Journal of Engineering Research and Reports

Volume 26, Issue 7, Page 462-471, 2024; Article no.JERR.120075
ISSN: 2582-2926

Energy Audit and Alternative Energy Source for Sustainable Processing of Cassava Products in Oyo State, Nigeria

Ogundahunsi, O. E. [a*], Akpan, G. E. [b], Agbaje, C. O. [c], Oyeniyi, K [a], Olaoye, I. O. [a] and Oyewusi, T. F [d]

[a] Department of Agricultural Engineering, First Technical University, Ibadan, Oyo State, Nigeria.
[b] Department of Agricultural Engineering, Akwa Ibom State University, Ikot Akpaden, Nigeria.
[c] National Center for Agricultural Mechanization (NCAM), Ilorin, Kwara State, Nigeria.
[d] Department of Agricultural Engineering, Osun State University, Osun State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jerr/2024/v26i71222

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/120075

Review Article

Received: 11/05/2024
Accepted: 14/07/2024
Published: 17/07/2024

ABSTRACT

Recently, the increase in electrical energy tariff in Nigeria coupled with the epileptic electricity supply has led to the rise in production cost and price of cassava products. In this study, an audit of the electrical energy used in three cassava processing industries (Niji farm, ATMANCorp Nigeria, and Psaltry International Limited) in Oyo state, Nigeria was carried out and biofuels as an alternative energy produced from cassava processing waste to enhance the sustainability of cassava processing are presented. The audit investigates the cost of energy consumption in producing different cassava products, ranging from garri, cassava flour, and cassava starch. The

**Corresponding author: Email: ogundahunsioluwafemi@gmail.com;*

Cite as: *O. E., Ogundahunsi, Akpan, G. E., Agbaje, C. O., Oyeniyi, K, Olaoye, I. O., and Oyewusi, T. F. 2024. "Energy Audit and Alternative Energy Source for Sustainable Processing of Cassava Products in Oyo State, Nigeria". Journal of Engineering Research and Reports 26 (7):462-71. https://doi.org/10.9734/jerr/2024/v26i71222.*

computation and analysis of energy use were carried out using the spreadsheet on Microsoft Excel. The results showed that the observed monthly energy consumed with the cost of the energy for Niji farm, ATMAN Corp Nigeria, and Psaltry International Limited were 45002.16 kW/h (NGN1,330,560), 65581.92 kW/h (NGN1,668,535), and 923774.40 kW/h (NGN27,501,120) respectively. The analysis also observed that bioenergy such as bioethanol, biodiesel, biomass, or biogas produced biochemically from cassava processing by-products can be used as a suitable biofuel to run types of machinery in cassava processing. This study proffers a solution to the high cost of energy used in cassava processing industries thereby reducing the production cost resulting in lower prices of cassava products in the market.

Keywords: Energy audit; renewable energy; biofuel; cassava processing; cassava by-product.

1. INTRODUCTION

The concept of energy efficiency has become increasingly pertinent as industries worldwide grapple with the twin challenges of resource scarcity and operational sustainability. Within this context, the practice of energy auditing has emerged as a critical tool for industries seeking to optimize their energy consumption, reduce operational costs, and minimize their ecological footprint [1,2]. An energy audit entails a systematic evaluation of an organization's energy usage, identifying inefficiencies, and proposing strategies to enhance energy efficiency and reduce operational costs [3]. The adoption of energy audit findings into effective energy management strategies not only benefits industries financially but also contributes to the broader goals of energy conservation and environmental protection. Energy auditing is achieved in three stages (i.e., pre-audit stage, audit stage, and post-audit stage) which are further segmented into different steps as shown in Fig. 1.

