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FABRICATION OF SAWDUST BRIQUETTES USING LOCAL BANANA PULP AS A BINDER

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ABSTRACT
Sawdust is generated in large quantities in sawmills in Manicaland province in Zimbabwe, posing an environmental threat if incinerated or left to accumulate. This presents an opportunity for valorising the waste into briquettes. To make the briquettes cost effective, a cheap and locally available binder is needed. Hence, the use of banana waste pulp (green banana, ripe banana, pseudo-stem pith and fruit-bunch-stem) as a sawdust briquettes binder was investigated in this study. The quality of fabricated briquettes was evaluated based on relative density, shatter index, ignition time, burning rate, and time taken to boil a constant amount of water. The briquettes showed improved qualities with the increase in binder ratios. The sawdust-binder ratio of 1:4 showed the best briquettes qualities. Factor rating method was done in order to obtain the best scored (scale 0-100) briquettes reflecting weightier factors (scale 0-1). The weightiest factors were time taken to boil water (0.25) and shatter index (0.25), with three other factors weighing 0.5. The best five binder formulations in their order were; banana-pseudo stem-pith (pith) and ripe banana (RB) in the ratio of 3:1 respectively (score weight of 68.75), fruit-bunch-stem, banana-pseudo-stem-pith (pith), green banana (GB) and ripe banana (RB) in the ratio of 2:2:1:1 respectively (score weight of 68.3), banana-pseudo-stem-pith (pith), ripe banana (RB) and green banana (GB) 2:1:1 respectively (score weight of 66.95), banana-pseudo-stem-pith, ripe banana and green banana in the ratios of 2,5:1,5:1 respectively (score weight of 66.05) and banana-pseudo-stem-pith and ripe banana in the ratios of 1:1 (score weight 65.55).

1. INTRODUCTION

The majority of biomass waste is incorrectly disposed of in Zimbabwe and other developing countries, creating an ecological concern in a variety of ways (Charis et al., 2019). Zimbabwe has a significant number of timber plantations. In 2009, plantation forests covered 89, 862 hectares, with about 90% of these plantations located in the Eastern Highlands (Manicaland province) owing to the high altitudes and high rainfalls in the area (Mtisi & Prowse, 2012) . Timber processing into various products generates a lot of waste products, such as tree cut offs, sawdust, and tree bark, and this waste has become prominent due to the high demand for timber and its derived products (Owoyemi et al., 2016). A small percentage is being used in boilers to produce steam used for drying timber mainly (Manyuchi et al., 2018) whilst the rest, especially sawdust, is largely unutilized. Throughout the year, heaps of wood waste accumulate across the whole timber value chain. Although local people and timber processors use some of this waste for fuel, they have been unable to keep up the accumulation of sawdust, reported to be well over 70, 000 tonnes per annum (tpa) (Mtisi & Prowse, 2012). Some of the sawdust is incinerated, while some burns spontaneously as a result of hotspots within the heaps, endangering the environment and its various ecosystems (Charis et al., 2019). The local city council has actually restricted the disposal of sawdust into its dumpsites due to such fire hazards (Manyuchi et al., 2018). There is also a host of other environmental impacts including organic wood leachate and marring of the aesthetic appeal of Manicaland (Arimoro et al., 2006). Similarly, health and environmental issues arise from banana wastes as they frequently harbour disease vectors such as flies and mosquitos (Akala M. B., 2021). Perhaps, the threat to health from such undermanaged wastes is what justifies the call to condescend from the 3R (Reduce, Reuse,

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Recycle) to the 3S (Sanitisation, Subsistence economy and Sustainable landfilling) concepts (Lavagnolo and Grossule, 2018). In this case, there would be an urgent need to address sanitization aspects if the capacity to engage in the 3R is still low, as is characteristic of low income nations. The aim of this project however, was to begin exploring the potential to achieve a circular economy involving locally available sawmill and banana waste, using an affordable recycling method. This also contributes to the achievement of a 'zero waste' society.

Timber waste from sawmills can be valorised using different methods like gasification, pyrolysis, direct combustion, liquefaction, biochemical and densification (Jingura et al., 2013). Whereas the other routes are mostly industrial at medium to high scales of productivity to make economic sense, densification appeals for a wider market from domestic, small scale and commercial/industrial scales. The densified sawdust would then be replacing the traditional use of wood or coal as fuel with the advantage that it is renewable. Indeed, biomass (especially waste) is a more sustainable source of energy than fossil fuels, which are not. The low bulk density (typically 150 to 200 kg/m^3 for woody resources such as wood chips and sawdust), relatively high moisture content and low energy density, of biomass are some of the significant drawbacks on its use as an energy feedstock (Rajaseenivasan et al., 2016). The low bulk density and dusty characteristics of the biomass also cause problems in transportation, handling and storage (Husan et al., 2002) .The application of biomass briquetting i.e. densifying the loose biomass is an effective way to increase the bulk and energy density of the loose chips or sawdust for easier use domestically and industrially (Ogwu et al., 2014). Such briquettes can even be used to fuel power plants for electricity generation. It was on these premises that three potential co-generation projects in Nyanga, Chimanimani and Charter sawmills were proposed by the Department of Energy to produce 3.5 MW, 3 MW and 10 MW of energy respectively from briquettes made from sawdust wastes at those sites (Jingura et al., 2013). These excluded additional wastes from scattered bush mills, Chinese sawmills and dysfunctional sawmill sites. Mechanical compaction of sawdust into briquettes is a costly venture hence the reason why companies prefer to simply dispose of the waste (Nyemba et al., 2018). There is therefore a need for affordable, economic and sustainable ways of making briquettes that are acceptable and meet the needs of both industry and the community (Jingura et al., 2013).

