COMPARATIVE STUDY OF BIOETHANOL PRODUCTION FROM IRISH AND SWEET POTATO PEELS BY HYDROLYSIS AND FERMENTATION PROCESSES USING *Saccharomyces cerevisiae*

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Abstract: The quest for green and sustainable sources of energy has led to various studies on the production of biofuels such as bioethanol from different agricultural materials. This study presents a comparative analysis of bioethanol produced from Sweet and Iris potato using simultaneous saccharification and fermentation (SSF). 5.00, 10.00, and 15.00 g each of the Sweet and Irish potato peels were hydrolyzed using dilute acid (5% H_2SO_4). A dried baker's yeast strain (*Saccharomyces cerevisiae*) was subsequently introduced to ferment the substrates for 7 days. The bioethanol yield, average bioethanol yield, density, and proximate composition of the substrates were determined. The yield of bioethanol for Sweet potato peels at 5.00, 10.00, and 15.00 g were 43.50, 64.50 and 82.00 cm^3 while for Irish potato peel at 5.00 , 10.00 and 15.00 g were 22.00, 41.50, and 59.00 cm^3, respectively. The average bioethanol yield for Sweet potato and Irish potato peels were 63.33 and 40.83%, while the density for Sweet and Irish potato peels were 0.853 and 0.891 g/cm^3, respectively. The proximate composition for Sweet potato peel was 5.10±0.01% moisture, 4.00±0.023% ash, 2.99 ± 0.044% lipid, 3.50±0.03% fiber, 7.00±0.05% protein, and 77.41±0.01% carbohydrate while for Irish potato peel were 8.75± 0.63% moisture, 3.55± 0.05% ash, 4.48± 0.03 lipid, 4.50± 0.55% fiber, 4.38± 0.67% protein and 74.34±0.15% carbohydrate. Therefore potato peels can be harness as a potential feedstock for bioethanol production with Sweet potato peel having a higher yield of bioethanol compared to Irish potato due to higher carbohydrate content.

Keywords: Bioethanol, potato peels, proximate, *Saccharomyces cerevisiae*, distillation, fermentation

Introduction

The global energy demand has increased over the last few decades and will continue to rise greatly due to rapid population growth, increasing industrialization, and technological advancements among many others. The world's current energy requirement is heavily reliant on fossil fuels. These fossil fuels are unsustainable, and their global reserves are getting depleted increasingly and could lead to a shortage of supply and future energy crisis (Dresselhaus & Thomas, 2001; Chu & Majumdar, 2012; Candell *et al.*, 2007). Furthermore, fossils fuel releases CO_2 as a by-product of combustion which is a notorious atmospheric pollutant responsible for global warming (Feldman *et al.*, 2015). It has therefore become imperative to focus on alternative sources of energy that are sustainable, essentially bio-based, and environmentally benign to replace fossil fuels with the prospect of mitigating the concerns earlier mentioned.

Bioethanol is one of the most promising alternatives to fossil fuels (Wang *et al.*, 2016). It can be produced from agricultural residues such as starchy biomass, lignocellulosic biomass, and other agro-industrial wastes (Anwar *et al.*, 2014; Mojovic *et al.*, 2009).

Although, the utilization of starchy biomass for biofuel production leads to the production of value-added products by converting them into useful bio-substrates that serves as a substitute to fossil fuels, thereby reducing the cost of energy and negative impacts to the environment as well as offer routes to clean and alternative source of energy (Bušić *et al.*, 2018).

Bioethanol is an alternative source of energy derived from petrochemicals and has the potential to meet the increasing energy demand for industrial processes, heating, and transportation (Ayoola *et al.*, 2017). Bioethanol is produced in commercial quantity mainly by the sugar fermentation process, although it can also be made by the chemical reaction of ethylene with steam via the reaction scheme below (Isah *et al.*, 2019):

$$2C_2H_{4(g)} + H_2O_{(l)} \longrightarrow C_2H_5OH_{(g)}$$

The fermentation process on the other hand involves the enzymatic breakdown of simple sugars such as glucose by an enzyme known as zymase.

The reaction scheme is as follows:

$$C_6H_{12}O_{6(s)} \longrightarrow 2C_2H_5OH_{(aq)} + 2CO_{2(g)}$$

Starchy substrates are often used for bioethanol production due to their economic viability as well as availability in large quantities all across the world (Robak & Balcerek, 2018). The bioethanol used as a substitute for fossil fuels can be produced either by microbial fermentation of sugar or from petrochemical sources, however, the production of bioethanol by microbial fermentation of sugar is the most widely used due to its simplicity. This process involves the bioconversion of starch into sugar and then to bioethanol by the fermentation process (Selim *et al.*, 2018).

