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RESEARCH ARTICLE

ASSESSMENT OF AVAILABILITY AND ENERGY POTENTIAL OF THE AGRO-PASTORAL RESIDUES FOR ANAEROBIC DIGESTION IN DOKANME PUBLIC PRIMARY SCHOOL OF TORI BOSSITO (BENIN)

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ABSTRACT

The present study aims to quantify the agro-pastoral residues available in the municipality of Tori-Bossito and to assess the potential of said residues to supply the energy in Dokanme public primary school through anaerobic digestion. Field surveys were made to identify the different types of waste and the generation sites, then, based on statistical data collected and biogas productivity indexes from the literature the quantities of agro-pastoral residues, biogas and energy were estimated. The residues consist of cassava peelings, palm oil clarifying sludge and cow dung. The amount of cassava peelings that can be collected is estimated to 76.565 tons, 20075 liters for palm oil clarifying sludge and 118.260 tons for cow dung. A total energy potential in biogas from residues found to be 661.722 GJ. The exploitation of this energy resource can contribute to the conservation of forest and reduce women and schoolchildren occupation in searching for wood-energy.

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INTRODUCTION

In recent years, the need of alternative energies has increased due to population growth, strong industrialization, limited fossil energy resources and the need to reduce energy consumption (Bamisile *et al.* , 2021). The abundance of biomass in Sub-Saharan Africa makes it one of the most attractive sources of renewable energy. Biomass can be of animal or plant origin, solid or liquid, and comes from a variety of sources: dedicated energy crops, agricultural and agro-industrial residues (Mathiesen *et al.* , 2011)(Srirangan *et al.* , 2012). However, at the same time, the biomass (wood, charcoal and agricultural waste) remains the principal energy source of the majority of population and contributes for more than 90% of energies consumed. The use of traditional bioenergy for various uses by rural and urban population causes does not promote the socio-economic development of the population and poses major environmental problems (soil degradation, deforestation, desertification, reduction of CO_2 sink), health (pulmonary diseases and eyes) and women Occupation (Felix and Gheewala, 2011). Moreover, the availability of wood becomes rare in certain zones because of their overexploitation, which obliges women and children to cover long distances for their collection.

Anaerobic digestion is a biochemical process that transform the biomass resource in biogas and digestate through the activities of a microorganism. Biogas is a mixture of gases comprising mostly of methane (40-75%), and carbon dioxide (25-50%) as well as a lower quantity of other gases such as hydrogen sulphide (H_2S), ammonia (NH_3), oxygen (O_2), hydrogen (H_2), Nitrogen (N_2) and carbon monoxide (CO) (Li *et al.*, 2019) ; (Nwokolo *et al.* , 2020). The heating value of well- purified biogas close to that of natural gas (Yentekakis and Goula, 2017). Methane contained in biogaz can used to generate heat and/or electrical power (Sibilio *et al.* , 2017). Anaerobic digestion technology has the advantage of treating various organic waste (Abdeshahian *et al.* , 2016), giving biogas a strong potential for sustainability (Tagne *et al.* , 2021). Benin economics are based upon agriculture and relative activities. It contributed to 27.1% of national Gross Domestic Product (GDP) in 2020. As a consequence, there is a massive production of agro-pastoral residues. The municipality of Tori-Bossito is one of the world's agricultural development hubs, with abundant potential for biomass (vegetable waste, animal waste, food waste, fruit waste and agricultural residues) produced through farming, agri-food processing and livestock breeding activities. Dokanmè Public Primary School, one of school of

Tori Bossito, has a major difficulty to supplying wood fuel for cooking. In addition, women are exposed an average of 4 hours a day to wood-burning fumes. The generated agro-pastoral residues in the locality could be mobilized and converted into biogas. An estimate of the availability of biomass resources in the area is essential to get an idea of the energy production potential of a zone. There are usually spatial and temporal variations in the availability of biomass feedstock. It is therefore necessary to carry out a proper assessment to fully understand the availability of raw materials in order to make planning based on biomass residues potential. This paper focuses on the identification and quantification of the available agro-pastoral residues for energy supply in Dokanmè Public Primary Schoolthrough anaerobic digestion process.