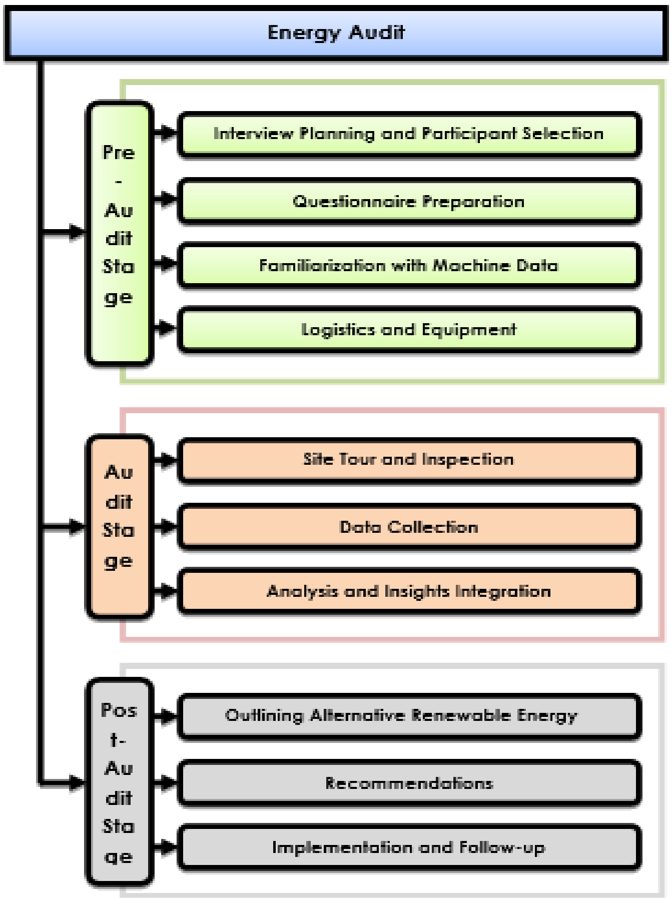

Fig. 1. Three stages of energy auditing
(Adapted from Kubule et al., 2020)

