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EFFECT OF PAPER PULP ADDITIVE ON SOME MECHANICAL PROPERTIES OF MAIZE STALK BIOMASS BRIQUETTES

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Abstract

The increase in the world's population has led to the increase in the demand for energy which is the base rock for economic growth of any country. In developing countries, the use of firewood, charcoal etc has been the major source of heat energy particularly in rural areas. The over dependant on fossil fuel as a source of energy both for heating and electricity generation is a major challenge facing developing countries. There is the need for finding alternative source of fuel that will address both health and environmental consequence of firewood for cooking. The use of biomass briquette can be a better alternative since it is relatively cheaper than fossil fuel. This research centres on the effect of paper pulp additive on some mechanical properties of maize stalk biomass briquette. The paper pulp additive was added to the various sizes of maize stalk biomass briquette in different proportions using starch as binder. Some mechanical properties such as length expansion, swelling thickness compressed and relaxed density of the various sizes and different proportions of maize stalk biomass to the paper pulp briquettes were examined. The maize stalk biomass briquette with particle size 1.5 mm and mixing proportion of 70:30 (maize stalk biomass to paper pulp) has Relaxed Density of 27.07 x 10^{-5} g/mm^3 and Compressed Density of 34.02x10^{-5}g/mm^3 which is the best result from this research. With these densities it shows this particular size with this proportion will have a longer burning time, better calorific value than others and easy transportation. Also, because of its low swelling thickness and length expansion after briquetting, it is recommended that in the case of maize stalk biomass mixture with paper pulp briquette, the ratio of 70:30 for particle size of 1.5 mm diameter should be used..

Keywords: *Densification, Briquettes, Biomass, Length Expansion, Swelling Thickness, Relax Density and Compressed Density*

1.0 INTRODUCTION

World population growth has resulted in increase demand together with growing global consciousness about the scarcity of the earth's natural resources which has turned energy into a precious good (Solano *et. al*., 2016). In many developing countries, the use of energy in the form of firewood, twigs and charcoal has been the major source of energy due to the high cost of cooking gas and kerosene (Omojogberun and Olabisi, 2016). One of the most challenging tasks facing Nigeria just like other developing countries is finding a means of expanding its energy services especially to the rural households and at the same time addressing the health and environmental consequences of over dependence on firewood for cooking (Onuegbu et. al., 2012). The development of a substitute fuel for conventional fuels such as wood, coal and Liquified Petroleum Gas (LPG) is very important. Briquettes are very cheap as they are manufactured from waste. They are additionally use as substitute for cooking purpose and several other heating processes (Tamilvanan, 2013). Many developing countries produce huge quantities of agro residues (biomass) which are used inefficiently causing extensive pollution to the environment. The major residues are rice husk, coffee husk, coir pith, jute sticks, bagasse, groundnut shells, maize stalk, saw dust, mustard stalks and cotton stalks etc (Omojogberun, 2016). Every year, millions of tons of agricultural wastes and forest residues are generated and are either wasted or burnt inefficiently in their loose form causing air pollution. Many waste materials from sawdust, rice husks and other agricultural residue mentioned above can be turned into clean-burning, easy-to-handle fuels that cut waste and carbon emission, reduce cost, improves bulk density and also increase handling characteristics (Shukla and Vgas, 2015). Biomass has received tremendous attention as it is one of the best alternatives to replace the use of fossil fuels for energy generation. However, there are problems associated with the utilization of raw biomass which could be resolved through densification process (Law et. al., 2018). Densification of biomass improves its properties for use as fuels (Orisaleye et al., 2018). The cost of biomass transportation is also reduced through densification technologies (Clarke, 2019). Densification enables several advantages which include improved handling and conveyance efficiencies throughout supply system and biorefinery infeed, controlled particle size distribution for improved briquette uniformity and density, and fractionated structural components for improved compositional quality (Tumulure et. al., 2011).

2.0 MATERIALS AND METHODS

The materials for this research work includes maize stalk, paper pulp, water and cassava extract (starch). Large quantities of maize stalks were collected from the farm, cut into smaller pieces for easy carriage and sun dried for three (3) days in order to obtain uniform moisture content and then grounded into tiny particle sizes so as to obtain the desired particle sizes. The grounded maize stalk was sieved using wire meshes of three (3) different dimension (1.5mm, 1.8mm and 2.3 mm). For each particle sizes, five different proportions of the maize stalk and paper pulp were mixed together, so as to have five (5) samples for each grain size and 15 samples all together for the biomass. The combination of each of the maize stalk and paper pulp was then mixed with a measured quantity of starch and vigorously stirred together to obtain a uniform mix (Starch was used as a binder). A screw press briquetting machine was used to produce the briquettes. The weights of each briquette were recorded. The briquettes were then oven dried at 100^0C. 6% starch as binder was used for maize stalk and paper pulp briquette.

