

Groundnut shells to bioethanol: comparative yeast performance and ethanol characterization

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Received: 23.01.2026

Accepted: 08.04.2026

Early view: 21.04.2026

Published: XX.07.2026

Citation: Adiya, Z.I.S.G, Ahmad, M, & Olamilekan, M.S.A. (2026). Groundnut shells to bioethanol: comparative yeast performance and ethanol characterization.

The European chemistry and biotechnology journal, 6, 00-00. <https://doi.org/10.62063/ecb-80>

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Peer Review: Double Blind Refereeing.

Ethics Statement: It is declared that scientific and ethical principles were followed during the preparation of this study and all studies utilized were indicated in the bibliography (Ethical reporting: editor@euchem-bioj.com).

Plagiarism Check: Performed (iThenticate). Article has been screened for originality.

Abstract

The effect of three different yeast species (*Saccharomyces cerevisiae*, *Saccharomyces cariocanus*, and *Schizosaccharomyces pombe*) on bioethanol production from groundnut shells was investigated at exactly same process conditions i.e temperature of 35 and five days fermentation period. The physicochemical properties of the generated bioethanol from the optimal yeast species (*Saccharomyces cariocanus*) was also evaluated. It was found that the descending sugar concentrations were similar across all the three species (72.76–74.35 mg/dL) with negligible variations. However, significant variations were observed in bioethanol quantity and percentage yield. *Saccharomyces cariocanus* generated the highest quantity of bioethanol (102 mL) and yield (34%), followed by *saccharomyces cerevisiae* (90 mL, 30%), with *Schizosaccharomyces pombe* having the lowest performance (73 mL, 24%). This reveals the superior fermentative efficiency of *Saccharomyces cariocanus* in converting sugars to ethanol. The physicochemical properties of bioethanol produced by *Saccharomyces cariocanus* were generally comparable to ASTM standards (indicating acceptable fuel quality) with slight deviations in density and boiling point which could be attributed to impurities. The study emphasizes the importance of yeast species selection in enhancing bioethanol production from groundnut shell feedstocks and identifies *Saccharomyces cariocanus* as a promising yeast for effective ethanol fermentation. It is concluded that groundnut shells are promising feedstock for bioethanol production but further process optimization is required to fully meet fuel standards.

Keywords: Bioethanol, Biomass, Fermentation, Groundnut shells, Hydrolysis, Yeast.

Introduction

The world population is expected to reach 10 billion by the end of 2050 (Abdul Kareem Joyia et al., 2024). This means there will be a sharp increase in energy demand, increased pressure on energy resources, an acceleration of renewable energy expansion, energy efficiency and technological innovation, as well as environmental and climate impacts. Overall, this will significantly affect energy production, demand and consumption. The rising demand for energy, coupled with the environmental and economic limitations of fossil fuels (Owusu & Marfo, 2023), further depicts the critical need to develop and enhanced sustainable alternative energy sources (Adiya & Shehu, 2022). The dependence on fossil fuels causes some global concerns, such as greenhouse gas emissions, environmental degradation, price instability, and long-term resource depletion (Zhang et al., 2023). The world is striving to meet development goals and mitigate climate change, thus, renewable and biomass-derived fuels have become significant gears of future energy (Das et al., 2023, Vasilakou et al., 2023).

Bioethanol is a clean fuel and one of the most promising substitutes for fossil fuels (Jain & Kumar, 2024, Kazmi et al., 2025). This is because it is biodegradable (Adiya et al., 2022), has a low to zero carbon footprint, and is well suited with present fuel infrastructures (Kazmi et al., 2025). Despite those obvious benefits, large-scale production of bioethanol relies strongly on finding cost-effective, abundant and nonfood biomass feedstocks. Groundnut shells are agricultural waste with little or zero use and are often underutilized or disposed of in an environmentally harmful way. They are generated in extensive amounts in several developing regions,



especially Nigeria. 51% of groundnut produced in the West African region comes from Nigeria, making it the largest groundnut producer. To be precise, Nigeria contributes 10% of the world production and 39% production in Africa. Before the fossil oil boom, groundnut was one of the main sources of income and foreign exchange earnings in Nigeria. Interestingly, groundnut production has been rising since 1984 due to increased productivity and area expansion, which strengthens the case for using groundnut shells as feedstock for bioethanol production in Nigeria (Ajeigbe et al., 2015, Adiya & Atiku, 2024). Moreover, groundnut shells are not only a good potential for second generation bioethanol feedstock, but they are also affordable, widely available, and does not compete with food resources, making it an appealing raw material for the production of sustainable fuels. To fully harness this potential of converting groundnut shells to bioethanol, intensive research is necessary to optimize conversion efficiency. This and rising demand for renewable and alternative energy sources form the basis of this study.

