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Short communication

Utilization of cellulosic cassava waste for bio-ethanol production

Elias Emeka Elemike[a,*], Ojiefoh Charles Oseghale[b], Anthony C. Okoye[c]

[a] Department of Chemistry, Federal University of Petroleum Resources Effurun, Nigeria
[b] Department of Chemistry, Federal University Lafia, Nigeria
[c] Department of Environmental Management, Nnamdi Azikiwe University Awka, Nigeria

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ABSTRACT

Cassava cellulosic waste (*Manihot esculenta*,) obtained from starch processing was utilized in this work for bio-ethanol production. The chemical composition such as insoluble carbohydrate, protein, fibre and residual starch content of the waste was determined. The substrate was then hydrolysed (acidic and enzymatic), saccharified and fermented using α-amylase/HCl, amyloglucosidase and *Saccharomyces cerevisiae* respectively. The results showed that combination of enzymatic and acid hydrolysis recovered much of the starch and cellulose than when either of them was used. Dilute HCl was more helpful in converting the cellulosic materials to reducing sugars. A total of 32.4% alcohol (2.7 g ethanol/15 g cellulosic waste) was obtained which indicates that cassava wastes actually could be transformed to chemicals for use as fuels, biochemicals, synthetic intermediates etc.

1. Introduction

Prior to oil boom in Nigeria, the country had been surviving through the export of commodities like hides and skins, groundnuts from the north, palm oil and cassava from the east, cocoa and kolanuts from the west. The advent of crude oil had the effect of de-emphasizing these commodities until recently when the imperatives of international trade dictated a move away from mono-economy, total dependence on a non-renewable export commodity, crude oil [1]. The production and diversification of available agricultural commodities mentioned above, in particular for export purposes became an absolute necessity [2].

Accordingly, these have been of recent considerable interest in agricultural products in present Nigeria especially cassava, cocoa and other such crops [3]. Apart from being sources of staple food, these crops have been found to equally serve as raw materials for a variety of items such as drugs, agro-allied products and beverages. The increasing cost of crude petroleum in the world market and thereby rising energy prices as well as threats of global warming have led to increased interest in alternative fuels and such interest is currently centered on alcohol fuels which are obtainable from bio-renewable sources. Such alcohols are sometimes referred to as bioalcohols [4]. The current research interest in the developed countries focuses on the hydrolysis of ligno-cellulosic biomass which is a second generation source (2G) followed by the enzymatic conversion into ethanol. The first generation biofuels derived from sugar rich crops have shown promising results but there are more criticisms in using them as raw materials for biofuel as they equally serve as food though sugar cane could be an exception. The 2G feedstock therefore may serve as better option being more abundant and of lower cost. This necessitates a drive towards future expansion of biofuel production from lignocellulosic materials [5–7].

Cassava in Nigeria is a celebrated food crop because of its vast and varied use. In every zone in the country, extensive projects have been established to ensure considerable cassava production and utilization. A typical example of an expansive cassava project is the Niger Delta Development Commission (NDDC) cassava project in Edo State. There are also considerable cassava varieties available at the International Institute for Tropical Agriculture (IITA) at Ibadan, Oyo state.

Many countries have also been commissioning massive cassava production projects because of its use as substrate in the production of ethyl alcohol, a very important biofuel.

Brazil for example that imported more than 80% of its petroleum products as at 1979, has reduced the importation rate by investing extensively on alcohol fuel production from biomass and has produced cars that run on more than 17% alcohol blends with a view to the total elimination of the importation of petroleum by the end of the 21st century. In fact, the government policy has mandated the minimum of 20–25% blends of ethanol with petroleum products [8,9]. Moreover, the Brazilian vehicle production company (FIAT) currently manufactures vehicles that run on 100% bioalcohol creating a diversified economy and

* Corresponding author.
E-mail address: chemphilips@yahoo.com (E.E. Elemike).

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ensuring a greater energy security. This has made many countries to become interested in importing bioalcohol fuel from that country [10,11].

Other countries like South Africa, a pioneer in the conversion of coal to liquid fuel are considering projects that would produce 800,000 tons of alcohol per year from biomass [11].

Nigeria and other countries should not be left out in this global energy transformation. Other crops that can be used for alcohol production includes sugar cane, cereal grains(maize, barley, rice etc), sugar beets, sweet potatoes, raffia palm etc. Among all these, cassava has been chosen for this study because it is cheaply available and has become a source of hope for developing countries .The lignocellulosic wastes that could be utilized for ethanol production include rice husks, coconut fibres, groundnut shells, wheat straw and stalks, bamboo, wood flour, sugar cane straw, banana peels etc [7]. Bio-fuels could be instrumental for the enhancement of rural economy coupled with the employment generation at the grass roots level [7,13]. This is because many people would be employed in the cultivation of the energy crops and in the collection of the cellulosic wastes for the 2G biofuel. Moreover, due to the negligible amounts of sulfur and nitrogen biomass contains, the energy that is being utilized does not contribute to environmental pollution. Biofuels are generally considered as offering many priorities, including sustainability, reduction of greenhouse gas emissions, regional development, social structure and agriculture, security of supply [13–15]. India has recognized the importance of biomass utilization for making biofuels as excellent technology and business opportunities. Integration of the 2G ethanol with first generation source(1G) such as cereals or other starch containing food could facilitate the introduction of the 2G technology [12]. The capital cost per ton of fuel produced would be diminished and better utilization of the biomass can be achieved [16]. The aim of this work is to utilize an agricultural residue(cassava cellulosic waste) to produce 2G bioethanol using both acid and enzymatic hydrolysis.

