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Energy Characterisation of Briquettes Produced from Admixture of *Arundo donax L.* and Coconut Coir

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Abstract

The study was carried out to evaluate the combustible energy characteristics of briquettes produced from *Arundo donax,* coconut coir and admixture of both agricultural wastes, using cassava starch as binder. The 2 x 5 factorial experiment was carried out in a completely randomized design (CRD), and replicated 3 times to give a total of 15 samples. Physical parameters assessed in the study were: moisture content and density while combustion properties included: ash content, percentage fixed carbon, percentage volatile matter, heating value and water boiling test value. The results obtained from the assessment of the physical properties of the briquettes produced from the admixture of 50g *Arundo donax* and 50g of coconut coir showed the lowest mean value of 32.72±1.86% for moisture content while 100g of coconut coir recorded the highest density of 0.56± 0.03g/cm^3. For the combustion properties, it was observed that admixture of 50g of *Arundo donax* and 50g of coconut coir produced briquette with the lowest ash content of 4.33 ±0.76%. The results also revealed that briquette produced form 50g of *Arundo donax* and 50g of coconut coir had the highest mean value of percentage fixed carbon, heating energy and cooking efficiency (water boiling test value) as 14.83 ±1.89%, 32.13 ± 255.39 kJ/g and 3.39 ± 0.10 kJ/kg respectively. A relatively high volatile matter of 84.83 ± 2.08% was also recorded for briquette from this admixture. Inspite of the limitations posed by the use of manual moulding equipment for the briquetting process -- low densification and less compression of loose biomass materials into briquette blocks -- biomass briquette was successfully produced., based on the results of this study, However, it is recommended that briquette should be produced from *Arundo donax* and coconut coir mixed together in equal proportion for improved combustion properties, due to its low moisture content, low ash content, high heating value, high percentage fixed carbon and highest cooking efficiency.

Keywords: Briquette; *Arundo dona;* coconut coir; cassava starch; physical and combustion properties.