2.1 Determination of Length Expansion

Length expansions of each briquette were obtained by subtracting the length of the briquettes after compression from the length of the briquette after drying. Mathematically;

$$Lenght\ Expansion, LE = RL - CL$$

Where;

LE = Length Expansion

RL = Relaxed Length

CL = Compressed Length

Table 2.1: Length Expansion for Maize Stalk and Paper Pulp Briquette

Sample	Ratio	Compressed Length CL (mm)	Relaxed Length RL (mm)	Length Expansion LE (mm)
Sample size1.5mm	90:10	65.10	81.10	16.00
	85:15	81.20	97.20	16.00
	80:20	75.60	91.60	16.00
	75:25	82.50	97.50	15.00
	70:30	83.50	98.50	15.00
Sample size 1.8mm	90:10	68.50	88.50	20.00
	85:15	67.91	86.91	19.00
	80:20	67.70	85.70	18.00
	75:25	68.00	86.00	18.00
	70:30	69.40	87.40	18.00
Sample size 2.3mm	90:10	60.70	90.70	30.00
	85:15	68.50	98.50	30.00
	80:20	77.10	106.10	29.00
	75:25	79.20	107.20	28.00
	70:30	68.40	96.40	28.00

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2.2 Determination of Swelling Thickness

Swelling thickness of each briquette was obtained by subtracting the diameter of the briquettes after compression from the diameter of the briquette after drying. Mathematically;

$$\text{Swelling thinkness}, ST = RT - CT$$

where;

ST = Swelling Thickness

RT = Relaxed Thickness

CT = Compressed Thickness

Table 2.2: Swelling Thickness for Maize Stalk and Paper Pulp Briquette

Sample	Ratio	Compressed Thickness CT (mm)	Relaxed Thickness RT (mm)	Swelling Thickness ST (mm)
Sample size1.5mm	90:10	70.00	70.50	0.50
	85:15	70.00	70.50	0.50
	80:20	70.00	70.50	0.50
	75:25	70.00	70.50	0.50
	70:30	70.00	70.50	0.50
Sample size 1.8mm	90:10	70.00	71.50	1.50
	85:15	70.00	71.50	1.50
	80:20	70.00	71.50	1.50
	75:25	70.00	71.50	1.50
	70:30	70.00	71.50	1.50
Sample size 2.3mm	90:10	70.00	73.00	3.00
	85:15	70.00	73.00	3.00
	80:20	70.00	73.00	3.00
	75:25	70.00	73.00	3.00
	70:30	70.00	73.00	3.00

2.3 Determination of Densities

2.3.1 Compressed Density

Compressed Density is the density of the briquette obtained immediately after compression. The briquettes were weighed using mass balance to a precision of ± 0.1g. The dimensions of each briquette (i.e. height, internal diameter and external diameter) were measured using vernier calipers, then the volume of each briquette was calculated using;

$$CV = \pi \times CH \times \frac{\left[D^2 - d^2\right]}{4}$$

where;

CV = Volume of the Briquettes after compression

CH = Height of the briquette after compression

D = External diameter of the briquette immediately after compression

d = Internal diameter of the briquette immediately after compression

The compressed density of each briquette was then calculated using;

$$CD = \frac{Cm}{CV}$$

Where;

CD = density of briquette after compression

Cm = mass of briquette after compression

CV = volume of briquette after compress

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Table 2.3: Values of Compressed Density for Maize Stalk Briquette at Various Proportions

Sample	Ratio	Initial diameters immediately after compression		CH(mm)	CV(mm^3)	Cm (g)	Compressed Density x 10^{-5} (g/mm^3)
		Internal Diameter d (mm)	External Diameter D (mm)				
Sample size1.5mm	90:10	20.00	70.00	81.10	286668.23	102.50	34.76
	85:15	20.00	70.00	82.20	290556.45	100.50	34.59
	80:20	20.00	70.00	74.60	263692.35	90.60	34.36
	75:25	20.00	70.00	81.50	288082.12	98.80	34.30
	70:30	20.00	70.00	84.50	298689.38	101.60	34.02
Sample size 1.8mm	90:10	20.00	70.00	68.50	242098.87	50.20	20.73
	85:15	20.00	70.00	68.61	242487.77	50.30	20.74
	80:20	20.00	70.00	68.70	253544.27	50.70	20.82
	75:25	20.00	70.00	68.00	240331.72	50.20	20.89
	70:30	20.00	70.00	69.40	245279.73	51.40	20.96
Sample size 2.3mm	90:10	20.00	70.00	60.70	214531.40	80.50	37.52
	85:15	20.00	70.00	68.50	242098.87	88.40	36.51
	80:20	20.00	70.00	77.10	272493.75	99.30	36.44
	75:25	20.00	70.00	79.20	279915.77	100.40	35.87
	70:30	20.00	70.00	68.40	241745.44	85.60	35.41

