5338	12.4094	10.9733
Average	1.1237	13.2349	63.3668	11.2112	71.7476	12.6957	12.1872

Table 1: TGA analysis of the chicken litter biomass

3.2.1 Weight

Weight in this case is the mass of chicken litter biomass that was subjected to heat in a TGA to obtain the thermal values of moisture content, volatile matter, ash content and fixed carbon.

3.2.2 Moisture Content

This is the quantity of water contained in the chicken litter biomass at the time the analysis took place. When the moisture content is low, it means the material is suitable for fuel making.

3.2.3 Volatile Matter

This is the amount of elements in chicken litter which easily burn in the presence of oxygen. The less the volatile matter, the less the amount of emissions released during combustion.

3.2.3 Ash Content

This is the amount of incombustible components present in the chicken litter biomass sample.

3.2.4 Fixed carbon

This is the amount of solid combustible residue present in the chicken litter sample.

3.2.5 Calorific value

This was determined using a Bomb Calorimeter at Makerere University labs and it was found to be 18.09 mj/kg. The calorific value is 4299.568 kcal/kg.

The TGA analysis results of other Biomass fuels.

Raw biomass	Moisture content %	Volatile matter %	Ash content %	Fixed carbon %	Calorific value mj/kg	Source
Sugar cane	<15	77.4	7.70	14.90	17.43	Rajeev Jorapur & rajvanshi, (1997)
Wood chips	3.10	69.29	5.93	24.78	19.78	Barzegar et al., (2020)
Bagasse	10.15	75.80	4.20	20.10	18.11	Rajeev Jorapur and rajvanshi, (1997)
Tea waste	7.26	70.29	3.88	18.57	16.19	Nagaraja et al., (2013)
Coffee husk	7.22	76.6	0.68	15.50	18.07	Gordillo and Rodriquez, (2011)
Wheat straw	5.30	75.88	4.69	14.12	18.39	Singh et al., (2022)
Rice husks	6.73	62.61	17.06	14.96	17.91	Gajera al.,(2020)

Table 2: TGA analysis of other biomass

Comparing the Calorific Values of Chicken Litter and Other Biomass

Only Wood Chips Have A Much Higher Calorific Value Of 19.78mj/Kg, Whereas Chicken Litter Has A Calorific Value Of 18.09mj/Kg, Which Is Close To That Of Bagasse And Wheat Straw, Higher Than Sugar Cane, Tea Waste, And Rice Husks, Which Shows That It Can Be A Very Good Alternative Biomass For Energy Production Because A Higher Calorific Value Means That The Biomass Can Produce A Higher Thermal Energy During Combustion. The Presence Of Low Volatile Matter In The Biomass, As Well As Continuous Drying To Minimize Moisture Content, Contributed To The High Calorific Value Of Chicken Litter Biomass. As A Result, It Is A Feasible Feedstock For Briquetting.

3.2.6 Production Process of the Briquettes.

Carbonization of the chicken litter biomass.

The chicken litter was carbonized in carbonizing drum using slow pyrolysis method of temperature 350 °C . The process took 45 minutes to obtain the carbon.

Figure 2: Carbonization of chicken litter

Addition of binder
The obtained char (10.3 kg) was mixed with 2 L of molasses as seen in Fig. 3

Figure 3: Mixing of the char with binder

Briquetting process
The mixture was then fed into the briquetter press machine (Fig. 4). The machine was locally facbricated at the Ndejje University department of Mechanical Engineering and is housed at the University's renewable energy hub.

Figure 3: The briquette press machine producing briquettes

Storage and dryiung of the briquettes

The produced briquettes were then placed on a wire mesh tray for storage and drying. These were sun dried for 4 days. Solar drying is used in this case. The moisture content of the of the briquette was analyzed using a TGA and it had 9.2% moisture level as seen in Table 3.

TGA version : Tga 1.4.3.2a3							
Date of Analysis: : 05.06.2023 2:53							
Operator: Administrator							
Application: Thermal properties of chicken litter briquettes							
Id	**Weight (g)**	**%Moisture content**	**%Volatile matter**	**%Analytical ash**	**%Volatile dry basis**	**%Ash dry basis**	**%Fixed carbon**
Chicken litter briquette	1.1218	9.1104	23.0910	33.3304	25.1947	36.3669	34.4683
Chicken litter briquette	1.4159	9.2874	22.3258	34.6988	24.3993	37.9214	33.6880
Average	1.2689	9.1989	22.7084	34.0146	24.7970	37.1442	34.0782

Table 3: TGA analysis of the briquettes

3.2.7 Weight

The TGA machine has precise scale with a sample pan inside a furnace surrounded by several pots within which the samples to undergo a thermal test are placed. The pots are calibrated to work with a mass of around 1.4g. The sample to be tested was crashed into small particles and then put into the pots in small portion until a mass that can sensed by the TGA machine is reached at which it produces a sound showing that no mass should be added.

