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Composition Analysis for Implementing Small Scale Sawdust Briquette Manufacturing Process

H.L.J.M. Liyanage,
Department of Applied Computing,
Faculty of computing and technology,
University of kelaniya,
Kelaniya, Sri lanka
lmjeewani229@gmail.com

R.L. Peiris,
Department of Applied Computing,
Faculty of Computing & Technology,
University of Kelaniya,
Kelaniya, Sri Lanka.
rajithalakshanpeiris@gmail.com

Shanika M.A. Arachchi,
Department of Applied Computing,
Faculty of computing and technology,
University of kelaniya,
Kelaniya, Sri lanka
shanikami@kln.ac.lk

***Abstract*— A compressed block of flammable biomass material, such as charcoal, sawdust, wood chips, peat, or paper, is called a briquette and is used as kindling and fuel for a fire. The study was conducted with the objective of improving product quality, testing domestic briquette production in Sri Lanka, and providing a solution to the current fuel crisis. Production process analysis was done here, and the production of briquettes was evaluated using a homemade production machine. Several primary (sawdust and planner scraps), secondary (Jack fruit leaves) and binding (Paper waste and cow dung) materials were used as raw materials and briquettes were manufactured under various compositions. Several home-based tests were performed to determine the physical and combustion properties of the briquette samples produced. These are density, boiling and firing, ash content and shatter resistance tests. Based on the results of the experiments, it was found that adding a binder to the briquette product rather than using only the primary material would increase the quality of the final product. Paper waste and cow dung were used as binders, and it was found that adding 30% - 40% more paper to the primary material than cow dung would increase the stability of the product. Also, jackfruit leaves were used as a secondary material and it was found that using 15% of jackfruit leaves does not harm the quality of the final product, which can reduce the cost of production. According to correlations between all results, the optimum composition found was 45% of primary material + 15% of secondary material (Jack fruit leave) + 40% of binding material (paper waste). These tested small briquettes can be easily used to light a fire during excursions. It can also be concluded that medium-sized products can be used for cooking.**

Keywords— Biomass, Sawdust briquette, Binder, Compositions Analysis, Briquette testing

I. INTRODUCTION

All forms of forestry and agricultural waste are included in briquettes, which are compacted blocks of biomass. This product was commonly used for BBQ, room heaters and industrial fuels. Bio-Briquette is a solid biofuel that is environmentally benign, saving valuable foreign currency and reducing pollution [1][2][3]. There are many types of bio briquettes. Some of examples are, saw dust briquette, charcoal briquette, rice husk briquette, coconut shells briquette, and cotton stalk briquette. Also, small in size products are called pellets [4][5]. According to the literature review, Briquettes were mostly utilized in developing countries where access to cooking fuels was limited. Leading countries to produce briquettes were India, Nigeria, Bangladesh, the Philippines, and Indonesia. In these countries, briquette production took place industrially and domestically [6][7]. The technologies that were mainly used there were piston press and screw press technologies [8][9]. It was found that various parameters affected the quality of the briquettes. There, the parameters affecting the briquette production process played a key role. Those parameters are the type of raw material and particle size, moisture content, composition percentages and so on [10]. The quality of a briquette produced could also be calculated by various tests. Moisture content, boiling time, ash content, shatter-resistant, firing time, etc. were some of those tests [11][12][13].

One of the most widely used biomass briquettes, both in developed and developing nations, was sawdust. In order to produce a reconstituted log that can be used as a fuel substitute, this involves compressing and extruding sawdust. Sawdust briquette can be used directly as fuel for burning and compared to other natural wood, it has a higher density and heating value, which is the main reason for using this product [14][15]. Based on the research paper review, most relevant papers were summarized below

TABLE I. SUMMARY OF THE LITERATURE REVIEW

Category	Sub categories	Reference indices									
		1	2	3	4	5	6	7	8	9	10
Background of Biomass	Introduction	√									
	Biomass categories		√								
	Types & Properties		√	√							
Briquettes production	Similar countries						√	√			
	Production Methods				√	√			√	√	
Raw material	Composition /Additive										√
Parameter	Raw material/ process										√

The study hopes that if briquette production could be done domestically in Sri Lanka, it would be a more effective method to address the domestic energy requirement. During this time, people faced a lot of stress due to the lack of domestic gas. Briquette production could be introduced and introduced as a solution to the gas and wood problem. It was also sure to be an effective and cost-effective method as prices were low.

