JASEM ISSN 1119-8362


Full-text Available Online at
www.ajol.info and
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J. Appl. Sci. Environ. Manage. Dec. 2016
Vol. 20 (4) 1179-1188

# Investigation of Mechanical Properties of Briquette Product of Sawdust-charcoal as a Potential Domestic Energy Source

***[1]AJIBOYE, TK; [2]ABDULKAREEM, S; [3]ANIBIJUWON, A. O. Y.**

*Mechanical Engineering Department, Faculty of Engineering and Technology,*
*University of Ilorin*
**Corresponding author email: engrtkajiboye@gmail.com*

**ABSTRACT:** This research investigated the relaxed densities of biomass briquettes produced from combination of sawdust and charcoal. Cassava starch gel and orange waste were used as binder for briquetting. Five sizes; 0.2 mm, 0.4 mm, 0.6 mm, 0.8 mm and 1.0 mm and mixing ratios 50:50, 60:40, 70:30, 80:20 and 90:10 of biomass materials, sawdust and charcoal were used with 16.6% binder. The ignition time, water boiling test, afterglow time and shattered index of the briquettes were analyzed. Descriptive tools were used to determine the optimum sizes and mixing ratios for effective production of briquette biomass. The results showed that the relax density of 663.33 kg/m$^3$ and 589.31 kg/m$^3$ were obtained for Cassava starch gel binder and orange waste at size 1.0 mm and mixing ratio of 90:10 while Ignition time of 12 sec and 19 sec were obtained for cassava starch gel and orange waste at size 0.2 mm and mixing ratio 50:50 respectively. Also water boiling time of 18.05 minutes and 15.00 minutes were obtained for cassava starch gel and orange waste at size 0.2 mm and mixing ratio 50:50 while the afterglow time of 321.00 sec and 318.00 sec at size 0.2 mm and mixing ratio 60:40 were obtained for cassava starch gel and orange waste respectively. The highest retention of shattered index of 98.21% and 96.71% were respectively recorded for cassava starch gel and orange waste at size 0.2 mm and mixing ratio 50:50. ©JASEM

http://dx.doi.org/10.4314/jasem.v20i4.34

***Keywords:*** Biomass, Terminalia superb, Briquette, Cassava starch gel, Orange wastes, Afterglow time, Shattered index.

Forests and other tree systems in Africa constitute an important component of household livelihood (Sene, E.H., 2000). Nigeria, like other sub-Saharan countries, has faced forest degradation problems due to combination of factors. Some of the factors are clearing of land for agricultural and industrialization purposes, over grazing, bush fires, drought, over exploitation, ever- increasing deforestation along with the increased in the consumption of fuel wood etc. About 80% of Nigerians live in the rural or semi-urban areas and they depend solely on fuel wood for their energy needs. Fuel wood accounts for about 37% of the total energy demand of the country. Investigations showed that out of the total wood demand from the forest, 90% goes to fuel wood. Presently, Nigeria reportedly consumes about 43 x 109 kg of fuel wood annually (Energy Commission of Nigeria, 2010).

It is widely accepted that the looming fossil-fuel depletion is one of the most crucial issues for many countries. The resulting ever increasing price of such fuels in the world market seems to adversely affect economies worldwide. The use of fossil fuels is also partially responsible for global warming due to the greenhouse effect of emissions, such as carbon dioxide (Sajjakulnukit B, Verapong P, 2003). Therefore, reducing the fuel consumption together with increasing the use of alternative renewable energy sources seems to be a promising solution to these problems since the renewable energy is generally clean, safe and environmentally friendly. Out of renewable energy sources, biomass is expected to play a major role in the foreseeable future, particularly for developing countries whose economies are largely based on agricultural. It has a potential to substantially reduce carbon dioxide emissions since nearly zero net gain $CO_2$ can be achieved when sustainable production and utilization are implemented (Sajjakulnukit B, *etal*, 2005).

