Physico-Mechanical Characterisation of Fuel Briquettes made from Blends of Corncob and Rice Husk

H. A. Ajimotokan¹, S. E. Ibitoye¹*, J. K. Odusote², O. A. Adesoye¹ and P. O. Omoniyi¹

¹Department of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria
²Department of Materials and Metallurgical Engineering, University of Ilorin, Ilorin, Nigeria

Corresponding Author; ibitoye.se@unilorin.edu.ng, ibitoyeesegun@gmail.com

Abstract:
Densification of agricultural residues such as husks, shells and cobs into fuel briquettes is an alternative renewable feedstock for producing solid fuels because it improves their physico-mechanical, storage and combustion properties. This paper presents the physico-mechanical characterisation of fuel briquettes made from blends of corncob and rice husk. The raw samples of corncob and rice husk were collected, sorted and pulverised. The pulverised samples were screened to 0.25, 1.0 and 1.75 mm particle sizes, blended at mixing ratios of 80:20, 70:30, 60:40, and 50:50, and afterwards, briquette samples were produced at 25, 50, and 65 kPa compaction pressures respectively with starch as the binder. The variations in the particle size, mixing ratio and compaction pressure have significantly influenced the investigated physico-mechanical properties of the produced briquettes. The briquette made from 80:20 mixing ratio of corncob to rice husk, 0.25 mm particle size and 65 kPa compaction pressure had the highest compressive strength of 111 kN/m² and the least compressive strength of 39 kN/m² from briquette with 50:50 ratio of corncob to rice husk, 1.75 mm particle size and 25 kPa compaction pressure. The briquette made from 50:50 mixing ratio of corncob to rice husk, 0.25 mm particle size and 65 kPa compaction pressure spent the longest time to collapse when immersed in water; taking up to 972 seconds and the least time of 480 seconds from briquette with 80:20 mixing ratio corncob to rice husk, 1.75 mm particle size and 25 kPa compaction pressure.

Key words: Briquette, durability, density, compressive strength, corncob, rice husk

1. Introduction

Fossil fuel has been largely utilized since its discovery as a major energy source for meeting the global energy demands [1]. The uses of these fuels, which are mainly coal, crude oil and natural gas, have increased rapidly to satisfy the rising energy demand due to growing global population growth, rapid industrialization and urbanization [1-3]. With the growing concern over the Earth’s limited fossil fuel reserves and effects of greenhouse gas emissions [4], there is renewed interest in alternative renewable energy sources for domestic and industrial applications. Among these, biomass such as biomass residues are promising sustainable energy sources that can serve as a substitute to the non-renewable fossil fuel due to its global availability and renewability nature [5], contributing about 14% of the world energy consumption [6]. Biomass residues, in particular, agricultural residues such as bagasse, husks, stalks, shells, and cobs among others; have gained prominence as one of the widely utilized renewable energy sources and they contribute to the affordability and security of energy supply [7-8].
As an alternative energy source, agricultural residues could be used either directly as solid fuel through combustion, or harnessed and transformed through densification for domestic and industrial applications [9]. However, only a small proportion of these agricultural residues are being used as solid fuel in sustainable energy solutions because they are bulky and contain high moisture, which made them difficult to use as solid fuel in their raw form [9-10]. These inherent properties make agricultural residues not readily available as excellent sources of solid fuel, thus their densification; that is, briquetting, palletization or cubing into solid fuel to improve their densities, handling, storage and combustion properties, and overcome the logistic economics in sustainable energy solutions [6], [11-12]. These agricultural residues from all renewable energy sources are expected to be one of the utmost beneficial energy sources in the near future and studies have shown that the world production of agricultural residues is projected to be approximately 2,000 billion tons per year [13].

The densification process is concerned with increasing the density of biomass residues to nearly 1000 to 1200 kg/m$^3$ of loose biomass, reducing the volume by 8 to 10 times is known as briquetting [3], [14]. This densification process of making fuel briquettes demonstrates the potential of appropriate technology for producing solid fuel from forest and agricultural residues [15-16]. For domestic and industrial heating purposes, the practice, in recent times, includes the use of briquettes of biomass residues from agricultural produces, food industry, or combinations of different types of plant residues with other additives [17-21].

