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EFFECT OF PAPER PULP ADDITIVE ON THE DENSIFICATION OF SAWDUST BIOMASS BRIQUETTE

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Abstract
The use of fossil fuel as source of energy has led to the problem of global warming. Also, its high cost of purchase and possible depletion has led to the search of alternative source of energy that is reliable and cost effective. Biomass as alternative source of energy is the biological degradable fraction of products, waste and residues from agriculture (including animal and plants materials), forestry and the biological degradable fraction of industrial and household waste. Sawdust as a biomass when compacted to form briquette can serve as a good source of renewable energy. In this work, sawdust biomass was use to make briquette using paper pulp as additive; three different sizes of the sawdust biomass were mixed with paper pulp in five different ratio. Their length expansion, swelling thickness, compressed density, relaxed density, density ratio as well as relaxation ratio was determined. The result showed that the larger the particle size, the more the length expansion and swelling thickness irrespective of the ratio of paper pulp additive to the sawdust biomass in the briquette. Also, the best result of compressed density is $41.44x10^{-5}$ g/mm^3 *which is the result for particle size of 2.3mm and a ratio of 90% sawdust biomass and 10% paper pulp while for the relaxed density, the best result is* $30.20x10^{-5}$ g/mm^3 *for a particle size of 1.5 mm and ratio of 90% sawdust biomass and 10% paper pulp. For the density and relaxation ratio, particle sizes of 1.5 mm has the highest set of density ratio and least set of relaxation ratio. Considering particle size of 1.5mm and the sawdust biomass to paper pulp additive ratio of 90% to 10%, it has good compressed density as well as relaxed density and also, the length expansion and swelling thickness are low indicating that it will be better in terms of handling, transportation and durability, therefore, it is recommended.*

Keywords: biomass, briquettes, sawdust, energy, length expansion, swelling thickness, compressed Density and relaxed density

1.0 Introduction

Fossil fuel and its combustion may eventually leads to enhancement of global warming and greenhouse gas effect (Ekpeni and Olabi, 2012). Global warming is a phenomenon that has negative impact on the environment and its effect can be minimize through the introduction of green technology. Green technology comprises of proper utilization of plants or agricultural remains which are considered wastes and converting them to products that can be applied in many sector including power and energy (Muriana *et al*., 2017). In the last decades, the problem of carbon dioxide (CO_2) emission in to the atmosphere has driven an increasing use of biomass fuels in addition to conventional fuels in power generating industries (Osvalda, 2011). Direct use of agricultural wastes as solid fuel is often difficult due to their varied physical and combustion characteristics (Ujjinappa and Sreepathi, 2018). Biomass is defined as the biological degradable fraction of products, waste and residues from agriculture (including animal and plants materials), forestry and the biological degradable fraction of industrial and household waste. The usage of biomass for production of energy is one of the various means of reacting to the problems associated to energy crisis. The use of biomass as a source of energy is a matter of growing importance (Oyelaran,et. al.,2014). Biomass has received tremendous attention as it is one of the best alternatives to replace the use of fossil fuels for energy generation both for the richer and developing world. At present, briquetting is commonly used in developing countries (Deepak and Jnanesh, 2015 and; Omojogberun and Olorunnisola, 2019). However, there are problems associated with the utilization of raw biomass which could be resolved through densification process (Law et. al., 2018). Briquetting is a process of compaction of agricultural residues into a product of higher density than the original material (Oladeji and Ojetunji, 2013). The process of compaction of wastes into a product of higher density than the original raw material is known as densification. Briquetting is a compacting or densification process to increase the low bulk density of biomass to high density (Ujjinappa and Sreepathi, 2018). Densification of biomass improves its properties for use as fuels (Orisaleye et al., 2018).

2.0 Materials and Methods

The materials used for this research were Sawdust biomass, paper pulp and boiled liquid starch (cassava extract) as binder. Considerably large quantities of sawdust were collected and sun-dried for five (5) days in order to obtain equal uniform moisture content. It was then sieved with wire meshes of three different sizes (1.5mm, 1.8mm and 2.3mm). Thus, three different particle sizes of the sawdust were obtained. For each particle size, five different ratio of sawdust and paper pulp were mixed together thereby obtaining five (5) samples for each grain size, making it 15 samples in all. The mixture of the Sawdust biomass and paper pulp was then mixed with a measure quantity of liquid starch and then vigorously mixed to obtain a uniform mix. A screw press briquetting machine was then used to produce the briquettes; this was done by feeding the mixtures into a mould and pressed by tightening the screw. After compaction, the briquettes were removed by loosening the screw of the machine. A total of 25 briquettes was produced for each particle size and for the three particle sizes, a total of 75 briquettes were produced. The briquettes were then oven dried at 100^{o}C. The weights, length, thickness, internal and external diameters of the each briquette were obtained. Both immediately after compression and after allowing the briquettes to dry. The length expansion, swelling thickness, compressed density, relaxed density, density ratio as well as relaxation ratio of the briquettes were determined as follows:

2.1 Determination of Length Expansion

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

$$Lenght\ Expansion, LE = RL - CL \quad (1)$$

Where;

LE = Length Expansion

RL = Relaxed Length

CL = Compressed Length

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;

$$\text{Swelling thinkness}, ST = RT - CT \quad (2)$$

Where;

ST = Swelling Thickness

RT = Relaxed Thickness

CT = Compressed Thickness

2. 3 Determination of Density

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;

$$CV = \pi \times CH \times \frac{\left[D^2 - d^2\right]}{4} \quad (3)$$

Where;

CV = Volume of the Briquettes after compression

CH = height of the briquette after compression

CD = external diameter of the briquette after compression

Cd = internal diameter of the briquette after compression

The compressed density of each briquette was then calculated using;

$$CD = \frac{Cm}{CV} \qquad 4$$

Where;

CD = density of briquette after compression

Cm = mass of briquette after compression

CV = volume of briquette after compression

2. 3. 2 Relaxed Density

The relaxed density is the density of the briquettes obtained after dying 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;

$$RV = \pi \times RH \times \frac{[D^2 - d^2]}{4} \qquad 5$$

Where;

RV = Volume of the Briquettes after relaxation

RH = height of the briquette after relaxation

RD = external diameter of the briquette after relaxation

Rd = internal diameter of the briquette after relaxation

The Relaxed Density of each briquette was then calculated using;

$$RD = \frac{Rm}{RV} \qquad 6$$

Where;

RD = density of briquette after relaxation

Rm = mass of briquette after relaxation

RV = volume of briquette after relaxation

2.3.3 Density and Relaxation Ratio

2.3.3.1 Density Ratio

This is the ratio of the compressed density to the relaxed density i.e

$$Density\ Ratio, DR = \frac{\mathrm{RD}}{\mathrm{CR}} \qquad 7$$

Where;

DR = Density Ratio

RD = Relaxed Density

CD = Compressed Density

2.3.3.2 Relaxation Ratio

This is the ratio of compressed density to relaxed density

Mathematically,

$$RR = \frac{CD}{RD} \qquad 8$$

Where;

RR = Relaxation Ratio

CD = Density Ratio

RD = Relaxed Density

3.0 Result and Discussion

From the results in tables 3.1, 3.2 and, figures 3.1 and 3.2, the larger the particle size, the more the length expansion and swelling thickness irrespective of the ratio of paper pulp additive to the sawdust biomass in the briquette. Also, from the results in table 3.3 and figure 3.3 which represent the results from the compressed density, the best result of compressed density is $41.44x10^{-5}$ g/mm^3 which is the result for particle size of 2.3mm and a ratio of 90% sawdust biomass and 10% paper pulp additive while for the relaxed density, the best result is 30.20 x 10^{-5} g/mm^3 for a particle size of 1.5 mm and ratio of 90% sawdust biomass and 10% paper pulp additive. It was also discovered from the result that for all the particle sizes, the more the paper pulp additives the lesser the compressed and relaxed density. For the density and relaxation ratio, particle sizes of 1.5 mm has the highest set of density ratio and least set of relaxation ratio.

4.0 Conclusion and recommendation

From the results in tables 3.1 to 3.4, it could be inferred that although particle size of 2.3mm of the ratio 90% sawdust biomass to 10% paper pulp has the best compressed density yet the relaxed density, length expansion and swelling thickness are high indicating that in course of handling, it may not the best option since there are others with better result. Considering particle size of 1.5mm and the biomass to paper pulp additive ratio of 90% to 10%, it has good compressed density as well as relaxed density and also, the length expansion and swelling thickness are low indicating that it will be better in terms of handling, transportation and durability. It is therefore recommended that in deciding which particle size of sawdust biomass with paper pulp additive will be the best from this research, it is recommended that sawdust biomass of particle size 1.5mm and biomass to paper pulp additive ratio of 90% to 10%.