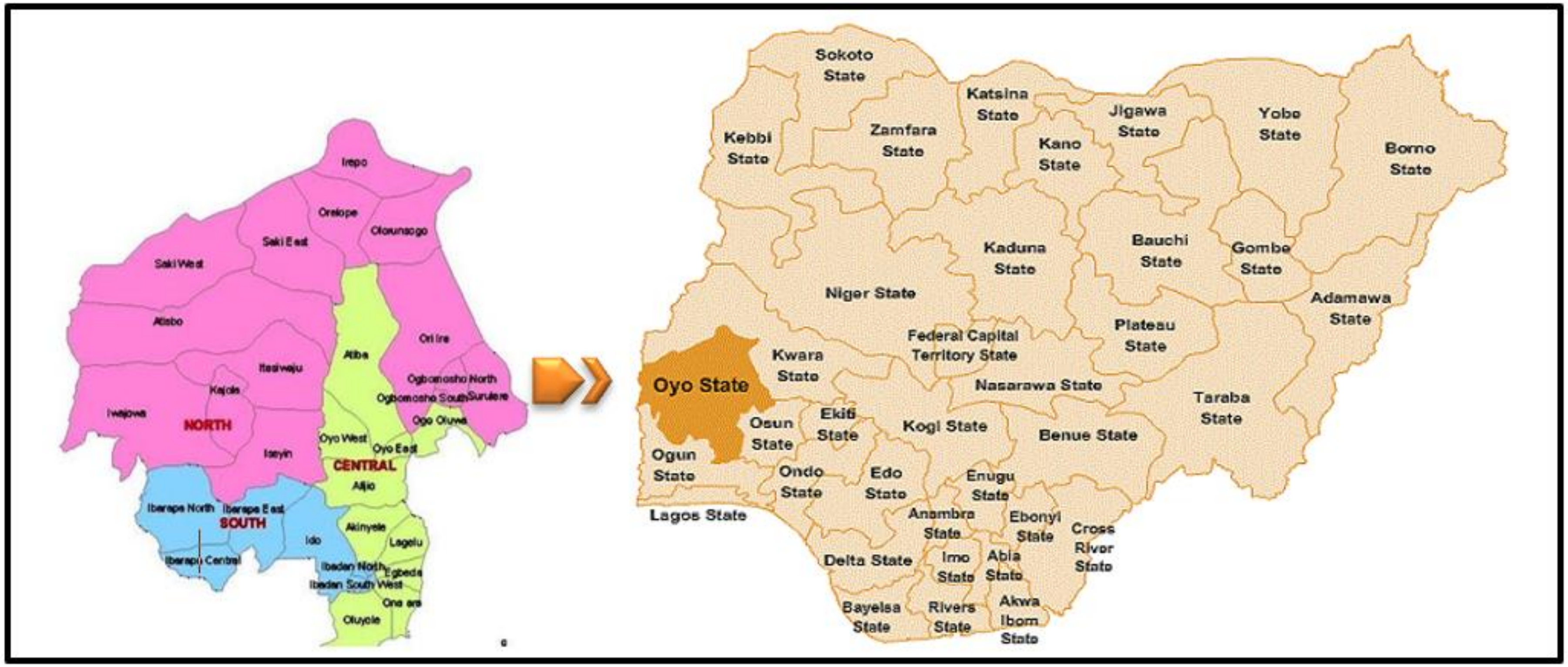

Fig. 2. Map of Oyo State from the map of Nigeria

Cassava is a valuable commodity that is widely used in various industries due to its unique functional properties. Cassava processing is of paramount importance as it not only ensures food security by converting cassava, a staple crop, into various food products but also stimulates economic development by generating income and employment opportunities, while concurrently diversifying the range of available products and industries [4-6]. Waste from cassava processing can be bio-converted into biofuels which are value-added products that can be used to supply the energy needed in processing cassava into other products thereby self-supplying some major energy needed for the operation of the industries [7-9].

Oyo State shown in Fig. 2 is situated in southwestern Nigeria and renowned for its active participation in cassava cultivation and processing. The cassava processing industry in this region comprises a diverse range of enterprises, from traditional small-scale operations to larger mechanized processing units. This sector is faced with a serious energy problem which is frequently wasteful and unsustainable. While these industries are crucial for Oyo State's economy, their energy consumption patterns cum alternative renewable energy for its sustainability have not been comprehensively studied. To maximize energy usage, an energy audit that involves a systematic assessment of energy use and the identification of some biofuels as an alternative energy source for cassava processing sustainability and competitiveness in Oyo State is essential.

Jekayinfa and Olajide [10] investigated the energy utilization patterns in cassava processing mills in Nigeria. The study reveals that cassava starch production required the highest energy per ton of fresh cassava tuber, followed by cassava flour and 'garri.' Energy-intensive operations within each production line were identified, and optimization models were developed to minimize energy input. Oladimeji *et al.* [11] researched an "analysis of energy consumption on energy-dependent electrical devices in garri production in Nigeria". In the research, energy consumption data were obtained and energy losses in the process line were identified, isolated, and eliminated to maximize the energy use. In another study, the energy evaluation and processing cost reduction in the maize and cassava processing industry was investigated, analyzing the cost incurred on the use of electricity, diesel, and labor. The study discovered that diesel contributed more to production costs than electricity and labor and therefore, recommended the setting up of an energy monitoring team to monitor procurement and control utilization of diesel to reduce production cost.

Through bioconversion of cassava processing by-products, bioethanol, biodiesel, biogas, bio-hydrogen, and bio-electricity can be produced [9]. Cassava wastewater by-product obtained from starch or garri production has energy potential which makes it particularly appealing as a substrate for bio-energy generation using the microbial fuel cell (MFC) since degradation of biological substrate is the driving force for electricity generation in the MFC. Also, cassava leaves, peels, pulp, chips, and stalks obtained in cassava processing can be used as a feedstock for biodiesel, bioethanol, biogas, and bio-hydrogen production and the usage of this cassava processing by-product in this procedure would lessen the environmental effect of disposing of it without first treating it Amorim et al., [8], Zhang et al., [7], Ogundahunsi et al., [12], Ogundahunsi et al., [13].

