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Comparative Assessment of the Proximate Composition of Selected Biowastes for Optimum Gasification

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ABSTRACT

Major challenges in biogas production is the inefficient, and incomplete conversion of biowastes into energy. Limited thermochemical data exist on a variety of biowastes which might inform the efficient operations of biogas production. The aim of the present study was to perform a comparative study on the proximate composition and gasification potential of selected biowastes found in Bayelsa State, Nigeria. Rumen digesta was collected from an abattoir in Sagbama town, pineapple peels were collected from road side fruit sellers in Sagbama town, unripe plantain peels were collected from road side roasted plantain sellers in Toru – Orua community, while cow dung was collected from a cattle farm in Toru-Orua. Ten grams of each biowaste was weighed out and the moisture content, total solids, ash content, volatile matter (gasification potential) and fixed carbon content were analyzed in triplicate using standard methods. The moisture content (%) of rumen digesta, pineapple peels, unripe plantain peels and cow dung were 47.26±1.05, 84.04±1.20, 40.60±2.05, and 51.70±2.23 respectively, while their total solids (%) were 52.74±0.67, 15.96±0.88, 59.40±0.55 and 48.30±2.00 respectively and their ash content (%) were 10.70±1.22, 5.00±0.56, 9.00±1.12, and 6.00±0.78 respectively. The volatile matter content / gasification potential (%) of rumen digesta, pineapple peels, unripe plantain peels and cow dung were 8.50±1.05, 4.50±0.22, 21.00±2.55, and 13.5±0.67 respectively, while their fixed carbon content (%) were 33.50±1.55, 6.46±0.45, 29.40±1.56, and 28.80±1.87 respectively. The present study found variations in the proximate composition and gasification potential of selected biowastes in Bayelsa State, Nigeria. Based on the findings of the present comparative study, further studies to analyze the volatile matter / gasification potential of other biowastes in order to bring out more scientific evidences for the basis of their utilization in biogas production is recommended. Also given the high amount of fixed carbon content found in nearly all the biowastes analyzed in the present study, measures to reduce the amount of fixed carbon for biogas production is recommended.

Keywords: Moisture, total solids, ash, volatile matter, fixed carbon, biowastes

1. Background of the study

Provision of cheap and sustainable cooking fuel for the population in Nigeria remains a major challenge. Nigerians are still battling with the high cost of liquefied petroleum gas (cooking gas) which has increased to N1500 / kilogram [1]. The use of biowastes as sources of sustainable energy and as an alternative to liquefied petroleum gas has been previously reported [2-5]. Different biomass and biowastes exist in different locations majorly due to differences in climatic factors [7]. The Niger Delta region of Nigeria, is the largest wetland in Africa [8] and Bayelsa State is a riverine terrain with major navigable channels in Niger Delta [9]. Bayelsa State consist of tropical forest biomass which houses part of the national forest [10]. Proximate analysis of the biowastes and biomass in Niger Delta, Nigeria to know the gasification potential of each waste is yet to be carried out. Data from such proximate analysis might provide evidence based data which might inform the utilization of each waste as raw materials for gasification. Biowaste gasification is a vital means of achieving sustainable energy. It is a thermochemical process that converts carbon-based biomass to gas [6].

Proximate analysis is a technique that evaluates four major components in a biomass. The four components are moisture, ash, volatile matter and fixed carbon [11]. Proximate analysis is of fundamental importance in biomass energy technology [12]. Proximate analysis is used to determine the suitability of wastes for various uses like composting, animal feed, or biofuel production [13, 14]. A component of proximate analysis known as volatile matter analysis provides information on the amount of gas that can be produced from a given amount of biomass [15]. Thus, proximate analysis can be used to determine the combustion characteristics of a given waste [15]. Moisture, ash and fixed carbon increase the bulkiness of waste, scum and slurry but do not have a gasification value [5].

A previous study carried out to investigate the effect of total solids on biogas yield in a batch anaerobic digestion experiment found that the higher the total solids, the lower the biogas produced. The study also found that higher percentage of volatile matter favours anaerobic digestion [16]. Limited studies exist on proximate analysis of biowastes for biogas production and gasification. Therefore, the aim of the present study was to perform a comparative study on the proximate composition and gasification potential of selected biowastes.

