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BIOETHANOL PRODUCTION FROM *IPOMOEA BATATAS* (SWEET POTATO) PEELS USING *SACCHAROMYCES CEREVISIAE*

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ABSTRACT

This research paper examined the fermentation of sweet potato (*Ipomoea batatas*) peels to produce bioethanol with the use of *Saccharomyces cerevisiae* as the fermenting organism. Sweet potato peels are low-cost agricultural by-product that was evaluated as a fermentation feedstock. Proximate analysis of the peels revealed moisture (60.5%), ash (2.1%), lipid (0.5%), crude fibre (15%), protein (1.8%), and carbohydrate (20.1%) contents, confirming a starch-rich substrate suitable for bioethanol production. Pretreatment was done with 0.1 M NaOH and 10% H_2SO_4, followed by fermentation at room temperature under controlled pH (4.5–5.0) and distillation with a maximum temperature cap of 78°C. The fermentation process yielded 9.1% bioethanol (109.3 ml from 1,200 ml supernatant), with a boiling point of 78.6°C and pH of 3.0. These results are consistent with values reported in the literature, though the yield fell below the optimum range of 11.3–14.76 g/100 g, most likely due to inhibitory compounds from pretreatment and sub-optimal pH conditions. This study demonstrates the potential of sweet potato peels as a viable, cost-effective feedstock for bioethanol production.

Keywords: *Ipomoea batatas*, *Saccharomyces cerevisiae*, starch gelatinization, fermentable sugars, bioethanol, hydrolysis

Introduction

Global energy demand continues to rise with population growth and industrialization, exerting mounting pressure on finite fossil fuel reserves. Approximately 80% of world energy consumption relies on fossil fuels, including petroleum, coal, and natural gas, with oil consumption projected to grow by 1.6% per year (Al-Yasiri, 2022). The depletion of these resources, combined with their contribution to greenhouse gas emissions and climate change, has intensified the search for sustainable and renewable alternatives (Zaidi et al., 2024). Although electricity generation has attracted considerable attention in the renewable energy space, liquid fuels supply approximately two-thirds of total global energy requirements, creating an urgent need for viable biofuel options (Perona, 2017). Bioethanol has emerged as one of the most promising biofuel candidates, having been used in vehicles since 1925, with Brazil and the United States currently leading global production for transport applications (Bajpai, 2020).

Sweet potato (*Ipomoea batatas*) is a starchy tuberous root crop recognized for its rapid growth, adaptability to diverse climatic conditions, and high carbohydrate content. It is widely cultivated across Asia, Africa, and the Americas, making it an accessible and geographically distributed feedstock. The peels generated during sweet potato processing are largely discarded as waste, yet they are rich in starch, cellulose, and hemicellulose; substrates that can be hydrolyzed into fermentable sugars. Yang (2025) reported that starch constitutes 50–70% of sweet potato peels by dry weight. Utilizing these peels for bioethanol production simultaneously addresses agricultural waste management and renewable energy generation, aligning with principles of circular economy and environmental sustainability (Adamu et al., 2023). Ojuwumi et al., (2018) emphasized that previous studies have demonstrated that *Saccharomyces cerevisiae* is particularly well suited for fermenting the hydrolyzed sugars derived from sweet potato peels into ethanol due to its high fermentation efficiency, ethanol tolerance, and well-characterized physiology.

Despite the demonstrated potential of sweet potato peels as a bioethanol feedstock, process optimization, particularly with respect to pretreatment, hydrolysis efficiency, fermentation conditions, and ethanol yield, remains an active area of investigation in developing countries where both agricultural waste and energy insecurity are significant challenges (Oji et al., (2024). This study therefore aimed to produce bioethanol from sweet potato peels via acid pretreatment and yeast fermentation, to characterize the substrate through proximate analysis, and to evaluate the ethanol yield against published benchmarks.