In this study, an energy audit of three major cassava processing industries in Oyo state (Psaltry International Company Limited in Ado Awaye, ATMANCorp Nigeria Limited in Ibadan, and Niji farm in Ilero) was carried out and some biofuels that can be produced from their processing by-product were outlined and suggested to supplement the use of electricity from the grid.

2. METHODOLOGY

This research was carried out on three selected cassava processing farms in Oyo State. In this research, Oyo State was deliberately selected due to its active participation in cassava cultivation and processing.

The three cassava processing industries were surveyed for the data collection on electrical-powered machinery used for cassava processing in the industries through unstructured questionnaires and interviews with the personnel who know the power consumption of machinery used operating time, and equipment details. The unstructured questionnaire consists of questions relating to energy consumption, equipment specifications, operational practices, and energy management strategies. The industries understudied were; Psaltry International Company Limited in Ado Awaye, ATMANCorp Nigeria Limited in Ibadan, and Niji Farm in Ilero.

Data obtained from electrical-powered machinery used in cassava processing in the industries were extracted from the questionnaire and were sectioned into starch and cassava flour production. To analyze these data, the daily and monthly power consumed was recorded concerning the daily and monthly number of hours the machinery operates respectively. This was further used to calculate the cost of running these machineries in these sectors.

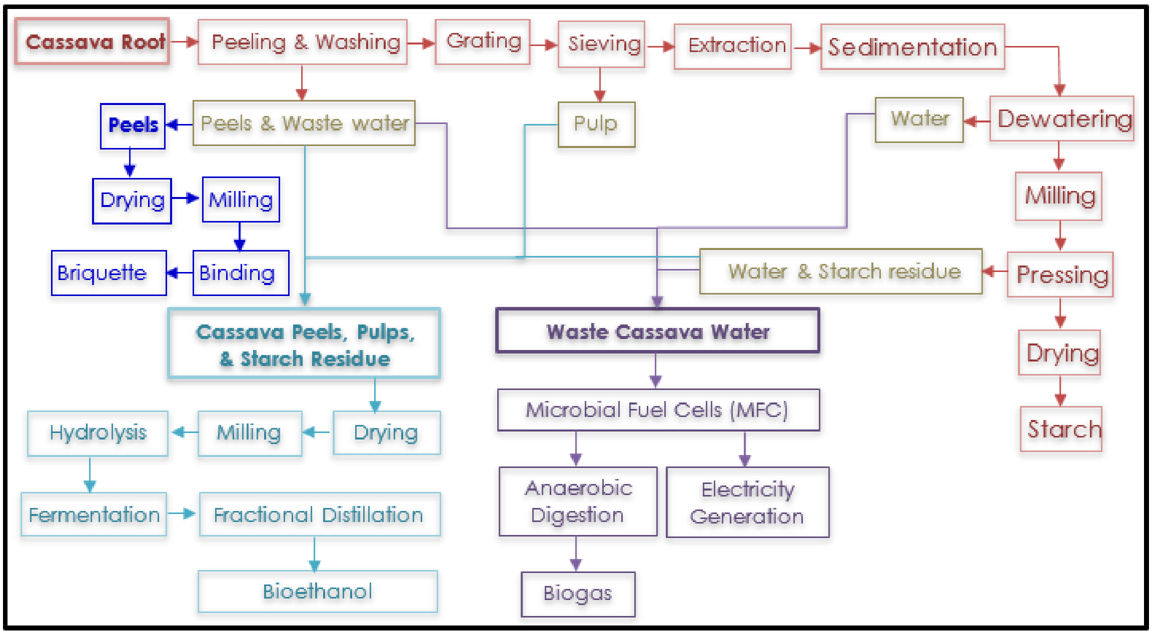

Fig. 3. Flowchart of the starch production process, waste generated during the process, and the biofuels produced from the waste.