Some agricultural wastes such as woodchips can be directly utilized as fuels. Nevertheless, the majority of them are bulky, uneven, fluffy and dusty. They also have low energy density and high moisture content as compared to fossil type fuels. These characteristics make this kind of waste difficult to handle, store, transport and utilize. One of the promising solutions to these problems is the briquetting technology. The technology may be defined as a densification process for improving the handling characteristics of raw material and enhancing the volumetric calorific value of the biomass. Considerable amount of research on briquetting technology has been conducted. Examples of biomass studied are wheat straw (Demirbas, A. 1999; Demirbas. A. and Sahin, A. 1998), hazelnut shell and grass (Finell M, *etal*, 2005; Paulrud, S. and Nilsson, C. 2001), cotton (Singh R.N, 2004 and Coates W, 2000), olive refuse (Yaman, S. *etal*, 2000) as well as rice straw and husk (Ndiema C.K.W, *etal,* 2002).

Fortunately, researches have shown that a cleaner, affordable fuel source which is a substitute to fuel wood can be produced by blending biomass (agricultural residues and wastes) with coal. Nigeria has large coal deposit which has remained untapped since 1950's, following the discovery of petroleum in the country. Also, millions of tons of agricultural wastes are generated in Nigeria annually. But it is unfortunate that farmers still practice "slash–and-burn" agriculture. These agricultural wastes which were encounter during clearing of land for farming or during processing of agricultural produce are usually burnt off. By this practice, not only that the useful raw materials were wasted, it further pollutes the environment and reduces soil fertility. Fire affects soil below ground biodiversity, geomorphic process, and volatilizes large amount of nutrients and carbon accumulated in the soil organic matter (PERACOD, Japan. R. Owsianowski; www.peracod.org).

In this study, the effect of particle size, mixing ratios and binder on relaxed density, ignition time, water boiling time, afterglow time and shattering index was investigated.

## MATERIALS AND METHODS

The materials used for the briquette were sawdust from common wood named *Terminalia Superba* charcoal particles and natural binders (cassava starch gel and orange waste). The sawdust was collected from a local sawmill in Tanke, Ilorin while charcoal particles were bought from charcoal seller at Tanke area in Ilorin. Cassava starch was bought at cassava industry in Ibadan and orange waste was collected from orange sellers at Tanke area, Ilorin.
The material (charcoal) was crushed down and pounded with a large mortar and pestle as shown in figures 1 and 2

**Fig1:** Crushing of charcoal

**Fig 2**: Pounding of charcoal

This was done to reduce the size of the charcoal to a smaller size that can pass through the sieve sizes 0.2 mm, 0.4 mm 0.6 mm 0.8 mm and 1.0 mm. Sieve analysis was carried out at engineering laboratory in Geology department, University of Ilorin, Ilorin, Kwara State, Nigeria. The two materials (charcoal and sawdust) were sieved in order to remove impurities and to obtain a desirable size fraction of 0.2 mm, 0.4 mm, 0.6 mm, 0.8 mm and 1 mm for sawdust and charcoal, this is shown in figures 3 and 4 respectively.

**Fig 3**: Sieving of sawdust

**Fig 4**: Sieving of charcoal

These particles sizes were determined using a standard test sieves in accordance with B.S.S (British standard sieve, 1986).

The two materials were weighed and mixed at ratios 50:50, 60:40, 70:30, 80:20, 90:10; Sawdust to charcoal. 16.6% of cassava starch gel and orange waste was used as binding agents.

The briquettes were produced and analyzed at the Forestry Research Institute of Nigeria, Jericho, Ibadan, Nigeria. The produced briquettes are shown in figures 5 and 6. Three replicates of the briquettes of the mixture of the materials and two different binding agents were produced.

**Fig 5:** Briquettes produced

**Fig 6**: Moulding of briquettes

*Starch Preparation*: The dry cassava starch powder obtained from the cassava industry was transformed into a smooth paste by dissolving 22.5g in $10cm^3$ of water. The starch paste was then poured into $80cm^3$ of boiling water while stirring continuously. The stirring was done in order to ensure that the solute dispersed in the water and prevent 'hot spots' building up in certain parts of the container to avoid uneven expansion. Figure 7 shows prepared starch.

**Fig 7:** Prepared starch

**Fig 8**: Stirring of orange waste

*Orange waste:* The orange waste was dried in the sun for five days in order to reduce its moisture content. After drying, size reduction of the orange waste to powder form was done using the household grinding machine. It was poured into pot of $80cm^3$ boiling water where it was stirred continuously until it turns into paste. Figure 8 shows stirring of orange waste.