2. Materials and methods

2.1 Materials

Oven, muffle furnace, foil paper, open crucible, closed crucible, weighing scale, measuring cylinder, spatula, homogenizer, petri dishes, paper tape, and 250 ml beakers

2.2 Study location

The study location was the University of Africa Toru – Orua, Sagbama Local Government Area, Bayelsa State, Nigeria. Bayelsa State consist of several river bank communities [17]. The State is centrally located in the core of the Niger Delta region of Southern Nigeria [18]. Bayelsa State is located on latitude 5.152239 and longitude 6.192479 with Sagbama LGA situated on the left bank of Forcados river [19]. The headquarters of Sagbama is Sagbama town [9].

2.3 Study design and collection of selected biowastes

Four biowastes commonly found in Bayelsa State were randomly selected for the present study and were grouped into four groups. Group I: rumen digesta, group II: pineapple peels, group III: unripe plantain peels and Group IV: cow dung. All the biowaste samples for the present study were collected from Toru-Orua community and Sagbama Town. Rumen digesta was collected from an abattoir in Sagbama town, pineapple peels were collected from road side fruit sellers in Sagbama town, unripe plantain peels were collected from road side roasted plantain sellers in Toru – Orua community, while cow dung was collected from a cattle farm in Toru-Orua. The samples were transported in their fresh state to the University of Africa Toru – Orua where previous studies on biogas production have been carried out [20, 21]. The National Environmental Standards and Regulations Enforcement Agency's (NESREA) guidelines for the handling of environmental wastes was followed in the present study in the handling of biowastes [22].

2.4 Determination of moisture content and total solids

Moisture content and total solids were determined as previously described [23]. Briefly, 10 g of sample was placed in an oven at 105 ± 2^0C for 16 hours. The sample was cooled in a desiccator at room temperature and weighed. Triplicate samples were prepared for each group of biowastes. To obtain the percentage composition of the moisture content in the biowaste, the weight of dried sample was subtracted from the weight of wet sample and the result was divided by the weight of wet sample and multiplied by 100. To obtain the percentage composition of the total solids in the biowaste, the weight of dried sample was divided by the weight of wet sample and multiplied by 100.

2.5 Determination of Ash Content

Exactly ten grams of each sample was weighed into a pre-weighed open muffle furnace pot and placed in a furnace for four hours at 550^0C. After cooling, it was weighed. The weight of the muffle furnace was subtracted from the weighed value to obtain the weight of ash. The weight of ash was expressed in percentage. Triplicate samples were prepared [24].

2.6 Determination of volatile matter

Volatile matter was measured as the weight percent of gaseous emissions from a biowaste sample. The gaseous emission was released by heating the sample to 950 C° in an oxygen-free closed environment. Exactly 10 grams of a biowaste sample was weighed out and the moisture was driven off as previously described [23]. Volatile matter estimation was carried out on the dried sample after the removal of moisture. The dried sample was placed in an air tight closed crucible in a furnace and subjected to high heat (950 C°) in an atmosphere of pure nitrogen gas. After heating, the closed crucible was opened for the gaseous emission to escape. After cooling. The residue left in the crucible was weighed. The difference in weight between the dried sample before high heating and the left over residue after heating was taken as the volatile matter. The volatile matter was expressed as weight percent lost as emissions during combustion [25].

2.7 Determination of fixed carbon

Fixed carbon was calculated as previously described [26]. Fixed carbon was calculated as a value that represents the amount of non-volatile carbon in a sample. Fixed carbon is the material remaining after the determination of volatile matter, moisture and ash. That is, it is a measure of the solid combustible material in biowastes after expulsion of volatile matter. Fixed carbon was calculated according to the equation below

$$FC = 100 - VM - M - A$$

Where: FC = fixed carbon, w%

VM = volatile matter (%)

M = moisture content (%)

A = ash content (%)

2.8 Statistical analysis

IBM SPSS software version 24 was used for data analysis. Values were expressed as mean ± standard error of mean (SEM) of three replicates. One Way Analysis of Variance (ANOVA) followed by Duncan Multiple Range Test was used to estimate differences between multiple means and the significance level was set at $p < 0.05$ [27, 28].

3. Result

3.1 Moisture content

Figure 1 below shows the moisture contents of the selected biowastes. The moisture content of pineapple peels was found to be significantly ($p < 0.05$) higher than the moisture content of the other biowastes, while unripe plantain peels had the lowest moisture content.