The use of a very cheap, locally available binders for briquettes binding has been found as a good way of reducing costs of making briquettes. A good briquette binder must be economically accessible, strong, environmentally pollution-free and produce strong bond. Therefore, finding a suitable binder in briquetting is an important step (Abdulmalik et al., 2020). Poor quality briquettes may crack and crumble back to the original components when stored, processed or handled (Idah & Mopah, 2013). A suitable binder which addresses these problems is imperative. Furthermore, the density, durability and combustion characteristics of fuel briquettes are influenced by the binder. Traditionally cement, clay, animal dung, bitumen, wood/coal tar, gum Arabic have previously been utilised as binders for making briquettes (Abdulmalik et al., 2020). However, economic viability of these materials is questionable for briquetting due to competition for their usage in other sectors. Moreover, combustibility and calorific values of briquettes based on these binders are low (Abdulmalik et al., 2020). These inorganic binders have good compaction ratio, hydrophobic nature and compressive strength than organic binders but inorganic binders decrease the net heating value of briquettes and increase the burn out temperature and ash content (Manyuchi & Mbohwa, 2018). Several studies have cited organic binders such as starch, protein, fibre, fat/oil, lignosulfonate, modified cellulose, rapeseed flour, coffee meal, orange peels, bananas waste, bark gums, molasses sugar, starch, sulphite liquor, cassava wastewater, microalgae and okra stem gum, pine cones and lignin powder as possible briquettes binders (Abdulmalik et al., 2020; Rajaseenivasan et al., 2016). To that effect some studies have been conducted where several binders have been tested in the production of briquettes from different biomass; rice husk/cassava peel gel, rice husk/banana peel, maize cob/cassava peel gel, maize cob/banana peel, groundnut shell/cassava peel gel, groundnut shell/banana peel, sugarcane bagasse/cassava peel gel, sugarcane bagasse/banana peel with encouraging bulk densities calorific values and other properties. Nevertheless, limited research is available on the use of banana waste (green bananas, ripe bananas, pseudo-stem pith and fruit-bunch-stem) as binders in the fabrication of pine sawdust-based briquettes. Banana waste briquette binders are encouraging since many parts of the banana are rich in starch and vast quantities of these materials are always discarded. Thus, there is ample scope for study on the use this cheap and locally available binder judging by the ever-increasing concerns on the economics of briquettes fabrication and marketing.

This study considered the potential of banana waste as a briquette binder. Bananas (Musaceae) in Zimbabwe are grown in Honde Valley, Burma Valley, Birchnough Bridge, Chimanimani and other areas with a tropical environment that has plenty of humidity, good drainage and fertile soil. In 2017, the Honde Valley in eastern Zimbabwe alone produced over 27 000 tons of bananas. Every month, farmers generate over 1000 kg of bananas (Lacey, 2018). Banana fruit- bunch- stem, pseudo-stem and some green bananas are discarded as banana waste which is thrown away as residue after banana harvesting hence this waste can be collected and put into good use. This study therefore investigated the integration of two wastes into compact wood briquettes, paying special attention to the binder formulation, composition and sawdust to binder ratio.

2. MATERIALS AND METHODS

2.1 Experimental design

A laboratory scale experimental design method was employed for production of briquettes. Sawdust and banana waste binder were prepared and mixed according to the chosen ratios. The resulting briquettes were sun dried and tested for quality. The variables chosen were binder composition and binder ratio. The response variables measured were relative density, shattering test, boiling water test, burning rate test and ignition time test. The binder ratios and the sawdust- binder ratios were as shown in Table 1.

A factor rating method was then done in order to obtain the best briquettes with high quality parameters.

2.2 Briquettes preparation equipment

A digital analytical balance (model KERN 19037) was used for weighing. A blender (model EM BL-1075) was used to make banana waste pulp. A stove (DSP model 4046) was used as a source of heat for boiling the binder solution.

2.3 Material preparation

2.3.1 Feedstock

Pine sawdust was chosen as the feedstock material for this study. Sawdust was solar dried for 3 weeks to achieve a moisture content ~6.50% as achieved previously by Charis et al (2020). The final moisture content of each sample was determined by determining the difference between the original and final sample mass after oven drying for 4 hours, according to the ASTM D4442 method.