*Briquette parameters' determination: Relaxed density***.**
The mass output divided by the total volume of the briquette.

$$\text{Re}laxed\ density\ {}^{kg}\!/_{m^3} = \frac{M_s(kg)}{V_b(m^3)} \qquad 1$$

where;
$M_s$ = weight of the sample after drying (kg); and
$V_b$ = volume of the briquettes ($m^3$).

*Ignition time (sec):* Each briquette sample was ignited at the base in a free drought corner. The time required for the flame to ignite the briquette was recorded as the ignition time using stop watch (Ikelle Issie, *etal*, 2014 and Suparin C, *etal*, 2008).

*Water boiling tests of the briquette samples (mins):* 100g of each briquette sample was used to boil $100cm^3$ of water in a kettle and each briquette samples were ignited in a locally made briquette stove. The time taken for a briquette sample to boil $100cm^3$ of water was noted using stop watch and recorded (Suparin C, *etal*, 2008).

*Shattered index of the briquette samples* **:** The percentage weight loss of briquettes was expressed as a percentage of the initial mass of the material remaining on the solid base, while the shatter resistance was obtained by subtracting the percentage weight loss from 100 (Sengar, S. H. etal, 2012). The shatter resistance of the briquettes was calculated (Sengar, S. H. *etal*, 2012; Ghorpade, S. S. and Moule, A. P., 2006).

$$Percentage weight loss = \frac{w_1 - w_2}{w_1} \times 100 \quad (2)$$

$$\%\ Shatter\ resistance = 100 - \%\ weight\ loss \quad (3)$$

where,

$w_1$ = weight of briquette before shattering

$w_2$ = weight of briquette after shattering

.

*Afterglow time of the briquette samples:* Essentially, this was by way of igniting a piece of oven-dried briquette over a Bunsen Burner and blowing out of the flame after a consistent flame was established. Thereafter, the time in seconds within which a glow was perceptible was recorded. The procedure of (Musa, N.A. 2007) was adopted.

## RESULTS AND DISCUSSION

*Effects of binders, mixing ratios and sizes on relaxed density*: Figures 9 and 10 show the results of relaxed density for sample A (cassava starch gel) and sample B (orange waste) briquettes. Sample A and sample B showed that binder type, size and mixing ratio has effects on the briquettes relaxed density

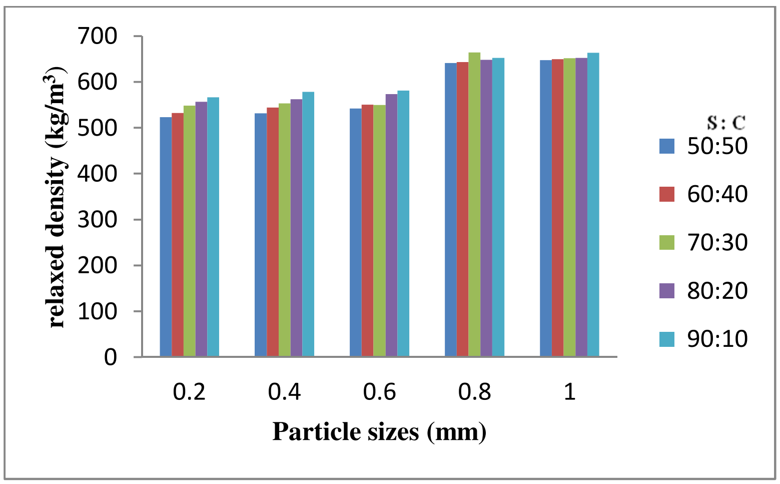


**Fig 9:** Effects of binder, mixing ratios and particle sizes on relaxed density for briquettes sample A (cassava starch gel)

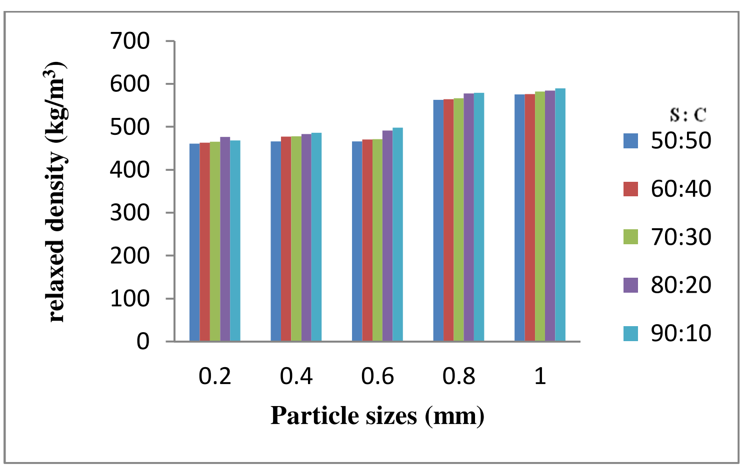


**Fig 10**: Effects of binder, mixing ratios and particle sizes on relaxed density for briquettes sample B (orange waste)