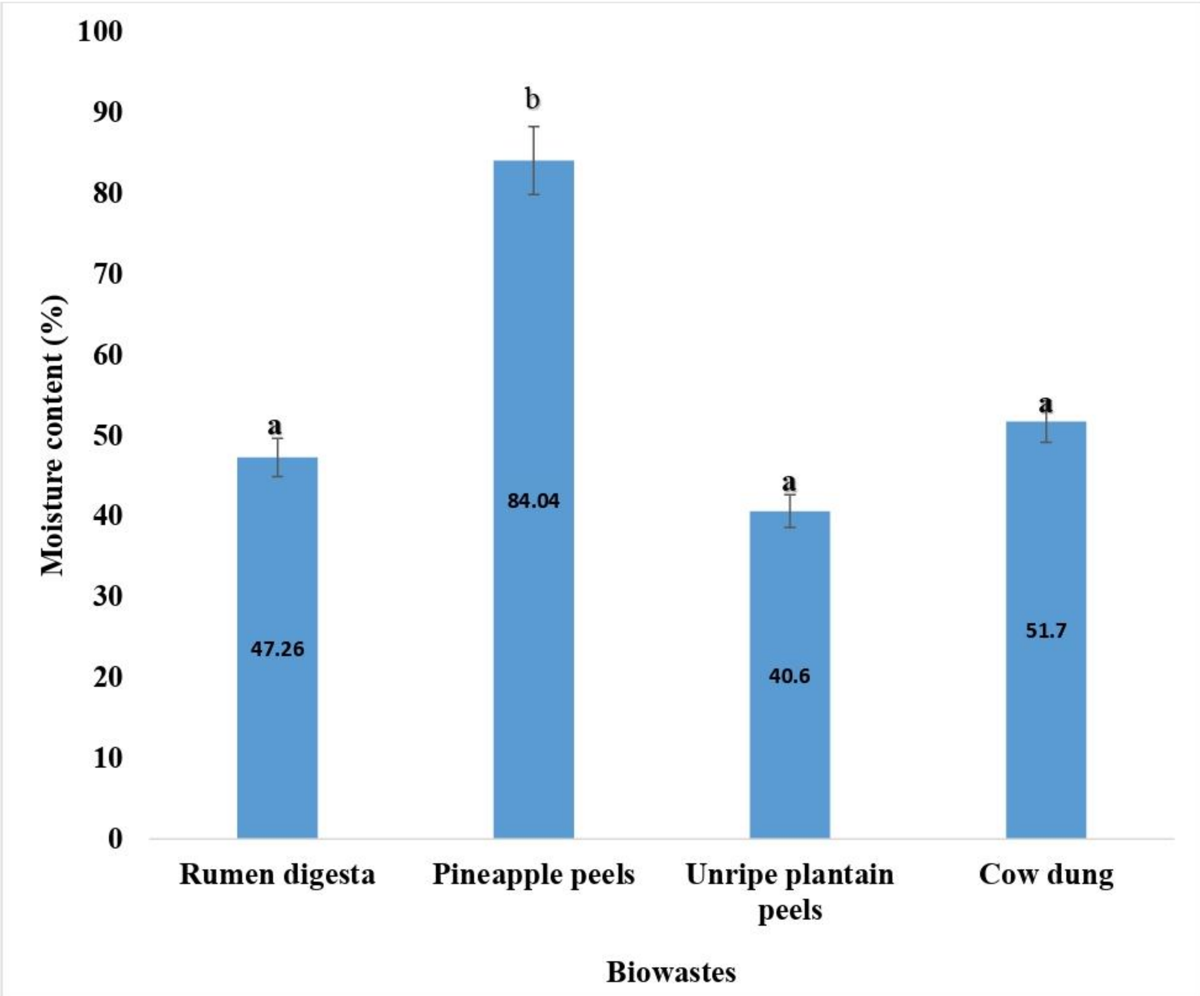

Figure 1 Moisture content of selected biowastes. Each value is the mean ± standard error of mean of three replicates. Bars with different superscripts are significantly different at $p < 0.05$.

3.2 Total solids of selected biowastes in Bayelsa State, Nigeria

Figure 2 below shows the total solids (dry matter) of selected biowastes in Bayelsa State, Nigeria. Total solids were significantly ($p < 0.05$) higher in unripe plantain peels compared with the other biowastes and was significantly ($p < 0.05$) lowest in pineapple peels.