2.3.2 Binder

The natural binder used was banana pulp. Banana waste which comprised of green bananas (GB), ripe bananas (RP), pseudo-stem pith (pith) and fruit-bunch-stem (stem) was collected from Burma Valley. These were cleaned to be devoid of foreign matters. 200 g of the waste was cut into 2-3 cm pieces and put in a blender and 100 ml of water was added to the pieces and the blender was set at a speed of 2. The contents where blended to puree form after which 600 ml of water was added to 300 g of the binder. The mixture was then boiled for 1 h under continuous stirring to refine the pulp, which contained sufficient starch for briquettes binding. The procedure was done for banana waste mixtures which were combined using the ratios shown in Table 1, with fruit-bunch-stem and pseudo-stem pith being higher in the ratio since these are found in large quantities as residue compared to discarded bananas.

TABLE 1: Binder and sawdust to binder ratios.

			Sawdust : Binder ratios			
			1:2	1:3	1:4	1:5
Binder ratios	GB: Stem	1:1				
		1:3				
	RB : Stem	1:1				
		1:3				
	GB : RB : Stem	1:1.5:2.5				
		1:1:2				
	GB : Pith	1:1				
		1:3				
	RB : Pith	1:1				
		1:3				
	GB : RB : Pith	1:1.5:2.5				
		1:1:2				
	GB : RB : Stem : Pith	1:1:2:2				

2.3.3 Mixing sawdust with binder

The sawdust-binder ratios used were 1:2, 1:3, 1:4 and 1:5. The mixing of sawdust and binder prior to compaction was done manually. In a 5L bucket using a wooden rod.

2.3.4 Densification process

The sawdust-binder mixture of 50 g mass was put into the cylindrical die of 2.3 cm diameter and 5 cm height. A cloth was used to cover the other end and allow water to pass through. Pressure was applied manually using a wooden rod. The assumption made was that every manual compression stroke was delivered with the same strength. The briquetting process is illustrated in Figure 1.

2.3.5 Briquettes drying

The as-fabricated briquettes were sun dried for 1 week in sunny weather conditions.

2.4 Briquettes quality parameters

2.4.1 Relative density

The relative density of samples was calculated by measuring the volume and weight. It was calculated in accordance to the equation (1) (Manyuchi et al., 2018):

$$Relative\ density\ (kg/m^3) = \frac{mass\ of\ dried\ briquette\ (kg)}{volume\ of\ briquette\ (m^3)} \quad (1)$$

2.4.2 Shatter index

Shatter index is used to assess how hard the briquettes are. The shatter index of the briquettes was determined by dropping 50 g of briquettes put in a plastic bag for five times from a height of 2 metres onto a concrete floor (Manyuchi et al., 2018). The weight of the fragmented briquette was recorded. The shattering index was determined according to ASTM D440-86 of drop shatter developed for coal using the equation (2) (Davies & Davies, 2013):

$$Shattering\ index = \frac{weight\ of\ briquettes\ after\ dropping}{weight\ of\ briquettes\ before\ dropping} \quad (2)$$

2.4.3 Water boiling test

A 50 g mass of each briquette sample was placed in a brazier made from a fabricated can and used as feel to boil 50 ml of water. A stopwatch was used to record the time it took to boil the water in minutes. The mercury dry bulb thermometer was used to pin point the exact temperature at which the water boiled (Thulu et al., 2016).

2.4.4 Ignition time

Each briquette sample was ignited at the base in a drought free corner using matches and the time required for the flame to ignite the briquette was recorded in seconds using a stop watch (Thulu et al., 2016).

2.4.5 Burning rate

A 50 g briquette sample from each blend was burnt and the initial time (ignition time) to the final time of burning (flame extermination) was recorded using a stopwatch. The burning rate was calculated using equation (3) (Hassan et al., 2017).

$$Burning\ rate = \frac{mass\ of\ fuel\ consumed\ (g)}{total\ time\ taken\ (min)} \qquad (3)$$

2.5 Factor rating method

Weight was assigned to briquettes quality parameters according to importance as obtained from literature. A scale of 0-1 was used to weigh each factor. The most important factors were the time taken to boil water (weight 0.25), which reflects on the heating value of the fuel; and the shatter index (weight 0.25), which reflects on the impact resistance and strength of briquette (Ige et al., 2020). Each parameter was scored out of a 100, using the factor scale. Scores were multiplied by weights for each factor and these were then summed.

3. RESULTS AND DISCUSSION

3.1 Physical properties of pine sawdust

The raw pine sawdust had been previously tested in work reported by Charis et al. (2020). The results of the proximate and calorific value tests are given in Table 1 (Charis et al., 2020). The ash content of pine sawdust obtained from the study is greater than the ash content value of 0.3-0.4% reported in literature (Garcia et al., 2021; Tillman et al., 2012; Chaula et al., 2014). The fixed carbon value obtained is closer to the value of 18.60% reported by other researchers (Chaula et al., 2014) whilst the value of the volatile matter obtained is inconsistent with the value of 81.03% from literature (Chaula et al., 2014). The moisture content was way above the moisture content value reported by other researchers (Garcia et al., 2021; Tillman et al., 2012; Chaula et al., 2014) and the heating value obtained was slightly lower than the value of 19.98 MJ/kg from literature (Garcia et al., 2021) . The inconsistency of the results with those reported in literature may be attributed to factors like climate conditions, growth conditions and sawdust handling.