Several studies have been conducted on the use of starchy biomass such as corn, sugar beet, sweet sorghum, sweet potato, or abundantly cheap cellulosic feedstocks like wheat straw, wood, and most importantly the use of agricultural wastes like corn cobs, cassava peels, etc. This agricultural biomass can be converted into value-added products as well as substitute's fossil fuels to reduce the cost of energy, help to manage agricultural waste economically, and also provide purer forms of fuels that are environmentally benign (Khoo *et al.*, 2013). Potatoes (sweet and Irish) are being exploited for the production of bioethanol due to their rich starch content, cellulose and sugars make them cheap substrates for fuel ethanol production (Saini *et al.*, 2014).

Potato is highly valued as a food crop, (Birch *et al.*, 2012) and is currently utilized in different forms, 60% frozen, 14% fresh,

13% chips, 13% dehydrated, and 1% potato seed in the US(USDA, 1993).

The world production of potatoes was recorded to be 330 million tons in the year 2011–2012. China has been the one-third potato-producing country in the world with a production of 20% followed by Russia (12%), India (8%), and the USA (8%) (Lee *et al.*, 2012).

Potato (*Solanum tuberosum*) belongs to the tuber crops and there are two main types, Irish potato, and sweet potato (*Ipoema batata*). Nigeria is the number one producer of potatoes in Africa with an annual output of 3.46 million metric tons and globally the second largest producer after China (Olagunju *et al.*, 2013).

Potatoes are generally an important class of food that is rich in carbohydrate content (Beals, 2018), having a concentration of starch for the dry matter to be ≥13% (Haase, 2003). They are one of the most abundant sources of food in most developing countries, and these starchy sources are used in food production and chemical industries to produce several food items and other commercial products for man's consumption (Devaux *et al.*, 2014). Industrial potato processing results in the generation of a large amount of solid waste matter, predominantly potato peels of which if not properly managed, could lead to environmental pollution. These waste materials can be explored as a cheap source of raw materials for other chemical processes hence, they are of commercial value (Jirasak & Buddhiporn, 2011).

More so, the "Zero waste" policy recently adopted by most food and chemical processing industries aimed at complete processing of raw materials into finished products with little or no waste. This is mostly achieved by recycling the byproducts obtained during production or conversion of these byproducts to value-added substances (Isah *et al.*, 2019). Therefore, potato peels as one of such byproducts have the potential of been processed into biofuels because it is rich in carbohydrate content.

In light of the aforementioned reasons, this study was aimed at producing and comparing the bioethanol potentials of Irish and sweet potato peels via acid hydrolysis and fermentation processes using *S. cerevisiae*.

Materials and Methods

Samples collection

Fresh peels of Sweet potato (*Ipomoea batatas*) and Irish potato (*Solanum tuberosum*) were obtained from Bosso Market in Minna, Niger State, Nigeria. The samples were collected in two separate polyethylene bags and were transported to the Chemistry Laboratory, Federal University of Technology, Minna Niger State for analyses.

Pretreatment of samples

The samples were washed with ordinary water followed by distilled water and crushed into smaller sizes for easy drying. The dried samples were ground into a fine powder using laboratory mortar and pestle and sieved with a 2.2 mm aperture sized sieve. The powdered samples were stored at room temperature in a separate polyethylene bag before the analysis (Isah *et al.*, 2019).

Bioethanol production

The procedures employed for bioethanol production were acid hydrolysis, fermentation, and distillation.

Dilute acid hydrolysis

This analysis was carried out following the method described by Isah *et al.* (2019); Gupta *et al.* (2009). Dried samples of each of the Sweet and Irish potatoes were weighed (5.00, 10.00, 15.00 g) into six 250 cm^3 conical flask and were labeled SP1, SP2, and SP3 for Sweet Potato and IP1, IP2 and IP3 for Irish Potatoes, respectively. Tetraoxosulphate (VI) acid (5%, 200 cm^3) was introduced into each of the conical flasks containing the dried samples.

