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# EFFECT OF STARCH BINDER ON BRIQUETTES AT VARIOUS BINDER CONCENTRATIONS

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## *Abstract*

Briquetting is a process of converting agricultural wastes into similar shaped solids that are easy to use, as a fuel for burning. Briquetting enhances the portability of the combustible material and increases the calorific value, and making it effective for a range of applications both industrial and domestic purposes. This study is aimed at exploiting the potentials of producing briquettes from carbonised sawdust using starch as binding agent at different binder concentrations. The calorific values of the

**Keywords:** Briquettes, Briquetting process, Solid Fuel, Calorific value, Agro waste.

## INTRODUCTION

Densification of agricultural residues may be used as fuel for the generation of energy. Many developing countries are interested in utilizing agricultural residues to produce energy and clean the environment. The agricultural residues are considerable in quantity and they can be effectively used as fuel. Some of the major agricultural residues are rice husks, bagasse, groundnut shells and cotton stalks.

Sawdust is another milling residue available in huge quantities. The major problems associated with these residues are transportation, storage, and handling. Further, direct burning of loose biomass in conventional grates has the problem of very low thermal efficiency and leads to heavy air pollution. To overcome these difficulties, briquetting is one of the better options because it solves the transportation, storage and handling problems.

briquettes obtained were 20.7714, 12.58000, 25.4037, 26.0945 and 28.1448 MJ/Kg for the binders at 5%, 10%, 15%, 20% and 25% respectively. While the Fixed carbon obtained were 57.713, 54.512, 69.639, 70.7905 and 74.788 % respectively. It can be observed that the briquettes produced using at 25% binder concentration gave the highest fixed carbon content and also calorific values which are among the properties that determines the quality of briquettes.

The combustion efficiency has also been increased considerably and reduces the pollution problems. (Asrori, 2024)

Briquetting is converting the low bulk density agro-residues into high density and energy concentrated fuel with the application of pressure, heat and binding agent on loose materials to produce briquettes. Briquettes are in fact good substitute of coal/wood in industrial boiler and brick kiln for thermal applications. These briquettes are non-conventional source of energy, renewable in nature, eco-friendly, and non-polluting and economical (Overand, 2022)

Historically, biomass briquetting technology has been developed in two distinct directions. Europe and the United States has pursued and perfected the reciprocating ram/piston press while Japan has independently invented and developed the screw press technology. Although both technologies have their merits and demerits, it is universally accepted that the screw pressed briquettes are far superior to the ram pressed solid briquettes in terms of their storability and combustibility (Adam and Elvianto 2025)

## RESEACH OBJECTIVE

- This work is aimed at investigating bench scale processing of agricultural wastes using starch as binding agent at various concentration properties of the product briquettes.
- Also to produce solid bio-fuels of high thermal efficiencies while reducing air pollution.

## BACKGROUND

The consequences of global warming, caused by $CO_2$ and other substances, has become an international concern in recent years. To protect forestry resources, which act as major absorbers of $CO_2$, controlling the ever-increasing deforestation, along with the increase in the consumption of wood fuels, such as firewood and charcoal, is an urgent issue (Mohan, 2025). Given this, the development of a substitute fuel for charcoal is necessary. Briquette production technology, a type of clean coal technology, can help prevent flooding and serve as a global warming countermeasure by conserving forestry resources through the provision of a stable supply of briquettes as a substitute for charcoal and firewood. (Muliani, 2024)

## EFFECTS OF BINDER ON DURABILITY OF BRIQUETTES

Binders are chemicals that tend to hold firmly two or more substances to produce a convenient homogenous and uniform solid(compound). A good briquette is one that burns for a long time, Examples of good binding materials are fish, waste, molasses, wood ash, manure, maize or wheat flour. If the press functions well, most mixtures for briquettes will not need binding materials. The binders used for most biomass briquettes were molasses and starch.

## FORCES OF ATTRACTION BETWEEN SOLID PARTICLES

The existing forces of attraction between solid particles e.g. molecular, electrostatic, and magnetic contribute significantly to the adherence of particles. These forces decrease as the size of particles increases. (Ciferno, 2022).