Literature is replete with several research works reported on briquetting of corncob or rice husk and no known published research on the blend of both corncob and risk husk. For instance, Oladeji [22] investigated the comparative characterisation of corncob and rice husk briquettes. The properties of the produced briquette samples were investigated to evaluate which of the two agricultural residues can be used to gain comparative advantages as solid fuel. The produced briquettes of these two residues were reported that they would make good solid fuels but the corncob briquette has better physico-mechanical properties of fuel briquette than the rice husk briquette because it has a relatively moderate moisture content, higher density and lower relaxation ratio among others. Obi and Okongwu [3] characterized fuel briquettes from blends of rice husk and palm oil mill sludge (POMS). The increase in the percentage of POMS in the blends was reported to significantly influence the physical and combustion properties of the produced briquettes. Moreover, there is a need to carry out physico-mechanical characterisation of fuel briquettes made from biomass residues to gain comparative advantage in selecting suitable biomass and their blends for fuel briquettes production. Thus, this study investigates the physico-mechanical characterisation of fuel briquettes made from blends of corncob and rice husk. Selected fundamental physio-mechanical properties of fuel briquettes such as compressive strength, durability, and green and relaxed density among others were evaluated.

2. Methodology

The biomass employed for this work was sourced from Ilorin, Kwara state, Nigeria. Raw samples of corncobs were obtained from the agricultural residues of corn farms in the University of Ilorin and rice husk from the rice production farmers at Ganmo, Ilorin, Nigeria. The starch used as the binder was obtained from cassava processing factory at Gaa-Akanbi, Ilorin, Nigeria. The raw samples of corncob and rice husk were sorted and pulvèrisè. The pulvèrisè samples were screened to 0.25, 1.0 and 1.75 mm particle sizes, blended at the mixing ratios of 80:20, 70:30, 60:40 and 50:50 respectively, and stored separately. Afterwards, briquette samples were produced at 25, 50, and 65 kPa compaction pressures with starch as the binder, and the physico-mechanical characterisation of the produced briquette samples was carried out.
2.1 Preparation of biomass Samples and Starch Gelatinisation
The raw samples of corncobs and rise husks were sorted to remove every form of dirt such as sand, stone, and plant residues, and then sundried to reduce the moisture content. The raw samples were then pulverised into fines for densification using a hammer mill and screened to 0.25, 1.0 and 1.75 mm particle sizes respectively in accordance with BS EN 15149-2 [23] standard method using the sieving machine. Afterwards, they were stored separately in a zip-locked polythene bag for later processes. 270 ml of boiling portable water was employed to gelatinised a thoroughly mixed 130 g of starch with 180 ml portable water to form a uniform jelly-like starch gel.

2.2 Formulation and Production of Briquette Samples
The corncob and rice husk fines were weighed using electronic weighing balance and blended at different mixing ratios of 80:20, 70:30, 60:40, and 50:50 respectively. The blends of corncob and rice husk were mixed with the binder (starch gel) using an electric mixer at 100 rpm, and afterwards, the feedstock was poured into the prepared molds after thorough blending. The compaction of the feedstock was done using 1560 kN hydraulic jack machine (Model: EL31 072) at the Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria. The holding time for each briquette was 120 seconds and samples were produced in duplicate at three different compaction pressures. Immediately after the ejection of the briquettes from the molds, the mass and dimensions were taken using a digital weighing balance and Vernier caliper and afterwards, they were sundried for five days to remove moisture and later cured at room temperature. Figure 1 presents the samples of the produced briquette with different particle sizes.

![Briquette samples of particle size 0.25 mm](image1.png)

![Briquette samples of particle size 1.0 mm](image2.png)

![Briquette samples of particle size 1.75 mm](image3.png)

Figure 1: The produced briquettes samples, showing the briquette samples of particle size 0.25 mm in (a), briquette samples of 1.0 mm in (b), and briquette samples of particle size 1.75 mm in (c)
2.3 Physical and Mechanical Properties of the Produced Briquettes

The physical and mechanical properties investigated include the compressive strength, green and relaxed density, porosity index, durability and water resistance.

2.3.1 Compressive Strength

The compressive strength or cold crushing strength of the produced briquette; i.e., the maximum crushing load the briquette can withstand before failure, was determined using the universal strength testing machine (Model: Test metric FS5080) with standard method ASTM D2166-85 [24]. The test was carried out 21 days after briquetting. The peak stress (compressive strength) displayed at the end of each test was taken. For each of this test, the experiment was done in duplicate.