Adapted from Ullah et al., [14], Siddique et al., [15]; Izah and Ohimain, [16]

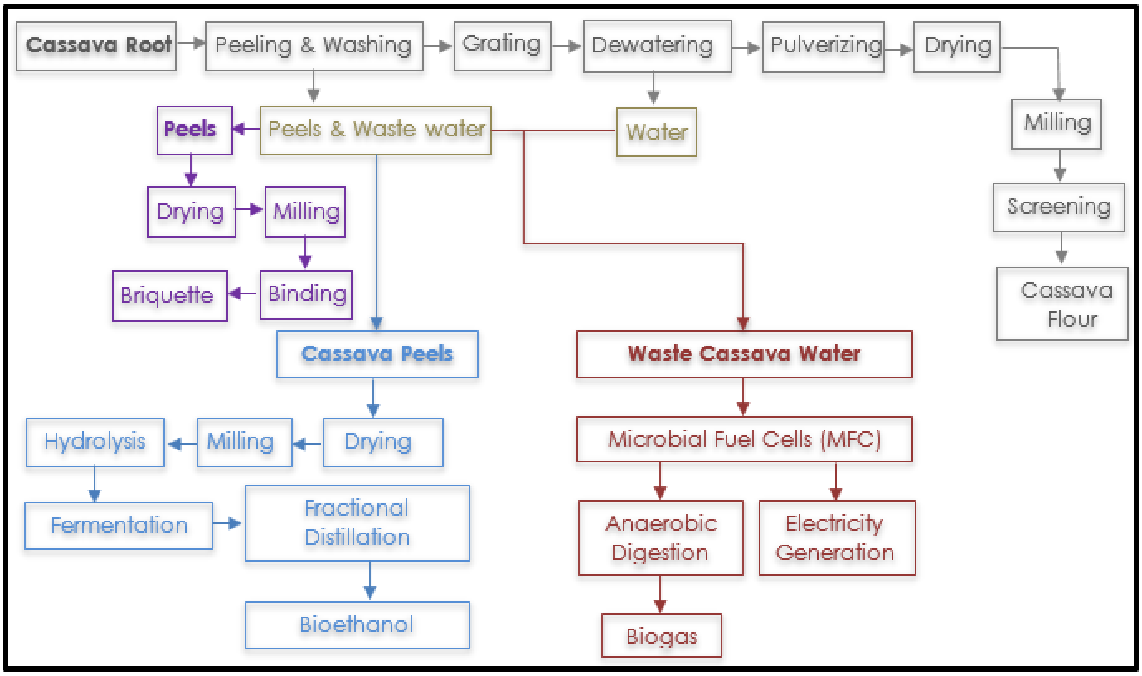

Fig. 4. Flowchart of cassava flour production process, waste generated during the process, and the biofuels produced from the waste

Adapted from Ullah et al., [14]; Ekop et al., [17]; Siddique et al., [15]; Izah & Ohimain, [16]

