



ASSESSMENT OF FRUIT WASTE AS RENEWABLE FEEDSTOCK FOR BIOETHANOL PRODUCTION

Energy

Chethan S.G. *

Department of Chemistry, Jawaharlal Nehru New College of Engineering, Shivamogga-577201. *Corresponding Author

ABSTRACT

Bioethanol is an environmentally friendly energy source and a green transport fuel. Currently, many countries use 10% ethanol with conventional petrol. The current bioethanol supply is insufficient to meet fuel demand; thus, there is a need to seek new bioethanol resources. Numerous lignocellulosic biomasses (e.g., fruit waste, vegetable waste, and agricultural residues) have been analyzed as potentially sustainable feedstocks for producing bioethanol. In this work, we explore the resources of various residues of fruit waste such as Ananas comosus (Pineapple), Manilka razapota (Chikoo), Citrus sinensis (Orange), Vitis Vinifera (Grapes), Punica granatum (pomegranate), Citrus limetta (moussami) and Mixed fruits extract (MFR) for bioethanol production. The collected residual fruit extracts were fermented in the presence of yeast (*Saccharomyces cerevisiae*). The concentration of bioethanol was measured using an Abbs Refractometer every 24, 48, and 144 h. The results showed that after 144 h (one week). The *Vitis Vinifera* (grape) residue extract yielded 65% more bioethanol than the other fruit residue extracts. The bioethanol quality was characterized using FTIR and Gas chromatography.

KEYWORDS

Fruit residue waste, Total sugar content, Bioethanol, FTIR, Gas Chromatography, waste management

1. INTRODUCTION

The excessive use of fossil fuels has resulted in global warming and climate change. Consequently, there is a drive to replace fossil fuels with clean, renewable fuels such as bioethanol and biodiesel. However, owing to the rapid depletion of conventional fossil fuels and their unpredictable prices, it is necessary to encourage the use of alternative renewable sources of energy, such as biomass conversion, for national energy security. Ethanol, also known as ethyl alcohol (C₂H₅OH), is a clear, colorless, biodegradable liquid that is low in toxicity and causes low environmental pollution. When ethanol is burned in the presence of air, carbon dioxide and water are produced. Ethanol produces carbon dioxide and water upon combustion. Ethanol is a high-octane gasoline that is mostly substituted for TEL. The fuel combination can also oxygenate by blending ethanol with conventional petrol, leading to the complete combustion of fuel and a reduction in noxious emissions. Ethanol fuel blends are widely used in the United States and other countries. The most preferred blend is 10% ethanol and 90% petrol (E10).

Lignocelluloses can be utilized for bioethanol production as raw materials, including fruit and vegetable waste, forest waste, agro-residues, and municipal solid waste (MSW). India ranks second in the world in terms of fruit and vegetable production, accounting for 10% and 14% of the total fruit and vegetable output, respectively. The annual fruit and vegetable output in India is expected to exceed 243 million tonnes. [1]. Fruit and vegetable processing by-products are abundant in cellulose, hemicellulose, pectin, and minerals; however, they contain less lignin than agricultural residues such as maize, wheat straw, and rice straw. Fruit waste is rich in fermentable soluble sugars, cellulose and hemicellulose. These components suggest that fruit waste is a viable source of ethanol [2]. Disposing of fruit waste can incur extra costs for processors, and direct disposal into soil or debris can cause significant environmental pollution [3]. Transforming abundant fruit and vegetable processing waste (FVPW) into value-added products offers a practical and sustainable approach to reducing pollution, enhancing energy security, and lowering greenhouse gas emissions [4]. Microorganisms, such as yeasts, are crucial for bioethanol production as they ferment a wide range of carbohydrates into ethanol. *Saccharomyces cerevisiae* is considered the most important yeast strain because of its biotechnological relevance in fermentation technology [5]. To decrease net greenhouse gas emissions, bioethanol is considered a promising alternative to petroleum-based transportation fuels. Alcohol has been used as a fuel since the early days of automobiles. Ethanol fuel blends are effectively used in all types of vehicles and engines that require gasoline [6]. Cellulosic materials are renewable, cost-effective, and available in large quantities, including crop residues, grass, sawdust, wood chips, and agro-waste.