3.2 Relative density

3.2.1 Effect of binder ratio on relative density

Figure 2 shows the relationship between binder ratio and relative density. The binder formulations as a ratio to sawdust were averaged and so were the densities of briquettes formed using those sawdust: binder rations. The aim was to see the general trend as the amount of binder increased in the mix.

The lowest relative density was recorded at the sawdust binder levels of 1:2. The density of the briquettes increased as the binder ratio increased up to the sawdust-binder ratio of 1:4. This suggests that briquettes produced with high concentration of binder are denser and have a longer burning time when used for heating while those produced with low concentration of binder are less dense and therefore are likely to ignite much easier when compared with high concentration of binder (Ige et al., 2020). The relative density of the briquette however, decreased from the sawdust-binder ratio of 1:4 to 1:5. The density increase with increase in sawdust-binder ratio could be due to the filling up of air spaces between sawdust particles by the binder (Musa, 2007).

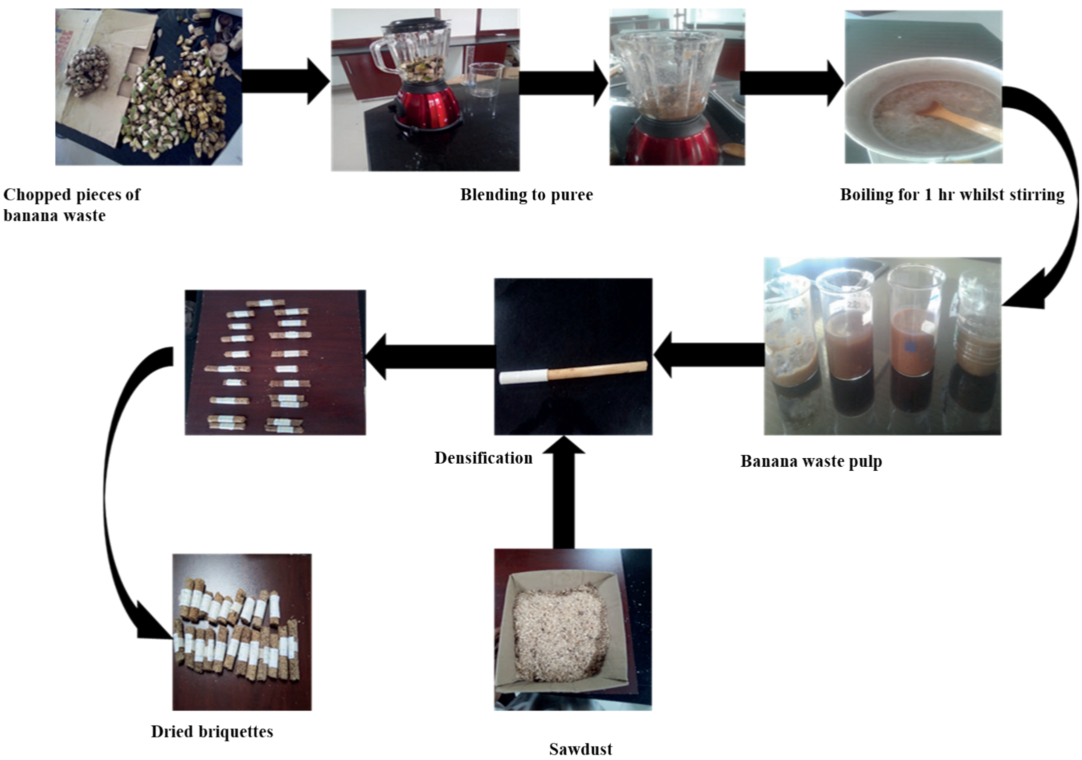

FIGURE 1: Briquetting process.

TABLE 2: Sawdust properties (Charis et al., 2020).

Physical property	Value (% dry basis)
Ash	0.83
Fixed carbon	20.00
Volatile matter	79.16
Moisture content	65.41
HHV (MJ/kg)	17.568

3.2.2 Relative densities of different binder mixtures

Figure 3 shows the relative densities of different binder mixtures of banana waste binders. The highest relative density recorded for a binder mixture with stem was 0.238 g/cm^3 which was a mixture of stem and ripe banana in the ratio of 1:1. The lowest recorded for a stem mixture was 0.18 g/cm^3 for a ratio of 2.5:1.5:1 of stem, green banana and ripe banana, respectively. Banana pith mixture with green banana and ripe banana in the ratio of 2:1:1 exhibited the highest relative density of 0,238 g/cm^3. The results showed that the mixtures of banana pith with green banana in the ratio of 1:1 exhibited the lowest relative density (0.187 g/cm^3) for a binder mixture which included banana-pseudo-stem-pith.