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Table 3.1: Length Expansion for Sawdust Briquette

Sample	Ratio	Compressed Length CL (mm)	Relaxed Length RL (mm)	Length Expansion LE (mm)
Sample size1.5mm	90:10	72.50	84.50	12.00
	85:15	71.50	83.50	12.00
	80:20	73.00	85.00	12.00
	75:25	74.50	86.50	12.00
	70:30	74.30	86.30	12.00
Sample size 1.8mm	90:10	69.60	84.60	15.00
	85:15	68.20	83.20	15.00
	80:20	69.30	84.30	15.00
	75:25	69.30	84.30	15.00
	70:30	68.90	83.90	15.00
Sample size 2.3mm	90:10	69.30	89.30	20.00
	85:15	70.60	92.60	22.00
	80:20	70.20	92.20	22.00
	75:25	70.80	92.80	22.00
	70:30	71.20	93.20	22.00

Table 3.2: Swelling Thickness for Sawdust Briquettes

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	71.20	1.20
	85:15	70.00	71.20	1.20
	80:20	70.00	71.20	1.20
	75:25	70.00	71.20	1.20
	70:30	70.00	71.20	1.20
Sample size 2.3mm	90:10	70.00	72.50	2.50
	85:15	70.00	72.50	2.50
	80:20	70.00	72.50	2.50
	75:25	70.00	72.50	2.50
	70:30	70.00	72.50	2.50

Table 3. 3: Values of Compressed Density for Sawdust Briquette at Various Proportions

Sample	Ratio	CH (mm)	Final diameters		CV (mm^3)	Cm (g)	CD ($x 10^{-5}$) g/mm^3
			Internal diameter d (mm)	External diameter D (mm)			
Sample size1.5mm	90:10	72.50	20.00	70.00	256236.15	101.10	39.45
	85:15	71.50	20.00	70.00	252701.86	99.20	39.26
	80:20	73.00	20.00	70.00	258003.29	98.80	38.29
	75:25	74.50	20.00	70.00	263304.73	99.40	37.75
	70:30	74.30	20.00	70.00	262597.87	98.20	37.39
Sample size 1.8mm	90:10	69.60	20.00	70.00	245986.71	73.10	29.72
	85:15	68.20	20.00	70.00	241038.69	71.00	29.46
	80:20	69.30	20.00	70.00	244926.42	70.60	28.82
	75:25	69.30	20.00	70.00	244926.42	68.20	27.84
	70:30	68.90	20.00	70.00	243512.70	66.30	27.33
Sample size 2.3mm	90:10	69.30	20.00	70.00	244926.42	101.50	41.44
	85:15	70.60	20.00	70.00	249520.99	101.20	40.56
	80:20	70.20	20.00	70.00	248107.28	100.40	40.47
	75:25	70.80	20.00	70.00	250227.85	101.00	40.36
	70:30	71.20	20.00	70.00	251641.50	101.20	40.22

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Table 3.4: Values of Relaxed Density for Sawdust Briquette at Various Proportions

Sample	Ratio	RH (mm)	Final diameters		RV (mm^3)	Rm (g)	RD (x 10^{-5}) g/mm^3
			Internal diameter d (mm)	External diameter D (mm)			
Sample size1.5mm	90:10	84.50	16.00	70.50	312866.32	94.50	30.20
	85:15	83.50	16.00	70.50	309163.76	91.50	29.60
	80:20	85.00	16.00	70.50	314717.60	93.00	29.55
	75:25	86.50	16.00	70.50	320271.44	94.50	29.51
	70:30	85.30	16.00	70.50	315828.37	92.50	29.29
Sample size 1.8mm	90:10	84.60	16.00	71.20	319827.50	67.60	21.14
	85:15	83.20	16.00	71.20	314534.85	66.20	21.05
	80:20	82.30	16.00	71.20	311132.43	62.30	20.02
	75:25	84.30	16.00	71.20	318693.36	58.30	18.29
	70:30	83.90	16.00	71.20	317181.18	57.80	18.22
Sample size 2.3mm	90:10	89.30	15.00	72.50	352872.03	86.30	24.46
	85:15	92.60	15.00	72.50	365912.09	87.60	23.94
	80:20	94.20	15.00	72.50	372234.55	87.20	23.43
	75:25	93.20	15.00	72.50	368283.02	85.80	23.29
	70:30	91.20	15.00	72.50	360379.93	82.89	23.00