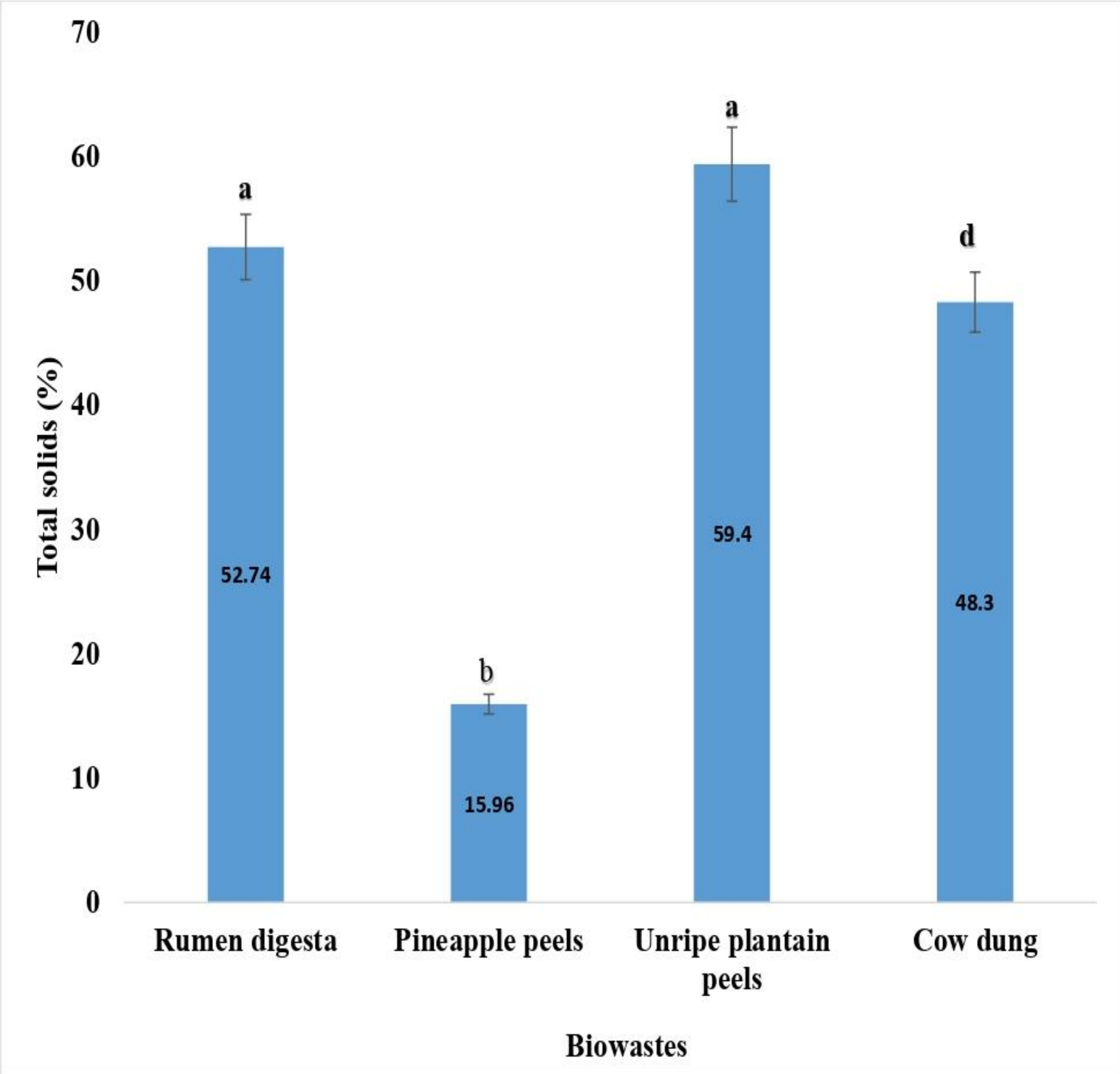

Figure 2. Total solids (dry matter) of selected bio-wastes. Each value is the mean ± standard error of mean of three replicates. Bars with different superscripts are significantly different at $p < 0.05$.