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1. Introduction

From time immemorial, wood has served as fuel for domestic and industrial purposes. But as the population of the world continues to grow, the demand for energy increases, outstripping the capacity of fuel wood, hence becoming a critical challenge for the world energy leaders [1]. According to [2], global energy consumption has about doubled in the last three decades of the past century. In 2004, about 77.8% of the primary energy consumption was from fossil fuels (32.8% oil, 21.1% natural gas, 24.1% coal), 5.4% from nuclear fuels, 16.5% from renewable resources, of which the main one was hydro (5.5%), whereas the remaining 11% consisted of non-commercial biomasses such as wood, hay, and other types of fodder, which still constitute the main resource in rural economies. With improvements in energy efficiency, it is expected that global energy demand will double by 2050. This is the consequence of global population growth, global economic growth, continued urbanization, as well as the resulting increased demand on mobility and other energy dependent services [3].The solution to the global energy and future needs in developing countries, including Nigeria, requires diversifying the energy sources. Previous studies have suggested that energy production methods be best matched with the available natural resources [4]. The pattern of fuel consumption has been noted to be increasing in Africa with the estimation that about 583 million people depend on fuel wood, charcoal, fossils, etc [5]. This is projected to increase by 20 million within the next three decades [6].Wood in the form of fuel wood, twigs and charcoal has been a major source of renewable energy in Nigeria, accounting for about 51% of the total annual energy consumption. The other sources of energy include natural gas (5.2%), hydro-electricity (3.1%) and petroleum products (41.3%) [7]. In Nigeria, large quantities of agricultural and forestry residues produced annually are vastly under-utilized. The common practice is to burn these residues or leave them to decompose [8, 9].Agro-residues like many other combustible materials are often generated either at post harvest or after consumption and are more often than not indiscriminately disposed off or used rather inefficiently, thereby causing extensive pollution and becoming environmental menace to the society [10]. However from past studies, it has been observed that these agricultural residues, including such biomass materials as rice husk, coffee husk, coconut husk, bagasse, groundnut shell, cotton stalk are useful in providing heat energy [11], though they are difficult to store, handle and even transport due to their low density, high bulkiness and high moisture content [12]. This means that there is need to compress them into less voluminous but compacted utilizable product through briquetting Biomass briquetting is the densification of loose biomass material with the application of pressure to produce compact solid composites of different sizes. Thus, briquetting of residues takes place with the application of pressure, heat and binding agent on the loose materials to produce the briquettes. This binding agent acting as an adhesive can be any fibrous organic material such as starch, gum, collagen; top bond, etc. Briquettes are often used as a development intervention to replace firewood, charcoal, or other solid fuels. In the proper context, biomass briquettes can save time, save money, decrease local deforestation rates, and provide some income generating opportunities [13]. According to [14], the realization that deforestation and wood fuel shortages are likely to become pressing problems in many countries has turned attention to other types of biomass fuel. Agricultural residues are, in principle, one of the most important types of biomass fuel. They are generated in large volumes in the rural areas, where some of the worst pressures on wood shortage abound. Briquetting, therefore, provides a decent, convenient and efficient way of using agricultural wastes, thereby improving the economics of material handling, transportation and storage as well as enhancing more versatile application. Amongst the positive attributes of agro-waste briquettes are low moisture content, high crushing strength, high density, and slow flame propagation, low ash content, high amount of hydrogen and substantial heating value [15]. Apprehensive studies have been carried out on different materials that can be used to produce biomass briquettes. Such materials include coconut husk [16], groundnut and melon shells [17], rice husk and groundnut shell [18], and maize cob mixed with waste paper [19], amongst others. Maize cob, a residue of maize crop, is a ligno-cellulosic biomass material which contains high amount of organic constituents and energy, attributes of high quality biomass material for briquetting. Waste paper appears to be a viable material in blend with agricultural waste in the production of briquette. While the prevailing practice is to recycle these products in the paper industry, the process constraints posed by the recycling process could be expensive in terms of re-sorting, re-pulping, de-inking and decontamination of the reclaimed materials [16]. However, previous studies have shown that waste paper could be mixed with other biomass materials to produce relatively cheap and durable binder-less briquette [19, 20]. *Arundo donax,* commonly referred to as Giant cane, is a tall perennial cane growing in damp soils, either fresh or moderately saline. Other common names include Carrizo, Arundo, Spanish cane, Colorado River reed, Wild cane, and Giant reed [21]. It grows to 6 metres in ideal conditions and can exceed 10 metres in height, with hollow stems 2 to 3 cm in diameter [22]. Coconut coir is a natural fibre extracted from coconut and used in products such as floor mats, doormats, brushes, mattresses, etc. Coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. The individual fibre cells are narrow and hollow, with thick walls made of cellulose. They are pale when immature, but later become hardened and yellowish as a layer of lignin is deposited on their walls. Each cell is about 1mm long and 10 to 20 μm in diameter. Fibers are typically 10mm to 300mm long [23].

2. Materials and Methods

2.1 Materials sourcing and Briquetting process

Samples of *Arundo donax* were obtained from the National Horticultural Research Institute (NIHORT), Ibadan while the coconut coir was sourced from Bode market in the outskirts of Ibadan.Both materials were sun-dried for 7days to reduce their moisture content before being respectively ground in a hammer milling machine. A sieve with 1.0 μm size mesh was used to sieve each of the ground mill products. The cassava starch was later turned into slurry by boiling with water. Both ground samples of *Arundo donax* and coconut coir were thoroughly mixed in five different mixing ratios with starch slurry of constant weight to give a total of 140 g of biomass furnish for each treatment. The resultant uniformly blended furnish was then hand-fed into a manual mould for manual compression into briquette. The cylindrical block of briquette obtained was left in the open area for 48 hours before the required tests were carried out [24]. Each treatment was duplicated three times and fifteen samples were produced in total. The use of manual moulding equipment was a major constraint of the research study, impacting poorly on the compacting process and densification of the loose biomass materials into briquette blocks. The mixing proportions for the biomass admixture are presented as follows:

A – *Arundo donax* (100g) + coconut coir (0g) +40g of starch

B – *Arundo donax* (0g) + coconut coir (100g) +40g of starch

C – *Arundo donax* (50g) + coconut coir (50g) +40g of starch

D – *Arundo donax* (25g) + coconut coir (75g) +40g of starch

E – *Arundo donax* (75g) + coconut coir (25g) +40g of starch

2.2 Physical Properties Assessed

The physical properties evaluated include:

2.2.1 Moisture Content

The moisture content was calculated according to [25]. The briquette sample was weighed and placed in a laboratory oven at a temperature of 103 ± 2^0C and weighed at intervals of 2 hours until constant weight was achieved.