Table 3.5: Density Ratio for Sawdust Briquette

Sample	Ratio	Compressed Density, CD (x 10^{-5}) g/mm^3	Relaxed Density, RD (x 10^{-5}) g/mm^3	Density Ratio DR (x 10^{-5})	Relaxation Ratio, RR (x 10^{-5})
Sample size1.5mm	90:10	39.45	30.20	0.77	1.31
	85:15	39.26	29.60	0.75	1.33
	80:20	38.29	29.55	0.77	1.30
	75:25	37.75	29.51	0.78	1.28
	70:30	37.39	29.29	0.78	1.28
Sample size 1.8mm	90:10	29.72	21.14	0.71	1.41
	85:15	29.46	21.05	0.71	1.40
	80:20	28.82	20.02	0.69	1.44
	75:25	27.84	18.29	0.66	1.52
	70:30	27.33	18.22	0.67	1.50
Sample size 2.3mm	90:10	41.44	24.46	0.59	1.69
	85:15	40.56	23.94	0.59	1.69
	80:20	40.47	23.43	0.58	1.73
	75:25	40.30	23.29	0.58	1.73
	70:30	40.22	23.00	0.57	1.75

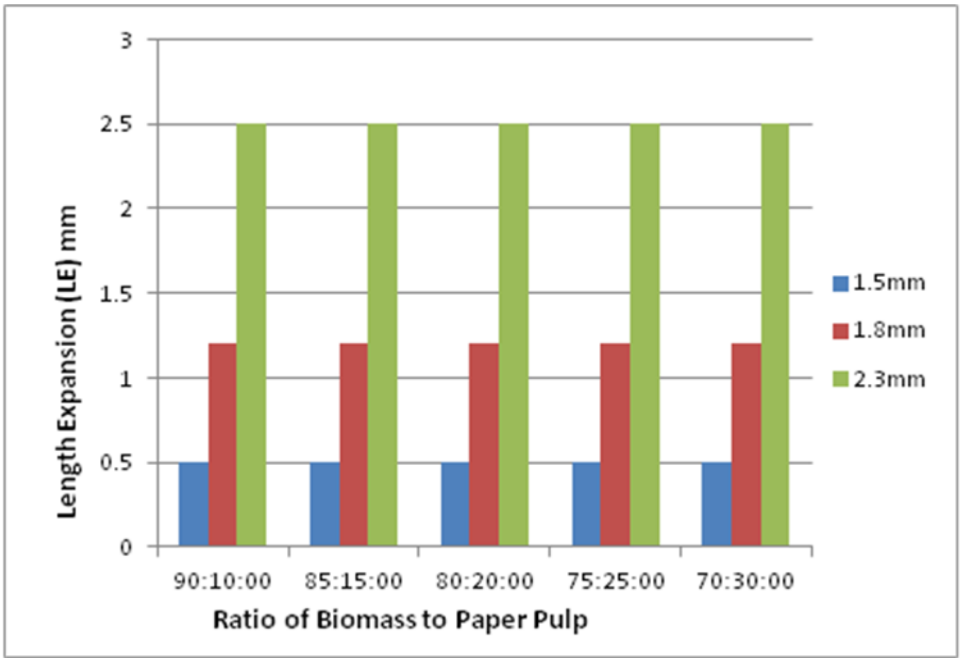

Figure 3.1 : Chart showing the length expansion of sawdust Biomass

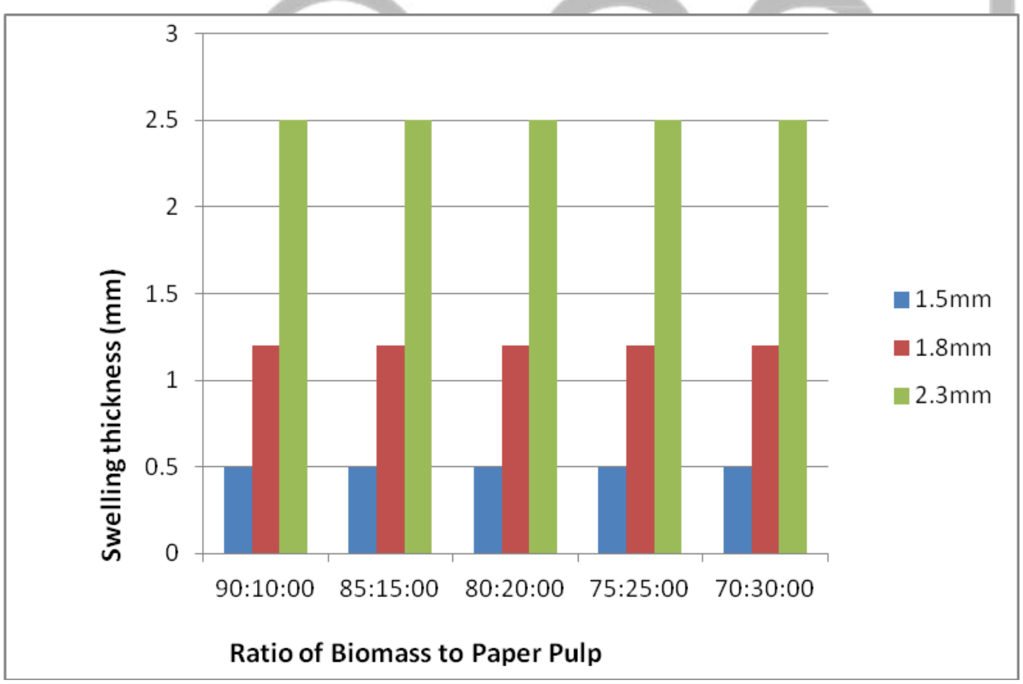

Figure 3.2: chart showing the swelling thickness of the sawdust biomass