METHODOLOGY

Study area: The study was carried out in the commune of Tori Bossito,the department of the Atlantic. This commune is located between 6°25 and 6°30 north latitude and 2°1 and 2°17 east longitude. It covers an area of 328 km² and is subdivided into six (6) districts (Avamè, Azohouè-Aliho, Azohouè-Cada, Tori-Bossito, Tori-Cada et Tori-Gare)and fifty-eight (58) villages. It is bordered by the commune of Allada to the north, Ouidah to the south, Abomey-Calavi to the east and Kpomassè to the west. In the census of 2013, its population was of 57,632 inhabitants (INSAE, 2016). Socio-economic activities include agriculture, its by-products (fishing, livestock breeding and hunting), trade and crafts, product processing and firewood harvesting.The main crops grown are, in order of importance: pineapple, cassava, maize, oil palm and cowpea, according to data from the 2018-2019 agricultural season.

Selection of biomass resource and site production: The present study focuses on agro-pastoral residual biomass of the main agro-pastoral sectors identified in the area. It concerns agri-food processing and livestock residues. Biomass type and site production selection is based on expert opinion, the literature, field surveys and interviews with resource persons. The selection of potential sites of residues generation was based on three criteria:

- Presence of at least one category of residues;
- Proximity to EPP Dokanmè (≤ 6km) in order to reduce the cost of collection of waste;
- Intensity of production activity.

Spatial distribution of residual biomass: The exact geographical location of production sites could better specify the service area for the supply of methanizable residues. So, QGIS 2.14 software was used to create spatial distribution maps based on the total amount of mobilizable biomass. This mapping showed the spatial distribution of residues and identified the sites generating the largest volumes of agro-pastoral residues.

Evaluation of biomass residues quantities: The evaluation of biomass quantities can be done in various possible levels: theoretical, technical, economic, implementation and sustainable biomass residue potentials (Biomass Energy Europe, 2010). The theoretical method is usually the most straightforward for estimation of energy potential since it takes into consideration all the biomass available for collection and various uses. In practice, however, not all biomass can be collected and used for energy production due to economic, environmental and social concerns. In order to estimate the available energy potential from residual biomass, this paper, therefore, adopted the theoretical and technical concepts.

Estimation of agri-food processing residues: Usually, the residue-to-product ratio (RPR) technique is applied to estimate the theoretical quantity of residues generated (Lyakurwa, 2016)(Barry *et al.* , 2022). RPR depends on several factors, that may vary from agro-pastoral site to site include moisture content at time of measurement, yield of crops, and yield of biomass, which all depend on climatic conditions and the level of management (Kemausuor *et al.* , 2014). A robust estimate of potential is based on ratio value appropriate to study area (Morato *et al.* , 2019). For this study, data have been collected on the field. Biomass quantification was carried out at each production site in the study area.The quantity of waste produced was weighed and used to estimate the amount of material produced on a daily basis. The quantity of residues produced per day of activity was evaluated and then related to the number of days of activity in the year.

The technical potential is the fraction of theoretically available biomass which are technically recoverable(Kemausuor *et al.* , 2014). It can be used to indicate the maximum energy potential of residues withoutmodifying the current uses of the various actors producing this biomass (Lyakurwa, 2016).Biomass is either buried to improve or maintain soil fertility, and used for animal feed, or domestic heating and cooking(Scarlat *et al.* , 2010)(Gauvrit and Mora, 2010). These alternative uses add value to the residue, representing a competition that must be considered when evaluating its possible use for power generation (Roberts *et al.* , 2015). In this study, competitive uses were determined through interviews with biomass producers.In order to consider the aforementioned, we adopt a Residue Availability rate RA (%), which is calculated based on the user-defined percentage. Thus, the mobilizable or technical quantity of biomass (*QMi*) is calculated by applying the following equation:

$$QM_i = QT_i * RA_i \qquad (1)$$

Where QM_i (ton) is the mobilizable potential quantity of residue *i*, QT_i (ton), the theoretical potential amount of residue i and, RA_i, the recoverability fraction.