Over the past two decades, many scientists and researchers have focused on producing ethanol from lignocellulosic materials. Therefore, bioethanol production could be an effective means of utilizing agricultural residues and waste [7]. Agricultural waste can be safely and economically disposed of through bioconversion, which can also transform lignocellulosic waste into valuable forms, such as

reducing sugars for ethanol production. Approximately 3–4% of global ethanol production is synthetic, with the remainder derived from biomass fermentation, primarily from cereals and sugar crops, such as cane and beetroot [8]. The unique composition and bioactivity of these fruit wastes highlight the originality and importance of our approach to valorization. Additionally, these substrates have high pectin, hemicellulose, and cellulose contents (1.50–13.40% pectin, 7.20–43.60% cellulose, and 4.26–33.50% hemicellulose) [9]. Bakery yeast (*Saccharomyces cerevisiae*) is a commonly used microorganism for bioethanol production, favored for its high bioethanol yield, rapid fermentation rate, and adaptability to various fermentation conditions [10]. Various microorganisms ferment fruit and vegetable juice. *Saccharomyces cerevisiae* strains, known for their high bioethanol yield and efficient sugar conversion, have significantly evolved for bioethanol production in recent years. *S. cerevisiae* is a model organism used in genetic engineering, molecular biology, genetics, and synthetic biotechnology [11]. Forestry waste, energy crops, grains and corn, municipal and industrial wastes, and other wastes contributed 370, 377, 87, 58, and 48 MT, respectively [12].

2. MATERIAL AND METHODS

2.1 Sources of Chemicals and reagents:

Fruit waste residue, yeast culture, nutrient broth media, NaOH, Sodium metabisulfite, and Hydrochloric acid were supplied by SD Fine Chemicals.

2.2. Extraction of juices:

Various fruit waste, namely *Ananas comosus* (Pineapple), *Manilka razapota* (Chikoo), *Citrus sinensis* (Orange), *Vitis Vinifera* (Grapes), *Punica granatum* (Pomegranate), *Citrus limetta* (Musami), and Mixed fruits extract (MFR), are collected from local fruit stores in Shimoga, Karnataka, INDIA. All known masses of fruit waste (100 g) were washed and individually immersed in distilled water for 2 h in a 1:1 ratio before autoclaving at 120 °C for 30 min. The fruit waste was then pressed and filtered to obtain juice extracts. The extracted fruit juices were collected separately in a pre-sterilized fermenting vessel (Fig.1). The mixture was allowed to cool to room temperature.

2.3. Inoculum Yeast culture preparation

The inoculum culture was prepared by inoculating 3% (v/v) of stock yeast culture into 200 mL of sterilized nutrient agar broth and incubating it at 28°C -30°C for 24 h before inoculating it into the fruit extract medium [13].

2.4. Bioethanol Production from fruit waste by *Saccharomyces cerevisiae*.

To ascertain the concentration of bioethanol in the fruit processing waste, fruit juice extracts were collected in a fermentation bottle Fig. 1. The PH of all fruit juice media was initially measured and regulated to 5.0-6.0 by drop wise addition of 0.1M H₂SO₄ and NaOH solution. All of the fruit juice extract media in the fermentation setup were inoculated with 5% (v/v) inoculum and 2 g of sodium metabisulfite (to avoid bacterial contamination) and allowed to ferment in a dark room

with constant agitation for 24 h. Fruit juice media samples were obtained for ethanol analysis after 24, 48, and 144 h of fermentation [14-15].



Figure 1: Fermentation Step for Ethanol production from fruit waste

2.5. Recovery of bioethanol by distillation method

Fractional distillation is a technique used to separate ethanol-water mixtures. This technique is based on the boiling point of the liquids. Ethanol boils at a lower temperature (78.5 0C) than water, and the alcohol vaporizes, leaving behind water in the distillation unit. After 144 h (one week), all fermented fruit juices were filtered and transferred to a distillation unit (Fig. 2) for the recovery of bioethanol. To produce a high concentration of bioethanol, a series of distillations was performed. The ethanol quality was assessed using specific gravity, the RI index, FTIR procedures, and gas chromatography techniques.