2.3.2 Density

The green or compressed density was determined immediately after the produced briquette samples were ejected from the mould. On ejection of the briquette samples, the mass and dimensions were taken using a digital weighing balance and Vernier caliper to determine the green density. The relaxed density of the briquettes was determined 30 days after been sundried using standard method ISO 3131 [25]. The density $\rho$ of the produced briquette samples was calculated using the equation expressed as follows:

$$\rho = \frac{m}{v}$$  \hspace{1cm} (1)

where $m$ is the mass of the produced briquette and $v$ is the volume of the produced briquette. The volume of the produced briquette was computed using the equation expressed as follows:

$$v = \pi h(R - r)^2$$  \hspace{1cm} (2)

where $h$ is the height of the produced briquettes, $R$ is the external radius of the briquettes and $r$ is the internal radius of the briquettes.

2.3.3 Relaxation Ratio

The relaxation ratio is the ratio of maximum density to relaxed density and is calculated with the following expression:

$$Relaxation\ ratio = \frac{Compressed\ density}{Relaxed\ density}$$  \hspace{1cm} (3)

2.3.4 Durability

Durability or shattering index of the produced briquette; i.e., a parameter that indicates the toughness of the briquette during storage, handling and transportation, was measured by dropping the briquette from a 1.85 m height onto a flat steel plate for four times. The percentage durability is the ratio of the final weight of the produced briquette retained after four drops to the initial weight of the [26]. This can be expressed as follows:

$$Durability = \frac{Weight\ of\ the\ sample\ in\ plate\ after\ 4\ drops}{Initial\ weight\ of\ the\ sample} \times 100$$  \hspace{1cm} (4)

2.3.5 Water Resistance Capacity of Dry Briquette

The water resistance capacity of the produced briquette was determined by immersing the briquette in a container filled with cold tap water and the time taken to collapse was recorded [27].
3. Results and Discussion

The physico-mechanical characterisation of fuel briquettes made from blends of corncob and rice husk was carried out. The raw samples of corncob and rice husk were collected, sorted and pulverised. The pulverised samples were screened to 0.25, 1.0 and 1.75 mm particle sizes, blended at mixing ratios of 80:20, 70:30, 60:40, and 50:50, and afterwards, briquette samples were produced at 25, 50, and 65 kPa compaction pressures with starch as the binder.

Figure 1 shows the effect of variations in particle size, mixing ratio and compaction pressure on the compressive strength of the produced fuel briquette. It shows that the compressive strength of the produced briquettes varied from 39 to 111 kN/m². The briquette made from 80:20 mixing ratio of corncob to rice husk, 0.25 mm particle size and 65 kPa compaction pressure exhibited the best compressive strength and the least from briquette with 50:50 ratio of corncob to rice husk, 1.75 mm particle size and 25 kPa compaction pressure. This study presents better strength characteristic when compared with the result reported by Andres, Aileen and Ofero [28], with 0.24 kN/m² and 1.13 kN/m² for briquettes from carbonized rice husk and corncob respectively. However, Bianca et al., [29] reported compressive strength of 360 kN/m² with the briquettes of banana leave waste. The variation might be due to the nature of the materials and methods of producing the briquettes. The variations in the particle size, mixing ratio and compaction pressure have considerably influenced the compressive strength. The compressive strength of the produced briquettes increase as the particle size reduces. This is because briquette made from finer particle size had less pore space between particles, enhancing the inter-molecular bond of the particle due to larger contact surface area between the particles which in turn increases the strength of the briquette. Also, it was observed that as the percentage of rice husk in the blend increases, the compressive strength of the produced briquette reduces. This suggests that corncob played the prominent role in improving the compressive strength of blended briquette. The compaction pressure is another important factor that contributes to the strength properties. Compressive strength increases as the compaction pressure increases because the pressure applied to achieve compactness enhances the inter-molecular bonding property of the briquette particles, hence improve the strength property.

![Figure 1](image1.png)

**Figure 1**: Effect of variations in mixing ratio, particle size and compaction pressure on compressive strength

Figure 2 shows the effect of variations in particle size, mixing ratio and compaction pressure on the green density of the produced fuel briquette. It shows that the green density of the produced briquette varied from 1.1 to 1.86 g/cm³. The briquette made from 50:50 mixing ratio of corncob to
rice husk, 0.25 mm particle size and 65 kPa compaction pressure had the highest green density and the least from briquette with 80:20 mixing ratio of corncob to rice husk, 1.75 mm particle size, and 25 kPa compacting pressure. The result obtained in this study is higher than what was reported by Olaseni and Enweremadu [30], which ranges from 0.533 to 0.98 g/cm³ for briquette made from corncob residues. It was observed that green density increases as particle size reduces, increases as the percentage of rice husk in the blend increases and increases as the compaction pressure increases.