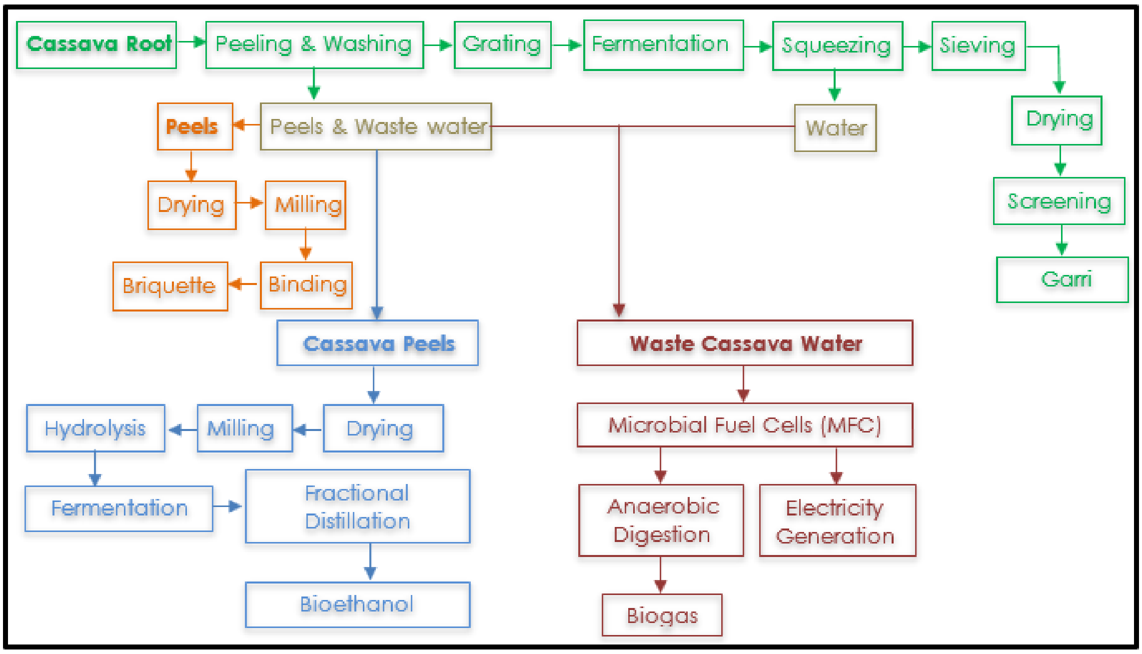

Fig. 5. Flowchart of the Garri production process, waste generated during the process, and the biofuels produced from the waste

Adapted from Ullah et al., [14]; Ekop et al., [17]; Siddique et al., [15]; Izah & Ohimain, [16]

3. RESULTS AND DISCUSSION

In Niji Farm, the result shown in Table 1a reveals that the total energy consumed for a month in the industry is 45,002.16 kW/h with the starch production section having 19,017.60 kW/h, cassava flour production (both wet and dry) section having 20,059.2 kW/h and garri processing section having 5,275.20 kW/hr. In ATMANCorp Nigeria the result shown in Table 1b shows that the total energy consumed per month is 65,581.92 kW/h with cassava flour (wet and dry) section and feed mill production section having 42,638.4 and 12,979.44 kW/h respectively. In Psaltry International Company Limited, the result shown in Table 1c revealed that the total energy is 923,774.40 kW/h with starch and cassava flour production sections having 767,448.00 and 149,256.00 kW/h respectively.

Table 1 shows the monthly energy used with its charges, and alternative biofuel produced from the cassava processing by-product in each of the three industries that can be used to supplement the electric energy used for the sustainability of the industry.

An audit of electrical energy usage in three cassava processing industries in Oyo state, Nigeria, was conducted. The industries included Niji Farm, ATMANCorp Nigeria, and Psaltry International Limited. The results showed significant variations in energy consumption among the three industries: Niji Farm: 45,002.16 kW/h (NGN1,330,560); ATMANCorp Nigeria: 65,581.92 kW/h (NGN1,668,535); Psaltry International Limited: 92,3774.40 kW/h (NGN27,501,120)

These figures highlight the substantial energy costs incurred by cassava processing industries in Nigeria, which are further exacerbated by the high electrical energy tariffs and unreliable electricity supply. The high energy costs in cassava processing industries have a direct impact on the production costs and prices of cassava products [9]. By reducing energy consumption through the use of biofuels, cassava processing industries can lower their production costs, leading to more competitive prices in the market. This is crucial for maintaining the economic viability of cassava processing businesses and ensuring that cassava products remain accessible to consumers.

The study found that bioenergy sources such as bioethanol, biodiesel, biomass, and biogas can be produced biochemically from cassava

Table 1. The monthly energy used, monthly charges, and alternative biofuel that can be used to supplement the electric energy

1a

NIJI Farm			
Sections	**Monthly Energy Used**	**Charges at NGN30 per kW/h**	**Alternative Biofuel Energy Used**
Starch Production	19,017.60 kW/h	NGN570,528	Wastewater from starch production can be used to generate electricity using the microbial fuel cell (MFC) which can be used to power hammer mills, crusher, and sieving machine.
Cassava Flour Production	**20,059.20 kW/h**	NGN601,776	Bye-product from cassava flour production such as cassava peels, pulp, and chips can be used for bioethanol, biodiesel, or biogas production to fuel conveyor, milling machine, and cassava peeler.
Garri	5,275.20 kW/h	NGN158,256	Biomass (Briquette) produced from cassava peels and leaves can be used as fuel for fryer. Also, bioethanol, biodiesel, and biogas produced from cassava pulp and chips can be used to fuel sieving and milling machine.