Figure 2: Distillation Setup for Ethanol Extraction

3. RESULTS AND DISCUSSION

Fruit and vegetable waste has a high concentration of fermentable carbohydrates, proteins, lipids, and fibers, which are essential carbon sources for microbial growth. Fruit and vegetable processed residue waste is disposed of in municipal open yards or direct dumping to soil or landfill, which may result in a significant environmental concern [14]. There is a lack of appropriate infrastructure to manage such a significant amount of biomass and well-established commercial technology for converting waste into valuable by-products. Thus, the current study explored the bioethanol concentrations produced from different waste fruits. The collected fruit waste was fermented in the presence of *S. cerevisiae* using a fermentation system (Fig.1). The concentration of ethanol was assessed during fermentation by measuring the refractive index using an Abbe Refractometer.

The refractive index (RI) is also referred to as the refraction index or index of refraction. The speed of light in a medium depends on the properties of the medium, and the measurement of the refractive index of a mixture (ethanol and water) provides a simple and rapid method for determining the purity of bioethanol. The absolute refractive indices of a series of different concentrations of alcohol and water were measured using an Abbe refractometer. Fig. 3. shows the standard Refractive Index (RI) value with time.

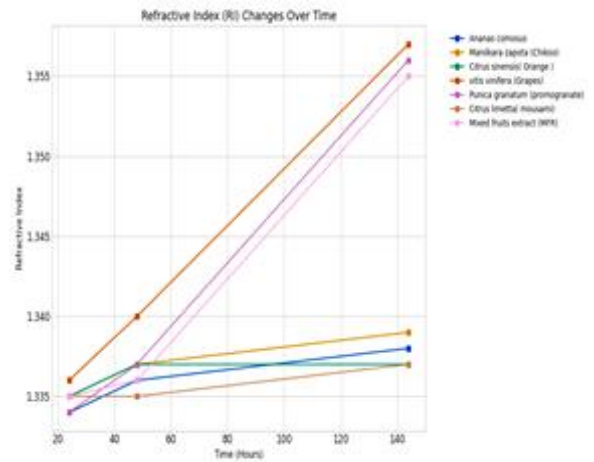


Figure 3. shows the standard Refractive Index (RI) value with time

3.1. Determination of bioethanol in fermented fruit residues:

The fruit juices extracted from various fruit residual wastes were fermented under appropriate conditions. During the fermentation process, samples were taken after 24, 48, and 144 h to determine the bioethanol percentage. Fig. 4 Shows the statistics on bioethanol yield after 24 h, 48 h, and 144 h (one week) of fermentation

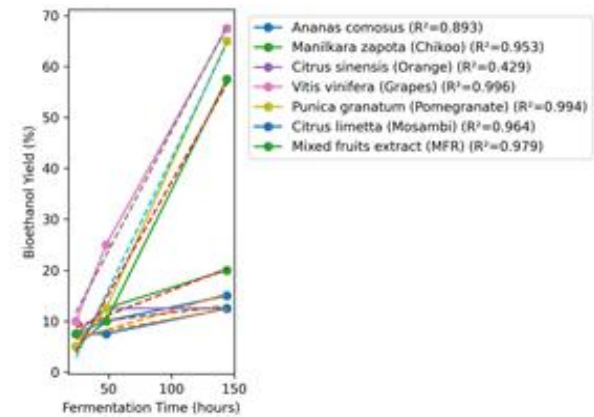
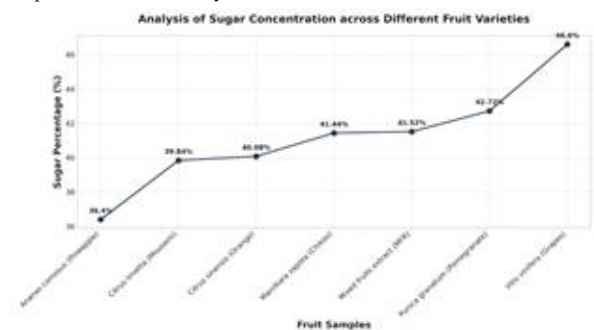


Figure 4: Bioethanol yield from various Fruit waste residue.

