



RESEARCH ARTICLE

Fermentation-based bio-ethanol production: A study on agro-waste utilisation with *Saccharomyces cerevisiae*

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Abstract

This research discusses how agro-waste like sugarcane bagasse, orange peels and banana peels could be converted into bioethanol using the hydrolysis and fermentation process involving the *Saccharomyces cerevisiae*. Biomass ethanol also supplies 10–14 % of the world energy needs and this is a step in the right direction in relation to such problems like global warming and fossil fuel depletion. After washing and drying the recovered wastes, the lignocellulosic substrates were pre-treated using dilute acid hydrolysis, whereas the orange peels were pre-treated using a direct extraction process. The fermented samples of the samples that had been hydrolysed were inoculated with the yeast and allowed to ferment in a period of 20 days under conditioned laboratory tests. The determination of the concentration of ethanol in each of the samples was carried out using the potassium dichromate titration procedure. Sugarcane bagasse was determined to be the most yielding ethanol (1.11 %), followed by orange peels (0.38 %) and banana peels (0.23 %). These findings demonstrate that fermentable sugars in agro-waste can be a low cost and efficient source of ethanol. This approach has a two-fold benefit as it employs waste resources other than in the production of sustainable biofuels, which is significant in the potential of renewable energy-related applications and enhanced control of agricultural wastes. These results will support the development of biofuel and effective use of agricultural waste to generate renewable feedstock, as agro-waste will prove to be a viable feedstock source to produce ethanol.

Keywords: banana peels; bioethanol; biofuel; fermentation; orange peels; renewable energy; sugarcane bagasse

Introduction

Renewable energy is currently capturing a significant portion of the global headlines due to concerns over dwindling fossil fuel sources, rising population and industrialisation generating constantly growing fuel needs. Escalating petroleum costs have primarily driven the recent expansion of biofuel research, with significant emphasis placed on bioethanol, biodiesel, and bio-hydrogen. Biofuels may be classified under the categories of first- or second-generation biofuels (1). The first-generation biofuels mostly use conventional technologies to convert carbohydrates, lipids and oils or agro-industrial wastes. The second-generation biofuels are usually produced out of lignocellulosic biomass such as cellulosic plant biomass like stalks, stems and wood. Many second-generation biofuels such as bio-hydrogen, bio-methanol and mixed alcohols are under development (2). Ethanol has found its major application as fuel and nowadays an alternative to a renewable energy source. Petroleum-based fuel has more greenhouse gas emissions; therefore, ethanol is an environment friendly fuel because it

produces fewer greenhouse gases. The manufacturing of ethanol is ever-increasing by the day on a huge scale due to its diverse uses and demand. Ethanol is replacing oil and gas since they have become a key issue in the world in terms of supply and price. Worldwide ethanol production as fuel reached 32.35 billion gallons in 2012 (3).

Organic resources like plants or agricultural waste are used to make biofuels. Biomass sources are broadly categorised into woody and non-woody materials. Woody biomass encompasses forest residues, untreated wood products, and dedicated energy crops managed via short-rotation coppice (SRC) systems, such as willow (*Salix* spp.). Conversely, non-woody biomass comprises agricultural and food processing wastes, animal manure, and high-yielding energy crops, including maize (*Zea mays* L.), sugarcane (*Saccharum officinarum* L.), and rapeseed (*Brassica napus* L.). The amount of carbon dioxide (CO₂) absorbed during the fuel's manufacturing closely balances the amount released when energy is produced from biomass. As a result, this is often viewed as a 'carbon-neutral' process, and its application contributes to broader

CO₂ reduction targets (2). Primary constituents of lignocellulosic raw materials of plant origin are cellulose, lignin and hemicellulose. Another significant structural component is cellulose (40–55 % in wood and up to 90 % in cotton), a carbohydrate member which consists of 3-D-glucose units. It is further hydrolysed to simple sugars during hydrolysis. Plant tissue is made strong by lignin (18–25 %), which is formed of phenylpropane systems. The plant level affects its greater heat status depending on the quantity of it. Hemicellulose, mainly pentosans and hexosans (15–25 %), have a structural and nutritional function in plants (4).