The aim of this study is to investigate the effect of three yeast species (*Saccharomyces cerevisiae*, *Saccharomyces cariocanus*, and *Schizosaccharomyces pombe*) on bioethanol production using groundnut shells as feedstock and determine the physicochemical properties of the bioethanol produced from the best specie. Converting groundnut shells biomass to bioethanol is a green way to deal with waste management and also support renewable energy production. It is highly important to find out how well different yeast species work in making bioethanol from groundnut shells. This is because fermentation efficiency varies between species, which directly affects the quantity and quality of ethanol produced as well as the feasibility of the process. Discovering the most effective yeast species aids in enhanced bioethanol production from groundnut shells. The physicochemical analysis of the ethanol produced from the optimal yeast species ensures that its quality adheres to fuel or industrial standard specifications, demonstrating its viability as a sustainable unconventional energy source. This study therefore advocates for sustainable energy development, value addition to agricultural residues and decreased reliance on fossil fuels.

Materials and methods

Sample collection and preparation

Groundnut shells were used for the study. Their choice for the study was based on their lignocellulosic composition, availability, and the fact that they are agro-industrial biomass residues (by products of agriculture or its related industry), thus considered as waste with little or zero use (Zheng et al., 2013, Adiya & Shehu, 2022, Adiya & Atiku, 2024). The feedstock was collected in polythene bags from Sokoto central market, Sokoto State, Nigeria. The groundnut shells were first sorted manually to remove dirt, stones, and other unwanted materials. The clean groundnut shells were dried (for five days at room temperature) to eliminate moisture in them. This was followed by size reduction of the samples (grinding to fine powder) using pestle and mortar and then sieved through 36 μm mesh (Adiya et al., 2022). The powdered sample served as the main feedstock for the production of bioethanol at a temperature of 35°C and a five-day fermentation period.

Isolation of yeast species

Saccharomyces cerevisiae yeast was obtained from the meat and vegetable market Sokoto state, Nigeria. The yeast species is already available in market and sold commercially for bread making (Amaefule et al., 2023). Pure cultures of *Saccharomyces cariocanus* and *Schizosaccharomyces pombe* were obtained from the Department of Microbiology, Usmanu Danfodiyo University, Sokoto, Nigeria. The strains were revived on Yeast Extract Peptone Dextrose (YPD) agar plates and incubated at 30°C for 48 hours prior to experimental runs.

Hydrolysis

One of the most commonly used chemical pretreatment methods is dilute acid hydrolysis (Fernandes et al., 2018). Dilute acid hydrolysis is preferred and chosen in studies over

concentrated acids hydrolysis owing to less inhibitor production, reduced equipment corrosion, and the absence of acid recycling, which in turn decreases investment, making the whole process more economical (Ceaser et al., 2025). Hydrolysis was carried out using 1% dilute sulfuric acid (H_2SO_4) (Torget et al., 2000). For each of the three yeast species, thirty grams (30 g) of the powdered groundnut shell was measured into a separate conical flask. The flasks were treated with 300 mL of 1% H_2SO_4 , then covered with cotton wool and aluminum foil paper. The mixtures were heated in a water bath at 60-70 for 1 hour. Then left to stand for 24 hours before filtration to remove solid residue from the liquid. The remaining solid residue was washed repeatedly with distilled water until neutralized pH was achieved and then filtered again (Sani et al., 2021). The filtrate was collected and analyzed for reducing sugar content.

Fermentation

A natural process used to break larger organic molecules into small or simpler ones is called microbial fermentation (Tse et al., 2021). The use of microorganisms in fermentation of sugars is one of the most significant steps during bioethanol production (Zabed et al., 2014). Sugar fermentation using a yeast species is among the ancient practices in biotechnology, commonly used for the generation of alcoholic drinks (beer and wine). Presently, this biotechnology is industrially used to generate ethanol fuel from biomass (Kosaric & Velikonja, 1995, Zabed et al., 2014).

Each yeast species (*Saccharomyces cerevisiae*, *Saccharomyces cariocanus* and *Schizosaccharomyces pombe*) was added to its own separate conical flask containing the acid hydrolyzed mixture. The flasks were properly labeled, covered with cotton wool and wrapped in aluminium foil, then secured with a masking tape as reported by Adiya et al., 2020 (Adiya et al., 2022). The samples were shaken and incubated for five days at 35°C.