2. Materials and method

2.1. Sample preparation

Cassava tuber was obtained from a farm in Nnewi Nigeria, peeled and washed with water. After washing, the tuber was weighed and the wet weight obtained as 1393 g. The tuber was grated, slurried in water and filtered using muslin cloth spread on a locally made sieve. Slurrying and filtration were repeated several times until the residue was deemed ready for disposal. This residue was now used for our research as it was sundried, ground to a fine powder and weighed 96.5 g. This process was used as it is a common practice in Nigeria for Garri processing [17]. When this is done, little do they know that the supposedly cassava waste can be applied for bioethanol production.

2.2. Proximate analysis

Some biochemical parameters such as starch content, fibre content, protein content and total carbohydrate of the cellulosic cassava waste was determined. The protein content was determined using Bradford reagent [18]. Protein standards were used to get a plot and the quantity of the protein in the sample was extrapolated from the graph. The fibre content was determined by digesting the waste sample with two different acids (0.5 M HCl and 0.5 M H_2SO_4) and heated for four hours. After that the residual fibrous material was washed, filtered and dried. The fibre content was then calculated. The starch content was determined by treatment with α-amylase which selectively digested the starch and left the insoluble fibre. The quantity was obtained by subtracting the fibre content from the total insoluble carbohydrate. The value shows the amount of hydrolysable material obtained both from the cellulose and equally contained in the sample that was saccharified and eventually fermented.

2.3. Enzymatic hydrolysis and saccharification

The fresh cassava residue (15 g) was slurried in 100 ml of water at a pH of 6.9. α-amylase (0.1%) was added to the slurry and then heated for 1 h at a temperature of 97–100 °C [19]. Further hydrolysis was done for 2 h using 0.5 M HCl which now attacked the fibrous material. This method was applied in order to expose the fibrous matrix of the material and improve its starch extraction by other enzymes. Amyloglucosidase was now used to saccharify the hydrolysed starch into reducing sugar by maintaining the temperature at 50–60 °C and pH of 4.60 while heating for 20 h. 0.1% and 0.15% of the enzymes were used separately and the reducing sugar was tested using Benedict's solution [20].

3. Fermentation by *Saccharomyces cerevisiae*

After saccharification by amyloglucosidase, the solution was diluted below 10% as 13.9% sugar was obtained using Benedict's solution and 0.2 g yeast cells was used. The dilution was made because yeast cells are inactive at high sugar concentration (>11%) [19,21]. Fermentation kinectics was studied at intervals of 0, 1, 2, 4, 6 and 8 h at about pH of 4.6–5.5 and temperature of 40–50 °C [21].

3.1. Distillation

After fermentation, distillation was carried out using simple distillation apparatus (Fig. 1).

4. Results and discussion

Fibre content was determined using 0.5 M HCl and 0.5 M H_2SO_4 and the percentages obtained were 15.8% and 39.3% respectively showing that HCl attacked the fibre more than the H_2SO_4. HCl was subsequently used for the hydrolysis of the cellulose and fibre as it serves as a substitute to relevant enzymes such as cellulase [22].

From the enzymatic hydrolysis and saccharification of 15 g of the cellulosic waste, a non-hydrolysate residue of 5.88 g was obtained after drying. This implies that the amount of hydrolysable component of the sample is 9.12 g giving a percent enzyme hydrolysable material of 60.8%. The percentage of starch obtained

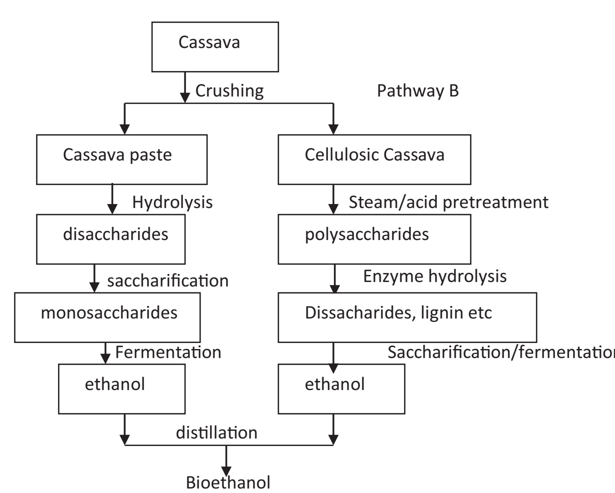

Fig. 1. Life cycle analysis of the biofuel production (Pathway B was followed in this research).