Sample A at size 1.0 mm with ratios of 90:10, 80:20 and 70:30, has the highest relaxed densities of 663.33 $kg/m^3$, 652.38 $kg/m^3$ and 651.28 $kg/m^3$ respectively; followed by size 0.8 mm with ratios of 90:10 and 80:20 which has relaxed densities of 651.39 $kg/m^3$ and 648.35 $kg/m^3$ while the lowest relaxed densities 523.12 $kg/m^3$ and 532.17 $kg/m^3$ was observed at size 0.2 mm with mixing ratio 50:50 and 60:40. For sample B, the highest relaxed densities 589.31 $kg/m^3$, 584.22 $kg/m^3$ and 582.18 $kg/m^3$ was recorded at size 1.0 mm with ratios of 90:10, 80:20 and 70:30 while the lowest relaxed densities 461.00 $kg/m^3$ and 463.09 $kg/m^3$ was observed at size 0.2 mm with mixing ratio 50:50 and 60:40. The briquettes relaxed density increases when briquettes were produced with larger particle size and decreases when briquettes were produced with smaller particle size; the relaxed density also increases with an increase in the ratio of sawdust and decrease in ratio of charcoal using sample A and the same happens when sample B was used as binding agents. The reason for this trend is that briquettes produced with smaller particle sizes were more compacted and closely packed than briquettes produced with higher particle sizes. The major disadvantage of briquettes as a fuel is their low relaxed density, which makes handling difficult, transport and storage expensive (Musa, N.A. (2007). The result of relaxed density were found to be 385.00 $kg/m^3$ in corncob, 236.00 $kg/m^3$ in groundnut shells, 286.42 $kg/m^3$ in melon shells, 386.40 $kg/m^3$ in cassava peel and 512.54 $kg/m^3$ in yam peels briquette (Oladeji, J.T., 2012). Therefore, from the highest relaxed density 663.33 $kg/m^3$ to the lowest relaxed density 461.00 $kg/m^3$ in this study compared well with briquettes from other biomass are good enough to transport briquette for domestic use.

*Effects of binders, mixing ratios and sizes on ignition time*: Figures 11 and 12 show the results of ignition time for sample A (cassava starch gel) and sample B (orange waste) briquettes. Sample A and sample B showed that binder type, size and mixing ratio has effects on the briquettes ignition time.

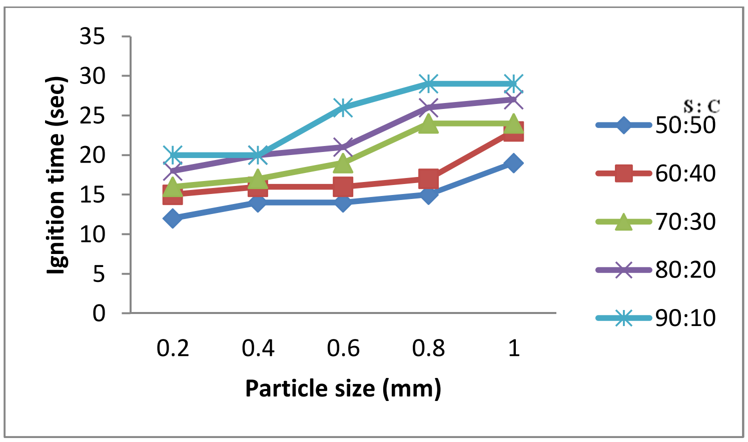


**Fig 11**: Effects of binder, mixing ratios and particle sizes on ignition time for briquettes sample A (Cassava starch gel)