3.3 Shatter index test

3.3.1 Effect of binder ratio on shatter index

Figure 4 shows the relationship between binder ratio and shatter index. The same concept of averaging mentioned in section 3.2.1 was applied to the both the dependent and independent variables. The highest shatter index was at the sawdust-binder ratio of 1:4 (1) and the lowest was recorded at the ratio of 1:2 (0.986). There was an increase in shatter index with an increase in sawdust-binder ratio. The binding agent helps in fusing the biomass particle and thus enhances the durability of the resulting briquette (Saeed et al., 2021). The shatter index is above 95% which falls within the standard pellet quality durability range of 95-100%. Lower durability hinders operation and transportation of briquettes (Saeed et al., 2021).

3.3.2 Shatter index tests for different binder mixtures

Figure 5 shows the shatter index of different binder mixtures. The best shatter index was recorded for the mixtures of banana stem/pith with green banana at the ratio of banana pith/stem to green banana of 1:1. Generally the shattering index for mixtures with banana pith were higher than those with banana stem.

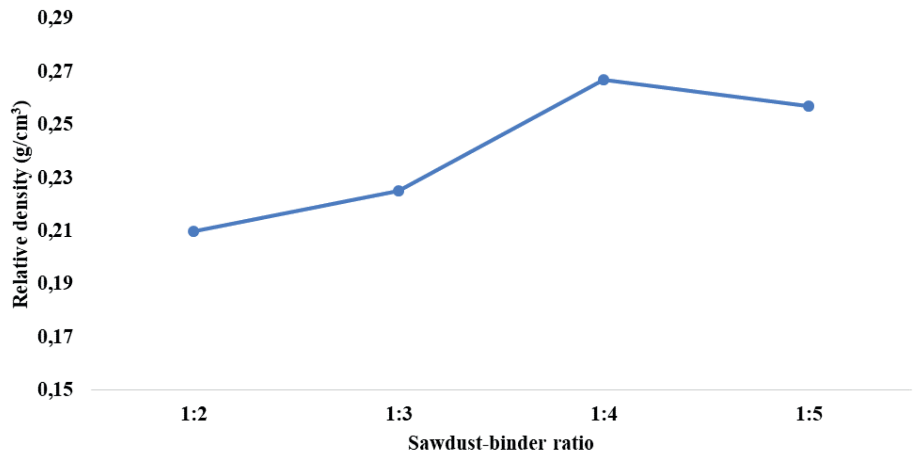

FIGURE 2: Effect of binder ratio on relative density.

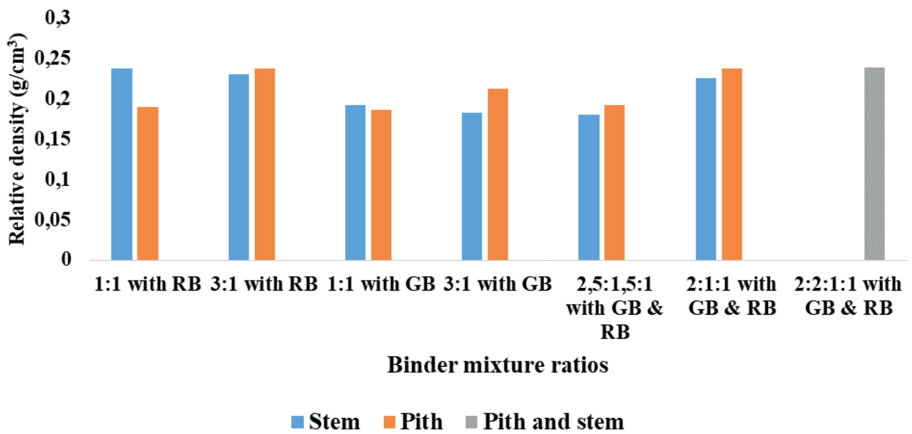

FIGURE 3: Comparisons of relative densities of different binder mixture ratios.

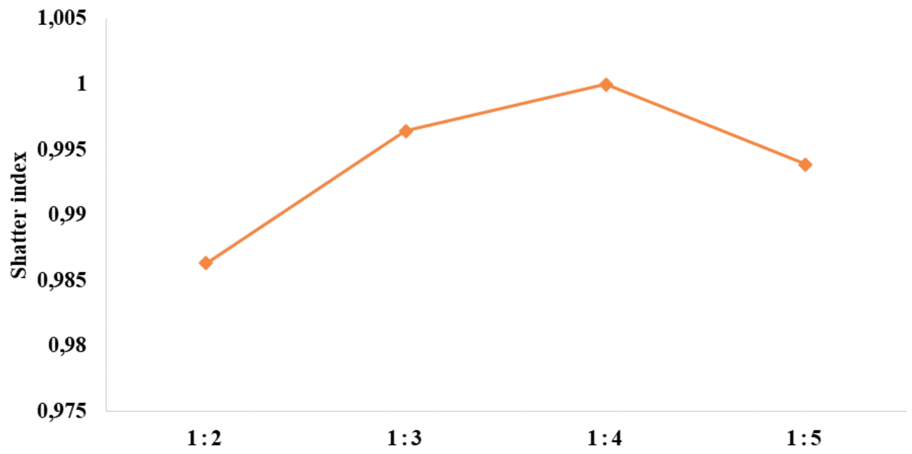

FIGURE 4: Effect of binder ratio on shatter index.