Fig 1. Research product

II. MATERIALS AND METHOD

A. Raw materials

Saw dust and planner scraps were used as the primary material, jack leaves as the secondary material and paper waste and cow dung as the binding material. The reason these materials were chosen because they had better advantages than other materials.

TABLE II. RAW MATERIAL SELECTION

	Used materials for product	Other materials for product
Materials	Sawdust, Planner scraps, jack leave, paper waste and cow dung	Charcoal, Peat, and starch
Reasons for material selection/non selection	Easy to find, high calorific value, cost effectiveness and more stability	Time limitation, High cost, Low availability and difficult to find

Sawdust

Planner scraps

Jack leaves

Paper waste

Cow dung

Fig 2. Raw materials

B. Sample preparation

Briquettes were produced using primary, secondary and binder raw materials under different compositions. The primary raw materials were sawdust and planner scraps. These were collected from sawmills/industry and three days of sun-dried to remove the moisture content (zero moisture). The dried materials were used to produce sawdust briquettes. A portion of the dried sawdust was screened by a standard mesh size of 3mm to remove unwanted substances and planner scraps were cut by a standard mesh size of 5cm. Secondary raw material was jackfruit leaves. That was collected of jack trees and blended for to make small pieces and three days of sun-dried to remove the moisture content until zero. Binding materials were paper waste and cow dung. Paper waste was cut or torn into small pieces. The pages of the exercise books were used for this purpose. Cow dung was collected from a cow. Those were dried until zero moisture and powdered using a hammer.

After the preparation of raw materials, all dried raw materials were packed in bottles to protect the moisture. Then, all bottles were labelled and indexed for easy identification and to protect against moisture.

Fig 3. Raw material labelling and indexing

The purpose was to manufacture briquettes using different compositions. All ingredients used should be in the dry state, i.e., 0% water content. Sawdust, planner scraps, jack leaves and binder materials (paper waste and cow dung) should have been prepared as mentioned above. Compositions of dry mixes were made in twelve sets. The following was a table of raw materials, composition percentages that made briquettes.

TABLE III. RAW MATERIAL COMPOSITION PERCENTAGES

Composition Index	Composition Name	Compositions percentages %		
		PMS	*PMP*	*Additive*
1	PMS	100	0	0
2	PMP	0	100	0
3	PMS+PMP	40	60	0
4	PMS+PMP+SMJ	55	30	15
5	PMS+PMP+SMJ	50	30	20
6	PMS+PMP+SMJ	45	30	25
7	PMS+PMP+BMP	50	30	20
8	PMS+PMP+BMP	40	30	30
9	PMS+PMP+BMP	30	30	40
10	PMS+PMP+BMD	50	30	20
11	PMS+PMP+BMD	40	30	30
12	PMS+PMP+BMD	30	30	40

PMS = Primary material sawdust, PMP = Primary material planner scraps, SMJ = Secondary material jackfruit leaves, BMP = Binding material paper waste, BMC = Binding material cow dung

As mentioned in the table above, the raw material was mixed in different percentages to produce six briquettes in one batch. This was because briquette samples were needed for various testing. Percentages were taken on a volume basis and a measuring cup was used. A percentage was marked on the cup so that the percentage could be easily measured. Raw materials from the measuring cup were measured by hand compaction. The percentages measured in each batch were put into the different jars and then the mixture containing the different raw materials in each jar was mixed well by hand.