The flasks were covered with cotton wool and wrapped with aluminum foil followed by heat treatment (50°C, 30 min) using a heating mantle. The flasks were allowed to cool and filtered through Whatman No. 1 filter paper.

pH adjustment

The pH of the samples was adjusted with NaOH (4.5, 40%) to neutralize acidity using a digital pH meter before the introduction of yeast (*Saccharomyces cerevisiae*), to the hydrolyzed samples to protect the yeast from hypertonic solution (Isah *et al.*, 2019).

Fermentation process

The fermentation process was carried out with saccharification (encompassing simultaneous saccharification and fermentation, SSF) (Khoo *et al.*, 2013; Brooks, 2008; Oyeleke *et al.*, 2009). The conical flasks containing the hydrolyzed samples were covered with cotton wool, wrapped with aluminum foil, and then autoclaved (121°C, 30 min) to destroy any microorganisms present before proceeding to the fermentation process. After it was allowed to cool at room temperature, baker's yeast (*Saccharomyces cerevisiae)* (10.00 g) was introduced into the conical flask containing the samples of Sweet and Irish potatoes and stirred thoroughly (Rabah *et al.*, 2011). Each of the conical flasks was covered using cotton wool and wrapped with aluminum foil then it was stored for about a week. The flasks were shaken with an orbital shaker to homogenize the solution and evenly distribute the organisms in the substrate mixture. The substrates were therefore fermented sequentially and concurrently. The yeast was added essentially to produce the required enzymes (*Invertase* and *Zymase*) for the conversion of the samples into bioethanol and carbon dioxide (Khoo *et al.*, 2013).

The chemical equation for the fermentation process is represented as follows:

$$C_{12}H_{22}O_{11} + H_2O \xrightleftharpoons{\text{invertase}} 2C_6H_{12}O_6 \text{ ---------- (i)}$$

$$2C_6H_{12}O_6 \xrightleftharpoons{\text{zymase}} 2C_2H_5OH + 2CO_{2(g)} \text{ ---------- (ii)}$$

Simple distillation

This was carried out using distillation apparatus. The fermented liquid was transferred into the distillation flask and was placed on a heating mantle fixed to a distillation column enclosed in running tap water. The distillate was collected at 78°C (boiling point of ethanol) with another flask was fixed to the other end of the distillation column (Isah *et al.*, 2019).

Proximate analysis

The proximate analysis of the samples of Sweet and Irish Potatoes was carried out by the standard method described by AOAC (2003) to determine the moisture content, ash content, crude lipid, crude protein, crude fiber, and total carbohydrate contents.

Results and Discussion

The result presented in Table 1 shows the quantity of samples, hydrolysate, and quantity of bioethanol distilled from Sweet and Irish Potatoes, respectively when hydrolyzed with dilute tetraoxosulphate (VI) acid and fermented with dried active baker's yeast strain (*Saccharomyces cerevisiae*).

Table 1: Quantity of substrates, hydrolysate, and quantity of distillate

Samples	Quantity (g)	Hydrolysate cm^3)	Distillate (cm^3)
SP_1	5	100	43.50
SP_2	10	100	64.50
SP_3	15	100	82.00
IP_1	5	100	22.00
IP_2	10	100	41.50
IP_3	15	100	59.00

Table 2: Average yield and density of bioethanol produced

Sample	Average yield (%)	Density (g/cm^3)
Sweet potato peel	63.33	0.853
Irish potato peel	40.83	0.891

Table 3: Proximate composition

Parameter	Sweet potato peels (%)	Irish potato peels (%)
Moisture	5.10±0.01	8.75± 0.63
Ash	4.00±0.023	3.55± 0.05
Lipid	2.99± 0.044	4.48± 0.03
Crude fiber	3.50±0.03	4.50± 0.55
Protein	7.00±0.05	4.38± 0.67
Total Carbohydrate	77.41±0.01	74.34±0.15

Proximate analysis

The results presented in Table 3 shows the result of proximate analysis of Sweet and Irish Potatoes, respectively.

The results presented in Table 1 showed that 5.00, 10.00, and 15.00 g of Sweet potato peels produced 43.50, 64.50, and 82.00 cm^3 distillates of bio-ethanol, respectively; while 5.00, 10.00, and 15.00 g of Irish potato peels yielded 22.00, 41.50, and 59.00 cm^3 distillates, respectively. These results show a direct proportionality between the amount of the substrate and the volume of the bioethanol produced. As the mass of the substrate increases the volume of bioethanol produce also increases. This could be attributed to an increase in the composition of carbohydrate content as the mass of the substrate increases. This result is in direct agreement with the findings of (Jin*et al.*, 2012).