This includes agricultural residues such as straw, bagasse, corn stover and rice husks, as well as organic waste streams like food waste and animal manure. The primary source of ethanol generation is crops. Using a lot of food waste to make ethanol can have major positive effects on the economy and the environment. Fruit wastes, such as bananas, oranges and sugarcane, are the finest choice since they contain considerable amounts of pectin, cellulose, hemicellulose and other sugars that, when hydrolysed, make them appropriate as fermentation substrates. By harnessing the energy content within these abundant waste materials, the extraction of ethanol offers a sustainable solution for both waste management and energy generation.

Using feedstock containing fermentable sugars, including glucose and properly regulated working conditions, biowaste fermentation produces bioethanol. In comparison to crude oil, bioethanol with a high energy content is produced by the breakdown of microbial bio waste. The energy equivalent of 1 L of crude oil is 1.7 L of bioethanol, which may be utilised in combustion engines (5). Alternative energy supplies are becoming more in demand due to the increased energy demand and volatile oil prices. Biomass crops, such as cereals, serve as a renewable feedstock for bioethanol production and represent a viable alternative to conventional gasoline. This utility is driven by high feedstock availability, declining production costs and a significant reduction in greenhouse gas emissions relative to fossil fuels (6). Bioethanol in its purest form is a non-coloured, odourless liquid that contains mild properties and has around 77 °C boiling point and a freezing point index of less than -110 °C (7). Most of these plants utilise the first-generation feedstock whose biomass is either sugar or starch, such as wheat or sugarcane.

The most well-known organism that is employed in ethanol production is *Saccharomyces cerevisiae* because it has a high yield of ethanol and it is also very tolerant. Currently, global ethanol production relies primarily on the fermentation of agricultural food crops, most notably corn and sugarcane. To realise a great economic and environmental impact, a large quantity of food waste can be exploited to manufacture ethanol (8). Utilisation of fruit waste for

bioethanol production is one of the best options. The utilisation of agro-waste for ethanol production not only provides an eco-friendly alternative to conventional fossil fuels but also offers additional environmental benefits. Moreover, ethanol production from agro-waste can contribute to rural development and economic growth by providing additional income opportunities for farmers and promoting local bioenergy industries (9). The objective of this study is to determine the bio-ethanol production from agro-waste (sugarcane bagasse, orange peels and banana peels) produced through a fermentation process using yeast *S. cerevisiae*.

Materials and Methods

Culture maintenance

Cultures of *S. cerevisiae* were collected from the Department of Microbiology, Dolphin (PG) Institute of Biomedical and Natural Sciences, Dehradun. *Saccharomyces cerevisiae* was maintained in yeast mannitol broth (YMB) agar slants and plates at 28 °C. The growth was confirmed by the whitish round or ovoid colonies on the agar plates after an incubation time of 2–3 days. These culture plates and slants were then sealed and stored at 4 °C. Yeast mannitol broth contains the essential nutrients (like yeast extract (0.1 %), mannitol (1 %) and other salts like magnesium sulphate (0.02 %), dipotassium phosphate (0.05 %), sodium chloride (0.01 %), calcium chloride (0.1 %) required for yeast growth and 2 % agar as well. The pH was adjusted to 6.8–7.0 and autoclaved at 121 °C for 15 min.

Preparation and pre-treatment of sugarcane bagasse, orange peels and banana peels for bioethanol production

Sugarcane bagasse, orange peels and banana peels were collected from local markets of Manduwala and Suddhowala, Dehradun, properly washed, cut into small pieces and air dried for few days. The dried biomass was grinded into fine powder and sieve by a mixer grinder (Fig. 1).

Hydrolysis of sugarcane bagasse and banana peels

A 20 g sample of finely powdered bagasse and peels was weighed and transferred into a 500 mL conical flask. Then, 198 mL of distilled water was added, and the flask was swirled to thoroughly disperse the sample. Finally, 2 mL of concentrated (98 %) sulfuric acid (H₂SO₄) was introduced to achieve a 1 % (v/v) acid concentration and a final liquid volume of 200 mL (Fig. 2) (10).