2.3.2 Relaxed Density

The relaxed density is the density of the briquettes obtained after drying process. The briquettes were weighed after drying using mass balance to a precision of ± 0.1g. The dimensions of each briquette were measured (i.e height, internal diameter and external diameter) using vernier calipers, then the volume of each briquette was calculated using;

$$RV = \pi \times RH \times \frac{[D^2 - d^2]}{4}$$

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where;

RV = Volume of the Briquettes after relaxation

RH = Height of the briquette after relaxation

D = External diameter of the briquette after relaxation

d = Internal diameter of the briquette after relaxation

The compressed density of each briquette was then calculated using;

$$RD = \frac{Rm}{RV}$$

Where;

RD = density of briquette after relaxation

Rm = mass of briquette after relaxation

RV = volume of briquette after relaxation

Table 2.4: Values of Relaxed Density for Maize Stalk Briquette at Various Proportions

Sample	Ratio	Final Diameters		RH	RV	Rm	RD
		Internal diameter d (mm)	External diameter D (mm)	(mm)	(mm^3)	(g)	($x10^{-5}$) g/mm^3
Sample size1.5mm	90:10	15.00	70.50	80.10	298524.69	92.10	25.22
	85:15	15.00	70.50	97.20	362254.68	91.60	25.30
	80:20	15.00	70.50	91.60	341384.04	86.70	25.40
	75:25	15.00	70.50	97.50	363372.75	94.50	26.00
	70:30	15.00	70.50	98.50	367099.65	95.70	26.07
Sample size 1.8mm	90:10	15.00	71.50	88.50	339701.69	44.40	13.07
	85:15	15.00	71.50	86.91	333598.58	43.80	13.13
	80:20	15.00	71.50	85.70	328954.07	43.60	13.26
	75:25	15.00	71.50	88.00	337782.47	45.50	13.47
	70:30	15.00	71.50	87.40	335479.41	45.40	13.53
Sample size 2.3mm	90:10	14.00	73.00	90.70	365652.52	62.70	17.15
	85:15	14.00	73.00	79.10	318887.70	60.80	17.37
	80:20	14.00	73.00	106.10	427736.85	75.00	17.53
	75:25	14.00	73.00	107.20	432171.44	76.20	17.63
	70:30	14.00	73.00	98.40	396694.68	71.40	18.15

3.0 RESULT AND DISCUSSION

From Table 3.1 and figure 3.1, it was discovered that the length expansion for the sample size of 2.3mm was more than that of 1.8mm and 1.5mm irrespective of the ratio of biomass to paper pulp which indicate that the more the particle size the more the length expansion of the briquetted biomass. Also, from table 3.2 and figure 3.2, the result shows that increasing the size of the particle increases the swelling thickness which means the bigger the particle size, the more the briquette will swell after compacting. Tables 3.3, 3.4 and figures 3.3 and 3.4 which represent the values of compressed and relaxed density shows that at particle size 2.3 mm and mixing ratio 90:10 of biomass to paper pulp, the highest Compressed Density is

37.52 $x10^{-5}$ g/mm^3 while the highest value of the Relaxed Density is 26.07 x 10^{-5} g/mm^3 (particle size of 1.5mm and mixing ratio 70:30).

4.0 CONCLUSION AND RECMMENDATION

The maize stalk biomass with particle size 1.5mm and mixing ratio of maize stalk biomass to paper pulp of 70:30 briquettes has the Relaxed Density of 26.07 x 10^{-5} g/mm^3 and Compressed Density of 34.02 x $10^{-5} g/mm^3$. A good Relaxed Density is as a result of good densification of the biomass during briquette production and the particle size of 1.5mm and mixing ratio of 70:30 gave this value for this research. The densification of biomass improves its calorific value as well as longer burning time and easy handling and, transportation. Moreso, because of it low swelling thickness and length expansion after briquetting, it is concluded that the maize stalk biomass mixture with paper pulp ratio of 70:30 and particle size of 1.5mm diameter is the best and therefore recommended