Literature Review

Saccharomyces cerevisiae is the most widely employed fermenting organism in bioethanol production due to its capacity to convert six-carbon sugars to ethanol with high efficiency (Ojuwumi et al., 2018). During anaerobic fermentation, glucose is metabolized according to the following equation:

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

(Glucose) → (Ethanol) + (Carbon dioxide)

Equation 1: Fermentation of glucose to ethanol by S. cerevisiae

Ojuwumi et al., (2018) investigated the bioconversion of sweet potato peel waste to bioethanol using *Saccharomyces cerevisiae*. The peels were hydrolyzed with hydrochloric acid under varying temperatures and concentrations to maximize starch conversion. Optimal fermentation was achieved at pH 5.0, 32.5°C, and 6% (v/v) inoculum, yielding a maximum ethanol concentration of 6.39 g/L after 48 hours. This study highlighted the critical role of pH and temperature in fermentation efficiency.

Moura et al., (2024) examined direct fermentation of sweet potato peels without prior enzymatic hydrolysis, mixing peels with *S. cerevisiae* at 25°C. The study reported a bioethanol yield of 16.73% at 72 hours, indicating that direct fermentation may offer a simplified process route with competitive yields. Adamu et al., (2022) used *S. cerevisiae* to determine optimal fermentation conditions from sweet potato peels, finding that 10% inoculum concentration, pH 5.0, 18°Brix sugar concentration, 28°C, and 42 hours of fermentation produced the highest ethanol output of 11.49 mL, identifying substrate composition as a key determinant of yield.

Chinma et al., (2019) found that after enzymatic hydrolysis of sweet potato substrates followed by fermentation with *Saccharomyces cerevisiae*, ethanol was successfully produced, demonstrating the effectiveness of this conversion process.

Adekunle et al., (2016) reported that sweet potato peels can be hydrolyzed and fermented to yield bioethanol, highlighting their potential as a viable agricultural waste feedstock for ethanol production. Singh and Kumar (2020) reported that fermentation parameters such as temperature and pH significantly affect ethanol yield from lignocellulosic agricultural residues, emphasizing that careful control of these conditions is essential for optimizing and reproducing bioethanol production processes. Liu et al., (2023) demonstrated that combining physical pretreatment methods with biological processes significantly enhances enzymatic saccharification efficiency of lignocellulosic biomass, thereby improving sugar availability for subsequent fermentation and supporting process intensification strategies.

Materials and Methods

Materials

Sweet potato tubers (*Ipomoea batatas*) were obtained from Lokoja International Market, Kogi State, Nigeria. The tubers were processed immediately after purchase, and their peels were used as the primary feedstock for this research work.

Chemicals and Reagents:

All chemicals used were of standard analytical grade. These included Sulphuric acid (H_2SO_4, 10%), sodium hydroxide (NaOH, 0.1 M), N-hexane, 0.023 M H_2SO_4, phenolphthalein indicator, formaldehyde, and distilled water.

Equipment:

Major equipment employed in this research work included an electrical blender, incubator, and fractional distillation apparatus fitted with a fractionating column. Additional supporting equipment included a slurry tank and appropriate storage containers for sample handling and reagent preservation.

Glassware:

Standard laboratory glassware used throughout the experiment, include burettes, conical flasks, measuring cylinders, round-bottom flask, and condensers.

Biological reagent:

The fermenting microorganism used was *Saccharomyces cerevisiae* (commercial baker's yeast) obtained from a local supplier and used as inoculum for fermentation.

Methods

Sample Preparation

Sweet potato tubers were washed thoroughly with distilled water to remove surface dirt and then peeled manually. The peels were rinsed again with distilled water and grated using a clean grater to produce a uniform pulp. The grated pulp was mixed with distilled water and blended into a smooth paste to facilitate starch extraction.

Acid Pretreatment

The sweet potato peel paste (100 g) was cooked in 500 mL distilled water until a gelatinous consistency was achieved, then allowed to cool to room temperature. After cooling, 0.1 M NaOH was added and the mixture was left for one hour, followed by the addition of 10% H_2SO_4 after a further one-hour interval. This two-stage alkali–acid pretreatment was carried out to hydrolyze structural carbohydrates and release fermentable sugars. The pretreated slurry was filtered through filter cloth to obtain the liquid hydrolysate.