Preparation of culture medium

Nutrient broth medium was prepared by dissolving a 10 g sample of nutrient broth powder in 60 mL of distilled water and autoclaving for 20 min at 121 °C and 15 PSI. *Saccharomyces cerevisiae* was subsequently inoculated under a laminar air flow to prevent contamination. The yeast was then transferred into the broth

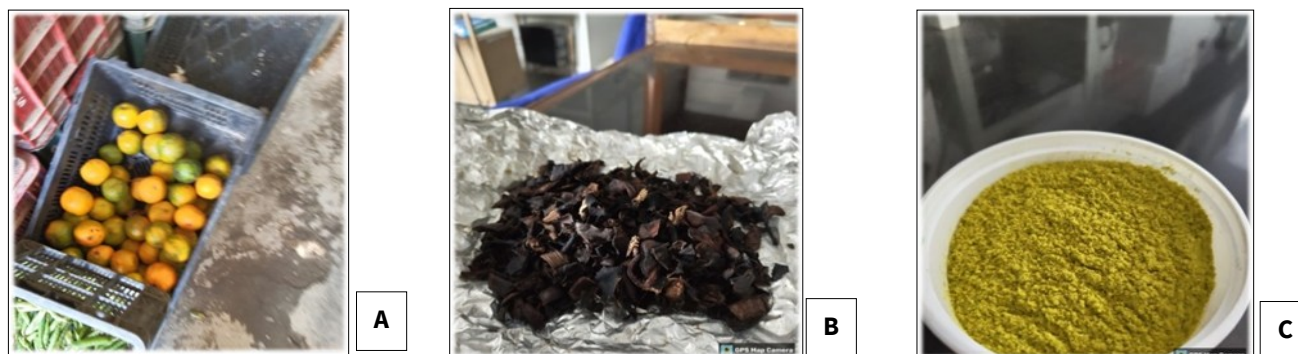


Fig. 1. (A) Fruits collected from local markets; (B) cut into small pieces and dried; (C) grind into fine powder.

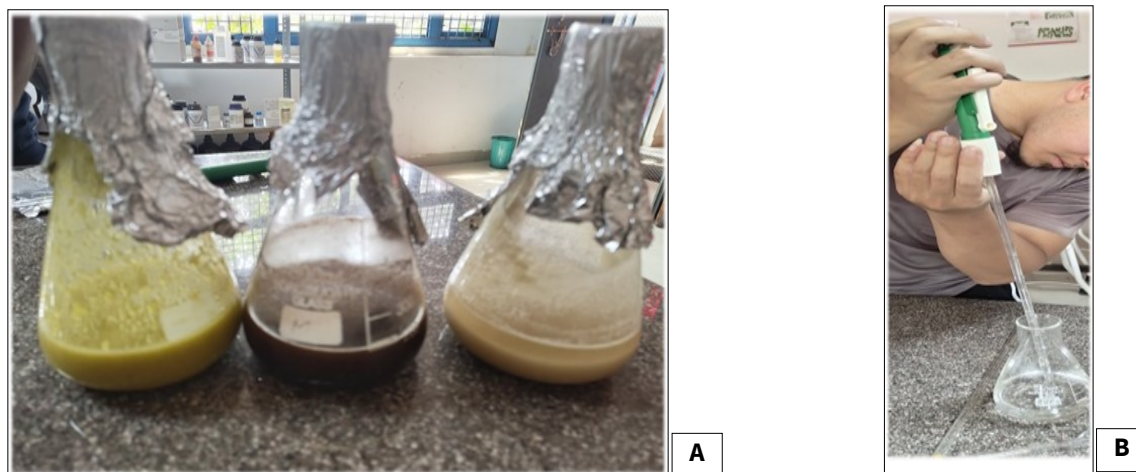


Fig. 2. (A) Powdered sample was added; (B) transfer of sulfuric acid.

