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Enhancing the Physical Properties of Briquettes from Sawdust of *Piptadenia africana* Through Combination with *Ceiba pentandra*

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Author's contribution

This whole work was carried out by the author SJM.

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ABSTRACT

This study sought to determine the effect of combining sawdust of *Piptadenia africana* with *Ceiba pentandra* on the physical and mechanical properties of briquettes produced at room temperature using low compacting pressure without a binder. Briquettes were produced from a mixture of sawdust of *Piptadenia africana* and *Ceiba pentandra*. Particle size of sawdust used for this study was 1mm or less. The two materials were combined at mixing proportions: 80:20, 60:40, 40:60 and 20:80 (*Piptadenia africana*: *Ceiba pentandra*). The results indicated that the relaxed density of briquettes produced from the mixed materials ranged from 534 to 766 kg/m^3 whilst that of compressive strength in cleft ranged from 12.46 to 60.28 N/mm. At compacting pressure levels between 30 and 50 MPa, all the briquettes produced from the mixed materials had adequate compressive strength in cleft. The impact resistance index of briquettes from the mixed materials was adequate and ranged from 128 to 500%. The compressive strength in cleft and impact resistance index of all the briquettes produced from the mixed species were better than those produced from *Piptadenia africana* only. Additionally, at 5% level of significance, the relaxed density, compressive strength in cleft and impact resistance index of briquettes were significantly affected by the biomass raw material and compacting pressure. Thus, the addition of sawdust of *Ceiba pentandra* to that of *Piptadenia africana* could significantly improve the physical and mechanical properties of briquettes produced from sawdust of *Piptadenia africana*. Therefore, production of briquettes from mixed timber species should be encouraged.

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Keywords: Briquettes; Ceiba pentandra; compressive strength; impact resistance index; Piptadenia africana; relaxed density.

1. INTRODUCTION

For over a century now densification/briquetting has been one of the technologies used in the conversion of sawdust into a more efficient biomass fuel for heating, cooking and generation of electricity. Briquetting is very useful, in that, it improves the physical strength, enhances the volumetric calorific value up to 500-1500 kcal/kg, help reducing volume by 8-10 times by increasing density up to about 1000-1200 kg/m^3 [1]. It helps in making fuel available for a variety of domestic and industrial applications and turns biomass residues into a cash income for farmers [1]. In order to produce a good quality briquette, the type of raw material and it preparation before pressing is very important. Besides, different briquetting machines require varying optimum conditions of raw materials and process variables to ensure production of good quality briquette [2]. Raw material characteristics that have great effect on briquette quality include moisture content, particle size, material mix, particle density and chemical composition [3]. Additionally, process variables which have effect on briquette's quality are temperature, compacting pressure, preheating of raw material and cooling lines [3].

Previous studies indicated that briquettes produced from *Piptadenia africana* at room temperature (28ºC) using low compacting pressure (compacting pressure≤50 MPa) had adequate relaxed density but weak compressive strength in cleft and impact resistance index [4,5]. Species characteristic of *Piptadenia africana* which predominantly contributed to the low compressive strength in cleft and impact resistance index was its high density (744.89 kg/m^3). Species density has been found to negatively correlate with compressive strength in cleft and impact resistance index of briquettes produced at room temperature using low compacting pressure [5]. This is because when sawdust is pressed at room temperature using low compacting pressure it is likely for particles of low density species to reach elastic and plastic deformation and therefore leading to the formation of stronger bonds.

Ceiba pentandra is a low density species (409.22 kg/m^3) with acid-insoluble lignin and alpha-cellulose content of 24.34% and 41.24% respectively [5]. It has been established that briquettes produced from sawdust of *Ceiba pentandra* at room temperature (28ºC) and low compacting pressure (20 to 50 MPa) without a binder had adequate relaxed density, high compressive strength in cleft and high impact resistance index [5]. Other studies indicated that the relaxed density, compressive strength in cleft and impact resistance index of briquettes produced from maize cobs were significantly enhanced when maize cobs particles were combined with sawdust of *Ceiba pentandra* [6]. Furthermore, the durability property of wheat straw briquette was enhanced as a result of blending the straw with wood waste [7-9]. The above research outcome confirms report from other researchers that combination of different biomass materials may enhance the quality characteristics of briquettes produced [10]. In this paper, the researcher reports the findings of a study conducted to determine the effect of combining sawdust of *Piptadenia africana* with that of *Ceiba pentandra* on relaxed density, compressive strength in cleft, impact resistance index and water resistance quality of briquettes produced at room temperature using low compaction pressure without a binder.