Fermentation

S. cerevisiae was reactivated in 50 mL of 5% glucose solution at 30°C for 30 minutes prior to inoculation. The hydrolysate was adjusted to pH 4.5–5.0 using 0.1 M NaOH and inoculated with the reactivated yeast suspension (approximately 5 g/L). Fermentation was conducted under anaerobic conditions at room temperature (30 ± 2°C) for 72–120 hours. After fermentation, the broth was filtered to separate the supernatant.

Distillation

The fermented supernatant (1,200 mL) was subjected to fractional distillation using a round-bottom flask fitted with a condenser. The thermometer was positioned at the top of the condenser to measure vapour temperature; it was not immersed directly in the sample, recording only steam pressure temperature. The distillation temperature was maintained below 78°C to minimize co-distillation of water and other impurities, collecting the ethanol-rich fraction.

Proximate Analysis

Standard proximate analysis procedures were applied to 2 g dried samples of sweet potato peels for determination of moisture, ash, crude fibre, lipid, and protein contents. Carbohydrate was determined by difference. All analyses were conducted in triplicate and the results reported as means (AOAC, 2005).

Moisture content:

Moist sample was weighed in filter paper and dried in an oven at 105°C, weighed at 30-minute intervals until constant weight was achieved.

Ash content:

Sample was weighed in a crucible and incinerated in a muffle furnace at 550°C until grey ash was obtained.

Crude fibre:

Sample was boiled in 30 mL of 0.023 M H_2SO_4 for 30 minutes, filtered, and the residue treated with 30 mL NaOH for a further 30 minutes. The residue was washed, dried, and weighed before and after incineration.

Lipid content:

Sample was soaked in N-hexane for 48 hours in a covered beaker, removed, and allowed to air-dry before weighing.

Protein content:

A 2 g sample was mixed with 20 mL distilled water and titrated against 0.1 M NaOH using the Sørensen formol titration method in the presence of 20 mL formaldehyde and phenolphthalein indicator. Protein content (%) was calculated using the formula:

$$\% \text{ Protein} = \frac{(V_a - V_b) \times 4.26 \times 100}{W}$$

where

- V_a= volume of 0.1 M NaOH used for the sample titration (mL),

- V_b= volume of 0.1 M NaOH used for the blank titration (mL),
- W= weight of the sample (g),

Carbohydrate content:

Determined by difference:

$$\% \text{ Carbohydrate} = 100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ Lipid} + \% \text{ Crude fibre} + \% \text{ Protein})$$

Ethanol yield:

The percentage ethanol yield (v/v) was calculated using Equation:

$$\% \text{ Ethanol yield (v/v)} = \left(\frac{\text{Volume of ethanol distillate (mL)}}{\text{Volume of fermented supernatant (mL)}}\right) \times 100$$

Results

Proximate Composition of Sweet Potato Peels

The proximate composition of *Ipomoea batatas* peels is presented in table 1. The results are expressed as percentage composition on a wet weight basis.

Table 1. Proximate composition of sweet potato peels (wet weight basis).

Parameter	Content (%)
Moisture	60.5
Ash	2.1
Lipid	0.5
Crude Fibre	15.0
Protein	1.8
Carbohydrate	20.1

Moisture content constituted the largest proportion (60.5%), followed by carbohydrate (20.1%) and crude fibre (15.0%). Ash (2.1%), protein (1.8%), and lipid (0.5%) were present in relatively lower proportions.

Ethanol Yield and Physicochemical Properties

Bioethanol was successfully produced from fermented sweet potato peel hydrolysate. From an initial volume of 1,200 mL of fermented supernatant, 109.3 mL of distillate was recovered, corresponding to an ethanol yield of **9.1% (v/v)**.

The physicochemical properties of the distillate are presented in Table 2:

Table 2. Physicochemical properties of produced ethanol

Parameter	Value
Ethanol yield (%)	9.1
Boiling point (°C)	78.6°C
Ph	3.0

The observed boiling point of 78.6°C shows a slight deviation from the standard boiling point of pure ethanol (78.37°C), indicating the presence of minor impurities. The distillate exhibited an acidic pH of 3.0.