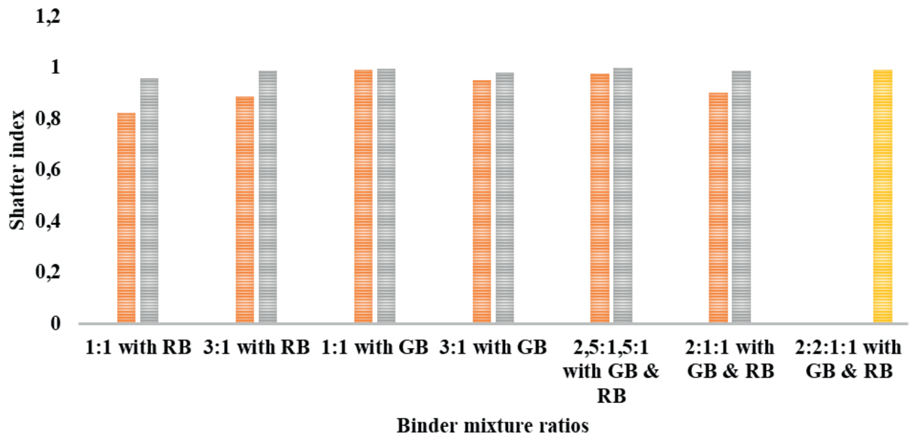

FIGURE 5: Shatter index tests for different binder ratios.

3.4 Ignition time and Water test

3.4.1 Effect of binder ratio on ignition time and time taken to boil water

The relationship between binder ratio and ignition time and time taken to boil water is shown in Figure 6. The same concept of averaging mentioned in section 3.2.1 was applied to the both the dependent and independent variables. The obtained trend indicated that ignition time and time taken for water to boil increased with decrease in binder proportion. This may be due to increase in density. This also indicates that the little the amount of volatile matter the longer the ignition time which is in agreement with the results obtained from studies done by Kimutai and Kimutai (2019) and Ige et al (2020).The briquettes with lower binder ratio burn slowly as a result, lots of the heat released was lost before the water boils.

3.4.2 Ignition time and time taken to boil water for different binder mixtures

Figure 7 and 8 show the ignition time and the time taken to boil water by different binder mixtures. Mixtures containing banana stem had lesser ignition time compared to those with banana pith. Banana stem/pith mixed with green banana in the ratio of 1:1 was the fastest to ignite whereas the mixtures of banana stem/pith with green banana in the ratios of 3:1 respectively were slowest to ignite. Banana stem mixtures took longer to boil water than banana pith mixtures. The longest time taken to boil water was 68 min by green banana with banana stem in the ratio of 1:1. The mixture of banana pith with green banana in the ratio of 3:1 respectively, took the shortest time to boil water.

3.5 Burning rate

3.5.1 Effect of binder ratio on burning rate

Figure 9 shows the relationship between binder ratio and burning rate. The same concept of averaging mentioned in section 3.2.1 was applied to the both the dependent and independent variables. The briquettes burnt fast with increasing binder proportion hence the highest binder ratio burnt for shorter period compared to the lowest. Low volatile matter makes the briquettes to burn slowly and the opposite is true (Ige et al., 2020). This is similar to the findings by Hassan et al (2017), the improvement of fuel ignition time and the burning rate with the increase in binder ratio is due to a higher volatile content (Hassan et al., 2017).

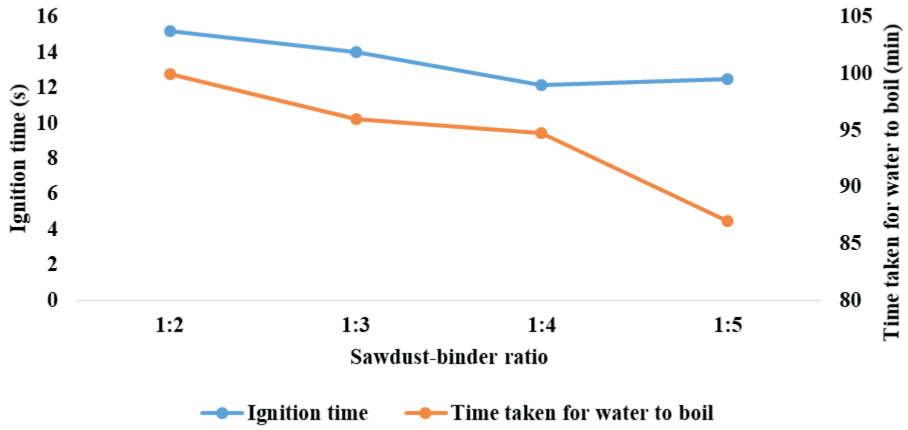

FIGURE 6: Effect of binder ratio on ignition time and time taken to boil water.