Distillation of the fermented broth

The distillation of the fermented broth was carried out using simple distillation. This is because pure ethanol has a low boiling point of 78.3°C, hence, it turns into a vapor state before water (boiling point of 100°C) and can be condensed and separated (Mangwanda et al., 2021).

The fermented mixture was placed into a round bottom flask connected to a condenser through which tap water was running. The flask was heated using a heating mantle and distillation was continued until the vapor temperature reached roughly 78°C. The distillates were collected in a receiving flask at the end of the condenser (Adiya et al., 2022). All experiments were performed in triplicate, and results are presented as mean values.

Analysis and characterization

Determination of reducing sugar

1 mL of each filtered sample was mixed with 2mL of dinitro salicylic acid (DNS) reagent in a lightly capped test tube. The mixture was heated at 90°C in a water bath for 15 minutes until a red-brown coloration was developed. The solution was allowed to cool to room temperature

Table 1. Fermentation conditions.

Parameters	Conditions
Temperature	35°C
Duration	5 days
Feedstock quantity per run	30g
Yeast concentration	3g
pH	Neutral

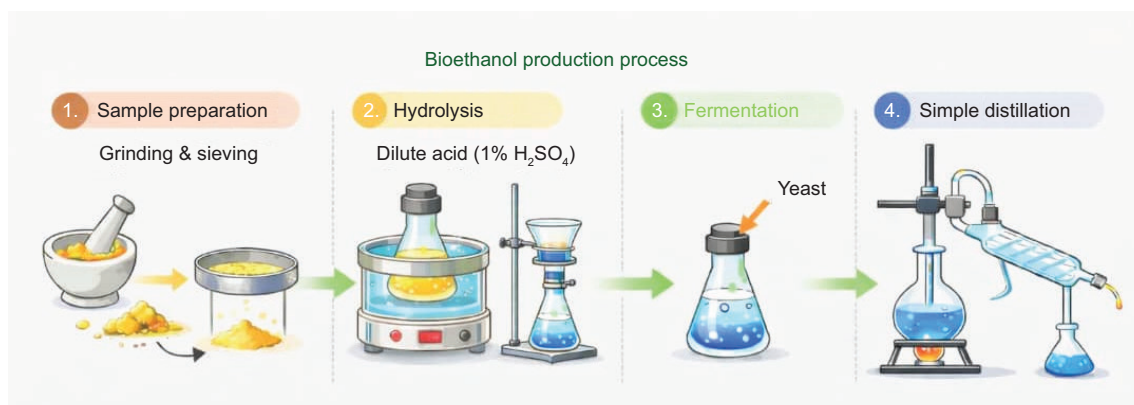


Figure 1. Schematic representation of bioethanol production process.

before the absorbance was measured using a UV-Vis spectrophotometer at 540nm. The procedure was repeated for each filtered sample (Adiya et al., 2022).

$$C.R.S = \frac{\text{Absorbance of sample}}{\text{Absorbance of glucose standard}} \times \text{Concentration of standard}$$

Determination of the presence of ethanol

Two drops of acidified 0.1 M potassium dichromate ($K_2Cr_2O_7$) were added to 2 ml of the distillate produced and gently heated for a few minutes in a water bath. The content of the test tube changed to a green color, revealing the presence of primary or secondary alcohol such as ethanol (Adiya et al., 2022).

Determination of the quantity of bioethanol produced

The distillate collected over a slow heat at 78°C was measured using a measuring cylinder and the quantity of ethanol produced was recorded in mL.

Determination of percentage yield of bioethanol produced

The formula below was used to calculate the percentage yield of the bioethanol produced (Nazli, 2020).

$$\text{Percentage yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

The actual yield refers to the final distillate while the theoretical yield is the acidic-hydrolyzed solution (Nazli, 2020; Sani et al., 2021).

Physiochemical characterization of bioethanol

The pH, density, viscosity, flash point and boiling point of the produced bioethanol were analyzed using ASTM standards D1293, D4052, D445, D93 and D1078, respectively.