Water was added to dry mixes made under different compositions. Water was added to make the mixture compact well and the ratio between composition and water was 1: 4. This was a weight-based measurement. After adding water to the mixture, it was mixed well by hand to mix the dry mixture well with water. All containers containing different percentages were labelled for ease of identification. All containers were kept at room temperature for three days after closing. The reason for that, was because it gives the mixture enough time to compact well.

A homemade piston briquette press machine was used to make the briquettes. Parts were taken from each mixture and filled into a cylinder measuring 5.6 cm. Also, the height of a briquette sample was1.5 cm. The mixture had to be filled to a cylinder height of 5.6 cm to maintain that pressure and the height of a briquette sample. Then compacted well by hand. Here the aqueous mixture is poured into the cylinder without releasing water. Two people pressurized the machine. By compression, the mixture in the cylinder compacts well and the piston stops at a height of 1.5 cm. The cylinder was perforated to allow excess water to escape when pressed. Thus, briquette samples were made from mixtures containing all the compositions.

Fig 4. Homemade briquette machine

After making all the briquette samples, the moisture content was controlled to 10 percent using sunlight. The reason for that was because the moisture content of the briquettes made by a piston briquette machine should be between 10 and 15 percent and it was more important to control the moisture content for the tests. The following equation was used to calculate the percentage of moisture content.

$$MCI = (WF - WD) / WF * 100\% \quad (1)$$

Where, MCI =Initial moisture content, WF = Fresh weight of briquette sample, and WD= Dry weight of briquette sample

The briquette samples prepared using primary, secondary, and binding material can be shown as follows,

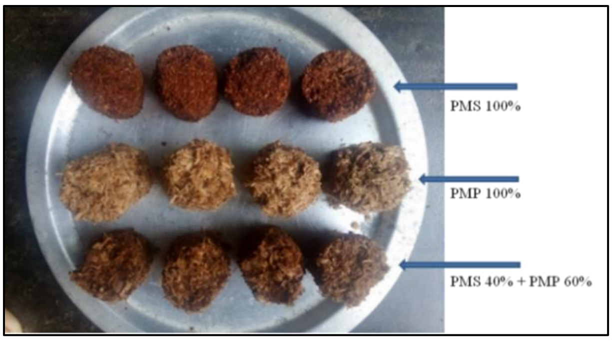

Fig 5. Briquettes used by primary material

Fig 6. Briquettes used by primary, and jack leave material

Fig 7. Briquettes used by primary and wastepaper material

Fig 8. Briquettes used by primary and cow dung material

C. *Experimental tests*

Density - Density was one of the key metrics used to evaluate the briquettes' handling, combustion, and ignite behavior. It was described as the volume-specific structural arrangement of the substance's molecules. A digital balance was used in the home to weigh the briquettes. All the briquettes were cylindrical in shape and the volumes of the briquettes were calculated using a straightforward formula based on direct measurements of their height and diameter (all briquette volumes were the same).

$$VB = \Pi R2 H \quad (2)$$

$$DB = MB / VB \quad (3)$$

Where, R = Radius of the briquette, cm, H = Height of the briquette, cm, MB = Mass of briquettes, g, VB = Volume of briquettes, cm3, π = Mathematical constant i.e., and DB = Density of briquette, g/cm.

Water boiling test - The effectiveness of the briquettes' cooking was evaluated using the water boiling test. We timed how long it took each set of briquettes (Samples I to XII) to boil an identical amount of water under comparable circumstances. As well as four briquette samples were used for these experiments of each set. Because heat loss was high for one sample more than few samples. Using a cooking kettle and a conventional tripod stove, 250ml of water was boiled using an equal amount of each sample briquette. Some fuel characteristics, including particular fuel consumption and water evaporation rate, were identified during this test.

$$WBC = TSB/TWB \quad (4)$$

Where, WBC = Water boiling coefficient, min/g, TSB = Total time spent to start boiling of water (Immediately after seeing bubbles-100c), min, TWB = Total weight of boiled water, g.