## DENSIFICATION

- •This is the process of compaction of residues into a product of higher bulk density than the original raw material.
- •Densification has stimulated a great deal of interest in developing countries all over the world in recent years as a technique of beneficiation of residues for utilization as an energy source. (Hood, 2020)

## MATERIALS AND METHODS

## MATERIALS

Materials used in this experiment includes:

- Sawdust
- Binders, which includes;
  - Starch
  - Gum Arabic
  - Molasses
  - $CaCO_3$
- Carboniser(Furnace)
- Compression Machine
- Mixing container
- Weighing balance
- Crucible
- Stirrer
- Stop watch
- Crusher
- Sieves

## METHODOLOGY

### FEEDSTOCK DRYING AND SIZE REDUCTION

The feedstock was dried to reduce the moisture content of the biomass material to ensure effective carbonization. The raw material was crushed to smaller form to increase surface area for carbonization.

**Figure 3.1:** crushed sawdust

**Carbonization**

The sawdust biomass was fed to a carbonising reactor at 5kg/batch. The wicks inserted at the bottom holes of the reactor were lighted thus transferring heat to the raw materials, in essence, the wicks are used in heating the reactor which kick starts the carbonization process. The lid was left open for approximately 10 min for the volatile gases to escape. The lid was closed thereafter, the kiln was sealed the prevent air from entering. The material was left to carbonize for 45min -1hr. The disparity in carbonization rate is as a result of the amount of air that was in the reactor at the start of the carbonization process. The fully carbonized materials were collected for further processing.

**Figure 3.2:** Carbonisation process.

**Crushing and Sieving**

The carbonized material was crushed to fine particles and sieved. The material was measured and divided into portions of 100g each.

**Figure 3.3**: carbonised sawdust

**Binder Preparation**

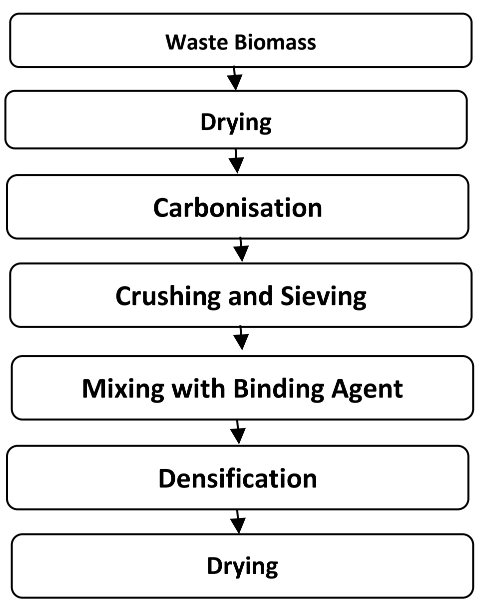
The binders used were Starch, Calcium carbonate, Molasses and Gum-arabic. The starch was prepared by boiling water and gradually mixing with the binder while it is being heated. 0.5 liter of water was used to prepare the binder mixture, The mixture was stirred properly to ensure a homogenous mixture. The increase in water increases binder yield but reduces the viscosity of the binder. While the gum-arabic was soaked in a warm water for some hours, The hot solution of the binders were then constantly stirred until the binder solution becomes gelly.

**Mixing**

The carbonized materials were mixed with the respective binders in such a way that the materials were coated all over with the binders to ensure perfect compaction.