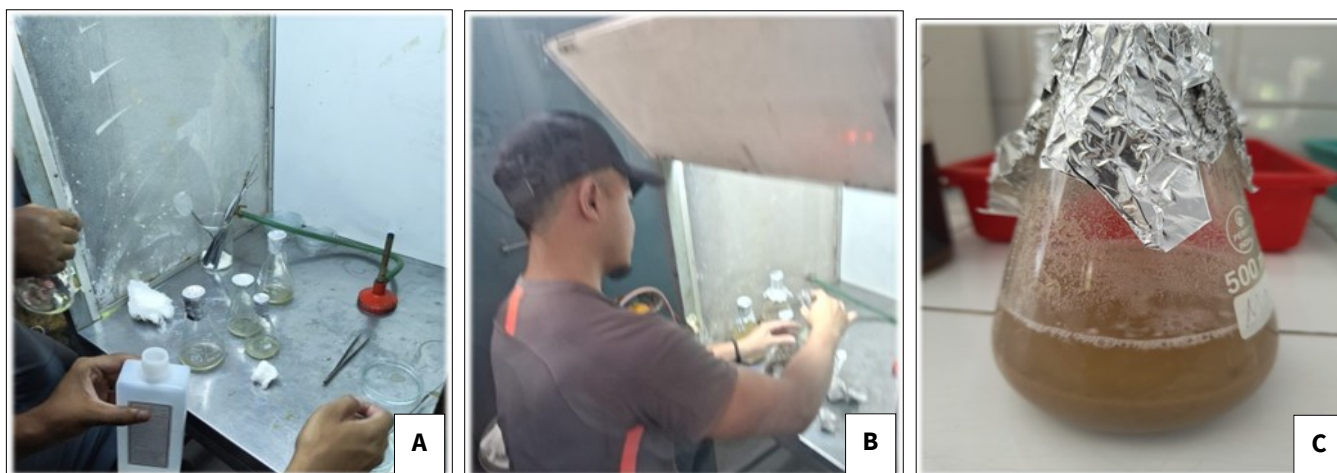


Fig. 3. Successively transfer of yeast in growth medium under control condition (A, B and C).

sample under a laminar air flow and the inoculated samples were incubated for 24 hr to facilitate fungal growth. After 24 hr, 20 mL of the yeast sample was transferred into each of the powdered samples and incubated for 20 days (11). The samples were then transferred into a centrifugal tube and centrifuged at 5000 rpm for 5 min and stored for further analysis (Fig. 3).

Determination of ethanol

A potassium dichromate solution was used for determination, following the preparation of the required reagent solutions (12). A 10 mL sample was transferred into a 100 mL volumetric flask and diluted to volume with distilled water. A 20 mL aliquot of this diluted material was pipetted into a conical flask, followed by the addition of 10 mL of acid dichromate solution via a measuring cylinder. The flask was loosely stoppered and heated in a water bath at 40–50 °C for 20 min. After cooling, 1 mL of a 1.2 mol/L potassium iodide solution was added, and the mixture was titrated against a standard thiosulfate solution. When the initial brown colour faded to a yellowish-green, 1–2 mL of starch indicator was added. The titration continued until the sharp disappearance of the blue starch-iodine complex signified the equivalence point (11). Because of the reduction of dichromate to chromium (III) ions, the solution did not become perfectly colourless at the endpoint but retained a light green background hue, the exact shade of which varied slightly depending on the specific sample matrix.

Titration calculations

To determine the ethanol content of the sample, triplicate consistent titration measurements were performed using sodium thiosulfate

($\text{Na}_2\text{S}_2\text{O}_3$) from which the average volume consumed was calculated ($n = 3$). A parallel control titration was executed using a modified volume of sodium thiosulfate to establish a baseline for comparison. The precise volume of titrant consumed was utilised to calculate the moles of $\text{S}_2\text{O}_3^{2-}$ reacted. The stoichiometric relationship between the moles of ethanol ($\text{C}_2\text{H}_5\text{OH}$) and $\text{S}_2\text{O}_3^{2-}$ was determined based on the underlying redox chemistry: 6 moles of $\text{S}_2\text{O}_3^{2-}$ is chemically equivalent to 1 mole of dichromate ($\text{Cr}_2\text{O}_7^{2-}$) and 2 moles of $\text{Cr}_2\text{O}_7^{2-}$ corresponds to 3 moles of $\text{C}_2\text{H}_5\text{OH}$. Consequently, a stoichiometric ratio was established where 1 mole of $\text{S}_2\text{O}_3^{2-}$ is equivalent to 0.25 moles of $\text{C}_2\text{H}_5\text{OH}$. The resulting molar concentration (mol/L) was subsequently converted into a mass-volume percentage (g/100 mL) to express the final alcohol content (13).

Preparation for orange peels

Due to the unsuitability of orange peels for conventional hydrolysis, a direct processing method was adopted. A 20 g sample of powdered orange peel was suspended in 250 mL of distilled water within a 500 mL conical flask. The initial pH of the mixture was adjusted to 5.5. The flasks were then sterilised by autoclaving at 121°C for 20 min (11). Following this thermal treatment, the prepared substrate was integrated into the subsequent steps of the standard culture medium preparation protocol.