Fig 9. Boiling test

Firing Time test - The burning test measured the time it took to heat 250 ml of water and all four briquettes were not lit. The firing test showed how long the four briquettes will last. This could be calculated by taking the time it took to light the four samples and the total weight of the four samples. The firing coefficient was calculated by the following formula.

$$BFC = TBF/TWB \quad (5)$$

Where, BFC = Briquette firing coefficient, min/g, TBF = Total time spend briquette firing, min, TWB = Total weight of briquettes, g.

Fig 10. Firing test

Ash content test - The sample turned to black ash during this period after the firing test. The crucible and its contents were then moved to desiccators and cooled after that. The crucible and its contents were reweighed to determine the weight of the ash after cooling. The same procedure was continued until all of the samples had been created. The percentage ash content was calculated as the ratio of the weight of ash to that of the weight of the dry sample and was determined by: -

$$PAC = (WA/WD) *100 \quad (6)$$

Where, WD = Weight of dried sample, g, WA = Weight of the sample after oven drying and full furnace combustion i.e., weight of ash, g and PAC = Percentage ash content, %.

Fig 11. Ash content test

Shatter resistant test - The durability of the briquettes was determined in this test. Each briquette sample was allowed to drop from a height of 1m onto a concrete floor one time.

$$WLP (\%) = (W1-W2)/ W1*100 \quad (7)$$

$$SR (\%) = 100- WLP \quad (8)$$

Where WLP (%) = Percentage of weight loss, W1 = Weight of briquette before shattering, g, W2 = Weight of briquette after shattering, g and SR (%) = Percentage of shatter resistance.

Fig 12. Shatter resistant test

III. RESULTS AND DISCUSSION

The briquette manufacturing process was evaluated in this study. The briquette production process has been experimented, with using primary (sawdust and planner scraps), secondary (jack fruit leaves) and binding (paper waste and cow dung) materials of various compositions. Density, boiling time, firing time, ash content and shatter resistance of briquettes were determined. Utilizing various operating elements, including the proportions of primary and secondary materials, the amount of binder and the types of different raw materials and binders, the quality of sawdust briquettes were assessed. Below is a summary table containing the results of the tests performed.

TABLE IV. SUMMARY OF THE EXPERIMENTAL RESULTS

Composition Index	Average Density (g/cm 3)	Water boiling coefficient (min/g)	Firing coefficient (min/g)	Ash content (%)	Shatter resistant (%)
1	0.66	0.08	0.86	14.29	71.43
2	0.66	0.1	0.93	3.57	57.14
3	0.66	0.09	0.82	7.14	71.43
4	0.57	0.05	0.67	16.67	66.67
5	0.57	0.06	0.71	12.5	50

6	0.47	0.03	0.5	20	40
7	0.66	0.06	0.68	3.57	85.71
8	0.75	0.03	0.38	9.38	100
9	0.66	0.03	0.5	10.71	100
10	0.75	0.05	0.44	6.25	62.5
11	0.75	0.04	0.34	12.5	62.5
12	0.66	0.04	0.43	14.29	71.43

The tests performed can be classified as physical combustion properties. Density and shatter resistance are physical properties, while burning time, firing time and ash content are combustion properties. The percentage of water was also controlled in this study but is also considered as a physical property of the briquette product. The results of each of these properties were as follows.