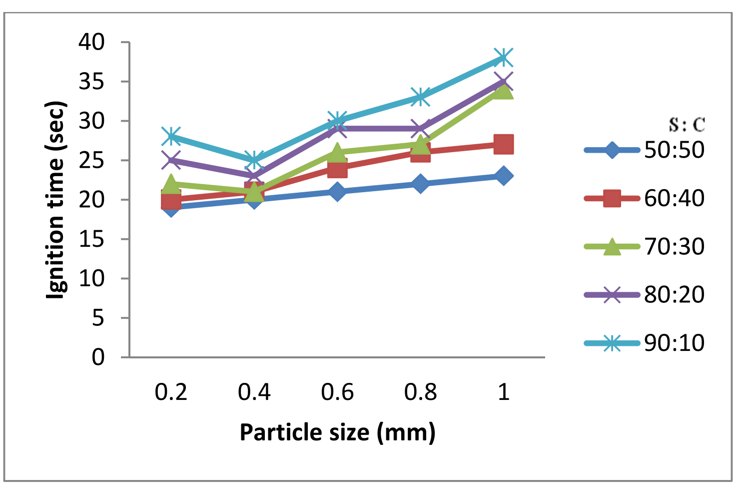

**Fig 12**: Effects of binder, mixing ratios and particle sizes on ignition time for briquettes sample B (orange waste)

For sample A, the highest ignition time of 29 sec and 27 sec was recorded at size 1.0 mm with mixing ratios 90:10 and 80:20, followed by 29 sec and 26 sec at size 0.8 mm with mixing ratios 90:10 and 80:20 while the lowest ignition time of 12 sec and 15 sec was observed at size 0.2 mm with mixing ratios 50:50 and 60:40, followed by 14 sec at size 0.4 mm and 0.6 mm at ratio 50:50. For sample B, the highest ignition time of 38 sec, 35 sec and 34 sec was recorded at size 1.0 mm with mixing ratios 90:10, 80:20 and 70:30 while the lowest ignition time of 19 sec and 20 sec was observed at size 0.2 mm with mixing ratios 50:50 and 60:40 followed by 20 sec and 21 sec at size 0.4 mm with ratios 50:50 and 60:40. The briquettes ignition time increases when briquettes particle size increases and the ignition time also increases when the ratio of sawdust increases and ratio of charcoal decreases. From this results, it is shown that briquettes with the lowest ignition time were found in briquettes produced with small particle size i.e. size 0.2 mm, 0.4 mm and 0.6 mm with an increase in the ratio of sawdust and decreases in the ratio of charcoal i.e. 50:50, 60:40 and 70:30 using sample A and the same trend happens using sample B. The lowest ignition time obtained was due to the low moisture contents of the briquette produced. It was recommended (Aina, O. M. etal 2009) that briquettes for domestic use must be easily ignitable. The lowest ignition results obtained in this study compared to other biomass briquettes lowest ignitions time; coal-dust briquette with ignition time 47.33 sec and coal dust-rice husk briquette with ignition time 41.00 sec (Ikelle Issie, *etal*, 2014) show that briquettes produced are good for briquetting.

*Effects of binders, mixing ratios and sizes on water boiling*: Figures 13 and 14 show the results of water boiling for sample A (cassava starch gel) and sample B (orange waste) briquettes. Sample A and sample B showed that binder type, size and mixing ratio has effects on the briquettes water boiling.

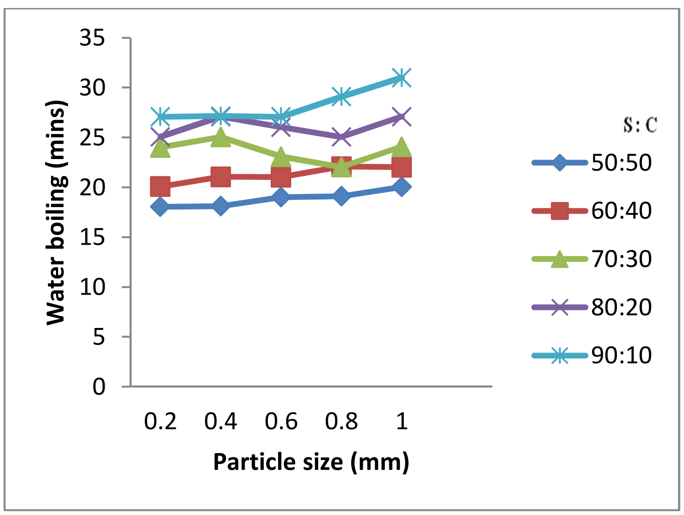


**Fig 13**: Effects of binder, mixing ratios and particle sizes on water boiling tests for briquettes sample A (cassava starch gel)