Results

The outcomes obtained in the present work, provide a clear example of how various agro-waste materials are effective in the production of bioethanol by fermentation with the help of

S. cerevisiae. The titer of ethanol in the different substrates differed significantly which is an indication of variance in the availability of fermentable sugars and composition of the substrates (Table 1). Ethanol estimation in a quantitative way was performed using the potassium dichromate titration method that was able to provide a good comparison of samples. The colour change was so clear during titration and this was an indication that there was ethanol in all the fermented substrates. The amount of sodium thiosulfate used in the process of titration displayed quantifiable change, which represents change in ethanol concentration (Table 2). These differences were also substantiated by the molar value and percentage ethanol yields. The results showed clearly that fermentation performance is substrate-dependent when both are in identical experimental conditions. The experimental results substantiate the viability of the selected agro-wastes as highly promising, renewable feedstocks for bioethanol production. By utilising these organic residues, the study demonstrates an effective pathway to valorise agricultural by-products while advancing sustainable, low-cost bioenergy generation.

Comparative ethanol yield and titration behaviour

A comparison study on the production of ethanol from various agro-waste sources showed variability in the fermentation efficiency as depicted in Table 3. Of the three agro-waste sources, the highest ethanol production was found to be in sugarcane bagasse (1.11 %), followed by orange peels (0.38 %) and then banana peels (0.23 %). A possible reason for the improved production of ethanol from the former source might be the resultant availability of fermentable sugars following dilute acid hydrolysis. Additionally, the differences in the end points of titration for the various sources can be inferred from the consumption of sodium thiosulfate, as depicted in Table 3, confirming the differences in the level of ethanol production.

Process efficiency and reliability of method

In fact, the potassium dichromate titration technique has been effective in detecting the concentration of ethanol in fermented samples, as indicated by the distinct changes in the colour noticed during the titration processes (Fig. 4 and 5). There were clear transitions from blue to colourless, showing the success of the oxidation of the components in the samples. Some minor cloudiness noted in sample constants hinted towards the possible presence of other reducible compounds, especially for fruit peel substrates, though it did not have a significant impact on the final

estimation of ethanol. The ability to read similar titrations, as well as the ability to determine similar ethanol percentages, indicates the reliability associated with the method applied within the analysis. In sum, the data obtained confirms that substances within agro-waste substrates can be effectively converted into bioethanol using *S. cerevisiae*.

The raw ethanol yield was quantified via a standard redox titration method. In this procedure, the sample was titrated against a standardised sodium thiosulfate solution to determine the concentration of unreacted dichromate ions. A starch-iodine complex was utilised as an indicator, with the equivalence point visually identified as the point where the distinct blue colour completely dissipated to yield a clear, colourless solution, as depicted in Fig. 4.

The variations in solution colour (Fig. 5) reflect differing ethanol concentrations across the samples. Interfering oxidising compounds within the fruit peels produced visible cloudiness in certain solutions. The corresponding quantitative analyses and calculations are detailed in Table 1, 2 and 3.

Discussion

The production of ethanol from agro-waste such as sugarcane bagasse, orange peels and banana peels involves several critical steps, beginning with the pre-treatment of these materials. The pretreatment using acid hydrolysis is essential for breaking down the lignocellulosic components, thus exposing the simple sugars that yeast can utilise (14). This is followed by alcoholic fermentation that takes 20 days under the influence of *S. cerevisiae*. The sugar content in the agro-waste is fermented by the yeast and it is converted to ethanol in an anaerobic environment. Titration data and subsequent calculation steps are distributed across three tables: Table 1 presents the raw titration results, and Table 2 outlines the moles of sodium thiosulfate calculated from the consumed volumes. Table 3 summarises the final parameters used to determine alcohol content, including the volume, the moles of ethanol in the sample dilution, and the final ethanol percentage (g/100 mL).

Saccharomyces cerevisiae undergoes physiological changes during fermentation. It is interesting to note that the initial stages of the process have an accumulation of unsaturated fatty acids and sterols that are essential in the nutrition of the yeast (15). These

Table 1. Titration results of sugarcane bagasse, banana peel and orange peel

Average volume of sodium thiosulfate used for control	Average volume of sodium thiosulfate used for sample		
	Sugarcane bagasse substrate	Banana peels substrate	Orange peels substrate
21.2	18.2	6.6	14.2
21.6	18	6.2	13.4
21.2	18.4	6.2	14.1
Average			
21.3	18.2	6.3	13.9