**Briquetting and Drying**

The material was briquetted using a manual screw press briquetting machine and was allowed to dry in order to lower the moisture content for storage purposes.
The process is simply described in the sequence below;



## METHOD

The raw materials were obtained from Carpentry waste. The wood residues selected in this study are produced in large quantity and are most often underutilized. Findings have shown that briquettes produced from sawdust would make good biomass fuel (Fox, 2006)

## BRIQUETTE PRODUCTION

Wood residues were sourced from waste dumps around Maiduguri Metropolis. The materials collected were screened of all external materials like dirt, stones, and sand. The prepared starch binder at concentrations of 5, 10, 15, 20 and 25g were added to each to a 100g of the sample. While the other binders were measured at 15g per material sample of 100g respectively. Then the mixture of the binder and the residues was stirred rigorously. A mould (10 cm height, 15 cm diameter) was used in producing the biomass briquettes. The rigorously mixed blend of the binder and the residue was fed into the mould and compressed. The briquettes were ejected after holding time of about 5 minutes is observed. This process produces briquettes of 2-2.5cm thickness and 15 cm in diameter for 100g charcoal powder.

The binder/residue mixture was fed into the briquetting machine mould and compressed. The content in the mould was then compressed into a briquette.

## RESULTS AND DISCUSSION

| Binder (%Starch) | %Ash content |
|---|---|
| **5** | 28.625 |
| **10** | 27.7976 |
| **15** | 16.8779 |
| **20** | 13.4792 |
| **25** | 11.1451 |

**Table 1:** Ash content for starch binded briquettes

**Table 2** moisture content for starch binded briquettes

| Binder (%starch) | moisture content |
|---|---|
| **5** | 6.9951 |
| **10** | 7.1903 |
| **15** | 6.6206 |
| **20** | 7.8872 |
| **25** | 5.324 |

**Table 3:** Bulk Densities for starch binded briquettes

| Binder (%Starch) | Bulk Density(g/m3) |
|---|---|
| **5** | 0.2398 |
| **10** | 0.25 |
| **15** | 0.2778 |
| **20** | 0.3125 |
| **25** | 0.3369 |

**Table 4:** Volatile matter for starch binded briquettes

| starch % | %Volatile matter |
|---|---|
| **5** | 6.6667 |
| **10** | 10.5000 |
| **15** | 6.8627 |
| **20** | 7.8421 |
| **25** | 8.5521 |

**Table 5:** Fixed Carbon for starch bonded briquettes

| Starch | %Fixed Carbon |
|---|---|
| **5** | 57.7132 |
| **10** | 54.5121 |
| **15** | 69.6388 |
| **20** | 70.7905 |
| **25** | 74.9788 |

**Table 6:** Calorific value for starch bonded briquettes

| Starch | Calorific Value(MJ/kg) |
|---|---|
| **5** | 20.7714 |
| **10** | 12.58 |
| **15** | 25.4037 |
| **20** | 26.0945 |
| **25** | 28.1448 |

## DISCUSSION OF RESULTS

From the experiments carried out, the results for the briquettes produced from the different binder samples at varying concentrations, Analysis were carried out for moisture content, ash content, bulk density, volatile matter, fixed carbon and calorific value whose results are demonstrated by the charts below;

### Effect of Binder concentration on Ash Content

The analysis for ash content of the charcoals for starch bonded briquettes for with variable binder concentrations was carried out, the results obtained are tabulated and represented below using a chart, showing the maximum ash content at 5% binder concentration. The effect of the binder to the ash content is attributed to the fact that the binder material also burns during ashing process hence contributing to the amount of ash present. A graph of binder concentration against ash content is demonstrated in Figure 4 below.