Mathematically,

$$MC = \frac{w_1 - w_2}{w_2} X100 \qquad (1)$$

Where,

MC=moisture content (%)

W_1=initial weight before oven drying (g)

W_2=final weight after oven drying (g)

2.2.2 Density

Density is defined as mass per unit volume of a sample material (kg/m^3). Meter balance was used to determine the mass of each sample. For accurate reading, there were three replicates for each mixing ratio. The volume was estimated from the dimensions obtained (height and radius) using a venier caliper [26].

$$Density = \frac{m}{v} (g / cm^3) \qquad (2)$$

Where,

M = mass of briquette (g).

V = volume of briquette (cm^3)

2.3 Combustion Properties

The combustion properties analyzed include:

2.3.1 Percentage Ash Content

2g of oven dried briquette sample was placed in the furnace at temperature of 550^0C for 4 hours and weighed after cooling [27].

$$\text{Percentage ash content} = \frac{D}{B} X100 \qquad (3)$$

Where,

D= weight of ash (g)

B= weight of oven dried sample (g)

2.3.2 Percentage Volatile Matter

The volatile matter was determined by placing 2g of pulverized briquette sample in a crucible oven to obtain constant weight after being kept in the furnace at temperature of 550^0C for 10 minutes. The oven dried sample was later cooled in a desiccator and then weighed to determine the percentage volatile matter according to [15].

$$\text{Percentage Volatile Matter} = \frac{B-C}{B} X100 \qquad (4)$$

Where,

B= weight of oven dried sample (g)

C= weight of sample after 10 minutes in furnace at 550^0C (g).

2.3.3 Percentage Fixed Carbon

This was calculated by subtracting the sum of percentage volatile matter and percentage ash content from 100 [27]

$$\text{Percentage Fixed Carbon} = 100 - \left({}^0/_0 V + {}^0/_0 A \right) \qquad (5)$$

Where,

%V= percentage volatile matter

%A=percentage ash content

2.3.4 Heating Value

Heating value was calculated using the formula according to [15].

$$HV = 2.3269(147.6C + 144V)KJ / g \tag{6}$$

Where,

HV= heating value (KJ/g)

C= percentage fixed carbon (%)

V= percentage volatile matter (%)

2.3.5 Water Boiling Test

This was carried out to compare the cooking efficiency of briquettes produced for each mixing ratio under the same process conditions. The test actually measures the time it takes a given quantity of fuel to heat and boil a given quantity of water. In this case, it measures the time taken by each set of briquettes to boil an equal volume of water under similar conditions. Firstly, the briquette was weighed to determine its weight. Each sample was stacked in a locally fabricated stove. Cooking pots, each containing 500 ml of water, were mounted on the stoves. The stoves were ignited and as soon as the flames were stabilized for 2 minutes, a stop watch was activated. The initial temperatures of the water were noted. The boiling was terminated after attaining boiling point and the weight of the residue was noted after discarding the ash. The pots were later washed to remove accumulated soot, and cooking efficiency determined according to [28].

$$\text{Cooking efficiency } (KJ / kg = \frac{[(100 - t)xwxkxLxH]}{W} \tag{7}$$

Where,

t= initial temperature of water (^{0}c)

w= initial weight of water (g)

k= conversion factor (0.0042kj/cal)

L= weight loss of water (g)

H= latent heat of vaporization of water (0.257kg/g) (8)

W= weight of briquette (g)

2.4 Experimental Design and Statistical Analysis

For determination of the parameters assessed, a 2 x 5 factorial experiment replicated 3 times to give a total of 15 samples was adopted in a completely randomized design (CRD).

The statistical model used for the experiment is given as

$$Y_{ij} = \mu + a_i + E_{ij} \quad (9)$$

Where,

Y_{ij}= individual observation

μ = overall mean

a_i = treatment effect

E_{ij} =experimental error

The data obtained for the physical and combustion properties from the produced briquettes were subjected to analysis of variance (ANOVA) at 0.05 level of probability. Mean separation was also carried out using Duncan Multiple Range Test (DMRT) to know the difference between means and to choose the best treatment combinations for the briquettes produced.