Results and discussion

Effect of yeast species on bioethanol produced from groundnut shell as feedstocks

The results presented in Figure 2 and Table 2 show that the type of yeast species used for bioethanol production has a vast effect on how well reducing sugar is used, the quantity of bioethanol produced and percentage yield of the produced bioethanol even when the feedstock (groundnut

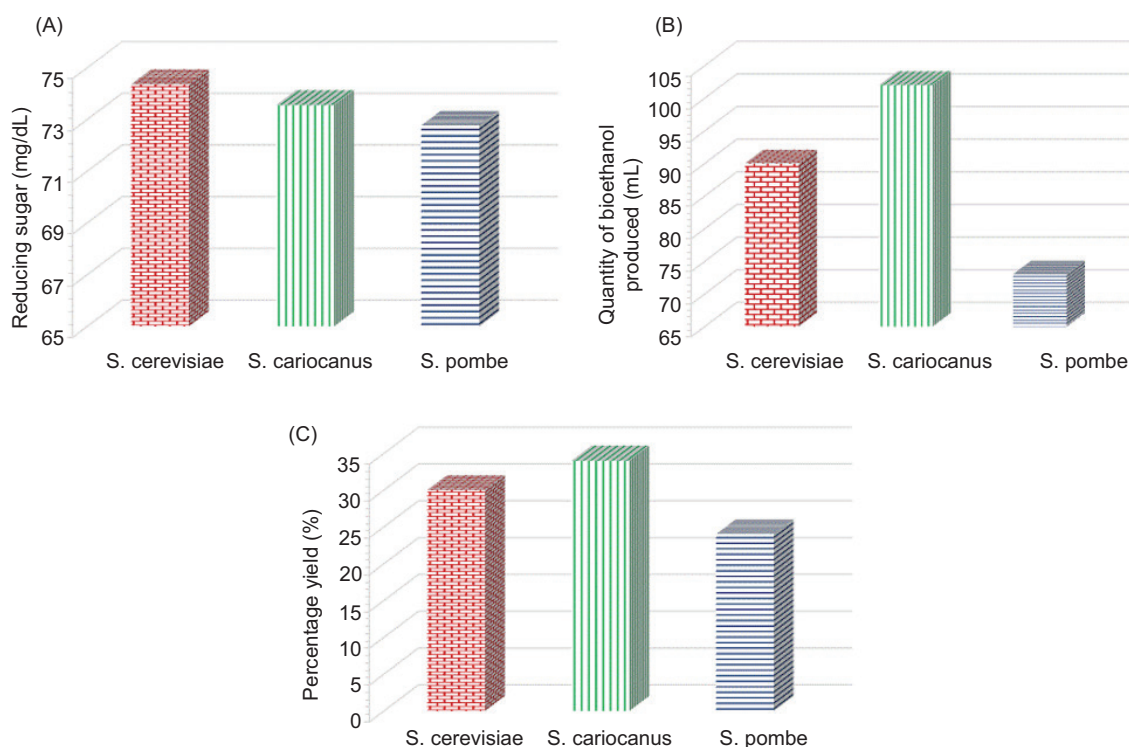


Figure 2. Effect of yeast species on (A) Reducing sugar (B) Quantity of bioethanol produced (C) Percentage yield of bioethanol produce from groundnut shells.

Table 2. Effect of yeast species on reducing sugar, quantity of bioethanol and percentage yield of bioethanol produce from groundnut shells.

No.	Yeast species	Value
Reducing sugar (Mg/dL)		
1	<i>Saccharomyces cerevisiae</i>	74.35
2	<i>Saccharomyces cariocanus</i>	73.55
3	<i>Schizosaccharomyces pombe</i>	72.76
Quantity of Bioethanol produced (mL)		
1	<i>Saccharomyces cerevisiae</i>	90
2	<i>Saccharomyces cariocanus</i>	102
3	<i>Schizosaccharomyces pombe</i>	73
Percentage yield (%)		
1	<i>Saccharomyces cerevisiae</i>	30
2	<i>Saccharomyces cariocanus</i>	34
3	<i>Schizosaccharomyces pombe</i>	24

shells) and other process variables such as temperature and fermentation time etc. are kept the same.

The reducing sugar values gotten for all yeast species were comparatively close, ranging from 72.76 to 74.35 mg/dL. *Saccharomyces cerevisiae* has the highest reducing sugar concentration, *Saccharomyces cariocanus* and *Schizosaccharomyces pombe* recorded slightly lower values as shown in Figure 2(A). However, the slight variations between the species meant that sugar availability was not a restrictive feature and that each yeast species was capable of using the sugars released from the groundnut shells hydrolysate.