3.3 Ash content of selected biowastes

Figure 3 below shows the ash content of selected biowastes in Bayelsa State, Nigeria. The ash content was significantly ($p < 0.05$) higher in rumen digesta followed by that of unripe plantain peels and other wastes.

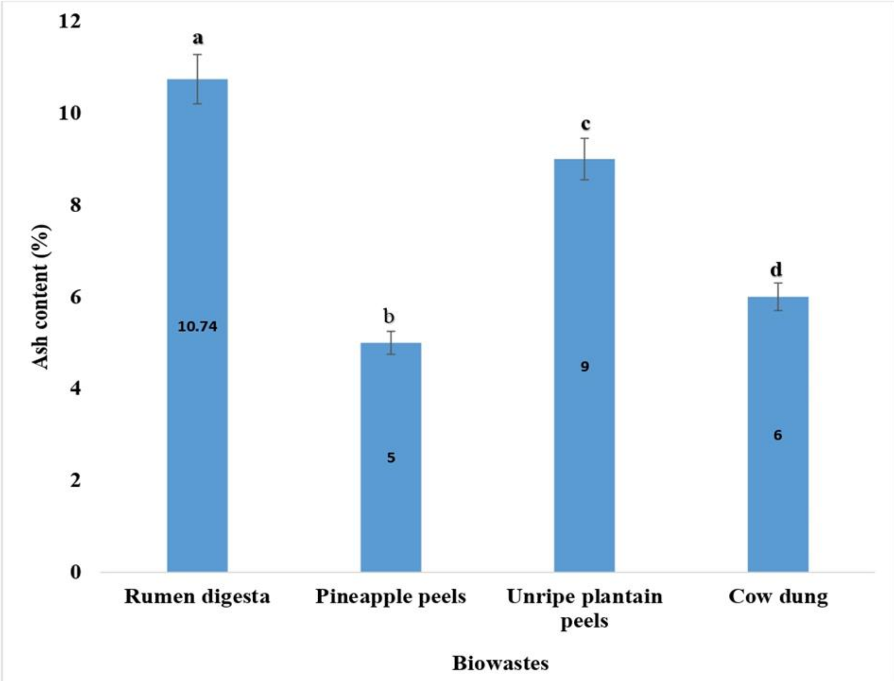

Figure 3 Ash content of selected bio-wastes in Bayelsa State. Each value represent mean ± standard error of mean of three replicates. Bars with different superscripts are significantly different at $p < 0.05$.

3.4 Volatile matter of selected biowastes

Figure 4 below shows the volatile matter of selected biowastes. The mean volatile matter of unripe plantain peels was significantly ($p < 0.05$) higher than that of the rest biowastes.