Figure 2: Effect of variations in mixing ratio, particle size and compaction pressure on green density

Figure 3 shows the effect of variations in particle size, mixing ratio and compaction pressure on the relaxed density of the produced fuel briquette. It shows that the relaxed density of the produced briquette varied from 0.42 to 0.78 g/cm³. The briquette made from 50:50 mixing ratio of corncob to rice husk, 0.25 mm particle size and 65 kPa compaction pressure had the highest relaxed density and the least from briquette with 80:20 ratio of corncob to rice husk, 1.75 mm particle size, and 25 kPa compacting pressure. It is observed that relaxed density increases as the particle size reduce; increases with an increase in the percentage of rice husk in the aggregate and increases with an increase in compaction pressure. The relaxed density increases with an increase in compaction pressure because an increase in compaction pressure results in a decrease in volume at constant mass [31].
Figure 4 shows the effect of variations in mixing ratio, particle size and compaction pressure on the relaxation ratio of the produced fuel briquette. It shows that the relaxation ratio varied from 2.21 to 2.94. The briquette made from 60:40 mixing ratio of corncob to rice husk, 1.75 mm particle size and 65 kPa compaction pressure had the highest relaxation ratio and the least from briquette with 80:20 mixing ratio of corncob to rice husk, 0.25 mm particle size, and 25 kPa compacting pressure. It is observed that the relaxation ratio increases with an increase in compaction pressure, which is similar to the finding reported by Gino et al. [32]. However, as the particle sizes decrease, the relaxation ratio decreases. The implication of this is that briquettes produced from particle size 0.25 mm and 1.0 mm is more stable than briquettes from 1.75 mm. These values compare favourably well with the result obtained by Olorunsola [1], which gave the relaxation ratio ranging between 1.80 and 2.5 for coconut and rice husk briquette. Oladeji et al. [30] also reported minimum and maximum relaxation ratio of 1.33 and 2.89 respectively for briquettes produce from corncob. The result of this study display better characteristics than that of Olorunsola [1] and Oladeji et al. [31] and this might be due to the nature of the biomass used in their studies. Values of relaxation ratio obtained in this study indicate that briquettes from the finer particles are more stable than the coarse particles. Also, high relaxation ratio implied more void in the compressed materials and small value indicates more volume displacement, which is good for packaging, storage and transportation. Above all, it is an indication of stable and good quality briquettes [30], [33].
Figure 4 shows the effect of variations in mixing ratio, particle size and compaction pressure on relaxation ratio. Figure 5 shows the effect of variations in mixing ratio, particle size and compaction pressure on the durability of the produced fuel briquette. It shows that the durability varied from 32.22 to 99.13%. The briquette made from 50:50 mixing ratio of corncob to rice husk, 0.25 mm particle size and 65 kPa compaction pressure had the highest durability and the least from briquette with 80:20 mixing ratio of corncob to rice husk, 1.75 mm particle size, and 25 kPa compacting pressure. These values are similar to the range of values reported by Odusote and Muraina [26] with durability range from 88.43 to 97.6% for briquette of Palm kernel shell and Mesocarp fibre. It was observed that durability increases as the percentage of rice husk in the aggregate an increase, which implies that the rice husk played a prominent role in enhancing the durability of the blend. The durability increases as the particle size of the produced briquette reduce. This is because smaller particle sizes have better inter-molecular bonding due to less pore space between the particles, and hence the adhesive forces between the blended particles are high which make the particle interlocked and bonded together, thereby improving the durability property. Also, the durability increases with an increase in compaction pressure of the produced briquette and this is because pressure enhances the intermolecular bonding property of particles.