Although there was a slight and negligible difference in the decreasing sugar concentration of the yeasts, significant differences were seen in the quantity of bioethanol produced. *Saccharomyces cariocanus* generated the highest volume of bioethanol (102 mL), followed by *saccharomyces cerevisiae* (90 mL), while *Schizosaccharomyces pombe* has the lowest quantity (73 mL). This indicates that *Saccharomyces cariocanus* had a better capacity to transform fermentable sugars into ethanol. Direct comparison of the present study with previous studies is not possible due to differences in feedstock, yeast type and most importantly process operating conditions. However, previous studies have shown that better performance in any yeast type when comparing different yeast species is probably due to more metabolic efficiency, higher ethanol tolerance, or improved adaptation to inhibitory compounds that may be present in lignocellulosic hydrolysates (Demeke et al., 2013, Pilap et al., 2022, Smith et al., 2014). *Saccharomyces cerevisiae*, commonly utilized in ethanol production (Mohd Azhar et al., 2017, Nissen et al., 2000) also produced a good quantity of ethanol as shown in Figure 2(B), proving its efficiency in bioethanol fermentation. On the other hand, the low quantity of ethanol generated using *Schizosaccharomyces pombe* could be attributed to less efficient fermentation, formation of biomass and low molecular weight metabolites or decreased tolerance to fermentation conditions (Papapetridis et al., 2017, Nissen et al., 2000).

When the percentage yield of the generated bioethanol was calculated, it depicts the same trend observed in the quantity of bioethanol produced as shown in Figure 2(C). *Saccharomyces cariocanus* still has the highest yield (34%), signifying the most effective conversion of the feedstock to ethanol. This was followed by *saccharomyces cerevisiae* with a yield of 30%, while *Schizosaccharomyces pombe* had the least yield (24%).

The superior yield obtained by *Saccharomyces cariocanus* further supports its effective and better fermentation performance. This is because most of the available sugars were converted into ethanol rather than diverted to by products (yeast biomass and glycerol) (Gombert & Van Maris, 2015, Zhang et al., 2011). As mentioned previously, direct comparison of the present study with previous studies is not possible primarily due to differences in experimental conditions. Nonetheless, previous studies such as the one conducted by Nyachaka et al., 2013 in their paper titled 'production and performance evaluation of bioethanol fuel from groundnut shell waste' successfully produced bioethanol from groundnut shells feedstock and conclude groundnut shells are potential feedstock for bioethanol production (Nyachaka et al., 2013) as concluded in the present study. Akubueze & Nwaze (2023) also successfully produce bioethanol from groundnut shells and *saccharomyces cerevisiae* yeast with a percentage yield of 27.5%. Although their experimental conditions such as temperature, substrate and yeast concentration vary from the present study, the percentage yield they obtained (27.5%) relatively aligned with this study (30%) with a less than 10% difference of 8.3%. Their conclusion that groundnut shells can be used as an excellent feedstock for bioethanol production is also in good agreement with the present study (Akubueze & Nwaze, 2023). Another study (Tikhe & Nadupuru, 2024) also made the same conclusion.

Physicochemical properties of bioethanol produced groundnut shells and *Saccharomyces cariocanus* yeast

The physicochemical properties of the bioethanol produced from groundnut shells using *Saccharomyces cariocanus* yeast are shown in Table 3. The values are generally comparable to

Table 3. Physicochemical properties of bioethanol produced from groundnut shells using *Saccharomyces cariocanus* yeast for fermentation compared with ASTM reference value.

No.	Parameter	Experimental bioethanol value	ASTM reference value
1.	pH	6.2	6.5-9
2.	Density (g/cm ³).	0.77	0.78
3.	Viscosity (cP)	1.43	1.20
4.	Flash Point (°C)	15	≥12
5.	Boiling Point (°C)	72.6	78.37

ASTM standards, representing satisfactory fuel quality with trivial deviations. The pH value (6.2) is marginally lower than the ASTM standard (6.5-9), indicating the bioethanol is slightly acidic. This acidic nature could be attributed to acid residue left after acid hydrolysis (Bekele Bayu et al., 2022). But this slight variation is insignificant and not likely to significantly influence fuel performance. The density (0.77 g/cm³) is also very close to the ASTM value (0.78 g/cm³) with a negligible difference of 0.01. The viscosity (1.43 cP) is a little higher than the ASTM standard (1.20 cP), probably because of the presence of trace impurities or partial dehydration (Bekele Bayu et al., 2022). The flash point of 15°C is within the ASTM standard value, meaning to some extent a better handling safety, as higher flash points decrease flammability hazard (Adiya et al., 2022). Its worth mentioning that the flammability of bioethanol is completely dependent on its purity. When the ethanol is highly flammable, i.e. has high flash point, its purity is also high, whereas, when the ethanol is less flammable, i.e. has low flash point, its purity is low (Bekele Bayu et al., 2022). The boiling point (72.6°C) is lower than the standard ASTM ethanol boiling point value (78.37°C). This observed phenomenon could be attributed to the presence of light volatile components. It has been found that ethanol has organic compounds with low boiling points, lower or similar to that of ethanol, because purification via distillation is not effective enough for their removal (Sánchez et al., 2020).