2. MATERIALS AND METHODS

2.1 Materials and Material Preparation

Sawdust of *Piptadenia africana* and *Ceiba pentandra* were used for the study. The two materials were sun dried at an average relative humidity and temperature of 75% and 28ºC respectively for between five and seven days. Particle sizes of sawdust used for the study were 1 mm or less. The materials were combined at mixing proportions: 80:20, 60:40, 40:60 and 20:80 (*Piptadenia africana*: *Ceiba pentandra*). The mixing proportions were adapted from literature [11].

2.1.1 Moisture content

The moisture content, on oven-dry basis, of the sawdust was determined in accordance with [12]. Samples of each weighing 2 g of the pure and mixed species of sawdust materials were weighed and placed in a laboratory oven at a temperature of 103ºC. The samples were dried until the difference in mass between two successive weighings separated by an interval of two hours was 0.01 g or less. The moisture content of the sample were then computed as follows:

$$Moisture\ content\ (\%)\ db = \frac{M_1 - M_o}{M_o} \times 100 \quad (1)$$

Where, M_1 and M_o were masses (g) of test samples before drying and after oven drying respectively.

2.1.2 Briquetting process

A 55.3-mm internal diameter × 52.5-cm height cylindrical mould was used to produce the briquettes. Ninety grammes of the mixed biomass material was weighed and filled into the mould. The average moisture content of the biomass materials was 12.11%. A manual hydraulic press with a gauge and piston was used to press the biomass raw material without a binder to form the briquettes. A clearance of about 0.1 mm was provided between the piston and the inner wall of the mould to allow for air escape. The samples were then pressed using the following predetermined compacting pressure levels: 20, 30, 40 and 50 MPa. The dwelling time for each pressing was 10 s. This process was repeated for all the biomass materials.

2.1.3 Physical properties of briquettes

The relaxed density, compressive strength in cleft, impact resistance index and water resistance quality of the briquettes were investigated using standard testing methods

2.1.3.1 Relaxed density

Relaxed density of briquettes was determined 30 days after removal from the pressing mould in accordance with [13]. The mass of each briquette was determined using a laboratory electronic balance with an accuracy of 0.01 g. The diameter and length of each briquette was measured at three points with a digital vernier calliper. Relaxed density (RD) was then computed as:

$$RD\ \left(\frac{g}{cm^3}\right) = \frac{108000\ x\ M(g)}{\pi[d_1(mm)+d_2(mm)+d_3(mm)]^2\ x\ [l_1(mm)+l_2(mm)+l_3(mm)]} \quad (2)$$

Where, d_1, d_2 and d_3 were diameters (mm) measured at three different points on the briquettes. L_1, L_2 and L_3 were lengths (mm) measured at three different points on the briquettes. M (g) is the mass of briquette.

2.1.3.2 Compressive strength in cleft

Compressive strength in cleft of briquettes was determined in accordance with [14] using an Instron Universal Strength testing machine (Norwood, MA, USA) with a load cell capacity of 100 kN. The cross-head speed was 0.305 mm/min. A sample of briquette to be tested was placed horizontally in the compression test fixture and a load was applied at a constant rate of 0.305 mm/min until the briquette failed by cracking. The compressive strength in cleft was then computed as follows:

$$\text{Compressive strength in cleft}\ \left(\frac{N}{mm}\right) = \frac{3\ X\ The\ load\ at\ fracture\ point\ (N)}{[l_1(mm)+l_2(mm)+l_3(mm)]} \quad (3)$$

Where L_1, L_2 and L_3 were lengths (mm) of briquettes at points one, two and three respectively.

2.1.3.3 Impact resistance index

Impact resistance index of the briquettes produced was determined in accordance with [15]. Five drops were set as the standard. Briquettes were released from a vertical height of 2 m and allowed to freely fall and impact on a concrete floor. After five drops, the broken pieces of briquettes were collected and weighed using an electronic balance with an accuracy of 0.01 g. Only the number of pieces which weighed 5% or more of the initial weight was recorded for the purpose of calculating the impact resistance index. Impact Resistance Index (IRI) was then computed as follows:

$$IRI = \frac{N}{n} \times 100 \quad (4)$$

Where, N was the number of drops and n was the number of pieces that weighed 5% or more of the initial weight of briquette after N drops.