From the above Fig. 4. The *Vitis vinifera* (grapes) juice media, *Punica granatum* (pomegranate), and Mixed fruit extract (MFR) fruit residue extract yielded maximum bioethanol production of 67%, 65 %, and 57 % respectively. This is because of the high sugar content in juice extract, which allows microorganisms to utilize it as a carbon source. Proper physicochemical qualities can boost ethanol production from trash, and the residue left after fermentation can be used as fertilizer to help maintain soil fertility



3.2. Characterization of Bio-ethanol by Infrared Spectroscopy

From the above Fig. 6 spectral shows that IR Spectral study of bioethanol from *Vitis vinifera* (Grapes). the stretching vibrations of bioethanol at 3402.43 cm⁻¹ corresponds to the -OH group and intense absorption peaks at 1055-1014 cm⁻¹. It corresponds to the -C-H group. The absorption peaks at 1685 cm⁻¹ are because of C=O stretching. This confirms the structure of ethanol in distilled fermented

fruit residual media.

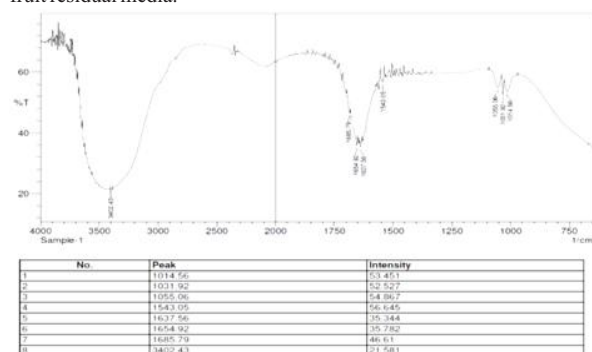
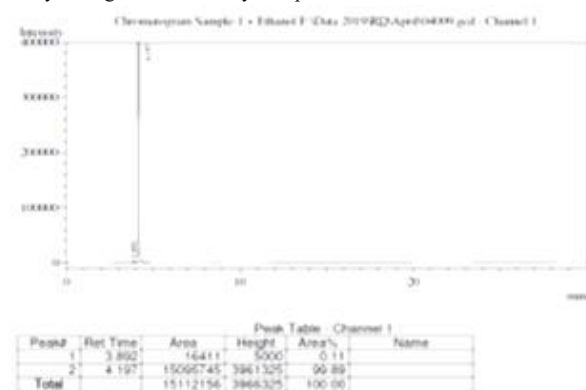


Figure 6. Infrared spectral studies of bioethanol

3.3. Characterization of Bioethanol by Gas Chromatography

The purity of the distilled bioethanol was analyzed using GC. The sample was tested using gas chromatography by passing through the column at a flow rate of 0.60 mL per min. With a pressure of 20.6 kPa, at 300°C. Nitrogen was used as the carrier gas during the bioethanol analysis. Fig 4. The GC analysis report of bioethanol.



4. DISCUSSION

In this study, bioethanol production from fruit waste was explored for its value addition. Fruit residues still retain 20–30 % non-extractable carbohydrates and other nutritional sources, which are easier for microorganisms to proliferate in the medium. All of the fruits residue waste, such as Ananascomosus (Pineapple), Manilka razapota (Chikoo), Citrus sinensis (Orange), Vitis Vinifera (Grapes), Punica granatum (Pomegranate), Citrus limetta (Musami), and Mixed fruits extract (MFR), were allowed to ferment in the presence of Saccharomyces cerevisiae (yeast) and bioethanol yield was examined after 24 hours, 48 hours and 144 hours of fermentation.

5. CONCLUSION

The major observations and importance of this study are as follows.

1. It has been discovered that Vitis vinifera (grapes), Punica granatum (pomegranate), and mixed fruit extracts (MFR) produce a higher fraction of bioethanol than other fruit residues.
2. This study contributes to the identification of numerous sources of fruit waste that may be repurposed to produce bioethanol at a reasonable cost.
3. The bioethanol concentration can be integrated under appropriate physicochemical reaction conditions.
4. Fermentation sludge is a rich source of nutrients and can be used as agricultural manure.
5. In India, every year, tons of fruit waste are discarded in the open air, causing pollution. This aims to facilitate the conversion of agricultural and municipal trash into valuable byproducts while also increasing the economy.
6. It is feasible to provide resources for future energy supplies.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the Department of Chemistry and Biofuel Information Centre for providing the facilities to carry out this research.

Conflicts of Interest: Authors must declare any conflicts of interest or state, "The authors declare no conflicts of interest."