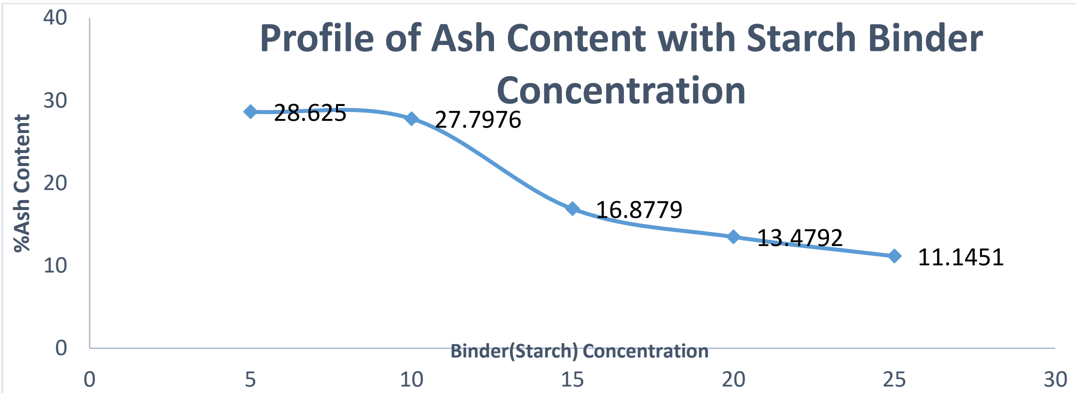



**Figure 4:** Effect of binder concentration on ash content for Starch bonded Briquettes.

Figure 4 represents the effect of various binders on ash content for charcoals bonded with different binders, the analysis gave the following results for the ash content. the results represented below shows the briquettes bonded with $CaCO_3$ had the maximum ash content, while that of Molasses gave the lowest ash content as shown in Figure 4.

**Effect of Binder Concentration on Moisture Content**

Binder concentration has slight effects on the moisture content of the charcoal, determined moisture contents of the five charcoal grades at respective starch binder concentration were determined as 6.99, 7.19, 6.62, 7.88 and 5.32 % respectively. The maximum moisture content of the briquette was at 20%, while the graph declines as the binder content increases. The low moisture content improves the heating value of the briquette. The result can be seen in figure 5 below.

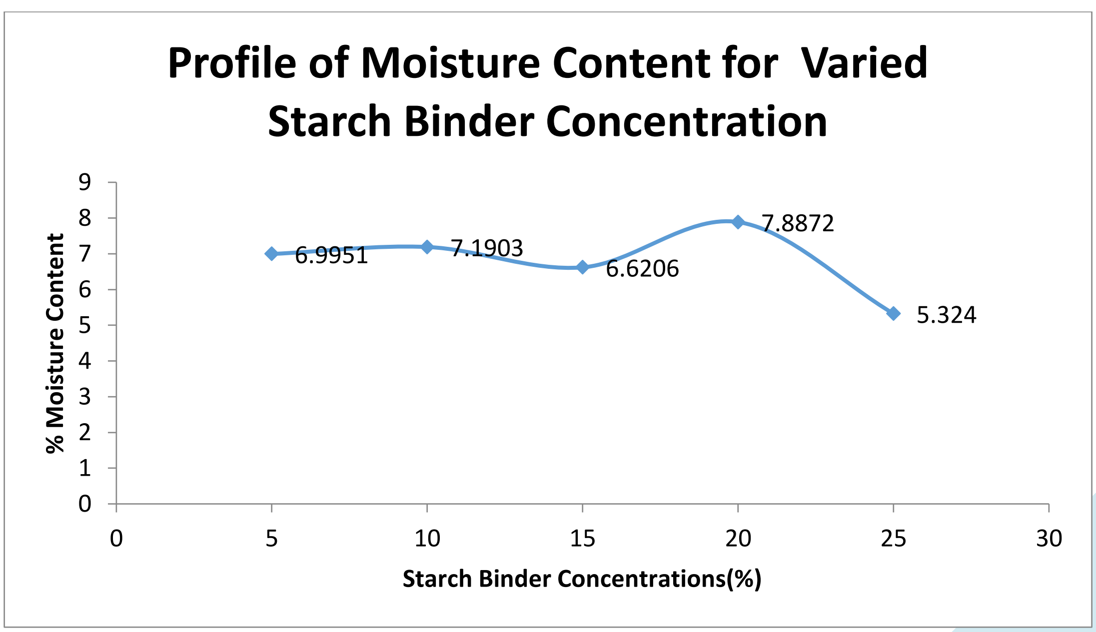



**Figure 5:** Effect of binder concentration on moisture content.

Figure 5 represent the analysis on moisture content shows that molasses binded briquettes exhibits the highest moisture content, while the lowest bar chart represents briquette binded using $CaCO_3$.