2.1.3.4 Water resistance quality

Briquette's water resistance quality was determined using [16]. This was done by immersing a briquette into a container filled with water at room temperature. The time taken for the briquette to completely disperse in the water was determined using a stop watch. Each experiment was replicated five times for each biomass material.

3. RESULTS AND DISCUSSION

3.1 Relaxed Density

Density is one of the major indices for assessing the combustion, handling and ignition characteristics of fuel briquettes. Table 1 indicates the relaxed density of briquettes produced from sawdust of *Piptadenia africana* and *Ceiba pentandra*, and their combination. The relaxed density of briquettes produced from a mixture of *Piptadenia africana* and *Ceiba pentandra* ranged from 534 to 766 kg/m^3. This could be deemed adequate in that it is consistent with those produced from other hydraulic piston presses. Studies by [3,17] suggested that briquettes produced from hydraulic piston press are less than 1000 kg/m^3 nevertheless they are usually between 300-600 kg/m^3. The result further shows that at mixing ratio 80:20 the relaxed density of all the briquettes produced from a mixture of *Piptadenia africana* and *Ceiba pentandra* were higher than those produced from pure sawdust of *Piptadenia africana* and *Ceiba pentandra*. Thus, mixing sawdust of *Piptadenia africana* with *Ceiba pentandra* at a mixing ratio of 80:20 could result in the production of briquettes that are denser than those produced from their corresponding pure species.

Additionally, with the exception of briquettes produced from mixing ratio of 20:80 at compacting pressure levels of 30 and 40 MPa, the relaxed density of all the briquettes produced from combination of *Piptadenia africana* and *Ceiba pentandra* were higher than that of *Ceiba pentandra* only. Thus, combining sawdust of *Piptadenia africana* and *Ceiba pentandra* could enhance the relaxed density and for that matter the heat per unit volume of briquettes produced from *Ceiba pentandra*.

The result further indicates that generally for the entire compacting pressure levels, the briquettes' relaxed density decreased with decreasing amounts of *Piptadenia africana* in the mixture. This result is supported by a weak significant positive correlation between the proportions of *Piptadenia africana* in the mixture and relaxed density of briquette produced (Pearson's $r=0.218$, p-value=0.026; N=80; 1-tailed, $\alpha=0.05$). This trend may be due to the fact that *Piptadenia africana* is a high density species (744.89 kg/m^3) whilst *Ceiba pentandra* is a low density species (409.22 kg/m^3). Thus, decreasing the proportion of *Piptadenia africana* in the mixture decreased the density of the raw material, therefore, leading to decrease in relaxed density of the briquettes produced. The result further suggests that there exists a strong positive correlation between compacting pressure and relaxed density of briquettes (Pearson's $r=0.964$, p-value=0.000; N=80; 1-tailed, $\alpha=0.05$). This trend is due to the fact that the higher the compacting pressure, the closer the particles of the biomass materials were packed together due to reduction of the void spaces, therefore leading to the formation of denser briquettes [18]. Analysis of variance (Table 2) indicates that at 5% level of significance, the biomass material (*Piptadenia africana*, *Ceiba pentandra* and their combination), compacting pressure and their interactions have significant effect on relaxed density of the briquettes (p-value<0.05). The multiple coefficient of determination value (R^2) and root mean square error (RMSE) of the ANOVA Model were 0.9829 and 9.97 respectively. This suggests that about 98.29% of the variability in the relaxed density of briquettes produced could be explained by the biomass raw material, compacting pressure and their interaction.

3.2 Compressive Strength in Cleft

Compressive test tends to simulate the compressive stress due to weight of the top briquettes on the lower ones during storage [19]. The compressive strength in cleft of briquettes produced from mixed species of *Piptadenia africana* and *Ceiba pentandra*, as indicated in Table 3, ranged from 12.46 to 60.28 N/mm. With the exception of briquettes produced from mixing ratios 80:20 and 60:40 and pressed at compacting pressure level of 20 MPa, briquettes produced from the mixed species had adequate compressive strength in cleft, that is, compressive strength in cleft greater than 19.6 N/mm [20]. The result further suggests that all the briquettes produced from the mixed species had compressive strength in cleft higher than their corresponding values for *Piptadenia africana* only. Additionally, the compressive strength in cleft of briquettes produced from the mixing ratio 20:80 (30.18 to 60.28 N/mm) were higher than those produced from both pure biomass materials of *Piptadenia africana* and *Ceiba pentandra*. The implication of this result is that briquettes of significantly improved compressive strength in cleft could be produced at room temperature using low compacting pressure if sawdust of *Piptadenia africana* is mixed with that of *Ceiba pentandra*.