1b

ATMANCorp Nigeria			
Sections	**Monthly Energy Used**	**Charges at NGN30 per kW/h**	**Alternative Biofuel Energy Used**
Feed Mill Production	12,979.44 kW/h	NGN389,383	The wastewater can be used to generate electricity using the microbial fuel cell (MFC) which can be used to power hammer mills and impeller and biomass produced from stems and leaves can be used as fuel for dryer.
Cassava Flour Production	42,638.40 kW/h	NGN1,279,152	Bye-product from cassava flour production such as cassava peels, pulp, and chips can be used for bioethanol, biodiesel, or biogas production to fuel cassava washer, peeling machine, shaker, crusher, and conveyor.

1c

Psaltry International Company Limited			
Sections	**Monthly Energy Used**	**Charges at NGN30 per kW/h**	**Alternative Biofuel Energy Used**
Starch Production	767,448.00 kW/h	NGN23,023,440	Wastewater from starch production can be used to generate electricity using the microbial fuel cell (MFC) which can be used to power some machines such as; washer, peeler, shifter, mixer, conveyor, and pumps.
Cassava Flour Production	149,256.00 kW/h	NGN4,477,680	Bye-product from cassava flour production such as cassava peels, pulp, and chips can be used for bioethanol, biodiesel, or biogas production to fuel conveyor, milling machine, grating machine etc..

processing by-products. These biofuels can be used to power the machinery and equipment used in cassava processing, providing a sustainable and cost-effective alternative to fossil fuels.

The analysis revealed that the three cassava processing industries in Nigeria have a substantial consumption of electrical energy, incurring monthly costs ranging from NGN1,330,560 to NGN27,501,120. However, upon using biofuels derived from their processing waste, these industries have the potential to achieve significant reductions in energy expenditures, resulting in more competitive overall production costs.

Biofuels are a sustainable energy source made from organic matter, offering an environmentally friendly alternative to traditional fossil fuels. When utilized in cassava processing, biofuels play a crucial role in decreasing the carbon footprint and environmental impact associated with these operations. From the study, it could be inferred that integrating biofuel production into the cassava processing supply chain can enhance the overall sustainability of the industry. By closing the loop and utilizing waste streams as energy sources, cassava processors can minimize waste, improve resource efficiency, and ensure the long-term viability of their operations.

In addition to biofuels, the study also highlighted the potential of combining solar energy with biomass-based biogas and ethanol to create a more comprehensive renewable energy system for cassava processing.

The unreliable electricity supply and high tariffs in Nigeria have been a significant challenge for cassava processing industries. By integrating biofuels and solar energy, these industries can reduce their dependence on the grid and ensure a more stable and reliable energy supply for their operations.

The combination of solar energy, biogas, and bioethanol can be used to power various components of the cassava processing system, such as grating machines and drying systems, in a more energy-efficient manner.

The study suggests that the fibrous component of cassava processing waste can be used to produce prebiotics, which can then be used to fortify cassava flour, creating a functional food product. Additionally, the biogas manure can be used as a bio-fertilizer, further minimizing waste and creating a closed-loop system [18].

4. CONCLUSION

The result obtained from this study shows an intricate energy consumption landscape in the cassava processing industries. It was also observed that the small-scale cassava processing industries spend at least over a million naira on energy while large-scale industries spend over twenty million naira which can be reduced drastically through the use of biofuel. From the analysis, it was also observed that biofuels such as bioethanol, biodiesel, biomass, or biogas produced biochemically from cassava processing by-products can be used as a suitable biofuel to run types of machinery in cassava processing to achieve sustainability of the industry. This study proffers a solution to the high cost of energy used in cassava processing industries thereby enhancing food security by reducing the production cost resulting in lower prices of cassava products in the market.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/120075