REFERENCES:

1. Mohammad Jahid, Akanksha Gupta, and Durlubh Kumar Sharma, *Production of Bioethanol from Fruit Wastes (Banana, Papaya, Pineapple, and Mango Peels) Under Milder Conditions*, Journal of Bioprocessing & Biotechnology, Vol.8, 2018.
2. In Seong Choi, Yoon Gyo Lee, Samir Kumar Khanal, Bok Jae Park, Hyeun-Jong Bae, *A low-energy, cost-effective approach to fruit and citrus peel waste processing for bioethanol production*, Journal of Applied Energy, Volume 140, 2015.
3. Neha Babbar and Harinder Singh Oberoi, *Enzymes in value-addition of agricultural and agro-industrial residues*, Enzymes in Value-Addition of Wastes. Nova Publishers, pp. 29–50, 2014.
4. Lowe, E.D., Buckmaster, D.R., *Dewatering makes a big difference in compost strategies*. Journal of Biocycle 36,78–82, 1995.
5. Sreenath, K.H. and T.W. Jeffries, *A variable- and S. Couri, 2002. tilt fermentation rack for screening organisms in the microtubes*. Journal of Biotechnology Techniques, 1996.
6. Balat, M., Balat, H., & Öz, C. (2008). Progress in bioethanol processing. Progress in Energy and Combustion Science, 34(5), 551–573. <https://doi.org/10.1016/j.pecc.2007.11.001>
7. Gupta, A., & Verma, J. P. (2015). Sustainable bioethanol production from agro-residues: A review. Renewable and Sustainable Energy Reviews, 41, 550–567. <https://doi.org/10.1016/j.rser.2014.08.032>
8. Ibrahim, N. A., Majeed, H. H., Abid, R. A., & Alsultan, G. A. (2025). Ethanol production from lignocellulosic waste materials: Kinetic and optimization studies. RSC Advances, 15, 26091–26103. <https://doi.org/10.1039/D5RA02272J>
9. Kechkar, S., Bensaad, R., & Benkacem, A. (2025). Biomass and bioethanol production from pretreated mixed fruit peel hydrolysate using Saccharomyces cerevisiae. BMC Biotechnology, 25, Article 74. <https://doi.org/10.1186/s12896-025-01074-1>
10. Gunjobi, J. K., Adebayo, E. A., & Afolayan, M. O. (2025). Bioethanol production from concentrated fruit waste juice using bakery yeast. Materials for Renewable and Sustainable Energy, 14, Article 6. <https://doi.org/10.1007/s40243-024-00283-6>
11. Rahman, M. M., Hasan, M. M., & Hossain, M. A. (2024). The prospect of fruit waste in bioethanol production: A review. Heliyon, 10, e38776. <https://doi.org/10.1016/j.heliyon.2024.e38776>
12. Saini, J. K., Saini, R., & Tewari, L. (2015). Lignocellulosic agricultural waste as biomass feedstocks for second-generation bioethanol production: Concepts and recent developments. 3 Biotech, 5, 337–353. <https://doi.org/10.1007/s13205-014-0246-5>
13. Bušić, A., Mardetko, N., Kundos, S., Morzak, G., Belskaya, H., IvančićŠantek, M., Komes, D., Novak, S., & Šantek, B., *Bioethanol Production from Renewable Raw Materials and Its Separation and Purification: A Review*. Journal of Food Technology and Biotechnology, 2018.
14. R. Sharma, H.S. Oberoi, G.S. Dhillon, *Fruit and Vegetable Processing Waste: Renewable Feed Stocks for Enzyme Production*, Journal of Agro-Industrial Wastes as Feedstock for Enzyme Production, 2016.
15. Suryaprabha, S, Akalya, V, Ramya, V, Manivasagan, V, Ramesh Babu N. *Comparative Studies Of Bioethanol Production From Different Fruit Wastes Using Saccharomyces cerevisiae*. Journal of bioethanol, Vol.6, 2017.
16. Joo Shun Tan, PongsathonPhapugrangkul, Chee Keong Lee, Zee-Wei Lai, Mohamad Hafizi Abu Bakar, ParamasivamMurugan, *Banana frond juice as novel fermentation substrate for bioethanol production by Saccharomyces cerevisiae*, Journal of Biocatalysis and Agricultural Biotechnology, Volume 21, 2019.