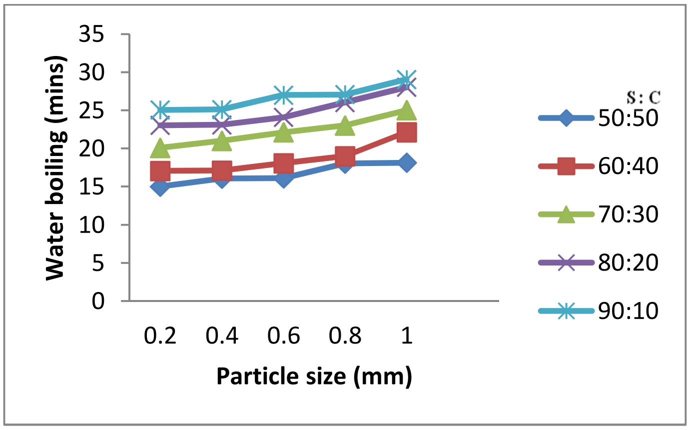


**Fig 14:** Effects of binder, mixing ratios and particle sizes on water boiling tests for briquettes sample B (orange waste)

For sample A, the longest water boiling time of 31 minutes was recorded at size 1.0 mm with mixing ratio 90:10, followed by 29.09 minutes at size 0.8 mm with mixing ratio of 90:10 while the shortest water boiling time of 18.05 minutes was observed at size 0.2 mm at mixing ratio 50:50 followed by 18.11 minutes at size 0.4 mm with ratio 50:50. For sample B, the longest water boiling time of 29.05 minutes and 28.03 minutes was recorded at size 1.0 mm with mixing ratios of 90:10 and 80:20 while the shortest water boiling time of 15.00 minutes was observed in size 0.2 mm with mixing ratio 50:50 followed by 16.05 minutes at size 0.4 mm with mixing ratio 50:50 and 16.09 minutes at size 0.6 mm with mixing ratio 50:50. The briquettes water boiling time increases with an increase in particle size, an increase in sawdust and decrease in charcoal. From the results, it is shown that briquettes with the shortest boiling time were recorded in briquettes produced with small particle sizes i.e. 0.2 mm, 0.4 mm, 0.6 mm and 0.8 mm with same ratio of sawdust to charcoal i.e. 50:50 using sample A and similar results occurred using sample B. The shortest water boiling time were obtained from briquettes with higher calorific value because of their higher burning rate. They were able to boil water faster than briquette with low heating values. Provision of sufficient heat for the time necessary is an important quality of any solid fuel (Ikelle Issie, *etal*, 2014). The results from other biomass briquettes shortest water boiling time, coal briquettes 26 minutes, spear grass 8.00 minutes and elephant grass 6.46 minutes (Ikelle Issie, *etal*, 2014), compared with the results of biomass used in this study, it can be stated that briquettes produced are good enough for household cooking.

*Effects of binders, mixing ratios and sizes on afterglow time*: Figures 15 and 16 show the results of afterglow time for sample A (cassava starch gel) and sample B (orange waste) briquettes. Sample A and sample B showed that binder type, size and mixing ratio has effects on the briquettes afterglow time.

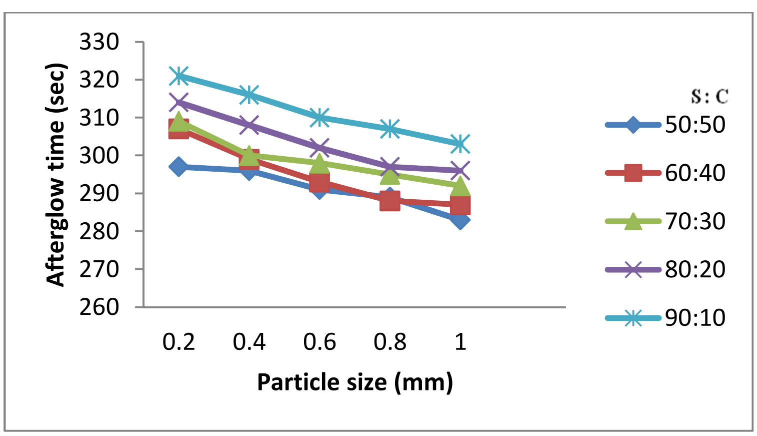


**Fig 15:** Effects of binder, mixing ratios and particle sizes on afterglow time for briquettes sample

A (cassava starch gel)