A strong significant negative correlation was established between the proportions of

Piptadenia africana in the mixture and compressive strength in cleft of briquette produced (Pearson's r=-0.561, p-value=0.000; N=80; 1-tailed, α=0.05). This suggests that larger proportions of *Ceiba pentandra* sawdust in the mixture could significantly enhance the compressive strength in cleft of briquettes produced from *Piptadenia africana* sawdust and that the compressive strength in cleft depends on the mixing ratio. This finding is consistent with that of [11]. Studies by [11] on production and characterization of rice husk based charcoal briquettes, found that the mixing ratio of the biomass materials have significant effect on the physical and mechanical properties of briquettes produced. In this study briquettes were pressed using low compacting pressure. Therefore, increasing the proportions of high density species (*Piptadenia africana*) in the mixture inhibited the tendency of the biomass material to undergo plastic deformation. The result also shows a consistent increase in compressive strength in cleft with increasing compacting pressure for briquettes produced from both the pure and the mixed biomass materials. This trend was confirmed by a highly, significant and positive correlation between compressive strength in cleft of briquettes produced and compacting pressure (Pearson's r=0.798, p-value=0.000; N=80; 1-tailed, α=0.05). Analysis of variance (Table 4) of the effect of biomass material and compacting pressure on the compressive strength in cleft indicates that at 5% level of significance the two variables and their interactions had significant effect on compressive strength in cleft of the briquettes (p-value<0.05).

The multiple coefficient of determination value and RMSE of the ANOVA Model were 0.9698 and 2.7612 respectively. Therefore, the biomass material, compacting pressure and their interactions could explain about 96.98% of the variance in the compressive strength in cleft of the briquettes produced. Post hoc multiple comparison of means shows that at 5% level of significance the compressive strength in cleft of briquettes produced from the biomass materials differed significantly (LSD>1.7332) and that those of the mixed species were significantly better than that of *Piptadenia africana* only. It is also worth noting that briquettes produced from mixing ratios 20:80 and 40:60 (*Piptadenia africana* and *Ceiba pentandra*) had compressive strength in cleft significantly higher than that of *Ceiba pentandra* only.

3.3 Impact Resistance Index

Briquettes impact resistance index is used to simulate the forces encountered during emptying of the products from trucks onto the ground. The impact resistance index of briquettes made from mixed species of *Piptadenia africana* and *Ceiba pentandra* as indicated in Table 5, ranged from 128 to 500%. All the briquettes produced had adequate impact resistance index in line with the Italian standard for briquettes/pallets CTI-R04/5 which considers briquettes' durability greater than or equal to 97.7% as adequate (Italian standard for briquettes/pallets CTI-R04/5 as cited in [21]).

Table 1. Relaxed density (kg/m^3) of briquettes produced from *P. africana*, *C. pentandra* and their combination using compacting pressure levels of 20 - 50 MPa

Biomass material	Mixing ratio (weight basis)	Compacting pressure			
		20 MPa	30 MPa	40 MPa	50 MPa
C. pentandra	Pure (100%)	523	622	666	716
P. africana	Pure (100%)	567	637	679	741
P. africana: *C. pentandra*	80:20	578	645	701	766
P. africana: *C. pentandra*	60:40	564	626	677	732
P. africana: *C. pentandra*	40:60	560	620	672	730
P. africana: *C. pentandra*	20:80	534	614	654	719

Table 2. ANOVA of effect of biomass material and compacting pressure (CP) on relaxed density of briquettes

Source	DF	ANOVA SS	Mean square	F-Ratio	p-value
Biomass raw material	5	25476.142	5095.228	51.28	< .0001*
CP	3	519735.625	173245.2083	1743.64	< .0001*
Biomass material x CP	15	3875.425	258.3617	2.60	< .0026*
Error	96	9538.400	99.3583		

**Statistically significant at 0.05 level of significance*

Table 3. Compressive strength in cleft (N/mm) of briquettes produced from *P. africana*, *C. pentandra* and their combination using compacting pressure levels 20 to 50 MPa