Table 2. Number of moles of sodium thiosulfate calculated from the volume

Sugarcane bagasse	Banana peels	Orange peels
$M_1V_1 = M_2V_2$	$M_1V_1 = M_2V_2$	$M_1V_1 = M_2V_2$
$M_1(3.1) = 0.03(1000)$	$M_1(15) = 0.03(1000)$	$M_1(8.9) = 0.03(1000)$
$M_1 = 9.67$	$M_1 = 2$	$M_1 = 3.37$

Table 3. Final volume, moles and percentage yield of ethanol from agro-waste fermentation

	Final volume used to determine alcohol concentration	Number of moles of ethanol in sample dilution	Percentage of ethanol produced (gm/100 mL)
Sugarcane bagasse	$21.3 - 18.2 = 3.1$ mL	$9.67 \times 0.25 = 2.41$ mol	$2.41 \times 46.07 / 100 = 1.1$ %
Banana peels	$21.3 - 6.3 = 15$ mL	$2 \times 0.25 = 0.5$ mol	$0.5 \times 46.07 / 100 = 0.23$ %
Orange peels	$21.3 - 13.9 = 8.9$ mL	$3.37 \times 0.25 = 0.84$ mol	$0.84 \times 46.07 / 100 = 0.38$ %

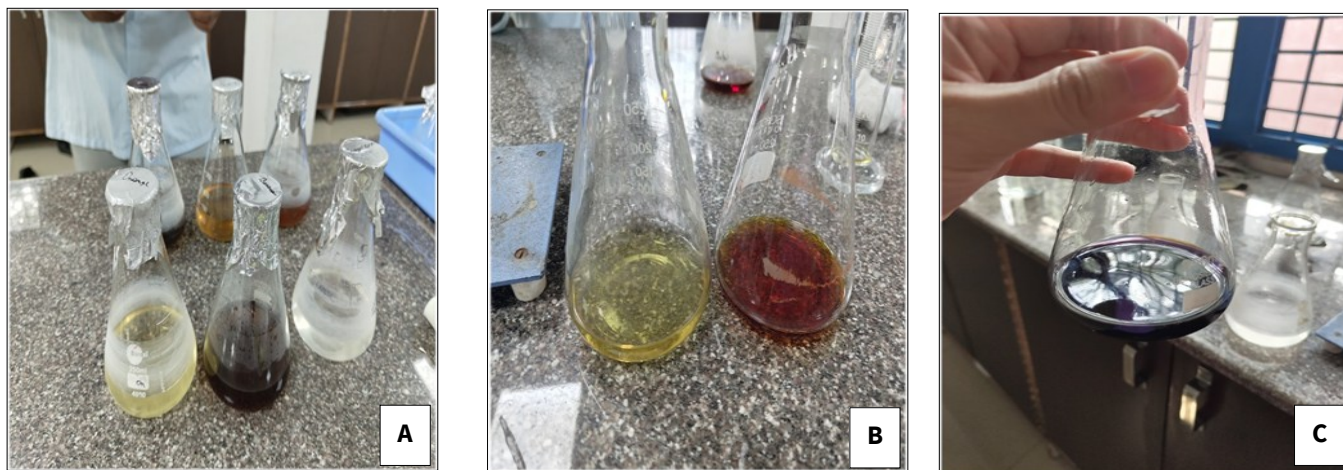


Fig. 4. (A) Aliquot sample; (B) sample turning red after the addition of potassium iodide, titration to a lime green end point; (C) blue colour formation after the addition of starch solution.

