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The potential of cassava biomass and applicable technologies for sustainable biogas production in South Africa: A review

Vincent Okudoh [a,*], Cristina Trois [b], Tilahun Workneh [b], Stefan Schmidt [c]

[a] Faculty of Applied Sciences, Cape Peninsula University of Technology, Cape Town, South Africa
[b] School of Engineering, University of KwaZulu-Natal, Durban, South Africa
[c] Discipline of Microbiology, School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa

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ABSTRACT

Bioenergy production from agricultural crop biomass or residues is gaining interest due to the escalating cost of fossil fuels and the need to mitigate global warming caused by increasing GHG emissions. Of all the different feed stocks used for bioenergy production in Africa, cassava biomass potentially offers multiple benefits for producing biofuels such as biogas. This critical review on cassava intends to highlight the bioenergy (biogas) potential of the crop in Africa. Initially, the basic agricultural properties of cassava will be reviewed. Cassava contains large amounts of fermentable sugars. Its starch content ranges from 20 to 35% based on fresh and at about 80.6% based on dry weight with 38.6% total dry matter. It has the highest yield of carbohydrates per hectare with the exception of sugarcane and sugar beet. It thrives well in all ecological zones with one of the best water-footprints especially on relatively low fertility soils, in drought conditions and requires low agrochemical input. High yielding and disease resistant cassava varieties have been developed for both food and non-food applications with China adopting the crop to meet its 2020 biofuel target. Based on the available literature, various pretreatment techniques including mechanical, chemical, thermal, ultrasonic and wet explosion strategies were considered. The advantages and disadvantages of each technology as well as adoptable technologies for cassava biogas production and its optimization in Africa and especially South Africa will be critically discussed. This review highlights the highly politicized food vs energy debate as the most relevant bottleneck for using "potential" food (like cassava and other energy crops) for energy production. It suggests a paradigm shift and a more holistic and complementary view of food and biomass energy production. In conclusion, it recommend considering cassava and its biomass as the next energy crop for biogas production in Africa and especially South Africa.

Contents

* Corresponding author. Tel.: +27 214603507.
E-mail address: okudohv@cput.ac.za (V. Okudoh).

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1. Introduction

The key issues faced by many developed and developing countries of the world today are mainly future energy security and better use of natural resources. A look at the African continent in terms of energy production and consumption shows the inequality in the distribution of fossil fuels. About 70% of the countries in Africa rely on imported energy. This situation is aggravated by huge unemployment and low gross domestic product (GDP). According to a recent report by the Food and Agriculture Organization (FAO) in 2013, Africa has the lowest overall GDP ($1629.5 billion) in the world, eight times less than Asia, five times less than Latin America and 26 times less than developed economies. GDP per capita in Africa was $1623.6 in 2010, two times less than Asia, five times less than Latin America and 21 times less than the per capita GDP of developed economies. GDP growth in 2010 was exceeding 6% only for Nigeria, Botswana and some East and Central African countries but was less than 3% for South Africa and Angola. A huge chunk of African countries' national budget which could have gone into development is spent on energy imports. Moreover, limited availability and lack of access to energy remains one of the most important factors affecting industrial development (i.e. agriculture, mining and tourism) in the continent. This leads to in-fighting (wars), violent service delivery protests, poor infrastructural development and spread of lethal diseases.

The above scenario supports the call for urgent development of renewable energy (RE) resources and in particular bioenergy. The bioenergy potential by 2050 on unutilized land for sub-Saharan Africa is estimated to be 317 Exajoules (EJ) per year [1]. This figure is higher than most other regions of the world. For example, only about 20% of South Africa's total land mass of 120 million hectares (Mha) is currently used for biomass production [2]. Conversion of biomass to energy will help reduce the dependence on fossil fuels as well as mitigate the negative social and environmental impacts such as rural unemployment and global warming [3].

Of all the different biofuels, biogas currently presents the most opportunities to the rural population in Africa while it is a major low-carbon fuel source. In addition, to the national governments in Africa, it offers multiple-benefits such as:

- Foreign exchange savings for non-oil producing countries.
- Boost for rural farming and economy through job creation and income gains.
- Beneficial use of organic agricultural and municipal solid waste (MSW) for energy production.
- Improved environmental quality through CO_2 emission reduction [4].

The use of cassava provides huge potential for bioenergy production and in particular biogas with several advantages. According to a report by the Forum for Agricultural Research in Africa (FARA) in 2010, there are thousands of acres of degraded and unutilized land in Africa where crops like cassava can be produced for biofuels on a large scale without damage to food production or natural habitats [5]. The advantage that cassava has over many other crops is that it can thrive in areas where the land has been degraded and has the highest yield of carbohydrates (4.742 kg/carb) per hectare with the exception of sugarcane and sugar beet [6]. It thrives very well on soils of relatively low fertility where the cultivation of other crops will be uneconomical [7]. It also has the ability to thrive in drought conditions and requires low input of agro-chemicals [8]. Cassava contains large amounts of starch (20–35% fresh and 80.6% dry weight) [9,10] and total dry matter (38.6%) [11], and has been reported to have the smallest water-footprint (21 m^3/GJ) compared to all other crops [12]. Based on the above reasons, cassava has recently gained considerable attention for the production of bioenergy [10] and in particular for the production of biogas [13–17].

Biogas from biomass is one of the best sources of renewable energy because it can be used for heating, as a fuel or natural gas equivalent and can be converted to electricity. In Germany, for example, the number of biogas plants has exceeded 7000 units in 2011 with electrical capacity already exceeding 2.8 GW [18,19]. The production of biogas from cassava biomass is a biochemical process that takes place through the anaerobic food chain involving mainly prokaryotes [20,21]. The major constituents of biogas are methane (CH_4) and carbon dioxide (CO_2). Trace amounts of H_2S, NH_3, H_2, N_2 are also present [22]. Methane is the most valuable component of biogas and typically accounts for more than 60%. Biogas is considered to be a valuable fuel [23,24] with the calorific value ranging from 5000 to 7000 kcal/m^3 depending on the concentration of CH_4 in it. For comparison, one cubic meter of biogas containing about