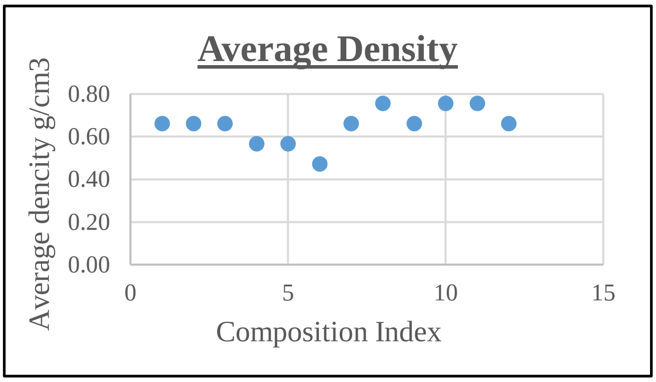

Fig 13. Results of average density

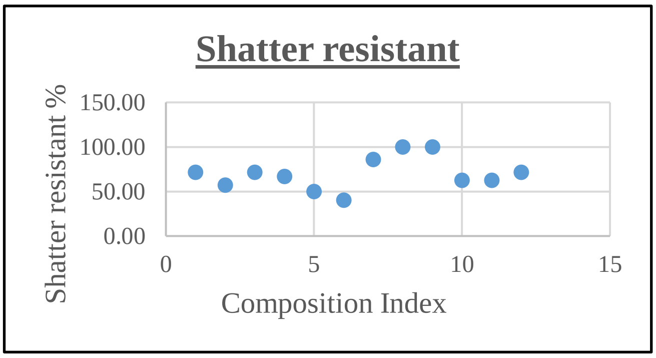

Fig 14. Results of shatter resistant test

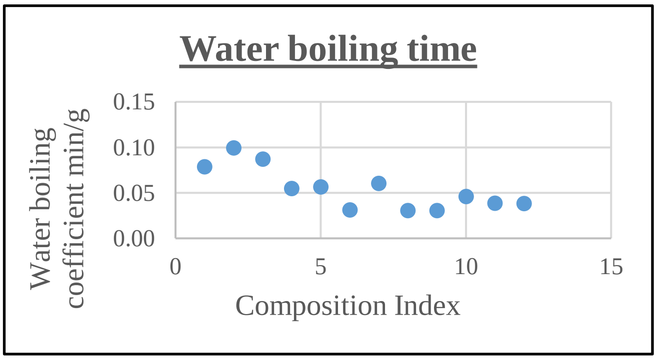

Fig 15. Results of water boiling time coefficient

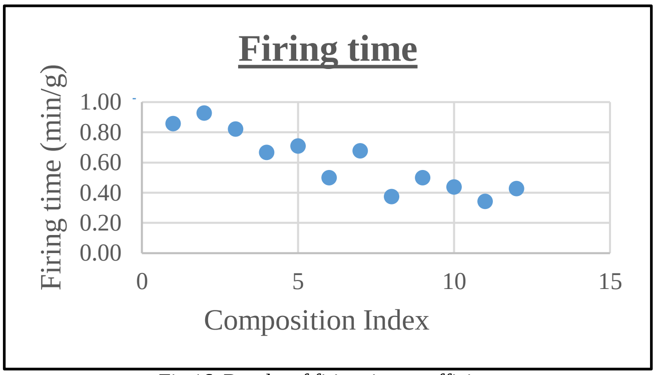

Fig 16. Results of firing time coefficient

It is clear from the results of the tests that all the above physical and combustion characteristics affect the quality of a briquette product. The composition of the raw material and the binding material types affected all the features. All the results obtained under each composition are taken as a whole and arranged in hierarchical order. This was done to distinguish better compositions.

The results of the tests show that the quality of the products with PMS 30% + PMP 30% + BMP 40%, PMS 40% + PMP 30% + BMP 30%, PMS 50% + PMP 30% + BMJ 20% respectively, was high. Also, it can be said that the composition of different ingredients affects the quality of the product.

A table containing the results arranged in hierarchical order is given below.