Biomass material	Mixing ratio (weight basis)	Compacting pressure			
		20 MPa	30 MPa	40 MPa	50 MPa
C. pentandra	Pure (100%)	29.23	39.26	40.40	44.58
P. Africana	Pure (100%)	5.95	10.13	17.06	21.14
P. africana: *C. pentandra*	80:20	12.46	20.43	27.03	39.66
P. africana: *C. pentandra*	60:40	18.95	27.19	34.87	48.53
P. africana: *C. pentandra*	40:60	27.08	37.08	43.96	56.33
P. africana: *C. pentandra*	20:80	30.18	39.34	46.45	60.28

Table 4. ANOVA of effect of biomass material and compacting pressure (CP) on compressive strength in cleft of briquettes produced

Source	DF	ANOVA SS	Mean square	F-Ratio	p-value
Biomass raw material	5	13168.875	2633.7751	345.45	< .0001*
CP	3	9540.080	3180.0266	417.10	< .0001*
Biomass material x CP	15	831.690	55.4460	7.27	< .0001*
Error	96	731.924	7.6242		

**Statistically significant at 0.05 level of significance*

The result further indicates that for all corresponding compacting pressure levels, the impact resistance index of briquette made from a combination of *Piptadenia africana* and *Ceiba pentandra* were greater than that made from *Piptadenia africana* only. This suggests that addition of *Ceiba pentandra* sawdust to that of *Piptadenia africana* could enhance the impact resistance index of briquettes made from *Piptadenia africana.* Briquettes made from the mixing ratio 20:80 had impact resistance index either equal to or more than their corresponding values for *Ceiba pentandra.* This, also suggests that impact resistance index of briquettes produced from *Ceiba pentandra* could be enhanced by introducing 20% of *Piptadenia africana* into *Ceiba pentandra*. Most of the briquettes produced from mixing ratios 80:20, 60:40, and 40:60 had impact resistance index lower than their corresponding values for *Ceiba pentandra*.

Correlation analysis between proportions of *Piptadenia africana* in the mixture and impact resistance index of briquette produced indicates that there exists a moderate significant negative correlation between the two parameters (Pearson's r = -0.466, p-value=0.000; N=80; 1-tailed, α=0.05). This may be due to the relatively high species density of *Piptadenia africana*. Additionally, in view of the fact that briquettes were formed using low compacting pressure and room temperature (28ºC) it was easier to press low density species to reach plastic deformation thereby enhancing bonding than high density species. Compacting pressure was also found to be significantly and positively correlated with impact resistance index (Pearson's r=0.655, p-value=0.000; N=80; 1-tailed, α=0.05). This finding is consistent with other research outcomes. Previous studies on densification behaviours of oak sawdust, oak mulch, oak bark, oak chips, pine sawdust, cotton wood sawdust, and cotton wood mulch in the pressure range of 34 to 138 MPa established that increasing compacting pressure resulted in increased abrasive resistance, impact resistance and compressive resistance of briquettes [22]. [23] also found that increasing compacting pressure from 5 to 44 MPa increased the wafer (150-mm diameter) durability rating (based on an impact resistance test) of grass hay (mixed with 20% alfalfa) from 5 to 91%. The increase in impact resistance index resulting from increased compacting pressure level could result from the fact that increase in compacting pressure enhances the formation of different binding mechanisms in densification. For instance, under high pressure, the natural binding components such as starch, protein, lignin, and pectin in the feed or biomass materials are squeezed out of the particles, which contribute to formation of solid-bridge bonds [24,25]. Additionally, increased compacting pressure could enhance bonding through Van der Waal's electrostatic force as well as the formation of stronger inter-locking bonds of the sawdust particles. Two-way ANOVA (Table 6) indicates that at 5% level of significance the biomass material and compacting pressure had significant effect on the impact resistance index of briquettes produced (p-value<0.05). Nevertheless, the interaction between the biomass material and compacting pressure at 5% level of significance did not have significant effect on the impact resistance index of briquettes produced (p-value<0.05).

The multiple coefficient of determination (R^2) and the RMSE of the ANOVA Model were 0.6515 and 78.0276 respectively. The implication of R^2 value of 0.6515 is that about 65.15% of the variance in the impact resistance index of the briquettes produced could be explained by the biomass raw material and compacting pressure. Post hoc multiple comparison of means of impact resistance index of briquettes produced from the biomass materials indicates that even though the impact resistance index for mixing ratio 20:80 was the best, it did not significantly differ from that of *Ceiba pentandra* only (LSD<48.978). However, the impact resistance index of briquettes produced from mixing ratio 20:80 was significantly higher than that produced from *Piptadenia africana* only and mixing ratios 40:60, 60:40 and 80:20 (LSD>48.978). Lastly, at 5% level of significance the impact resistance index of briquettes produced from *Piptadenia africana* only did not significantly differ from that of mixing ratio of 80:20 (LSD<48.978).