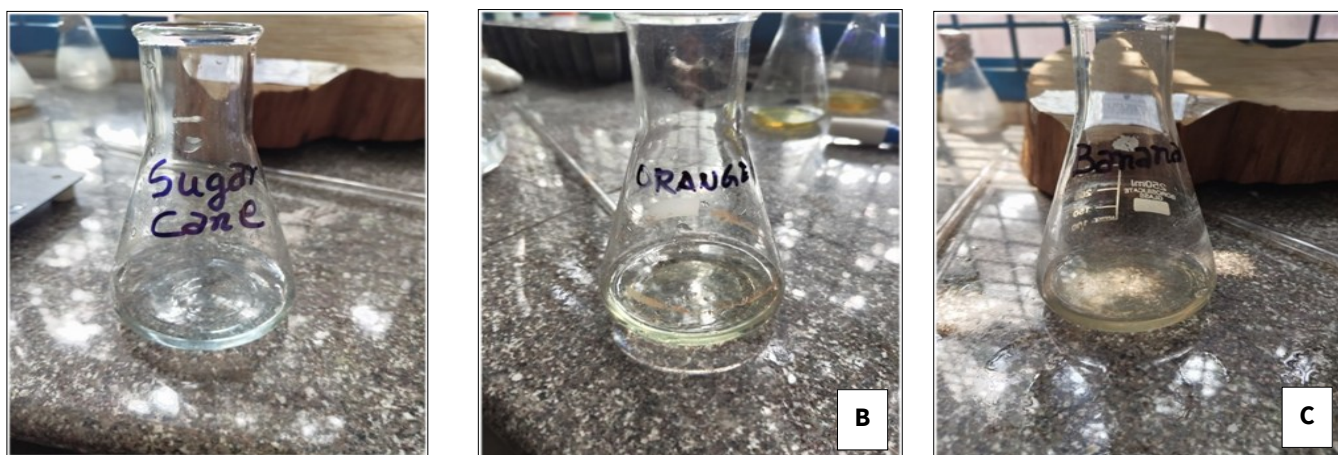


Fig. 5. The end products after titration. The differences in colour showing different concentration of ethanol presented in A, B and C sample.

nutrients get depleted as the fermentation continues and the concentration of sugars in the fermentation medium reduces as they are transformed to ethanol (16). Fermentation is considered complete when the percentage of sugar converted to ethanol remains almost 100 %.

The pH of the fermentation broth tended to decline within the fermentation period of five days, which is one of the important parameters affecting the yield of ethanol. The highest production of ethanol was monitored at the 72 hr of incubation in which the pH range was 3.6–4.0 (17). This acidic condition does not only give *S. cerevisiae* an advantage in ethanol production but also it reduces the chances of bacterial contamination (18). As the pH decreases, broth will be more acidic owing to the rise in acidity hence enhancing the metabolic activities of the organism yeast that increases the production of ethanol.

Residual sugar in the fermentation medium declines progressively as yeast metabolises available carbohydrates for growth, maintenance and ethanol production (19). This consumption peaks during the initial exponential growth phase, which drives active, rapid fermentation (20). Consequently, the specific gravity of the medium concurrently decreases, reflecting the reduction in total soluble solids as fermentable sugars are converted to ethanol (21).

The sugarcane bagasse was the most efficient in producing ethanol when compared to other raw materials, maybe because of the good amount of sugar that was available to be utilised by the yeast. The comparative analysis showed that the amount of ethanol obtained using sugarcane bagasse was 1.1 %, orange peels 0.38 %

and banana peels 0.23 % (Table 3). These findings indicate that most of the agricultural wastes have great potential as ethanol sources.

The results of present work showed that sugarcane bagasse, orange peels and banana peels are all potential candidates to perform as a substrate in ethanol production of the agricultural wastes under study. The superior sugarcane bagasse yield highlights its capability of being a raw material of choice, especially in the manufacturing of industrial ethanol and the other agro-wastes also offer robust opportunities, which can be used to promote sustainable waste disposal and the generation of biofuels.

Conclusion

This study proves that agricultural waste, specifically sugarcane bagasse, orange peels and banana peels can be effectively transformed into bioethanol using *Saccharomyces cerevisiae*. In this study, sugarcane bagasse yielded the highest ethanol production (1.10 %), followed by orange peels (0.39 %) and banana peels (0.23 %); this highlights its superior potential as a feedstock. These results underscore the importance of substrate composition and optimum fermentation conditions particularly pH, in enhancing ethanol production. This approach offers a sustainable solution for agricultural waste management while simultaneously contributing to renewable energy generation. Overall, these findings emphasise the dual benefits of effective waste utilisation and biofuel production. To further increase ethanol yield and production efficiency, future studies focusing on process optimisation and strain improvement are recommended.

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Authors' contributions

RTC, MKR and ST carried out the studies and drafted the manuscript. SG, PL and AU contributed to the sequence alignment. SS and SD participated in the design to the study and performed the statistical analysis. MR, HB and AD comprehended the study and participated in its design and coordination. AB and NS carried the final review and editing of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