Conclusions

The results highlight the significance of yeast species choice in optimizing bioethanol production from groundnut shells. While all three yeast species (*Saccharomyces cerevisiae*, *Saccharomyces cariocanus*, and *Schizosaccharomyces pombe*) were able to ferment the hydrolyzate, *Saccharomyces cariocanus* showed the highest ability for maximizing ethanol quantity and yield under the investigated experimental conditions. The findings imply that *Saccharomyces cariocanus* could be a promising alternative or complement to the commonly used *Saccharomyces cerevisiae* for bioethanol production from lignocellulosic feedstocks. The physicochemical characteristics of the bioethanol generated from groundnut shells as feedstock and *Saccharomyces cariocanus* yeast species show promising fuel characteristics. However, further purification and process optimization would be required to fully meet ASTM standards. Overall, it can be concluded that groundnut shells are promising feedstock for bioethanol production.

Acknowledgements

Not Applicable.

Funding

Not Applicable.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

Data can be obtained from the corresponding author upon a reasonable request.

Ethics committee approval

Ethics committee approval is not required for this study.

Authors' contribution statement

The authors acknowledge their contributions to this paper as follows: Study conception and design: Z.I.S.G.A; Data collection: M.A., M.S.A.O; Analysis and interpretation of results: Z.I.S.G.A; Manuscript draft preparation: Z.I.S.G.A. All authors reviewed the results and approved the final version of the manuscript.

Use of Artificial Intelligence

No artificial intelligence based tools or applications were used in the preparation of this study. The entire content of the study was produced by the author(s) in accordance with scientific research methods and academic ethical principles.

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References

- Abdul Kareem Joyia, M., Ahmad, M., Chen, Y.-F., Mustaqeem, M., Ali, A., Abbas, A., & Ashraf Gondal, M. (2024). Trends and advances in sustainable bioethanol production technologies from first to fourth generation: A critical review. *Energy Conversion and Management*, 321, 119037. <https://doi.org/10.1016/j.enconman.2024.119037>
- Adiya, Z. I. S. G., Adamu, S. S., Ibrahim, M. A., Okoh, E., & Ibrahim, D. (2022). Comparative study of bioethanol produced from different agro-industrial biomass residues. *Earthline Journal of Chemical Sciences*, 7(2), 143–152. <https://doi.org/10.34198/ejcs.7222.143152>
- Adiya, Z. I. S. G., & Atiku, F. A. (2024). Theoretical thermal efficiency of conventional steam reforming of groundnut shell. *DYSONA – Applied Science*, 5(1), 1–6. <http://dx.doi.org/10.30493/DAS.2023.377614>
- Adiya, Z. I. S. G., & Shehu, S. (2022). Thermodynamic analysis of hydrogen production from conventional steam reforming of groundnut shell. *UMYU Journal of Pure and Industrial Chemical Research*, 2(1), 54–63. <https://doi.org/10.55688/ujpicr21.007>
- Ajeigbe, H. A., Waliyar, F., Echekwu, C., Kunihya, A., Motagi, B., Eniaiyaju, D., & Inuwa, A. (2015). *A farmer's guide to profitable groundnut production in Nigeria*.
- Akubueze, E., & Nwaze, I. (2023). Suitability of groundnut shells for bioethanol production using *Saccharomyces cerevisiae*. *Journal of Materials Science Research and Reviews*, 2(11), 34–39.
- Amaefule, D., Nwakaire, J., Ogbuagu, N., Anyadike, C., Ogenyi, C., Ohagwu, C., & Egbuhuzor, O. (2023). Effect of production factors on the bioethanol yield of tropical sawdust. *International Journal of Energy Research*, 2023, 9983840. <https://doi.org/10.1155/2023/9983840>
- Bekele Bayu, A., Abeto Amibo, T., & Beyan, S. M. (2022). Process optimization for acid hydrolysis and characterization of bioethanol from leftover injera waste by using response surface methodology: Central composite design. *International Journal of Analytical Chemistry*, 2022, 4809589. <https://doi.org/10.1155/2022/4809589>
- Ceaser, R., Montané, D., Constantí, M., & Medina, F. (2025). Current progress on lignocellulosic bioethanol including a technological and economical perspective. *Environment, Development and Sustainability*, 27(11), 25993–26038. <https://doi.org/10.1007/s10668-024-04792-2>
- Das, N., Jena, P. K., Padhi, D., Kumar Mohanty, M., & Sahoo, G. (2023). A comprehensive review of characterization, pretreatment and its applications on different lignocellulosic biomass for bioethanol production. *Biomass Conversion and Biorefinery*, 13(2), 1503–1527. <https://doi.org/10.1007/s13399-021-01294-3>
- Demeke, M. M., Dietz, H., Li, Y., Foulquié-Moreno, M. R., Mutturi, S., Deprez, S., Den Abt, T., Bonini, B. M., Liden, G., & Dumortier, F. (2013). Development of a D-xylose fermenting and inhibitor tolerant industrial *Saccharomyces cerevisiae* strain with high performance in lignocellulose hydrolysates using metabolic and evolutionary engineering. *Biotechnology for Biofuels*, 6(1), 89. <https://doi.org/10.1186/1754-6834-6-89>
- Fernandes, M. C., Ferro, M. D., Paulino, A. F. C., Chaves, H. T., Evtuguin, D. V., & Xavier, A. M. R. B. (2018). Comparative study on hydrolysis and bioethanol production from cardoon and rockrose pretreated by dilute acid hydrolysis. *Industrial Crops and Products*, 111, 633–641. <https://doi.org/10.1016/j.indcrop.2017.11.037>