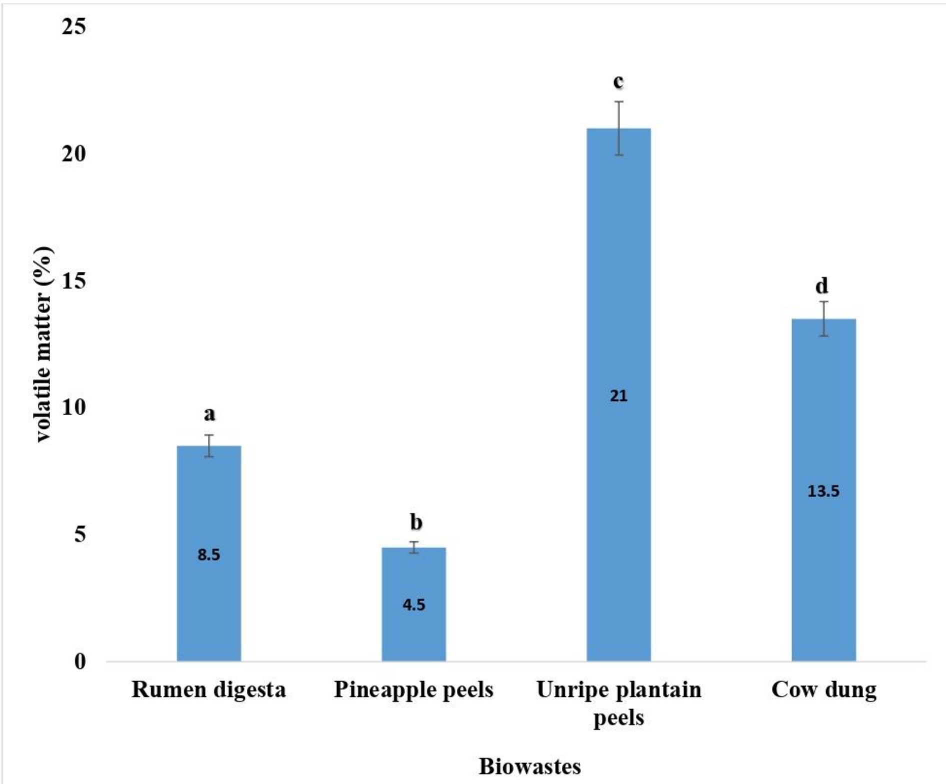

Figure 4 Volatile matter of selected biowastes in Bayelsa State. Each value represent mean ± standard error of mean of three replicates. Bars with different superscripts are significantly different. Significant level was set at $p < 0.05$.

3.5 Fixed carbon content of selected biowastes for biogas production

Figure 5 below shows the fixed carbon contents of selected bio-wastes for biogas production. The fixed carbon content of rumen digesta, ripe plantain peels and cow dung were significantly higher than that of pineapple peels ($p < 0.05$).