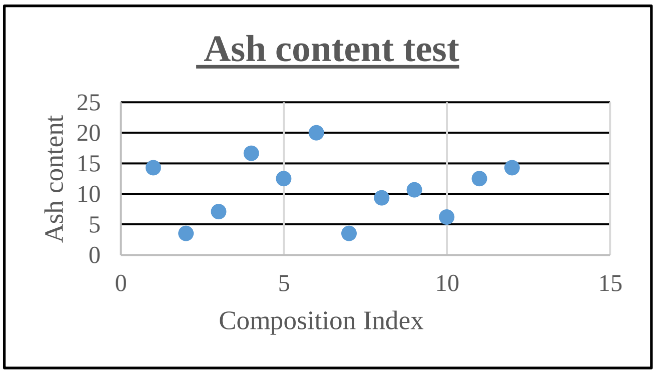

Fig 17. Results of ash content test

TABLE V. RANKING RESULTS OF ALL TESTS

Composition Index	Water boiling Coefficient (min/g)	Firing time coefficient (min/g)	Ash content (%)	Shatter resistant (%)	Rank Average	Final rank
1	0.08	0.86	14.29	71.43	21.67	4
2	0.1	0.93	3.57	57.14	15.44	11
3	0.09	0.82	7.14	71.43	19.87	7
4	0.05	0.67	16.67	66.67	21.02	6
5	0.06	0.71	12.5	50	15.82	10
6	0.03	0.5	20	40	15.13	12
7	0.06	0.68	3.57	85.71	22.51	3
8	0.03	0.38	9.38	100	27.45	2
9	0.03	0.5	10.71	100	27.81	1
10	0.05	0.44	6.25	62.5	17.31	9
11	0.04	0.34	12.5	62.5	18.85	8
12	0.04	0.43	14.29	71.43	21.55	5

All experiments in briquette production are done at home and there may be some variation in values. It can be thought that it influences the firing time coefficient more. The reason is that the weight of the briquette affects it. Therefore, the errors of the values related to each composition are calculated as follows.

TABLE VI. ERROR VALUES FOR FIRING TIME COEFFICIENT

Average (min/g)	0.86	0.93	0.82	0.67	0.71	0.5	0.68	0.38	0.5	0.44	0.34	0.43
Error (min/g)	+- 0.1	+- 0.2	+- 0.1	+- 0.1	+- 0.1	+- 0.1	+- 0.1	+- 0.06	+- 0.1	+- 0.1	+- 0.06	+- 0.07

IV. CONCLUTION

The briquettes were manufactured in a variety of raw materials percentages using primary (Saw dust & Planner scraps), secondary (Jack leaves) and binding (Paper waste and cow dung) materials. The aim of this research was to improve product quality and resolve the current domestic energy requirements. Among those products with different compositions, tests have been carried out on the physical and combustion characteristics to find the product with the optimal composition.

According to the results of the tests performed, the compositions PMS 30% + PMP 30% + BMP 40%, PMS 40% +PMP 30% + BMP 30%, PMS 50% + PMP 30% + BMP 20% respectively, showed a better ranking.

When comparing different materials, experiments revealed that adding not only the primary material but also the binding material to it enhances the quality of the briquette product and that it is best to use paper at 30% or 40%. As well as the paper was found to be more stable than cow dung. Also, sawdust and planner scraps were used as the primary materials, which showed more physical and combustion properties by sawdust. Therefore, using more sawdust with fewer planner scraps will increase the quality of the final briquette product.

Based on the cost analysis results, primary material and paper waste was slightly more expensive. Therefore, It can be concluded that adding 15% jackfruit leaves to this product does not reduce the quality of the product. This is because the product has received a mediocre result in terms of ratings.

Based on these correlations, It can be concluded that briquette products containing 45% of the primary material, 15% of the jackfruit leaves, and 40% of the paper show better physical and combustion properties. Also, the domestic experimental production of briquettes has been quite successful and has the potential to continue as a business in Sri Lanka with further enhancements. These tested small briquettes can be easily used to light a fire during excursions. It can also be concluded that medium-sized products can be used for cooking. This can be suggested as an alternative fuel to current domestic energy needs.

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