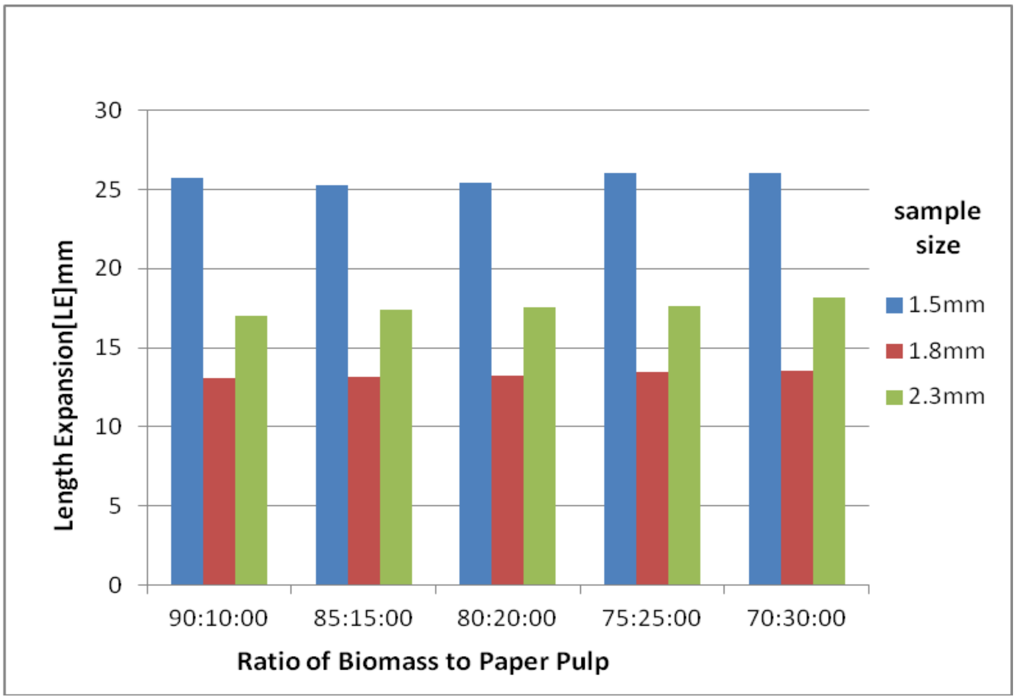

Figure 3.1: Chart showing the length expansion of the various proportions of mixing of maize stalk biomass and paper

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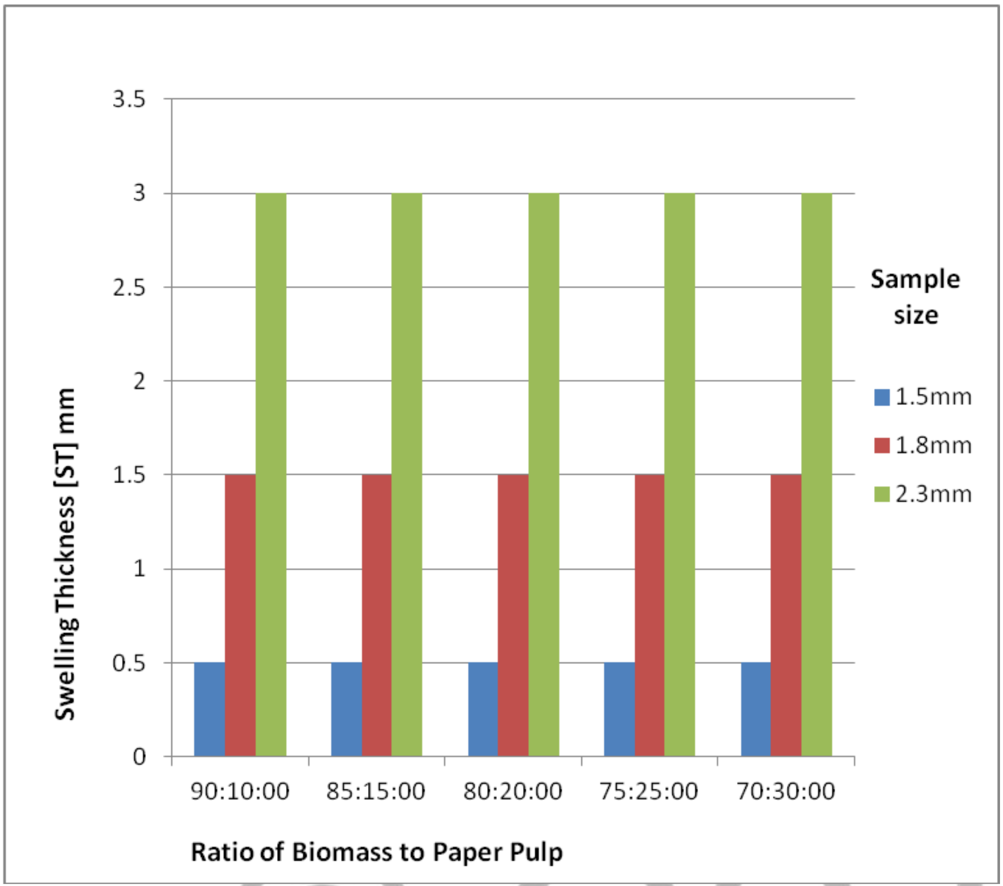