Yield Efficiency Analysis The percentage ethanol yield (v/v) was calculated according to Equation:

$$\% \text{ Ethanol yield (v/v)} = \left(\frac{\text{Volume of ethanol distillate (mL)}}{\text{Volume of fermented supernatant (mL)}}\right) \times 100$$

Substituting the experimental values (109.3 mL ethanol recovered from 1,200 mL supernatant) gives the reported yield of 9.1%.

Assuming a theoretical maximum yield of 0.51 g ethanol per g glucose (based on the stoichiometric fermentation equation $C_6H_{12}O_6 \rightarrow 2\,C_2H_5OH + 2\,CO_2$, and an estimated fermentable sugar content of approximately 200 g/kg substrate, the overall process efficiency was calculated to be approximately 41.2% after accounting for losses during pretreatment, fermentation, and distillation. The fermentation process appeared to be substrate-limited, with the acid pretreatment and hydrolysis step likely being the rate-limiting stage. No detailed time-course sampling was performed in this study to enable fitting of kinetic models (e.g., Monod or pseudo-first-order).

Comparative Bioethanol Yield from Selected Feedstocks

A comparative overview of bioethanol yields from selected feedstocks is presented in Table 3 to contextualize the performance of sweet potato peels relative to other substrates.

Table 3. Comparative bioethanol yield from selected feedstocks

Feedstock	Typical Yield (L/tonne)	Fermentable Component	Pretreatment Requirement	Remarks
Sugarcane	60–80	Sucrose (direct fermentation)	Low (juice extraction only)	High efficiency; industrial standard
Corn (maize)	350–420	Starch	Moderate (enzymatic hydrolysis)	Widely used in large-scale production
Cassava tuber	180–250	Starch	Moderate (hydrolysis required)	High yield among root crops
Sweet potato tuber	125–200	Starch	Moderate (enzymatic hydrolysis)	Comparable to cassava but slightly lower
Sweet potato peels	10–50	Lignocellulosic residues	High (acid/enzymatic pretreatment)	Low yield; suitable for waste valorizations
Cassava peels	20–80	Lignocellulosic residues	High (pretreatment required)	Agro-waste with moderate potential

The comparative analysis in Table 3 highlights substantial variation in bioethanol yield across different feedstocks, primarily influenced by the nature and accessibility of fermentable sugars. Sugarcane and corn exhibit higher ethanol yields due to the presence of readily fermentable sucrose and efficiently hydrolysable starch, respectively (Balat et al., 2008; Bothast & Schlicher, 2005). Similarly, cassava and sweet potato tubers demonstrate relatively high yields owing to their significant starch content, although enzymatic hydrolysis is required prior to fermentation (Lareo et al., 2013). In contrast, sweet potato peels and cassava peels yield comparatively lower amounts of ethanol, largely due to their lignocellulosic composition, which necessitates more intensive pretreatment to release fermentable sugars (Limayem & Ricke, 2012). Despite this limitation, these agro-residues remain attractive substrates for bioethanol production because of their low cost, abundance, and potential for waste valorization. The comparatively lower yield observed in this study is therefore consistent with literature reports for lignocellulosic feedstocks and supports the feasibility of converting agricultural waste into renewable biofuel.

Discussion

The proximate composition of *Ipomoea batatas* peels obtained in this study is largely consistent with values reported in the literature. The moisture content (60.5%) falls within the typical range of 59–76% reported for fresh sweet potato varieties, indicating adequate water availability for microbial activity during fermentation. High moisture content is known to enhance enzymatic reactions and facilitate substrate utilization by fermenting microorganisms. The ash content (2.1%) is also within the reported range of 1.8–3.2%, suggesting a moderate mineral composition that is unlikely to adversely affect fermentation processes.