Estimation of animal dung: The quantity of wastes produced depends on the amount of fodder consumed, fodder quality and animal weight (Junfeng *et al.* , 2005). The potential quantities of animal dung resource are estimated using number of animals, average annual dung production per animal, coefficient of dung collection and dry fraction (Cai *et al.* , 2008). The animal dung theoretically available was estimated by multiplying the number of animals by the estimated dung produced per day. Data on animal was obtained from the field surveys on each site production. The recoverability fraction used in the estimation of technically available animal dung, based on the user-defined percentage.

Calculation of the biogas and energy potential

The available potential of biogas generation from the residues was calculated following equation:

□□□ = □□□ ∗ □□□ (2)

Where *VBi* denotes the potential of biogas (m^3/year), IP*i* is the quantity of estimated biogas produced per kilogram of the fresh residue *i* (m^3/ton) andQM_i (ton) is the mobilizable potential quantity of residue *i*.

The raw energy in biogas (E_{biogas}) is calculated using the following equation:

$$E_{biogas} = \sum VB_{□} * LHV_{biogas} \qquad (3)$$

Where LHV_{biogas}represents the calorific value of biogas (MJ/m^3).

RESULTS AND DISCUSSION

Agro-pastoral residues available: In the study area, the agri-food processing residues inventoried are cassava peelings, palm oil clarifying sludge, pineapple cakes and crowns, and maize straw. Among these types of residue, those that are too acidic or woody, notably pineapple cakes and crowns, are not considered. They are not suitable to the fermentation process without pre-treatments and result in poor performance (Jha *et al.* , 2013);

Marone *et al.* (2014) and (Budiyono *et al.* , 2023). The valorization of these wastes to biogas is a relatively complex which may require waste crushing before digestion. In acidification of the digesters makes difficult the utilization of such substrates by non-experimented persons (Gunaseelan, 2004) like in this study context. Corn straw is more suitable for waste fermentation processes for biogas production in industrial level. Livestock residues include cow and pig dungs. However, pig dung is not suitable for collecting pig droppings, as they are not cemented and the droppings are trampled and mixed with sand. Hence, the biomass resources considered in this study include cassava peelings, palm oil clarifying sludge and cow dung (Figure 1).

a) Cassava peelings b) Palm oil clarifying sludger c) Cow dung

Figure 1. Agro-pastoral biomass residues considered in this study

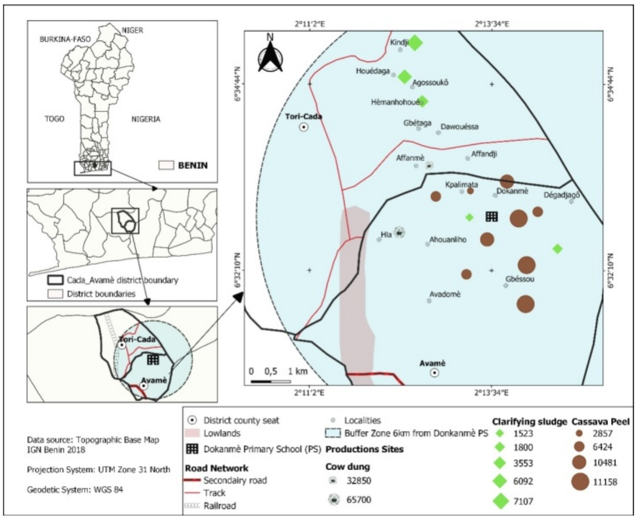

Figure 2. Map of spatial distribution of mobilizable potential of residual biomass