3. Results and Discussion

Table 1: Mean values of physical parameters assessed

Mixing proportion	Moisture content (%)	Density (g/cm^3)
A	60.24 ± 4.11^{a}	0.51 ± 0.02^{b}
B	33.29 ± 2.91^{b}	0.56 ± 0.03^{a}
C	32.72 ± 1.86^{b}	0.55 ± 0.04^{ab}
D	35.25 ± 1.81^{b}	0.53 ± 0.01^{ab}
E	33.15 ± 1.26^{b}	0.52 ± 0.01^{ab}
Mean total	38.93 ± 11.28	0.53 ± 0.03

Mean values with the same alphabet on the same column are not significantly different from each other at P = 0.05.

3.1 Physical Properties

3.1.1 Moisture Content

As shown in Table 1, the mean moisture content of the briquettes produced ranged from 32.72% to 60.24%. It was observed that briquette made from admixture of 50g *Arundo donax* and 50g of coconut coir had the lowest mean moisture of 32.72%, while that of 100g *Arundo donax* had a moisture content of 60.24%, which was the highest value. It was also observed that apart from the 100g furnish of *Arundo donax*, there was no significant difference between the moisture content obtained from the other admixtures for the briquettes produced (Table 1). The values obtained for moisture content in this study, though exceed the limits of 15% recommended by [29, 30] for briquetting of agro-residues, they are still below the data obtained by [31], who worked on the development of fuel briquettes using coconut coir, rice husk and waste paper, and obtained the values of 59.00%, 58.75% and 58.4% respectively. Moisture content is a very important property and can greatly affect the burning characteristics of the briquettes [32]. The moisture content of biomass briquette should be relatively low and should fall within the range of 10-15% [29], so as to engender complete combustion of the briquettes [30]. Low moisture content of biomass briquettes also helps in their storage to prevent rotting and decomposition.

3.1.2 Density

The mean density of the briquette produced ranged from $0.51 \pm 0.02 g/cm^3$ to $0.56 \pm 0.03 g/cm$ (Table 1). It was observed that briquettes from 100g of *Arundo donax* had the lowest density while that of 100g of coconut coir had the highest. In Table 1, it is also observed that there is difference between the mean densities of the produced briquettes from each mixing ratio. These differences could be as a result of the manually operated briquetting machine used. This invariably was the major constraint of the research study, accentuated by the absence of a standard briquetting machine.

The use of a manual moulding equipment for briquetting impacted poorly on the densification of the loose biomass materials. This limitation resulted in a less compressed and less compacted briquette blocks, with the attendant non-uniformity in density, and consequent reduction in burning rate and released heating energy of the briquettes produced. The author, [33], also observed similar trend in his work on briquette produced from rice husk and corncob. The values obtained for density in this research study are higher than the values obtained by [34], who worked on briquette produced from *Brachystegia eurycoma* sawdust using selected binders and sieve sizes.

The variation in these results could be attributed to the different mixing ratios adopted and the sieve sizes used. However, the higher the density of the briquette produced, the higher the quantity of heat that would be released per unit mass of briquette, because density has positive effect on the burning of briquette [35]. Nonetheless, low density improves handling and transportation of the material [36].

Table 2: Mean values of combustion properties assessed

Mixing Proportion	% Ash content	% Volatile matter	% Fixed Carbon	Heating value (KJ/kg)	Water boiling value (KJ/kg)
A	4.83 ± 2.47^{a}	86.17 ± 2.47^{a}	9.00 ± 2.91^{b}	31.95 ± 190.69^{a}	3.13 ± 0.07^{b}
B	4.83 ± 0.29^{a}	83.83 ± 1.53^{ab}	11.33 ± 1.26^{ab}	31.97 ± 87.12^{a}	3.30 ± 0.06^{a}
C	4.33 ± 0.76^{a}	84.83 ± 2.08^{a}	14.83 ± 1.89^{a}	32.13 ± 255.39^{a}	3.39 ± 0.10^{a}
D	5.00 ± 0.00^{a}	83.67 ± 1.04^{ab}	11.33 ± 1.04^{ab}	31.92 ± 8.72^{a}	2.95 ± 0.15^{c}
E	5.00 ± 0.50^{a}	80.83 ± 1.04^{b}	10.17 ± 1.04^{b}	31.93 ± 169.78^{a}	3.02 ± 0.05^{bc}
Mean total	4.80 ± 0.49	83.87 ± 2.33	11.33 ± 2.18	31.98 ± 162.10	3.16 ± 0.19

Mean values with the same alphabet on the same column are not significantly different from each other at P=0.05