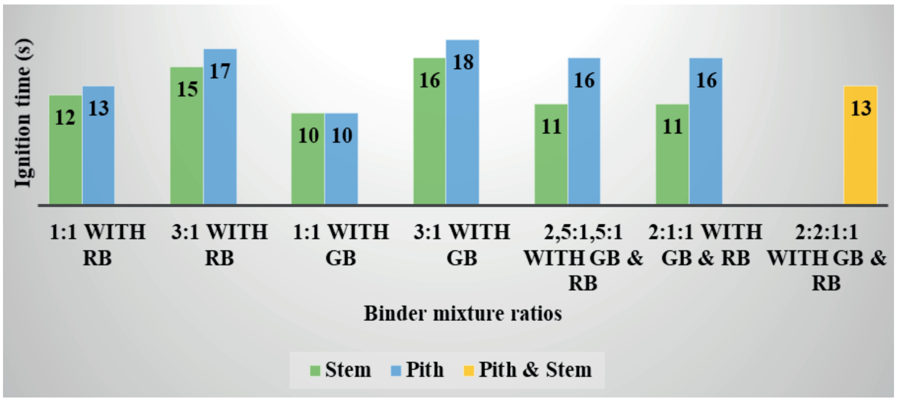

FIGURE 7: Ignition time for different binder mixtures.

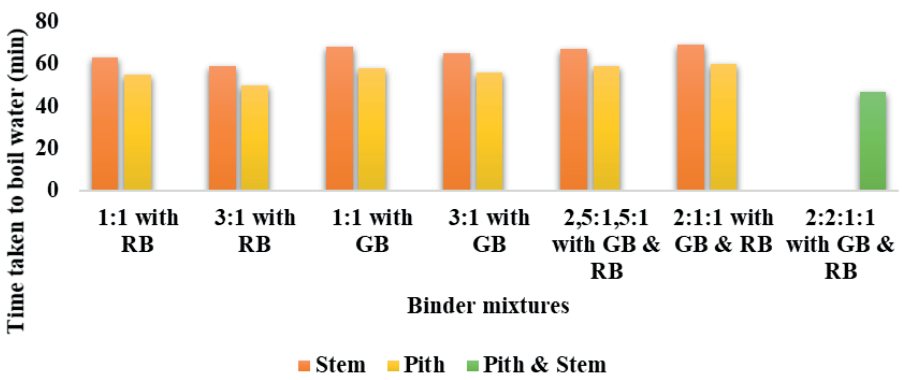

FIGURE 8: Time taken to boil water by different binder mixtures.

3.5.2 Burning rate for different binder mixtures

Figure 10 shows the burning rates for different binder mixtures. The mixture of green banana and ripe banana with pith in the ratios of 1:1:2 respectively, had the highest burning rate of 0.95 g/min whilst the lowest burning rate obtained was from the mixture of green banana with stem in the ratio of 1:1. The mixtures containing stem had the least burning rate compared to those containing banana pith.

This study examined the utilisation of banana waste pulp as a binder for sawdust briquettes. The effects of binder mixing ratio, sawdust moisture content and different binder mixtures on relative density, shattering index, ignition time, burning rate and time taken to boil water were examined. A factor rating method was then used in order to determine which binder mixtures were used to produce high quality briquettes. Tables 3 and 4 show the factor rating method. The factors were given weights considering their relative importance according to literature, with core factors around the physical integrity and thermal value of the briquettes scoring higher.

By using the factor rating method, the best five binder formulations (combinations and ratios) in their order

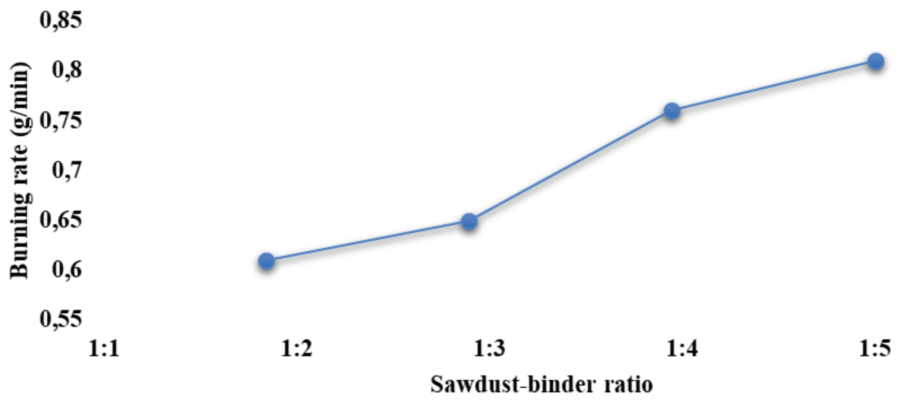

FIGURE 9: Effect of binder ratio on burning rate.