**Effect of Binder Concentration on Bulk Density**

Bulk density of the five (5) briquette charcoal grades produced was determined as 0.2398, 0.2500, 0.2778, 0.3125 and 0.3369 g/m$^3$. The bulk density varied only slightly with respect to the binder concentration. The powdered carbonized material assumed the weight of the binder material going by the fact that the binder material is viscous and capable of dissolving the material.

The volatile matter of the briquettes charcoal grades made from sawdust binded with starch at 5%, 10%, 15%, 20% and 25% were determined as;6.6667, 10.8910, 11.0000, 6.8627, 3.6827 g/m$^3$ respectively.

The volatile matter tend to decrease with increase in binder concentration. It varied only slightly with respect to the binder concentration as can be seen in figure 4.7 below.

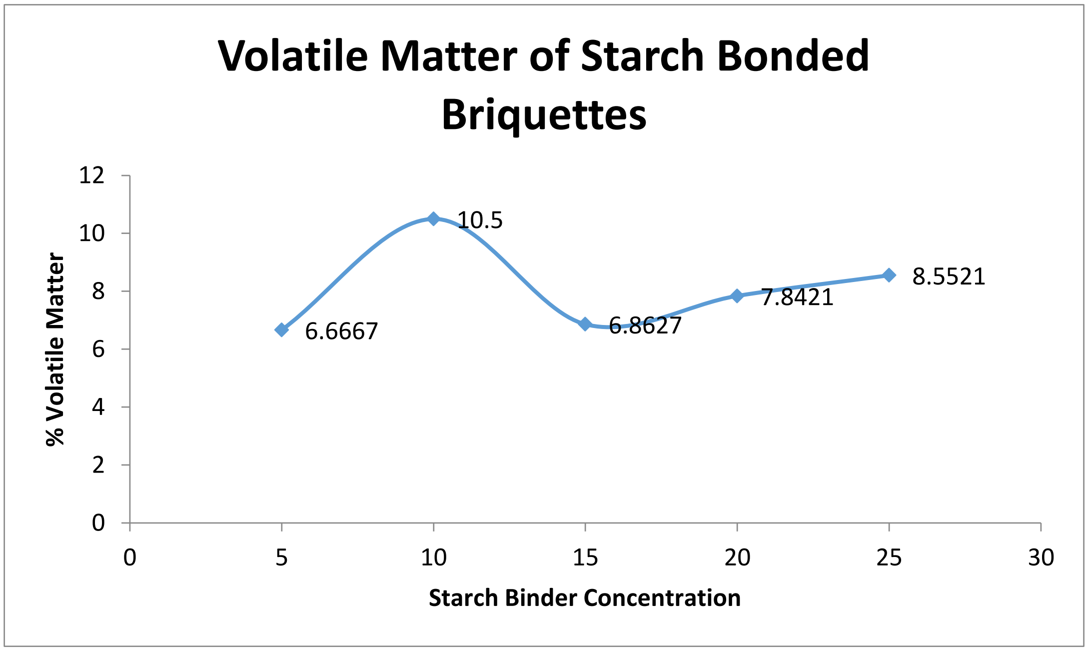



**Figure 6:** Effect of binder concentration on Volatile matter for Starch Bonded Briquettes

**Effect of Binder Concentration on Fixed Carbon**

The Binder concentration also affects the carbon content of the briquettes. The highest carbon content was at 25% binder concentration, lowest fixed carbon was achieved at 10% concentration. It was observed that carbon content increases with an increase in binder concentration to a maximum at 25%. The profile of the results is shown in Figure 7. The fixed carbon varies with binder concentration due to the fact that the binder is an organic compound which also contains carbon, and the result can be seen in figure 7 below.