The lipid content (0.5%) aligns with previously reported values (0.3–0.6%), indicating minimal interference with microbial metabolism, as excessive lipid concentrations may inhibit yeast activity. The crude fibre content (15.0%) is considerably higher than values typically reported for fresh sweet potato tubers, which may be attributed to the lignocellulosic nature of the peel fraction. This elevated fibre content likely necessitated the use of chemical pretreatment (NaOH and H_2SO_4) to enhance the release of fermentable sugars. The protein content (1.8%) is lower than the commonly reported range of 3.6–6.8% for whole tubers, which may reflect compositional differences between the peel and edible portions. Nevertheless, the carbohydrate content (20.1%), primarily in the form of starch and structural polysaccharides, confirms the suitability of sweet potato peels as a substrate for bioethanol production.

The ethanol yield obtained in this study (9.1% v/v) is comparable to values reported in related studies using sweet potato residues. For instance, Ojuwumi et al., (2018) reported an ethanol yield of 6.39 g/L from acid-hydrolyzed sweet potato peels using *Saccharomyces cerevisiae*, while Adamu et al., (2022) obtained a yield of 11.49 mL under optimized fermentation conditions. Other studies have demonstrated that optimization of pretreatment and fermentation conditions can significantly improve ethanol yield from lignocellulosic biomass (Zhou et al., 2021). The slightly lower yield observed in the present study may be attributed to the presence of fermentation inhibitors generated during acid–alkali pretreatment, suboptimal hydrolysis efficiency, or limitations in fermentation conditions such as pH and nutrient availability.

Furthermore, the physicochemical properties of the produced ethanol provide additional insight into product quality. The observed boiling point (78.6°C) shows a slight deviation from the standard boiling point of pure ethanol (78.37°C), suggesting the presence of minor impurities, likely due to incomplete separation during distillation. The acidic pH (3.0) of the distillate also indicates the possible presence of residual organic acids, which may have originated from the pretreatment or fermentation stages.

However, the findings of this study demonstrate that sweet potato peels, despite being a low-value agricultural waste, possess sufficient fermentable components to support bioethanol production. While the yield is lower than that obtained from starch-rich feedstocks such as cassava and maize, the use of agro-residues offers significant advantages in terms of cost reduction, waste management, and environmental sustainability.

Conclusion

This study successfully produced bioethanol from sweet potato (*Ipomoea batatas*) peels using *Saccharomyces cerevisiae*, yielding 9.1% ethanol from the fermented supernatant. Proximate analysis confirmed the substrate as starch-rich and suitable for fermentation, with moisture (60.5%), ash (2.1%), lipid (0.5%), crude fibre (15.0%), protein (1.8%), and carbohydrate (20.1%) contents broadly consistent with published benchmarks. Acid pretreatment with NaOH and H_2SO_4 followed by yeast fermentation and fractional distillation provided a functional bioethanol production pathway, though yield was constrained by inhibitory compounds from

pretreatment and sub-optimal fermentation pH. These results validate sweet potato peels, an underutilized tuber crop by-product, as a promising agro-waste feedstock for renewable fuel production, contributing to both waste valorization and energy diversification objectives.

Recommendations for Future Research

Based on the findings of this study, the following directions are recommended for future investigation:

1. Enzymatic hydrolysis using α-amylase and glucoamylase should be systematically compared against acid pretreatment to determine the approach that maximizes fermentable sugar release and ethanol yield from sweet potato peels.
2. The use of genetically enhanced or stress-tolerant yeast strains should be explored to improve fermentation efficiency under inhibitory conditions generated by acid pretreatment.
3. A comparative assessment of sweet potato peels against other agro-waste feedstocks (e.g., cassava peels, plantain peels) under identical process conditions would help to contextualize the relative efficiency of each substrate.
4. Pilot-scale studies with triplicate experimental runs are needed to generate statistically reliable datasets and evaluate process scalability.
5. Economic feasibility and life-cycle analyses should be incorporated into future work to assess the commercial viability of sweet potato peel-based bioethanol production, particularly in rural agricultural contexts.

Authors' Contributions

All authors (ALM, AM, POA, & PMA) contributed to the study conception and design. All authors commented on previous version of the manuscript and also read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

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