- Gombert, A. K., & Van Maris, A. J. (2015). Improving conversion yield of fermentable sugars into fuel ethanol in 1st generation yeast-based production processes. *Current Opinion in Biotechnology*, 33, 81–86. <https://doi.org/10.1016/j.copbio.2014.12.012>
- Jain, S., & Kumar, S. (2024). A comprehensive review of bioethanol production from diverse feedstocks: Current advancements and economic perspectives. *Energy*, 296, 131130. <https://doi.org/10.1016/j.energy.2024.131130>
- Kazmi, A., Sultana, T., Ali, A., Nijabat, A., Li, G., & Hou, H. (2025). Innovations in bioethanol production: A comprehensive review of feedstock generations and technology advances. *Energy Strategy Reviews*, 57, 101634. <https://doi.org/10.1016/j.esr.2024.101634>
- Kosaric, N., & Velikonja, J. (1995). Liquid and gaseous fuels from biotechnology: Challenge and opportunities. *FEMS Microbiology Reviews*, 16(2–3), 111–142. <https://doi.org/10.1111/j.1574-6976.1995.tb00161.x>
- Mangwanda, T., Johnson, J. B., Mani, J. S., Jackson, S., Chandra, S., McKeown, T., White, S., & Naiker, M. (2021). Processes, challenges and optimisation of rum production from molasses—A contemporary review. *Fermentation*, 7(1), 21. <https://doi.org/10.3390/fermentation7010021>
- Mohd Azhar, S. H., Abdulla, R., Jambo, S. A., Marbawi, H., Gansau, J. A., Mohd Faik, A. A., & Rodrigues, K. F. (2017). Yeasts in sustainable bioethanol production: A review. *Biochemistry and Biophysics Reports*, 10, 52–61. <https://doi.org/10.1016/j.bbrep.2017.03.003>
- Nazli, R. I. (2020). Evaluation of different sweet sorghum cultivars for bioethanol yield potential and bagasse combustion characteristics in a semiarid Mediterranean environment. *Biomass and Bioenergy*, 139, 105624. <https://doi.org/10.1016/j.biombioe.2020.105624>
- Nissen, T. L., Kielland-Brandt, M. C., Nielsen, J., & Villadsen, J. (2000). Optimization of ethanol production in *Saccharomyces cerevisiae* by metabolic engineering of the ammonium assimilation. *Metabolic Engineering*, 2(1), 69–77. <https://doi.org/10.1006/mben.1999.0140>
- Nyachaka, C., Yawas, D., & Pam, G. (2013). Production and performance evaluation of bioethanol fuel from groundnut shell waste. *American Journal of Engineering Research*, 2(12), 303–312.
- Owusu, W. A., & Marfo, S. A. (2023). Artificial intelligence application in bioethanol production. *International Journal of Energy Research*, 2023, 7844835. <https://doi.org/10.1155/2023/7844835>
- Papapetridis, I., Van Dijk, M., Van Maris, A. J., & Pronk, J. T. (2017). Metabolic engineering strategies for optimizing acetate reduction, ethanol yield and osmotolerance in *Saccharomyces cerevisiae*. *Biotechnology for Biofuels*, 10(1), 107. <https://doi.org/10.1186/s13068-017-0791-3>
- Pilap, W., Thanonkeo, S., Klanrit, P., & Thanonkeo, P. (2022). The potential of multistress tolerant yeast, *Saccharomyces ludwigii*, for second-generation bioethanol production. *Scientific Reports*, 12(1), 22062. <https://doi.org/10.1038/s41598-022-26686-x>