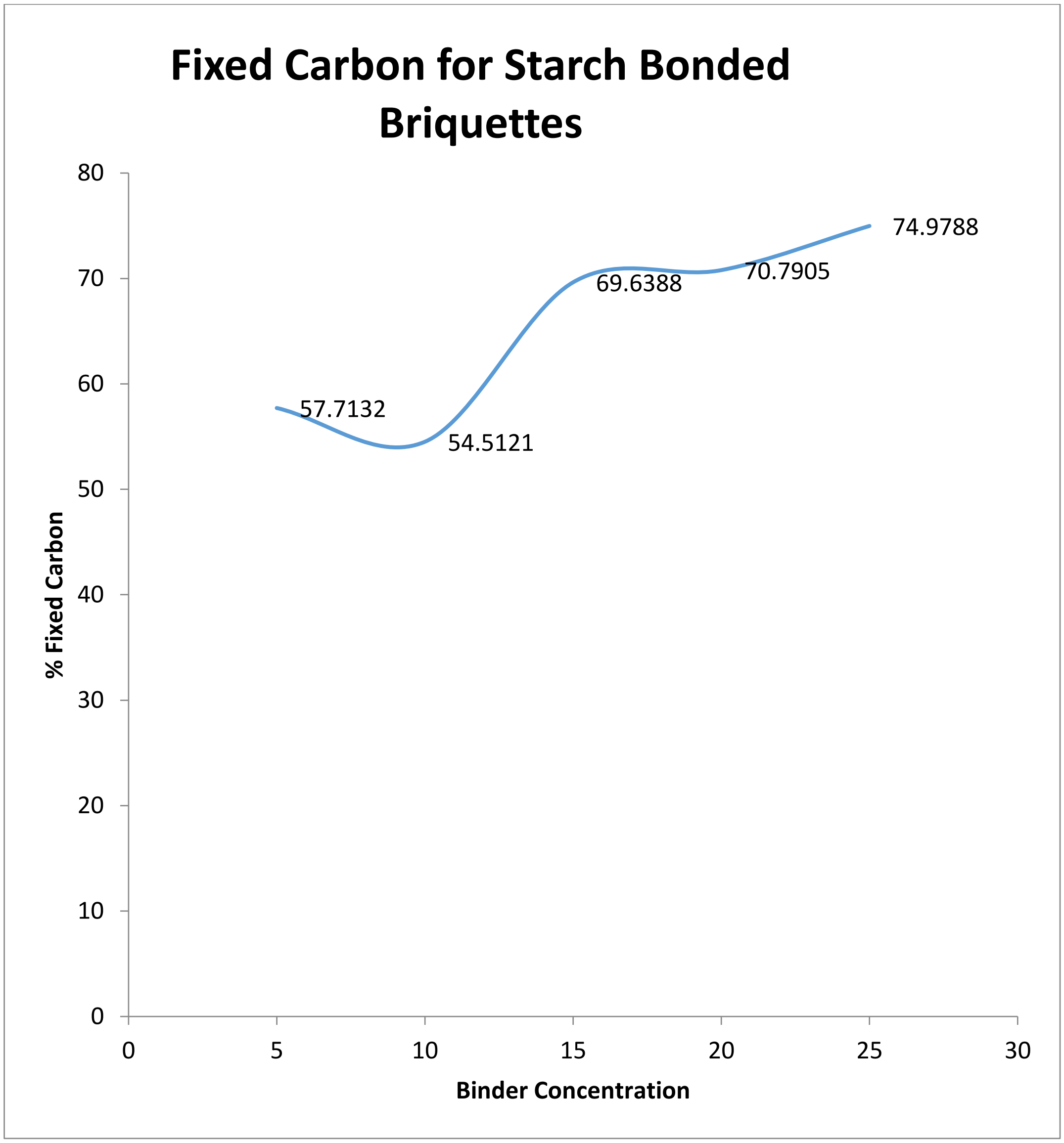



**Figure 7:** Effect of binder concentration on Fixed Carbon for Starch Bonded Briquettes

**Effect of Binder Concentration on the Calorific Value**

The calorific value or high heating value of the charcoal briquette is the amount of heat librated per unit mass of the briquette. Calorific values were calculated using the fixed carbon content of the charcoal briquettes. As with other properties the binder concentration has an effect on the calorific value of the charcoal briquettes. Heating values obtained at binder concentrations of 5, 10, 15, 20 and 25% are 20.77, 12.58, 25.40, 26.09 and 28.14 MJ/kg respectively. Calorific value of the briquettes increased with increase in binder concentration of the briquette. Maximum heating value was obtained at 25% binder concentration. Minimum calorific value was at 5% binder concentration as can be seen in figure 8.

