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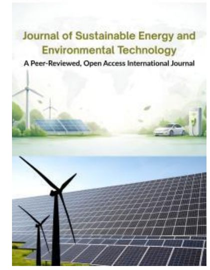

Production of Bioethanol from Cassava, Yam, Sweet Potato, and Plantain Peels via Acid Pretreatment

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Abstract: In this study, acid pre-treatment was used for the production of bioethanol from agricultural wastes, notably cassava peels, yam peels, sweet potato peels, and plantain peels. Three acid concentrations, 1, 1.5, and 2% H_2SO_4, were used to see how they affected ethanol yield. The experimental procedure involved physical and acidic pretreatments, fermentation with Saccharomyces cerevisiae via the simultaneous saccharification and fermentation (SSF) method, and finally distilling the ethanol. Maximum yield of ethanol for cassava and sweet potato peels was about 13%, with density and pH values nearly standard. Generally, yam and plantain peels have given slightly lower concentrations of ethanol. It indicates the possibility of using such waste agricultural by-products for sustainable bioethanol production and handling waste disposal problems.

Keywords: *Bioethanl Production, Agricultural Waste, Acid Pretreatment, Ethanol Yield, Fermentation Process.*

1. Introduction

Extensive research activities in biofuels have been propelled by worldwide search into alternative energy sources due to energy independence and greenhouse gas concerns. Bioethanol, which is produced from fermentable sugars, is a renewable alternative for fossil fuels and an answer to environmental pollution (Odunfa and Olanbiwoninu, 2012). Bioethanol is increasingly needed in various countries, including Nigeria, not only as a substitute for imported petroleum products but as a means of helping to revive the agricultural economy. Previous studies have pointed out the potential of producing bioethanol from crop residues, such as cassava, yam, sweet potato, and plantain peels, with emphasis given to their high carbohydrate content (Farrell *et al*., 2006; Balat, 2009).

In spite of that known potential, the production process has remained a challenge to optimize. This research fills the gap by investigating the effect of different acid pretreatment concentrations on the yield of bioethanol from these agricultural wastes. In this respect, the study has focused mainly on the application of acid (H_2SO_4) pretreatment for carbohydrate hydrolysis-enhancement, the very key process to the formation of fermentable sugar. In parallel, the study looks at the viability of transforming waste into energy while lowering environmental pollution.

The general purpose of this study will be to investigate the effect of acid pretreatment on the yield of bioethanol from cassava, yam, sweet potato, and plantain peels. Specific objectives of the study include the use of these agricultural wastes for the production of bioethanol, quantitative determination of bioethanol yield from fermentations using Saccharomyces cerevisiae, and comparison of the yield for a different type of raw material to determine the best substrate.

2. Materials and Methods

2.1 Materials

Standard equipment in the laboratory including weighing balance, conical flasks, beakers, measuring cylinders, spatulas, funnels, filter paper, cotton wool, aluminum foil, water bath, autoclave, distillation apparatus, and pH meter constituted the experimental set-up. Samples of cassava peels, yam peels, sweet potato peels, and plantain peels were sourced from Nasarawa Local Government Area of Nasarawa State.

2.2 Methodology

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The methods used were in accordance to some procedures as described by Nwokolo and Isitor, 2015.

2.2.1 Physical Pretreatment

Hand-sorted raw materials were thoroughly washed and dried, followed by grinding using a mechanical grinder. The dry material was then sieved to ensure particle size standardization and stored in a dry place off-direct sunlight in an airtight container at room temperature (20-25 °C).

2.2.2 Acidic Pretreatment

Powdered samples were subjected to acidic pretreatment in three different H_2SO_4 concentrations (1%, 1.5%, and 2%). For each experiment, 20g of sample was mixed with distilled water and the specified acid concentration in a 500 cm3 conical flask.

2.2.3 Sorting and Drying

After collection, the peels were carefully separated, and drying was initially conducted under open-air conditions. Due to weather constraints, final drying was completed using an oven.

2.2.4 Milling

Post-drying, the samples were milled into a fine powder and sieved through a 1 mm screen to ensure uniformity before being stored for further analysis.

2.2.5 Acid Hydrolysis

Each 20 g sample was placed in a conical flask; distilled water and the appropriate concentration of sulfuric acid were added, and the volume was adjusted with sterile distilled water.

2.2.6 Fermentation Process

Fermentation was performed using a simultaneous saccharification and fermentation (SSF) process (Kroumov *et al.*, 2006; Oghgren *et al.,* 2006). The hydrolyzed samples were covered with cotton wool, wrapped in aluminum foil, and autoclaved at 121°C for 15 minutes. After cooling, 5.0 g of yeast was added to each flask, and the fermentation proceeded for 72 hours.

2.2.7 Distillation

The fermented liquid was transferred to a round-bottom flask and distilled using a distillation apparatus. Distillation was carried out at 78°C—the boiling point of ethanol—for 2–3 hours to obtain the purified bioethanol product.

3. Results

The experimental results are summarized in three tables comparing bioethanol production from the various substrates under the three acid pretreatment conditions.

Table 1: Bioethanol Production Using 1% Acid Pretreatment

Sample	Mass of sample used (g)	Volume of bioethanol produced (cm^3)	Density (g/cm^3)	pH	Percentage yield %
Cp	20.00	20.00	0.80	7.31	13.00
Yp	20.00	19.05	0.76	7.30	12.70
Swp	20.00	20.05	0.80	7.25	13.00
Pp	20.00	19.40	0.77	7.22	12.90

Key: Cp—Cassava Peel; Yp—Yam Peel; Swp—Sweet Potato Peel; Pp—Plantain Peel.