3.4 Water Resistance Quality

The water resistance quality of briquettes produced from the biomass materials ranged from 1.01 to 6.63 minutes (Table 7). With the exception of briquettes produced from mixing ratio 20:80 using compacting pressure 50 MPa, all the other briquettes produced had very low water resistance quality. According to [15] briquettes for which when dropped into water falls into pieces sooner than 5 minutes are considered as having a very low water resistance quality. When the briquette falls into pieces before 15 minutes, it is of a medium water resistance quality, and up to 20 minutes it is of a good water resistance quality. The medium water resistance quality of briquettes produced from combination of *Piptadenia africana* and *Ceiba pentandra* at a mixing ratio of 20:80 and low compacting level of 50 MPa provides a breakthrough in the production of briquettes at room temperature using low compacting pressure.

A two-way analysis of variance indicates that at 5% level of significance the biomass material, compacting pressure and their interactions had significant effect on the water resistance quality of the briquettes produced (p-value<0.05). The multiple coefficient of determination value and the RMSE of the ANOVA Model were 0.9849 and 0.2088 respectively.

Table 5. Impact resistance index (%) of briquettes produced from *P. africana*, *C. pentandra* and their combination using compacting pressure levels 20 to 50 MPa

Biomass material	Mixing ratio (weight basis)	Compacting pressure			
		20 MPa	30 MPa	40 MPa	50 MPa
C. pentandra	Pure (100%)	200	283	316	350
P. africana	Pure (100%)	72	137	184	217
P. africana: *C. pentandra*	80:20	128	150	217	250
P. africana: *C. pentandra*	60:40	142	167	250	300
P. africana: *C. pentandra*	40:60	175	200	250	400
P. africana: *C. pentandra*	20:80	200	283	350	500

Table 6. ANOVA of effect of biomass material and compacting pressure (CP) on impact resistance index of briquettes produced from sawdust of *P. africana, C. pentandra* and their mixture

Source	DF	ANOVA SS	Mean square	F-ratio	p-value
Biomass raw material	5	449210.942	89842.1883	14.76	< .0001*
CP	3	557825.958	185941.9861	30.54	< .0001*
Biomass material x CP	15	85703.092	5713.5394	0.94	0 .5253†
Error	96	584477.600	6088.3080		

**Statistically significant at 0.05 level of significance; †Not statistically significant at 0.05 level of significance*
Legend: DF=Degree of freedom

Table 7. Water resistance quality (minutes) of briquettes produced from *P. africana*, *C. pentandra* and their combination using compacting pressure levels from 20 to 50 MPa

Biomass material	Mixing ratio (weight basis)	Compacting pressure			
		20 MPa	30 MPa	40 MPa	50 MPa
C. pentandra	Pure (100%)	2.76	3.19	3.82	4.81
P. africana	Pure (100%)	0.62	0.69	0.69	0.70
P. africana: *C. pentandra*	80:20	1.01	1.29	1.31	1.40
P. africana: *C. pentandra*	60:40	1.17	1.53	1.59	1.76
P. africana: *C. pentandra*	40:60	1.51	2.06	2.28	3.20
P. africana: *C. pentandra*	20:80	2.92	3.38	4.68	6.63

4. CONCLUSION

The results from the study indicate that combining sawdust of *Piptadenia africana* with *Ceiba pentandra* could significantly improve the compressive strength in cleft and impact resistance index of briquettes produced from *Piptadenia africana* at room temperature using low compacting pressure without a binder. The quality of briquettes was significantly influenced by the type and mixing proportion of biomass material used. Briquettes produced from mixing proportions: 80:20, 60:40, 40:60 and 20:80 (*Piptadenia africana*: *Ceiba pentandra*) using compacting pressure of 30 MPa or more could have adequate compressive strength in cleft. Finally, increase in proportion of *Piptadenia africana* in the mixture of biomass material could result in decreased compressive strength in cleft and impact resistance of briquettes. Generally, the water resistance quality of briquettes produced from the biomass materials at room temperature using low compacting pressure was low and they need to be protected from moisture.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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