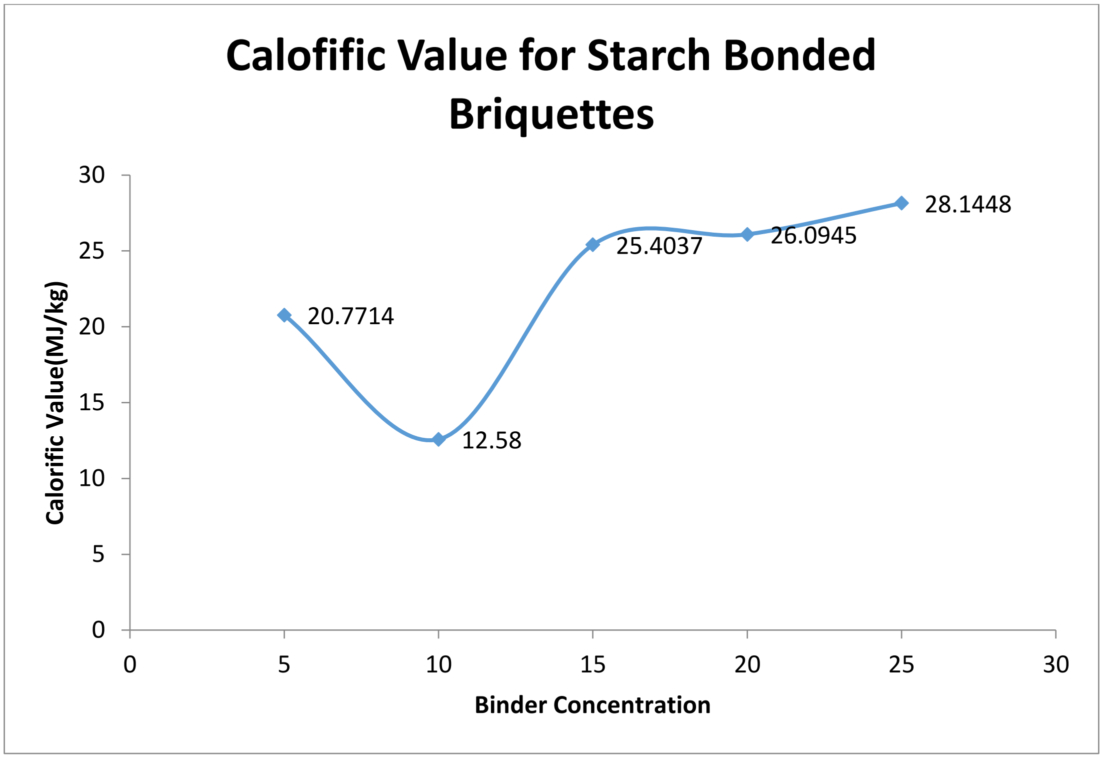



**Figure 8:** Effect of binder concentration on Calorific Value for Starch Bonded Briquettes

## CONCLUSION

Agricultural biomass residue is converted into briquette charcoal of high energy density produced by pyrolysis of biomass wastes to have high quality solid fuel.

Based on the experimental work that has been carried out, briquettes using 100g of carbonised sawdust material feed for each binder concentration sample, the material is prepared using carbonization method. The heating values of the briquettes obtained were 29.7714, 12.5800, 25.4037, 26.0945 and 28.1448 MJ/kg for 5%, 10%, 15%, 20% and 25% Starch concentrations respectively. The best heating value was obtained at 25% binder concentration.

Conversion of waste biomass resources into briquette charcoal is at the advantage of reducing air pollution due to atmospheric emissions and also carter for agricultural/solid waste management.

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