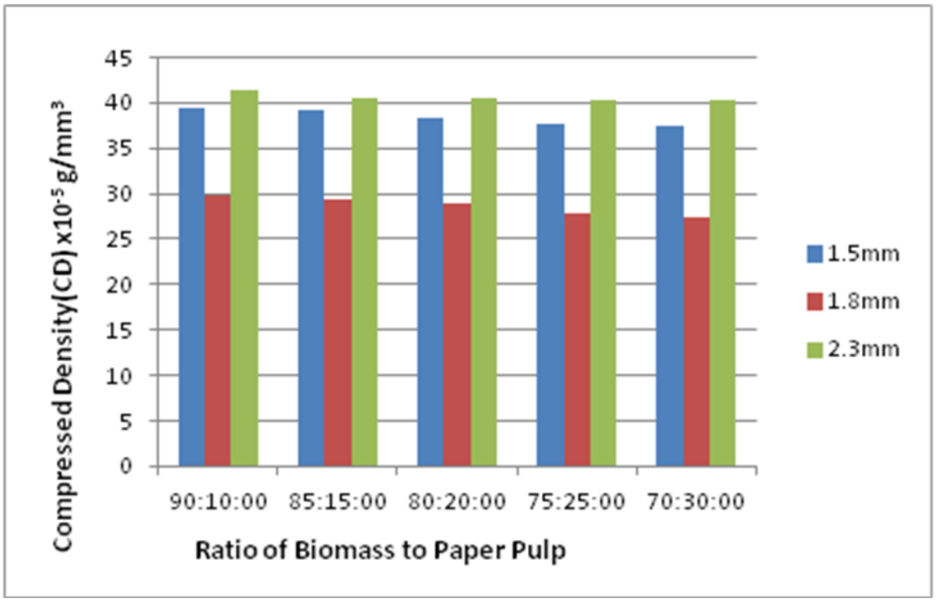

Figure 3.3: Chart showing the Compressed Density of the sawdust biomass

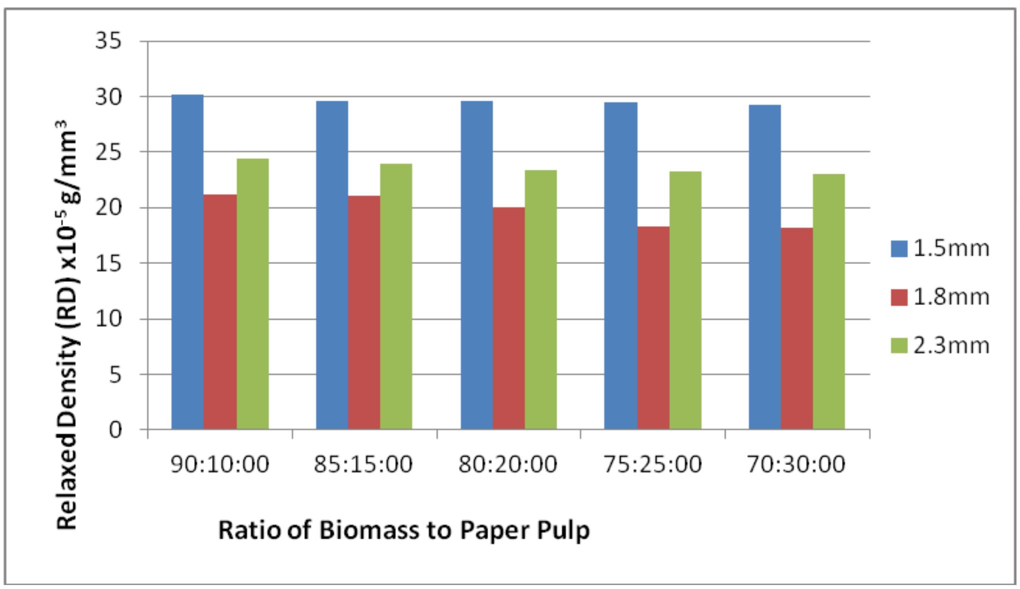

Figure 3.4: Chart showing the Relaxed Density of the sawdust biomass

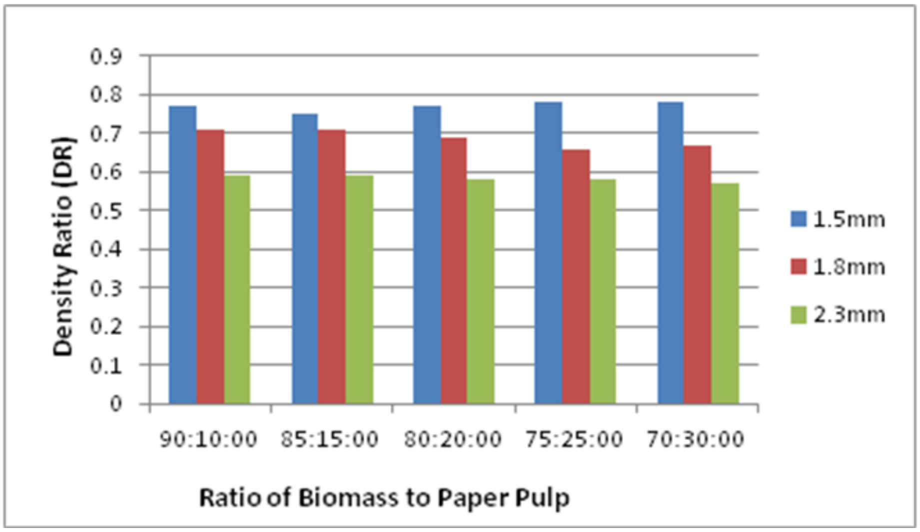

Figure 3.5: Chart showing the Density Ratio of the sawdust biomass

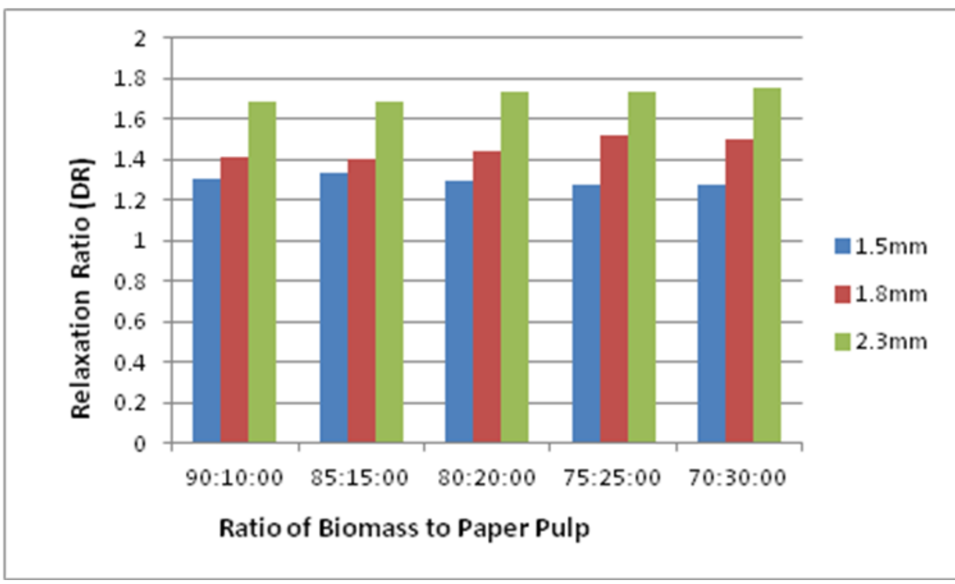

Figure 3.6: Chart showing the Relaxation Ratio of the sawdust biomass