Figure 6 shows the effect of variations in mixing ratio, particle size and compaction pressure on water resistance capacity of the produced fuel briquette. It shows that water resistance capacity varied from 480 to 972 s. The briquette made from 50:50 mixing ratio of corncob to rice husk, 0.25 mm particle size and 65 kPa compaction pressure spent the longest time to collapse when immersed in water and the least from briquette with 80:20 mixing ratio of corncob to rice husk, 1.75 mm particle size, and 25 kPa compacting pressure. The result shows that briquette with smaller grain sizes, higher percentage of rice husk and higher compaction pressure resists water penetration better. This is because briquettes with smaller particle sizes have fewer pore spaces, which reduces water percolation and capillary action in the briquette. In addition, higher compaction pressure improves the water resistance capacity because particles are more compacted at higher pressure, giving rise to fewer pore spaces and hence difficult for such briquette to absorb water when exposed to the humid environment.
Figure 6: Effect of variations in mixing ratio, particle size and compaction pressure on water resistance capacity

4. Conclusion

This study investigated the physico-mechanical characterisation of fuel briquettes made from blends of corncob and rice husk. Selected physical and mechanical properties of fuel briquettes such as compressive strength, durability, and green and relaxed density among others were evaluated. The variations in the particle size, mixing ratio and compaction pressure have significantly influenced the investigated physico-mechanical properties of the produced briquettes. The briquette made from 80:20 mixing ratio of corncob to rice husk, 0.25 mm particle size and 65 kPa compaction pressure had the highest compressive strength of 111 kN/m$^2$ and the least compressive strength of 39 kN/m$^2$ from briquette with 50:50 ratio of corncob to rice husk, 1.75 mm particle size and 25 kPa compaction pressure. The green and relaxed density increase with an increase in the percentage of rice husk in the produced briquettes and the durability of produced briquettes increases as particle sizes reduces and increases as the percentage of rice husk increase in the produced briquettes.

References

[1] Olorunsola, A. (2007). Production of Fuel Briquettes from Waste Paper and Coconut Husk Admixture (Vol. 9). Agricultural Engineering International: the CIGR E-journal Manuscript EE 06 006.
[2] Ajimotokan, H. A. (2014). A Study of Trilateral Flash Cycle for Low-grade Waste Heat Recovery-to-power Generation. PhD Thesis, Energy and Power Division, Cranfield University, Cranfield, UK.
[3] Obi, F. O., Okongwu, A. C. (2016). Charaterisation of Fuel Briquettes made from a Blend Of Rice Husk and Palm Oil Mil Sludge. Biomass Conversion and Biorefinery, 6(1), 449-456.
[4] Ajimotokan, H. A. and Sher, I. (2015). Thermodynamic Performance Simulation and Design Optimisation of Trilateral-cycle Engines for Waste Heat Recovery-to-power Generation. Applied Energy (154), 26-34.
[5] Soponpongipipat, N. and Sae-Ueng, U. (2015). The Effect of Biomass Bulk Arrangements on the Decomposition Pathway in the Torrefaction Process. Renewable Energy 81, 679-684.
[6] Rabiu, A. B., Lasode, O. A., Ajimotokan, H. A. and Afolayan, V. A. (2018). Combustion Characteristics of Selected Tropical Wood Residues in Relation to Particle Size. *The 33rd International Conference on Solid Waste Technology and Management, (pp. 320-330)*. PA 19013-5792, USA.

[7] Eddine, B. T., Salah, M. M. (2012). Solid Waste as Renewable Source of Energy: Current and Future Possibility in Algeria. *International Journal of Energy and Environmental Engineering, 3*, 1-12.

[8] Szyszklak-Barglowicz J., Zajac G. and Piekarski W. (2012). Energy Biomass Characteristics of Chosen Plants. *International Journal of Agro-Physics, 26*(2), 175-179.

[9] Ibitoye, S. E. (2018). Production and Characterisation of Fuel Briquettes made from Blend of Corncob and Rice Husk. *M.Eng Project Report, University of Ilorin, Department of Mechanical Engineering. Ilorin, Nigeria*.

[10] Wilaipon, P. (2007). Physical Characteristics of Maize-cob Briquettes under Moderate Die Pressure. *American Journal of Applied Science, 4*(5) 995-998.

[11] Kaliyan, N. and Morey, R. V. (2009). Factors Affecting Strength and Durability of Densified Biomass Products. *Biomass and Bio-energy, 2*(1), 337-359.

[12] Amoo, O. M. and Fagbenle, R. L. (2013). Renewable Municipal Solid Waste Pathways for Energy Generation and Sustainable Development in the Nigerian Context. *International Journal of Energy and Environmental Engineering, 4*(42), 1-17.

[13] Aleksandar, A., Eleonora, D. and Ljiljana R. (2017). Energy Efficiency Analysis of Corncob Used as a Fuel. *Energy Sources, Part B: Economics, Planning, and Policy, 12*(1), 1-7.