Figure 3.2: Chart showing the swelling thickness of the various proportions of mixing of maize stalk biomass and paper

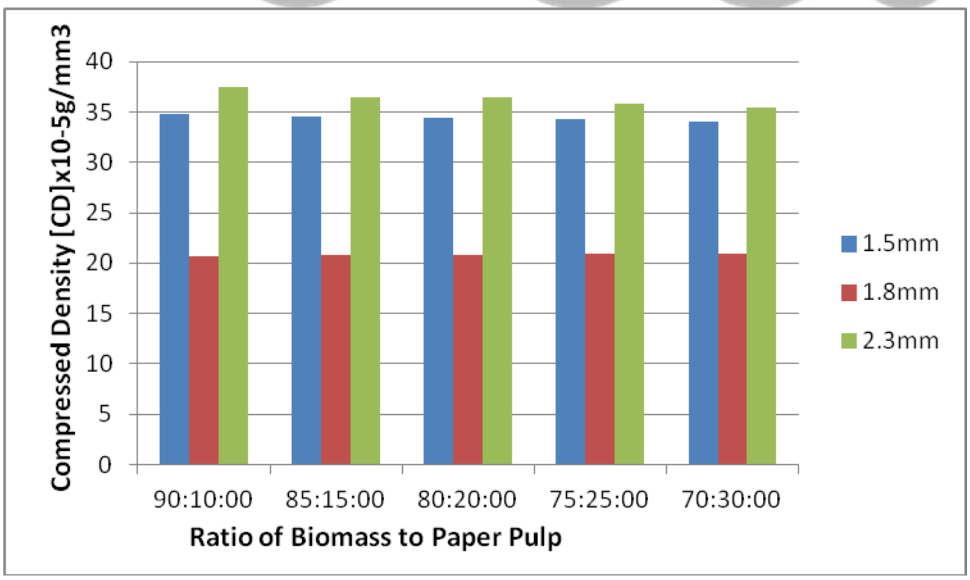

Figure 3.3: Chart showing the Compressed Density of the various proportions of mixing of maize stalk biomass and paper

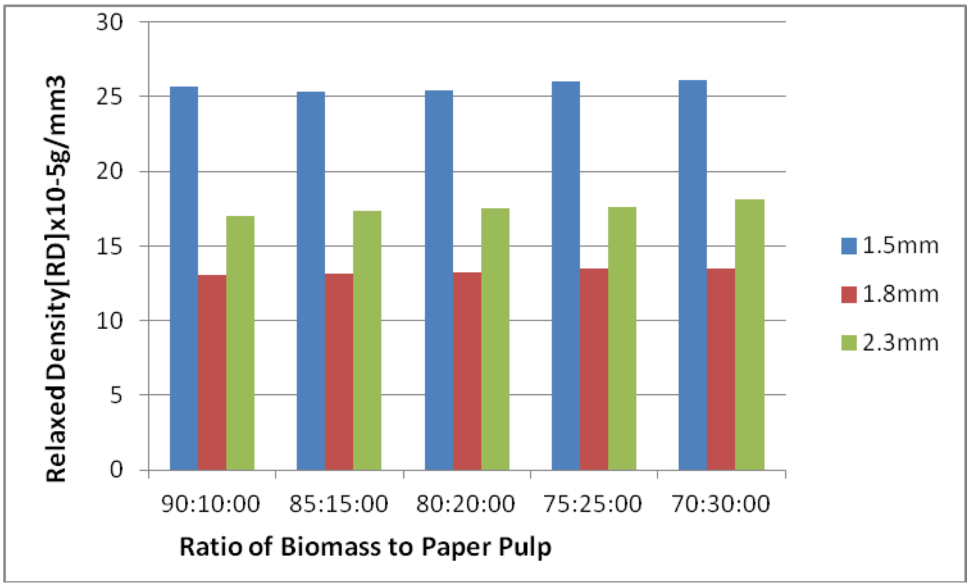

Figure 3.4: Chart showing the Relaxed Density of the various proportions of mixing of maize stalk biomass and paper

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