- Kumar P, Singh B, Patwardhan SB, Dwivedi S, Sarkar S, Roy A, et al. Brief introduction to first, second, and third generation of biofuels. In: Bio-Clean Energy Technologies. Vol. 1. Singapore: Springer Nature Singapore; 2022. p. 1–29. https://doi.org/10.1007/978-981-16-8090-8_1
- Ingale S, Joshi SJ, Gupte A. Production of bioethanol using agricultural waste: Banana pseudo stem. Brazilian Journal of Microbiology. 2014;45:885–92. <https://doi.org/10.1590/S1517-83822014000300018>
- Ruhul AM, Saquib H, Sarker M. Simulation of ethanol production by fermentation of molasses. Journal of Engineering. 2013;1(4):69–73.
- Hammond GP, Mansell RV. A comparative thermodynamic evaluation of bioethanol processing from wheat straw. Applied Energy. 2018;224:136–46. <https://doi.org/10.1016/j.apenergy.2018.04.123>
- Sudalai S, Prabakaran S, Varalaksmi V, Kireeti IS, Upasana B, Yuvasri A, et al. A review on oilcake biomass waste into biofuels: Current conversion techniques, sustainable applications, and challenges: Waste to energy approach (WtE). Energy Conversion and Management. 2024;314:118724. <https://doi.org/10.1016/j.enconman.2024.118724>
- Ibeto CN, Ofoefule AU, Agbo KE. A global overview of biomass potentials for bioethanol production: A renewable alternative fuel. Trends in Applied Sciences Research. 2011;6(5):410–25. <https://doi.org/10.3923/tasr.2011.410.425>
- Umeghalu IC. Potentials of selected crops for biofuel production [doctoral dissertation]. Awka (Nigeria): Department of Agricultural and Bioresources Engineering, Faculty of Engineering, Nnamdi Azikiwe University; 2016.
- Parapouli M, Vasileiadis A, Afendra AS, Hatziloukas E. *Saccharomyces cerevisiae* and its industrial applications. AIMS Microbiology. 2020;6(1):1–32. <https://doi.org/10.3934/microbiol.2020001>
- Nwosu-Obieogu K, Chiemenem L, Adekunle K. Biodiesel production from plant seed oil—a review. International Journal of Scientific Research in Science, Engineering and Technology. 2016;2(3):738–49.

- Braide W, Kanu IA, Oranusi US, Adeleye SA. Production of bioethanol from agricultural waste. Journal of Fundamental and Applied Sciences. 2016;8(2):372–86. <https://doi.org/10.4314/jfas.v8i2.14>
- Shilpa C, Malhotra G, Chanchal. Alcohol production from fruit and vegetable waste. International Journal of Applied Engineering Research. 2013;8(15):1749–56.
- Caputi A, Ueda M, Brown T. Spectrophotometric determination of ethanol in wine. American Journal of Enology and Viticulture. 1968;19(3):160–5. <https://doi.org/10.5344/ajev.1968.19.3.160>
- Meena RK, Sahu R, Shukla P, Thakur S. Bio-ethanol production from lignocellulosic banana waste using co-culture techniques. Current Trends in Biotechnology and Pharmacy. 2015;9(3):259–65.
- Das H, Singh SK. Useful byproducts from cellulosic wastes of agriculture and food industry—a critical appraisal. Critical Reviews in Food Science and Nutrition. 2004;44(2):77–89. <https://doi.org/10.1080/10408690490424630>
- Wyman C. Handbook on bioethanol: Production and utilization. Boca Raton (FL): CRC Press; 1996.
- Verbelen PJ, Saerens SM, Van Mulders SE, Delvaux F, Delvaux FR. The role of oxygen in yeast metabolism during high cell density brewery fermentations. Applied Microbiology and Biotechnology. 2009;82(6):1143–56. <https://doi.org/10.1007/s00253-009-1909-8>
- Nester EW, Anderson DG, Roberts CE Jr, Nester MT. Microbiology: A human perspective. 5th ed. New York: McGraw-Hill Higher Education; 2005.
- Braide W, Nwaoguikpe RN. Production of ethanol from cocoyam (*Colocasia esculenta*). International Journal of Plant Physiology and Biochemistry. 2011;3(3):64–6.
- Schügerl K. Agriculture wastes. A source of bulk products? Chemical Engineering & Technology. 1994;17(5):291–300. <https://doi.org/10.1002/ceat.270170502>
- Amerine MN. Encyclopida Americana. International edition; 1988.
- Okeke BC, Obi SK. Saccharification of agro-waste materials by fungal cellulases and hemicellulases. Bioresource Technology. 1995;51(1):23–7. [https://doi.org/10.1016/0960-8524\(94\)00061-5](https://doi.org/10.1016/0960-8524(94)00061-5)

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