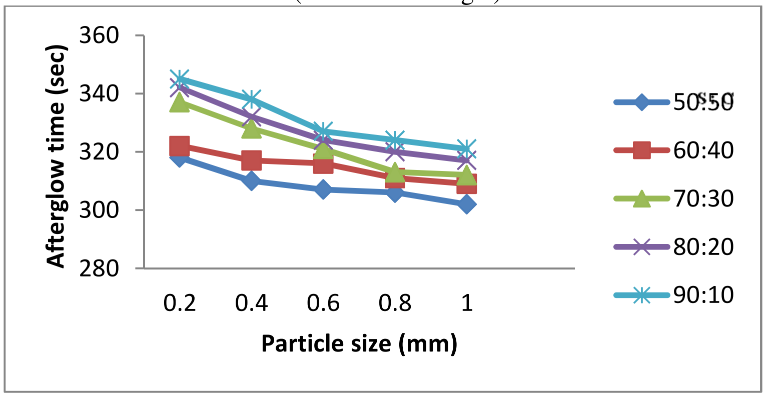


**Fig 16:** Effects of binder, mixing ratios and particle sizes on afterglow time for briquettes sample B (orange waste)

For sample A, the longer afterglow time 307 sec, 309 sec, 314 sec and 321 sec was recorded at size 0.2 mm with mixing ratios of 60:40, 70:30, 80:20 and 90:10; followed by 300 sec, 308 sec and 316 sec at size 0.4 mm with mixing ratios 70:30, 80:20 and 90:10 and afterglow time 302 sec and 310 sec at size 0.6 mm with mixing ratios 80:20 and 90:10 while the shortest afterglow time 289 sec and 288 sec was observed at size 0.8 mm with mixing ratios 50:50, 60:40 and 283 sec and 287 sec at size 1.0 mm with mixing ratios 50:50 and 60:40. For sample B, the longer afterglow time 318 sec, 322 sec, 337 sec, 342 sec and 345 sec was recorded at size 0.2 mm with mixing ratios 50:50, 60:40, 70:30, 80:20 and 90:10 followed by 317 sec, 328 sec, 332 sec and 338 sec at size 0.4 mm with mixing ratios 60:40, 70:30, 80:20 and 90:10 followed by 321 sec, 324 sec and 327 sec at size 0.6 mm with mixing ratios 70:30, 80:20 and 90:10 while the lowest ignition time 306 sec and 311 sec was observed at size 0.8 mm with mixing ratios 50:50 and 60:40 followed by 302 sec and 309 sec at size 1.0 mm with mixing ratios 50:50 and 60:40. The briquettes afterglow time increases with smaller particle size and decreases with lager particle size; the afterglow time also increases with an increase in the ratio of sawdust and decrease in the ratio of charcoal using sample A and the same was recorded when sample B was used as binding agent. The reason for this trend is that briquettes produced with smaller particle sizes were more compacted than briquettes produced with higher particle sizes. The longer afterglow time will ignite more easily and burn with intensity for a length of time (Demirbas. A. and Sahin, A., 1998). The results of afterglow obtained from briquettes produced in this study compared with the results of afterglow time from other biomass briquettes, waste paper and groundnut shell admixture 374.78 sec, groundnut shell 356.30 sec (Demirbas. A. and Sahin, A., 1998), corncob 370 sec, melon shells 367 sec, cassava peels 367 sec, yam peels 375 sec (Oladeji, J.T., 2012), are reasonable and satisfactory for briquettes production.

*Effects of binders, mixing ratios and sizes on shattered index***:** Figures 17 and 18 show the results of shattered index for sample A (cassava starch gel) and sample B (orange waste) briquettes. Sample A and sample B showed that binder type, size and mixing ratio has effects on the briquettes shattered index.