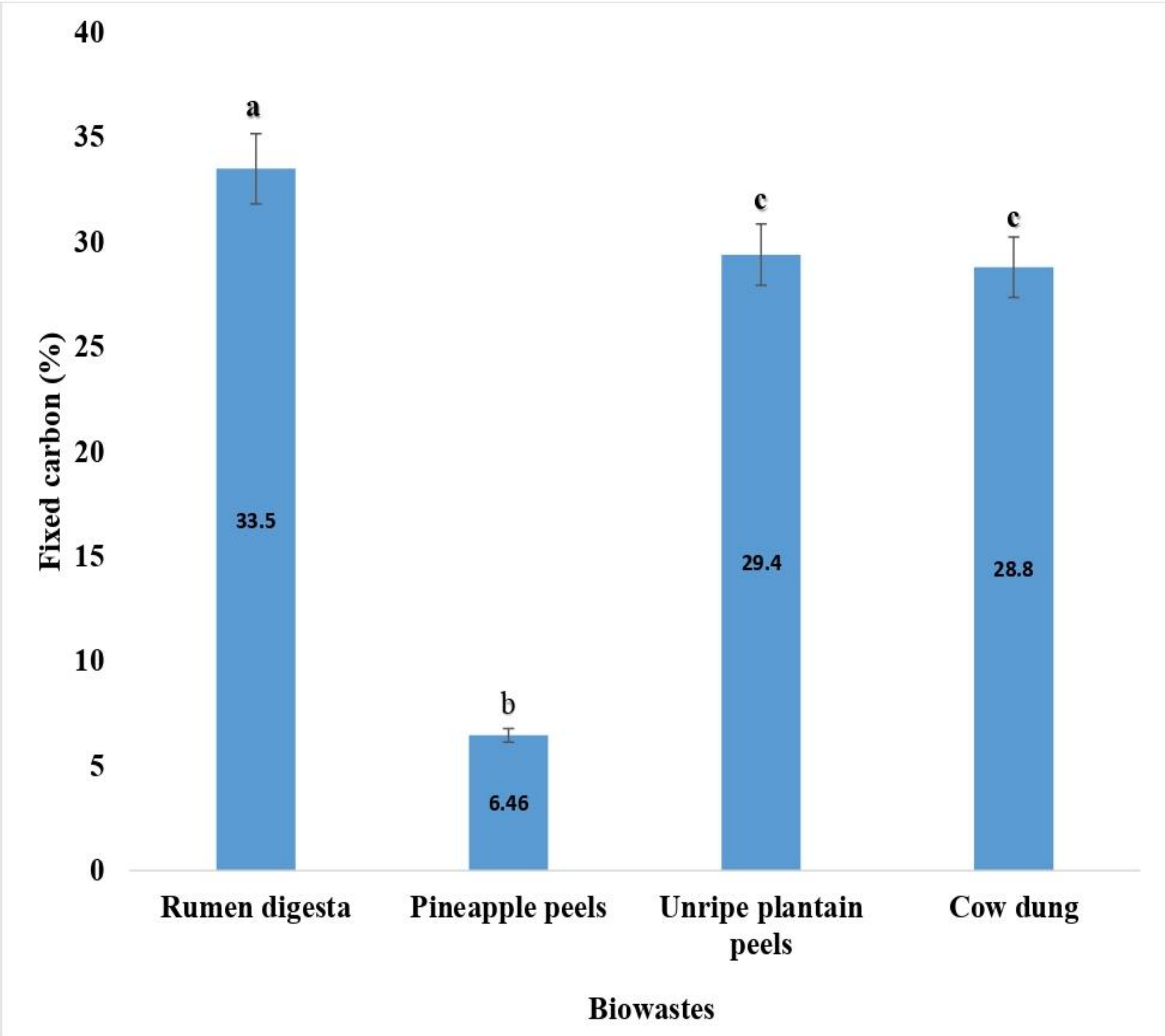

Figure 5 Fixed carbon content of selected bio-wastes. Each value represent mean ± standard error of mean of three replicates. Bars with different superscripts are significantly different. Significant level was set at $p < 0.05$.

4 Discussion

The present study investigated the moisture content, total solids, ash content, volatile matter and fixed carbon content of selected biowastes in Bayelsa State in other to evaluate their gasification potential. The present study found high total solids (dry matter) and low moisture content among the biowastes investigated except for pineapple peels where the reverse was the case. The total solids found in the present study for cow dung was higher than the findings of a previous study [29], while the moisture content of cow dung found in the present was lower than the moisture content found in a previous study [29]. Furthermore, the previous study [29] showed that anaerobic digestion is influenced by the volume of total solids (dry matter) in biowastes and biogas production is dependent on the volatile matter (gasifiction matter) of the biowastes. The ash content of cow dung found in the present study was lower than the ash content found in a previous study [30]. A previous study showed that a high ash content can adversely affect biogas production due to the fact that ash is an impurity that can reduce methane production [31].

The volatile matter found in the present study was lower than findings of a previous study [32]. Volatile matter indicate the gasification potential of a biowaste. A previous report showed that at present, only about 25% per weight of a given biowaste can be volatilized and converted into biogas [33]. Further studies on how to increase the amount of volatile matter in a given biowaste is highly recommended.

In addition, a very high fixed carbon content was found for the selected biowastes in the present study. No previous work has been carried out on the comparative fixed carbon content of rumen digesta, pineapple peels, unripe plantain peels and cow dung. Thus the present study is quite novel and has helped to fill a major gap in research. The fixed carbon content found for most of the selected wastes used in the present study were higher than the fixed carbon content of rice husk and maize bran found in a previous study, indicating that fixed carbon content varies from one biowaste to another [34]. Again, studies on the fixed carbon content of a variety of biowastes used for biogas production are sparse in literature. Thus the findings of the present is quite novel and has filled a major gap in the literature available on biogas research. Further studies on the fixed carbon content of biowastes used for biogas production is highly recommended.

Although a high level of fixed carbon is beneficial for biochar (charcoal) production because it indicates that a high amount of charcoal will be produced for heating, sale and commercial purposes [35], however, in biogas production, an inverse relationship exist between fixed carbon and biogas production [36]. A high level of fixed carbon for a given waste indicates that a small amount of biogas will be produced because the volatile matter will be low [36]. For biogas production, a very low fixed carbon content and a high volatile matter content is recommended [36].

Given the high level of fixed carbon found for the selected biowastes used in the present study therefore, measures to reduce the amount of fixed carbon in biowastes used for biogas production is recommended. Bayelsa State is a core state in the Niger Delta region of Nigeria [37] The State possesses unique freshwater and estuarine vegetation and aquatic as well as a diversity of biowastes [2, 38]. Given the limited number of biowastes evaluated in the present study, further study on the proximate composition of the vast majority of biowastes in Bayelsa State is recommended. The information provided in the present study can be used in process optimization for improved efficiency in the breakdown of wastes for biogas production and for further studies.

5. Conclusion

The present study has provided evidence based data on the existence of variation in the gasification potential and proximate composition of biowastes found in Bayelsa State, Nigeria. It has also provided more scientific evidences and basis for the utilization of these biowastes in biogas production. Based on the findings of the present comparative study, measures to reduce the fixed carbon content of biowastes is recommended. The present study has implications in biowastes gasification.

Declaration of conflicts of interest

The authors declare no conflicts of interest

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