3.2 Combustion Properties

3.2.1 Percentage Ash Content

The percentage ash content from the proximate analysis of the briquettes produced ranged from 4.33 ± 0.76% to 5.00 ± 0.50% as shown in Table 2. It was observed that briquettes produced from admixture 50g of *Arundo donax* and 50g of coconut coir had the lowest ash content of 4.33 ± 0.76% while that of 75g *Arundo donax* and 25g of coconut coir had the highest ash content of 5.00 ± 0.50%. The values obtained are within the range of 3.30% to 7.12% obtained by [36], who worked on experimental characterization of bagasse biomass material for energy production, and also falls within the range of values obtained by [37], who worked on development of an appropriate briquetting machine for use in rural communities.The values obtained were in contrary to the findings of [27] on density, shatter index and combustion properties of briquettes produced from groundnut shell, rice husks and sawdust of *Daniellia oliveri*. It was observed that there was no significant difference in the mixing ratio for the briquettes produced (Table 2).Author [38] reported that the lower the ash content, the higher the heating value. The ash content in briquette normally causes an increase in combustion remnant in the form of ash which lowers the heating value of combustible materials such as briquette as reported by [39].Therefore, briquette produced from 50g of *Arundo donax* and 50g of coconut coir would have higher heating value when compared to briquettes obtained from the other mixing ratios.

3.2.2 Percentage Volatile Matter

The percentage volatile matter obtained had a range value between 80.83 ± 1.04% and 86.17 ± 2.47% as shown in

Table 2. Values obtained revealed that briquette produced from 75g of *Arundo donax* and 25g of coconut coir had the lowest mean value of 80.83±1.04% while 100g of *Arundo donax* had the highest percentage of volatile matter of 86.17±2.47%. The result obtained is within the range of values reported by [40] after working on charcoal briquette produced from orange bagasse and corn starch. However, the values obtained are higher than values reported by [27] who worked on density, shatter index and combustion properties of briquettes produced from groundnut shells, rice husks and sawdust of *Daniellia oliveri*. There was significant difference between the mixing ratios for the briquettes produced (Table 2).However, author [11] reported that the higher the violate matter, the better the heating ability of briquette. Also, [41] established that low volatile matter supports low ignition (burning) of fuel. Therefore, briquette produced from admixture of 50g *Arundo donax* and 50g of coconut coir with its relatively high volatile matter would support high burning rate.

3 2.3 Percentage Fixed Carbon

Percentage fixed carbon indicates the proportion of char that remained after the devolitization phase [39]. The mean percentage fixed carbon obtained from the proximate analysis of the briquettes produced showed that the values obtained ranged from 9.00±2.91 to 14.83± 1.89% as shown in Table 2. Briquette produced from 100g of *Arundo donax* furnish had the lowest value of 9.00+2.91% while that of 50g *Arundo donax* and 50g coconut coir admixture had the highest mean value for percentage fixed carbon of 14.83±1.89%. The values obtained are also in line with values obtained by [37] who worked on development of appropriate briquetting machine for use in rural communities. These values are however extremely low compared to the values obtained by [34], who worked on briquette produced from *Brachystegia eurycoma* sawdust using selected binders and sieve sizes. The variation noticed in these results could be attributed to the different agricultural wastes, mixing ratios, sieve sizes and binder used. However, there was significant difference between the different mixing ratios for the briquettes produced (Table 2) Author [42] reported that the higher the fixed carbon content, the better the briquette produced because the corresponding energy that would be released is usually high. Therefore briquette produced from 50g *Arundo donax* and 50g of coconut coir mixing ratio would have high energy value compared to briquettes from the other mixing ratios because of the relative high fixed carbon of the former.

3.2.4 Heating Value

The figures obtained for the heating values show that there is no significant difference between the mixing ratios of the briquettes produced. From Table 2, it can be observed that the heating value obtained ranged between *31*.92±8.72kJ/kg and 32.13±255.39 kJ/kg. Briquette from 25g *Arundo donax* and 75g coconut coir had the lowest heating value of 31.92±8.72kJ/kg while that of 50g *Arundo donax* and 50g coconut coir admixture had the highest heating value of 32.13±255.39kJ/kg. The values obtained are in agreement with the values reported by [43], who worked on characterization of briquette produced form charcoal by carbonization of agro-wastes, but lower compared to values reported by [37] who worked on development of an appropriate briquetting machine for use in rural communities. Based on the results obtained, it is found that the briquettes produced from the admixture for the five mixing ratios fulfill the minimum requirement of calorific value for commercial briquette (>17.50KJ/Kg), as stated by [44].