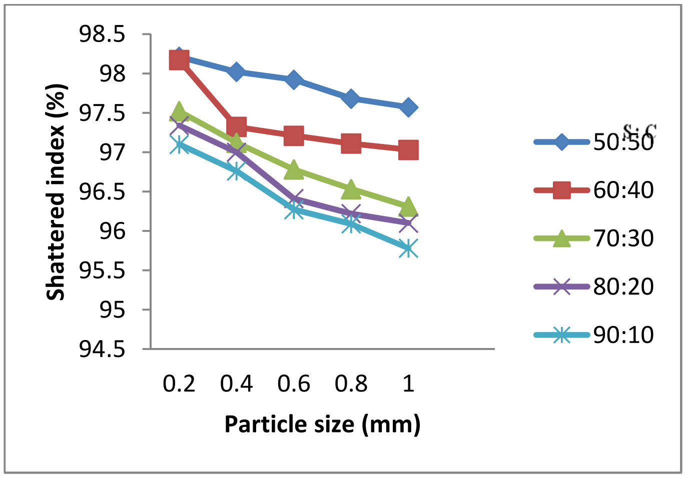


**Fig 17:** Effects of binder, mixing ratios and particle sizes on shattered index for briquettes sample A (cassava starch gel)

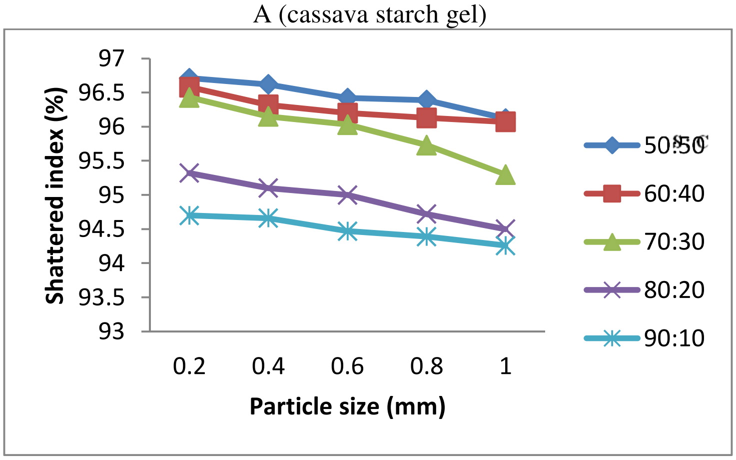


**Fig 18**: Effects of binder, mixing ratios and particle sizes on shattered index for briquettes sample B (orange waste)

For sample A, the best shatter index with retention 98.21% and 98.17% of its weight was recorded at size 0.2 mm with mixing ratios 50:50 and 60:40 followed by retention of 98.21% at size 0.4 mm with mixing ratio 50:50 while the lowest shattered index 95.78% of its weight was observed at size 1.0 mm with mixing ratio 90:10 and retention 96.09% of its weight at size 0.8 mm with mixing ratio 90:10. For sample B, the highest shattered index 96.71% was recorded at size 0.2 mm with mixing ratio 50:50 followed by 96.62% of its weight at size 0.4 mm with ratio 50:50 while the lowest shattered index 94.26% of its weight was observed at size 1.0 mm with mixing ratio 90:10 followed by 94.39% of its weight at size 0.8 mm with mixing ratio 90:10. The best retention of shattering index was found in briquettes with smaller size and equality in ratio. The same trend was recorded using sample A and sample B. This results shows that briquettes has high stability. Shattered index results from other biomass briquettes, daniellia + groundnut briquette 90.4% and daniellia + rice briquette 72.4% (Oyelaran, O. A., 2015) compared well with the briquettes produced in this study; shows that briquettes produced are good for domestic use.

*Conclusion*: This study examined the effect of particle sizes, mixing ratios and binders on relaxed density, ignition time, water boiling, afterglow time and shattered index of fuel briquettes. From the results of tests and analyses carried out, the following conclusions can be drawn on the possibility of using sawdust and charcoal as biomass in the production of briquettes. Sample A (cassava starch gel) produced high relaxed density values, ignition time, afterglow time and the best shatter index which was higher than sample B (orange waste). Sample A took lesser time to boil water and cook food than Sample B briquettes under similar conditions. It is therefore recommended that briquettes production using sawdust and charcoal be done at binary and tertiary levels because of the good results from this biomass.

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