[14] Wakchaure, G. C. and Indra, M. (2009). Effect of Binders on the Physical Quality of some Biomass Briquettes. *Journal of Agricultural Engineering, 46*(4), 24-30.

[15] Dasappa, S., Sridhar, H. V., Sridhar, G. and Paul, P. J. (2011). Science and Technology Aspects of Bioresidue Gasification. *Biomass Conversion and Bioenergy, 1*(3), 121-131.

[16] Akowuah, J. O., Kemausuro, F. and Mitchual, S. J. (2012). Physico-Chemical Characteristics and Market Potential of Sawdust Charcoal Briquette. *International Journal of Energy and Environmental Engineering, 3*(20), 1-6.

[17] Gil, M. V., Oulego, P., Casal, M. D., Pevida, C., Pis, J. J., and Rubiera, F. (2010). Mechanical Durability and Combustion Characteristics of Pellets from Biomass Blends. *Bioresource Technology, 10*(1), 8859-8867.

[18] Stelte, W., Holm, J. K., Sanadi, A. R., Barsberg, S., Ahrenfeldt, J. and Henriksen, U.B. (2011). A Study of Bonding and Failure Mechanisms in Fuel Pellets from Different Biomass Resources. *Biomass and Bioenergy, 35*, 910-918.

[19] Raslavicius, L. (2012). Characterization of the woody cutting Waste Briquettes Containing Absorbed Glycerol. *Biomass and Bioenergy, 45*, 144-151.

[20] Mitchual, S. J., Frimpong-Mensah, K., Darkwa, N. A. and Akowuah, J. O. (2013). Briquettes from Combination of Maize Cobs and Ceiba Pentandra at Room Temperature and Low Compacting Pressure Without a Binder. *International Journal of Energy and Environmental Engineering, 4*, 38.

[21] BS EN 15149-2. (2010). *Solid biofuels - Methods for the determination of particle size distribution. Part 2: Vibration Screen Method for Small Particle Using Screen Aperture of 315 mm and Below*. British International Standard. London.

[22] ASTM D2166. (2016). *International ASTM Standard Test Method for Unconfined Compressive Strength of Cohesive Soil*. West Conshohocken, PA.

[23] Obi, F. O. (2015). Evaluation of the Physical Properties of Composite Briquette of Sawdust and Palm Kernel Shell. *Biomass Conversion and Biorefinery, 5*(3), 271-277.

[24] Oladeji, J. T. (2010). Fuel Characterization of Briquettes Produced from Corncob and Rice Husk Resides. *The Pacific Journal of Science and Technology, 11*(1), 101-106.
[25] ISO 3131. (1975). International standard test method for density of regular solids. ISO, Geneva.

[26] Odusote, J.K. and Muraina, H.O. (2017). Mechanical and Combustion Characteristics of Oil Palm Biomass Fuel Briquette. Journal of Engineering and Technology, 14-29.

[27] Demirbas, A. (1999). Physical Properties of Briquettes from Waste Paper and Wheat Straw Mixtures. Energy Conversion Management, 40, 437-445.

[28] Andres, M. T., Aileen, R. L. and Ofero, A. C. (2016). Physico-chemical and Thermal Properties of Fuel Briquettes Derived from Biomass Furnaces as By-Products. 95(9), 859-867.

[29] Bianca, G. D., Oliveira, M., Ozair, S. A, Cintia, M. D., Antonio, P. N. Oliveira, D. E and Noeli, S. (2014). Production and Characterization of Fuel Briquettes from Banana Leaves Waste. The Italian Association of Chemical Engineering, 1(2), 2283-9216.

[30] Oladeji, J. T. and Enweremadu, C. C. (2012). The Effects of Some Processing Parameters on Physical and Densification Characteristics of Corncob Briquettes. International Journal of Energy Engineering, 2(1), 22-27.

[31] Oladeji, J. T. (2015). Theoretical Aspects of Biomass Briquetting: A Review Study. Journal of Energy Technologies and Policy, 5(3), 72-81.

[32] Gino, M. T., Arellano, Y. S. and Kato F.T. B. (2015). Evaluation of Fuel Properties of Charcoal Briquettes Derived from Combinations of Coconut Shell, Corncob and Sugarcane Bagasse. Proceedings of the De La Salle University Research Congress Vol. 3, 1-6.

[33] Yaning Zhang, A. E. G. and Bingxi, Li. (2012). Physical Properties of Corn Residues. American Journal of Biochemistry and Biotechnology 8(2), 44-53.