3.2.5 Water Boiling Value

The values obtained for the cooking efficiency show that there is significant difference between the mixing ratios for the briquettes produced. In Table 2, it can be observed that the cooking efficiency values obtained ranged between 2.95±0.15KJ/Kg and 3.39±0.10kJ/kg.

Table 3: Analysis of variance for physical and combustion properties of the briquettes produced.

Sources of Variation	**Degree of freedom**	**Sum of squares**	**Mean square**	**F cal**	**Sig.**
Moisture content (%)					
Between groups	4	1714.083	428.521	63661	0.000*
Within groups	10	67.33	6.731		
Total	14	1781.396			
Density (g/cm^3)					
Between groups	4	0.005	0.001	2.253	0.136*
Within groups	10	0.006	0.001		
Total	14	0.011			
Ash Content (%)					
Between groups	4	0.900	0.225	0.900	0.499^{ns}
Within groups	10	2.500	0.250		
Total	14	3.400			
Volatile matter (%)					
Between groups	4	46.400	11.600	3.888	0.037*
Within groups	10	29.833	2.983		
Total	14	76.233			
Fixed carbon (%)					
Between groups	4	41.162	10.292	4.089	0.032*
Within groups	10	25.167	2.517		
Total	14	66.333			
Heating Value (KJ/g)					
Between groups	4	91707.581	22925.395	0.830	0.536^{ns}
Within groups	10	2761556.501	27615.650		
Total	14	367858.083			
Water boiling Value					
Between groups	4	0.407	0.102	12.724	0.001*
Within groups	10	0.080	0.008		
Total	14	0.487			

* $\leq$ 0.05 means that there is significant difference between test means

ns $\geq$ 0.05 means that there is no significant difference between test means

Briquette from 25g *Arundo donax* and 75g of coconut coir admixture had the lowest value of 2.95±0.15KJ/kg while 50g *Arundo donax* and 50g coconut coir admixture had the highest cooking efficiency value of 3.39±0.10kJ/kg. These values obtained are also in agreement with the findings of [34], who worked on briquette produced from *Brachystegia eurycoma* sawdust using selected binders and sieve sizes. The best cooking efficiency value was obtained from briquette with 50g *Arundo donax* and 50g coconut coir. This is as a result of its low ash content, high volatile matter, high fixed carbon and high heating value.

As presented in Table 3, the results of analysis of variance show that there is significant difference for moisture content, density, volatile matter, fixed carbon and water boiling value between groups at 5% level of probability. On the other hand, ash content and heating value are not significant between groups (means) at same level of probability.

4. Conclusion and Recommendations

4.1 Conclusion

Agricultural wastes such as *Arundo donax* and coconut coir which are generated in large quantity and often disposed indiscriminately can be utilized for the production of solid fuel called briquette. Briquette was successfully produced from *Arundo donax* and coconut coir admixture at five different mixing proportions using cassava starch as binder. Briquette produced from 50g of *Arundo donax* and 50g of coconut coir admixture had the lowest mean moisture while briquettes produced from 100g of *Arundo donax* had the highest moisture content with the lowest density. Briquette produced form 100g of coconut coir had the highest density while briquette produced from the furnish composition of 50g *Arundo donax* and 50g of coconut coir had the highest heating value, lowest ash content, highest percentage fixed carbon and the highest cooking efficiency. Notwithstanding the limitations posed by the use of manual moulding equipment on densification and compacting process of loose biomass materials into solid briquette blocks, the heating values obtained from the briquettes produced from the admixtures at five mixing levels, are sufficient to provide adequate heat energy for domestic use.

4.2 Recommendations

Based on the results obtained from this study, production of briquette from *Arundo donax* and coconut coir biomass admixture should be encouraged as this will serve as an effective measure in curbing environmental hazard posed by the poor methods of agricultural waste disposal, besides serving as a veritable resourceful means of converting waste to wealth. Furthermore, *Arundo donax* and coconut coir mixed together in equal proportion should be adopted as the optimal blending ratio to improve the combustion properties of briquettes produced. Finally, the effect of variation of starch as binder in the briquette admixture should be investigated.

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