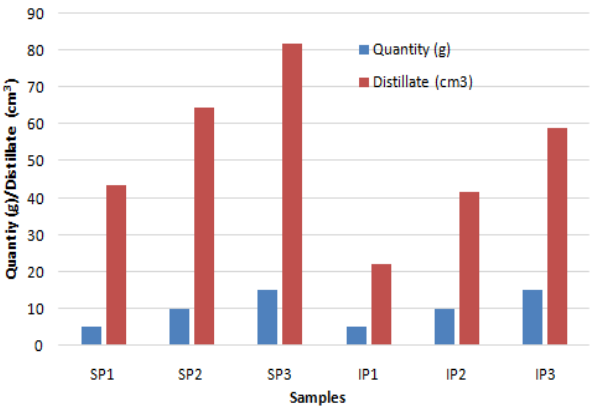

Fig. 1: ABar chart showing a relationship between the mass of substrate and the volume of distillate

The results presented in Fig. 1 revealed the increase in the volume of the bioethanol produced as the amount of substrate increases. This is evident that the higher the mass, the higher the amount of bio-ethanol produced. The results also revealed that the quantity of bioethanol produced from Irish Potatoes peels is lower compared to Sweet potatoes peels when tetraoxosulphate (VI) acid and *Saccharomyces cerevisiae* were used in hydrolysis and fermentation processes for about seven days. This may be due to the presence of high carbohydrate content in Sweet potato peels, which could be fermented to bioethanol.

These results agree with the finding of (Isah *et al.*, 2019) who reported that the quantity of bioethanol produced were 15.40, 18.00 and 20.00 cm^3 from Cassava peels and 6.80, 10.00 and 13.00 cm^3 from Sugarcane bagasse when *Saccharomyces cerevisiae* were used. This is an indication Sweet potato peels is significantly rich in carbohydrate than Irish potato peels as used in this study.

Table 2 showed an average yield of 63.33% with a density of 0.853 g/cm^3 from Sweet potato peels; while, the average yield for Irish potatoes was 40.83% with a density of 0.891 g/cm^3. This could equally be attributed to the high concentration of carbohydrates in the Sweet potato peel than in the Irish Potato peel that could be fermented in the presence of yeast to bioethanol. This finding is in accordance with the result of Isah *et al.* (2019), but with higher yield due to high carbohydrate content of cassava peel substrate and good pH conditions.

In the present results, the average yield of both Sweet and Irish potatoes is also higher than that reported by Isah *et al.* (2019) even though the quantity of substrate used differs. They reported 16.00% (v/v) and 9.03% (v/v) of ethanol from Cassava peels and Sugarcane bagasse using *S. cerevisiae*, respectively.

The densities obtained for the bioethanol produced fell within the same finding of(Isah *et al.*, 2019) who reported that the density of the bioethanol produced from Cassava peels and Sugarcane bagasse were (0.871 g/cm^3, and 0.893 g/cm^3), respectively.

The results of the proximate analysis of Sweet potato and Irish potatoes are presented in Table 3. The moisture content of Sweet potato peels is relatively lower than that of Irish potato peels with 5.10±0.01% and 8.75±0.63%, respectively. Ash content which is the index of mineral composition present in the samples is relatively higher in Sweet potato peel than Irish Potato peel with 4.00 ± 0.02% and 3.55 ± 0.05%, respectively. The lipid content which serves as the amount of fat and oil is relatively lower in Sweet potato peel than Irish potato with the value 2.99±0.04% and 4.48±0.03%, respectively. The values obtained for crude fiber, crude protein, and total carbohydrates content for Sweet potato peels were 3.50±0.03, 7.00±0.05, and 77.41±0.01%, respectively; while 4.50±0.55, 4.38±0.67, and 74.34±0.15% for Irish Potato peel, respectively.

Conclusion

The result of the comparative analysis revealed that Sweet Potato peels had a higher amount of carbohydrate content, which was found in this study to be 77.41% as compared to that of Irish Potato peels with a value of 73.34%. Sweet potato is rich in carbohydrate and could be harnessed for the production of bioethanol. Thus, the utilization of Sweet potato peel as a substrate for biofuel production will offer better waste management and recycling options by converting potato peels into value-added products and thereby mitigating environmental pollution challenge.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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