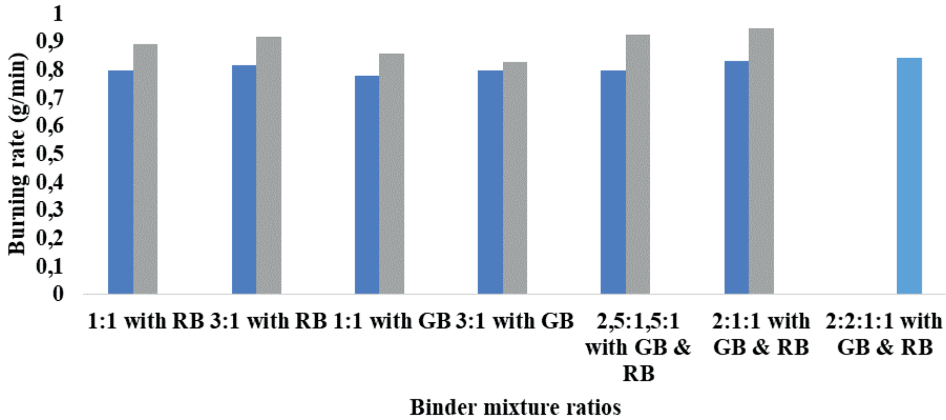

FIGURE 10: Burning rates for different binder mixtures.

were; banana-pseudo stem-pith (pith) and ripe banana (RB) in the ratio of 3:1 respectively (score weight of 68.75), fruit-bunch-stem, banana-pseudo-stem-pith (pith), green banana (GB) and ripe banana (RB) in the ratio of 2:2:1:1 respectively (score weight of 68.3), banana-pseudo-stem-pith (pith), ripe banana (RB) and green banana (GB) 2:1:1 respectively (score weight of 66.95), banana-pseudo-stem-pith, ripe banana and green banana in the ratios of 2,15:1,5:1 respectively (score weight of 66.05) and banana-pseudo-stem-pith and ripe banana in the ratios of 1:1 (score weight 65.55).

4. CONCLUSIONS

This study focused on the fabrication of sawdust briquettes using local banana pulp as a binder. The physical properties of the sawdust briquettes were found to be significantly affected by the binder ratio. The briquette properties improved with an increase in binder ratio and for the optimum sawdust briquette quality on the basis of relaxed density, shatter index and burning properties, a sawdust-binder ratio of 1:4 was obtained. Such cheaply made briquettes have the potential to provide sustainable fuel

TABLE 3: Factor rating for different binder mixture ratios containing stem.

Factor	Weight	1:1 Stem & RB		3:1 Stem& RB		1:1Stem& GB		3:1 Stem & GB		2,15:1,5:1 Stem & RB &GB		2:1:1 Stem & RB& GB		2:2:1:1 Stem & Pith& GB & RB	
		Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores
Relative density	0.20	24.0	4.8	23	4.6	19	3.8	18	3.6	18	3.6	23	4.6	24	4.8
Shatter index	0.25	82	20.5	89	22.25	99	24.75	95	23.75	98	24.5	90	22.5	99	24.75
Ignition time	0.1	88	8.8	85	8.5	90	9	84	8.4	89	8,.9	89	8.9	87	8.7
Time taken to boil water	0.25	37	9.25	41	10.25	32	8	35	8.75	33	8.25	31	7.75	53	13.25
Burning rate	0.20	80	16	82	16.4	78	15.6	80	16	80	16	83	16.6	84	16.8
Total	1		59.35		62		61.15		60.5		61.25		60.35		68.3

TABLE 4: Factor rating method for different binder mixtures containing pith.

Factor	Weight	1:1 Pith & RB		3:1 Pith & RB		1:1 Pith & GB		3:1 Pith & GB		2,15:1,5:1 Pith & RB &GB		2:1:1 Pith & RB& GB	
		Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores	Scores	Weighted scores
Relative density	0.2	19	3.8	24	4.8	19	3.8	21	4.2	19	3.8	24	4.8
Shatter index	0.25	96	24	99	24.75	100	25	98	24.5	100	25	99	24.75
Ignition time	0.1	87	8.7	83	8.3	90	9	82	8.2	84	8.4	84	8.4
Time taken to boil water	0.25	45	11.25	50	12.5	42	10.5	44	11	41	10.25	40	10
Burning rate	0.2	89	17.8	92	18.4	86	17.2	83	16.6	93	18.6	95	19
Total	1		65.55		68.75		65.5		64.5		66.05		66.95

and power needs for local consumption (Mtisi & Prowse, 2012. Utilisation of sawdust to generate energy could offset the lumber industry's power needs while also potentially injecting a surplus into the national grid. Furthermore, the use of briquettes from waste can curb deforestation for fuelwood. However, a stronger value proposition in this regard could be to make charcoal briquettes which could be more attractive because of their cleaner burning, encouraging users to prefer these to traditional fuelwood. This demonstrates that valorisation of fruit and timber wastes sustainably has great potential in producing convenient energy or fuel sources. As the economy expands and the population increases, Zimbabwe's energy demands are set to grow (Mtisi & Prowse, 2012). In order to fulfil the fast-expanding energy demand, renewable energy sources must be appropriately utilized. However, sustainable harvest and uses of such waste has to be observed, especially for banana wastes. The waste harvested should leave enough ground cover so that there is continuity of other ecosystems that depend on such waste, including breakdown into humus as a good agricultural process (Charis et al., 2022). At the same time, there should be investigations into alternative socio-economic uses of such waste, so that there is no unhealthy competition in the uptake of both wastes. Charis et al., 2019 already showed that timber sawdusts have minimal uses, however for banana waste, it depends with the part of banana. Although single bananas that fallout from the bunch are usually counted as waste, there could be arguments stemming from their potential uptake as human or animal feed.

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