- Sánchez, C., Santos, S., Sánchez, R., Lienemann, C.-P., & Todolí, J.-L. (2020). Profiling of organic compounds in bioethanol samples of different nature and the related fractions. *ACS Omega*, 5(33), 20912–20921. <https://doi.org/10.1021/acsomega.0c02360>
- Sani, U., Abubakar, S., Suleiman, F., & Olabode, H. (2021). Proximate analysis and production of bioethanol from sweet potato (*Ipomoea batatas*) white cultivars obtained from Samaru Zaria. *Bayero Journal of Pure and Applied Sciences*, 14(2), 157–168. <https://doi.org/10.4314/bajopas.v14i2.18>
- Smith, J., Van Rensburg, E., & Görgens, J. F. (2014). Simultaneously improving xylose fermentation and tolerance to lignocellulosic inhibitors through evolutionary engineering of recombinant *Saccharomyces cerevisiae* harbouring xylose isomerase. *BMC Biotechnology*, 14(1), 41. <https://doi.org/10.1186/1472-6750-14-41>
- Tikhe, K., & Nadupuru, S. R. (2024). Lignocellulosic valorization of groundnut shells for bioethanol: Energy potential and techno-economic feasibility. *Maejo International Journal of Energy and Environmental Communication*, 6(3), 40–49. <https://doi.org/10.54279/mijeec.v6i3.258826>
- Torget, R. W., Kim, J. S., & Lee, Y. (2000). Fundamental aspects of dilute acid hydrolysis/fractionation kinetics of hardwood carbohydrates. I. Cellulose hydrolysis. *Industrial & Engineering Chemistry Research*, 39(8), 2817–2825. <https://doi.org/10.1021/ie990915q>
- Tse, T. J., Wiens, D. J., & Reaney, M. J. T. (2021). Production of bioethanol—A review of factors affecting ethanol yield. *Fermentation*, 7(4), 268. <https://doi.org/10.3390/fermentation7040268>
- Vasilakou, K., Nimmegeers, P., Billen, P., & Van Passel, S. (2023). Geospatial environmental techno-economic assessment of pretreatment technologies for bioethanol production. *Renewable and Sustainable Energy Reviews*, 187, 113743. <https://doi.org/10.1016/j.rser.2023.113743>
- Zabed, H., Faruq, G., Sahu, J. N., Azirun, M. S., Hashim, R., & Nasrulhaq Boyce, A. (2014). Bioethanol production from fermentable sugar juice. *The Scientific World Journal*, 2014, 957102. <https://doi.org/10.1155/2014/957102>
- Zhang, H., Zhang, P., Wu, T., & Ruan, H. (2023). Bioethanol production based on *Saccharomyces cerevisiae*: Opportunities and challenges. *Fermentation*, 9(8), 709. <https://doi.org/10.3390/fermentation9080709>

- Zhang, L., Tang, Y., Guo, Z.-P., Ding, Z.-Y., & Shi, G.-Y. (2011). Improving the ethanol yield by reducing glycerol formation using cofactor regulation in *Saccharomyces cerevisiae*. *Biotechnology Letters*, 33(7), 1375–1380. <https://doi.org/10.1007/s10529-011-0588-6>
- Zheng, W., Phoungthong, K., Lü, F., Shao, L.-M., & He, P.-J. (2013). Evaluation of a classification method for biodegradable solid wastes using anaerobic degradation parameters. *Waste Management*, 33(12), 2632–2640. <https://doi.org/10.1016/j.wasman.2013.08.015>