Moisture content

The less the moisture content the more the heat produced while the more the moisture content the less the heat produced because high moisture content results into small calorific values due to absorption of heat that would be liberated during combustion. However, following Quality Standards of charcoal, the moisture content should range between 5-15% of the gross weight of the charcoal; therefore a moisture content of 9.1986% is hence higher combustion and more heat produced.

3.2.8 Volatile Matter

The less the volatile matter the less the amount of emissions during burning and the more the volatile matter the more the emission during burning. The quality specifications of a volatile matter ranges between 5-40%. Meaning a volatile matter of 22.7084% is low thereby giving out less emission. Volatile matter is comprised of combustible gases such as methane, chlorine, carbon monoxide, Sulphur, hydrogen sulfide, oxides of Sulphur.

3.2.9 Ash Content

When briquettes are burnt, they produce ash. The following reaction occur. The carbon in the briquettes reacts with oxygen forming carbon dioxide. The ash content of this briquette is shown in table 3

$C + O_2 \rightarrow CO_2$

Fixed carbon

Fixed carbon is solid combustible residue in briquettes, which remained after fuel particle was heated and the volatile matter is expelled.

Calorific value.

The calorific value = 4490.978kcal/kg

The higher the calorific value, the higher the thermal energy produced during combustion.

4. Mechanical Properties of Briquettes

Compression tests were carried out at Makerere labs using an FS 300 compression tester shown in fig. 5. A compression graph was generated as shown in Fig. 4.

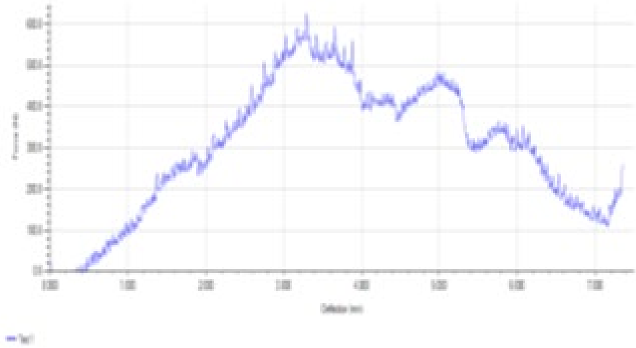

Figure 4: Compression test graph

The machine applied force onto the briquette which begun to undergo elastic deformation from the 0 N line to 200 N. 250 N was the yield point of the briquette. As more force was applied, the briquette underwent plastic deformation beyone 250 N and 300 N was the maximum load the briquette would handle.

Figure 5: The Compression tester

5. Conclusion

The thermal parameters of the chicken litter briquette were assessed by TGA analysis, which revealed a reduced moisture content of roughly 9.2%. These results show a greater heat produced because they fall between 5-15%, which is the normal range for briquette fuel [20]. The briquette alsoproduced a volatile matter of 22.7084% which is lower since the quality specifications line between 5-40% and therefore it produces less emissions [21]. The briquette also registered a lower ash content of 34.0146%, and a fixed carbon of 34.078% which makes it suitable for briquetting [22].

Chicken litter briquettes have relatively high calorific value which makes it an alternative source of fuel in the biomass fuel briquettes family. Comparatively, it is within the same calorific value range as most biomass fuel briquettes as well as being above others making it to have high combustion The physical properties of chicken litter briquettes are compacted loosely as seen from the lower bulky density of 0.000673 kg/m^3 . which makes it to disintegrate easily hence makes it hard to store. The shatter resistance of the developed briquettes was quite high of about 96.486% which makes it stronger against shattering, the resistance to water penetration was 77% and therefore it can slightly stand water penetration, the degree of densification was 47.22% which is lower hence they are bounded strongly together.

Therefore, chicken litter briquettes are a good alternative source of energy since their general thermal and physical properties meet the standards for biomass fuels.

Recommendations

Farmers should be educated on the handling and storing of chicken litter in order to maximize their yield per bird. Bird beddings should be well placed to reduce on the wastage of the litter. Chicken litter briquettes if being sun dried at 25 °C should be fully dried for at least eight days to remove the majority of the moisture content.

Addition of bagasse to the litter can to boost the calorific value of the briquette.

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