A total of 16 potential sites were identified. Twelve (12) of them are located in Avamè district to 1-3 km district from the EPP Dokanmè. On these sites, cassava peelings, palm oil clarifying sludge and cow dung are produced. On the others sites located in Tori-Cada district between 3-6 kmfrom the EPP Dokanmè, the main wastes are palm oil clarifying sludge and cow dung.Two (02) sites produce the cow dung, five (05) produce the palm oil sludge and nine (09) cassava peelings. No one of sites generates more than one type of residues. Among the nine sites of production of the cassava peelings, three are the same yield of 13.431 tons/year, others two are 12.617 tons/year each and others three are the same capacity of 7.733 tons/year. The low production of cassava peelings is 3.42 tons/year. Thus, the theoretical potential of cassava peelings is around of 92.146 tons/year. For the palm oil clarifying sludge, the high production is 8400 liters and the low is 1800 liters. The theoretical potential estimated is 25200 liters/year. The RA value defined in this study was 83% for cassava peelings and 79 % for palm oil clarifying sludge. So, the amount of cassava peelings that can be collected is estimated to 76.565 tons/year and 20075 liters/yearfor palm oil clarifying sludge. The theoretical potential of cow dung estimated is 131.400 tons per year. With 90% of recoverability fraction, the amount that can be collected is estimated to 118.260 tons.

Energy potential of residues: In the current study, the biogas productivity index (IP) value was considered as 267 m^3/ton for cassava peelings, 75 m^3/ton for cow dung (Lacour, 2011) and 73 m^3/ton for palm oil clarifying sludge (Tonavo, 2014). Based on mobilizable potential of all residues, the total potential volume of biogas is estimated at 30777.812 m^3/year. The contribution of each residue type is presented in the Figure 3.

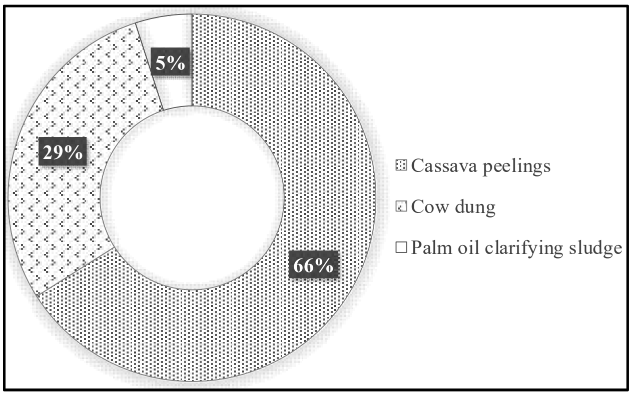

Figure 3. Contribution of each residue type of biogas production

The biogas production is mainly provided by cassava peelings, which amount to 20442.837 m^3/year of the total volume, cow dung, which amounts to 8869.5m ^{3}/year. The contribution of palm oil clarifying sludge is low and account for 5% of the total biogas production (1465.475m^3/year). The lower calorific value of biogas with a methane content between 50-70% ranges from 4.71 to 6.59 kWh/m^3(Coulibaly *et al*., 2013) or 16.95 to 23.72 MJ/m^3. Based on the study of Hosseini and Wahid (2014) it is assumed as 21.5 MJ per m^3 biogas in the present study.Thus, the energy potential in biogas from all residues found to be 661.722 GJ/year. The exploitation of aforesaid residues in the locality could be performed in small biogas units to satisfy domestic energy needs in the EPP Dokanmè. However, the sustainability of the anaerobic digestion could be influenced by the residues transportation cost. In addition, the installation of small units would make it possible to solve at least partially the requirements in energy of the school's canteen.

CONCLUSION

The biogas and energy potential of agro-pastoral residues (cassava peelings, palm oil clarifying sludge and cow dung) for energy supply in Dokanmè Public Primary School through anaerobic digestion has been investigated. The study shows that the wastes are abundantly produced. The production of biogas from these residues could permit the recovery of significant quantity of annual energy of 661.72 GJ. The exploitation of this energy resource can contribute to the conservation of forest and reduce women and schoolchildren occupation in searching for wood-energy and health problems.

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