Table 2: Bioethanol Production Using 1.5% Acid Pretreatment

Sample	Mass of sample used (g)	Volume of bioethanol produced (cm^3)	Density (g/cm^3)	pH	Percentage yield %
Cp	20.00	20.00	0.80	7.31	13.00
Yp	20.00	19.00	0.76	7.28	12.60
Swp	20.00	19.55	0.78	7.25	13.00
Pp	20.00	19.23	0.76	7.22	12.80

Key: Cp—Cassava Peel; Yp—Yam Peel; Swp—Sweet Potato Peel; Pp—Plantain Peel.

Table 3: Bioethanol Production Using 2% Acid Pretreatment

Sample	Mass of sample used (g)	Volume of bioethanol produced (cm^3)	Density (g/cm^3)	pH	Percentage yield %
Cp	20.00	19.50	0.78	7.30	13.00
Yp	20.00	19.00	0.76	7.30	12.60
Swp	20.00	19.00	0.76	7.26	12.60
Pp	20.00	19.00	0.76	7.24	12.60

Key: Cp—Cassava Peel; Yp—Yam Peel; Swp—Sweet Potato Peel; Pp—Plantain Peel

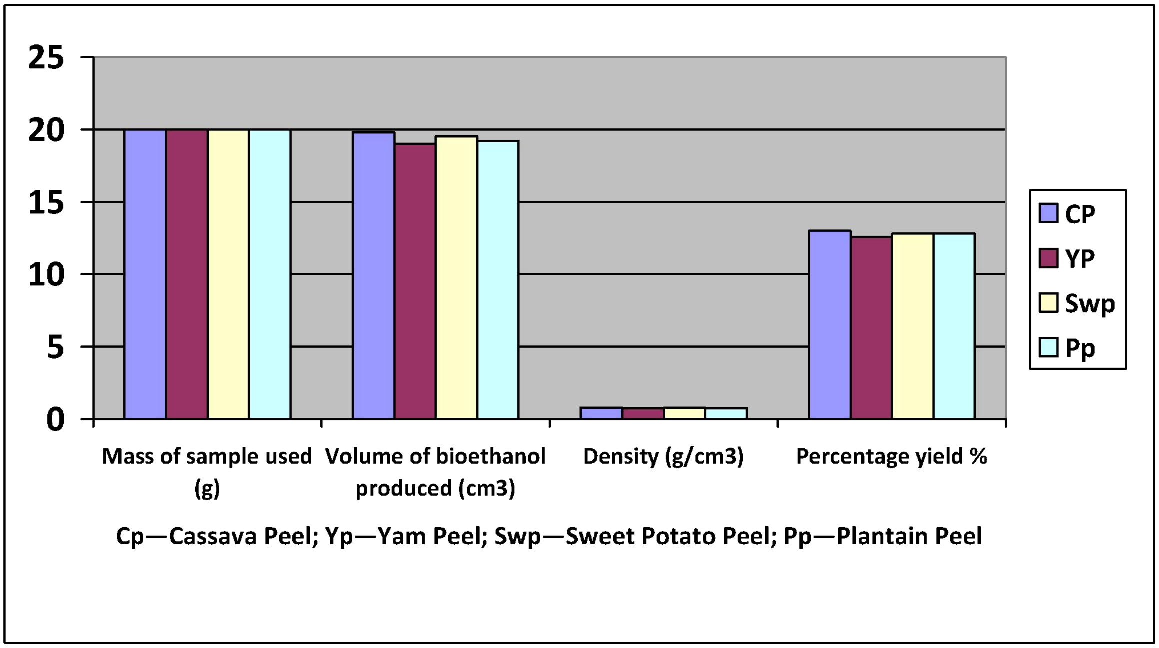

Fig 1: Average Bioethanol Production (Across 1%, 1.5%, and 2% Acid Pretreatments)

From cassava and Sweet Potato peels, bioethanol is produced in higher concentrations than yam and plantain peels consistently.

4. Discussion

The experimental results reveal that acid pretreatment is an important factor affecting bioethanol yield from the various agricultural residues. Under a 1% acid concentration, the maximum ethanol yield of 13% was attained by both cassava and Sweet Potato peels, with similar density value (0.80 g/cm^3) and pH values (7.31 and 7.25, respectively), very close to those of standard parameters given by FAO (2007) and NFAO (2020). Under a similar trend for 1.5% acid pretreatment, these two substrates again outperformed yam and plantain peels. In the case of 2% acid pretreatment, the cassava peels were favored, suggesting that higher acid concentration could be optimizing carbohydrate hydrolysis for cassava more than for other substrates.

The improved performance of cassava and Sweet Potato peels is attributed to higher carbohydrate contents important for the generation of fermentable sugars. The mean yield of cassava peel (13.0%) is comparable to previously reported values (Agunlejika *et al*., 2005; Oyeleke *et al*., 2009). On the other hand, the slightly lower yields of yam and plantain peels may be attributed to differences in their chemical composition and lower fermentable sugar contents.

In addition, this acid pretreatment combined with SSF processes was useful for converting non-food starchy wastes into biofuel and alleviating the environmental problems associated with agricultural waste disposal.

5. Conclusions

This study, therefore, confirms that bioethanol production from cassava, yam, sweet potato, and plantain peels through acid pretreatment is feasible. Among the substrates tested, cassava and sweet potato peels were superior, yielding as high as 13% ethanol under optimal pretreatment conditions. It is evident from the results that these agro-products not only provide renewable energy sources but also give a sustainable solution to environmental pollution caused by agro-industrial residues. Future works should look into using different microorganisms or enzymatic treatments for higher efficiency in hydrolysis and fermentation.

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