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Preparation of Ethanol from Fruit Waste

Production and Characterization of Bioethanol from Mixed Fruit Waste Using Fermentation Technique

Vishwas G B, Vikas S,
Yashavanth K L, Yashwanth P
Students of Mechanical Engineering Department
P.E.S. College of Engineering, Mandya Karnataka - 571401

Abstract - The increasing demand for renewable energy has created interest in bioethanol production from organic waste materials. In this study, ethanol was produced from fruit waste such as watermelon, papaya, pineapple, and pomegranate using fermentation and distillation processes. The fruit waste was pretreated, sterilized, and fermented using Saccharomyces cerevisiae under anaerobic conditions. After fermentation, ethanol was separated through distillation at temperatures near its boiling point. Refractometer analysis showed varying sugar concentrations among different fruit samples, which influenced ethanol yield. The obtained ethanol was clear, colourless, and confirmed through Gas Chromatography analysis. The study demonstrates that fruit waste can be effectively utilized for sustainable bioethanol production and waste management.

Keywords - Bioethanol, Fruit Waste, Fermentation, Distillation, Saccharomyces cerevisiae, Renewable Energy, Waste Management

I. INTRODUCTION

The rapid depletion of fossil fuel resources and increasing environmental pollution have created the need for sustainable and renewable energy alternatives. Bioethanol has emerged as one of the most promising renewable fuels because of its clean-burning characteristics and ability to reduce greenhouse gas emissions. Conventional ethanol production mainly depends on sugarcane, corn, and molasses, which may create competition between food and fuel requirements. Therefore, the utilization of fruit waste for ethanol production has gained significant attention as an economical and environmentally friendly solution. Fruit waste such as watermelon peels, papaya waste, pineapple waste, and pomegranate waste contains large quantities of fermentable sugars including glucose, fructose, and sucrose. These sugars can be converted into ethanol through microbial fermentation using yeast cultures. Large quantities of fruit waste are generated daily from households, markets, food processing industries, and agricultural activities, leading to disposal problems and environmental pollution. Converting this organic waste into bioethanol not only reduces waste accumulation but also generates a valuable renewable fuel. The process of ethanol production from fruit waste mainly involves pretreatment, fermentation, and distillation. During fermentation, microorganisms such as Saccharomyces cerevisiae convert sugars into ethanol and carbon dioxide under anaerobic conditions. The produced ethanol is then separated from the fermented mixture through distillation based on differences in boiling points. Bioethanol produced from fruit waste can be used as an alternative fuel or blended with gasoline to reduce harmful emissions from internal combustion engines. Globally, bioethanol production has increased significantly over the past few decades due to rising energy demands and environmental concerns. Countries such as the United States and Brazil contribute majorly to global ethanol production. The use of agricultural residues and food waste for ethanol production also supports the concept of a circular economy and sustainable development.

II. LITERATURE SURVEY

A. Production of Ethanol from Papaya Waste

Authors: P. Bosco Dhanaseli et al.

In this study, the authors investigated the production of ethanol from papaya waste using fermentation techniques. Brewer’s yeast and baker’s yeast were used as fermenting microorganisms, and their performances were compared. The study concluded that brewer’s yeast produced a higher ethanol yield due to better fermentation efficiency. The research highlighted the potential of papaya waste as a low-cost and renewable substrate for bioethanol production. The work also emphasized the importance of optimizing fermentation conditions to improve ethanol yield and quality.

B. Bioethanol Production from Watermelon Rind by Fermentation Using Saccharomyces cerevisiae and Zymomonas mobilis

Authors: Swapna Alex et al.

This paper focused on the production of bioethanol from watermelon rind using Saccharomyces cerevisiae and Zymomonas mobilis microorganisms. The researchers studied the fermentation characteristics of watermelon waste and evaluated ethanol production efficiency. The addition of peptone improved microbial growth and enhanced ethanol yield. The study demonstrated that fruit waste materials such as watermelon rind can be effectively converted into renewable biofuel through fermentation.

C. Simultaneous Saccharification and Fermentation of Watermelon Waste for Ethanol Production

Authors: Venkata Nadh Ratnakaram et al.

The authors carried out simultaneous saccharification and fermentation of watermelon waste using Aspergillus niger and

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Saccharomyces cerevisiae cultures. The study investigated the conversion of complex carbohydrates into fermentable sugars followed by ethanol production. The results indicated that toddy yeast culture showed higher fermentation efficiency compared to baker's yeast. The research highlighted the importance of microorganism selection in improving ethanol yield from agricultural waste.

D. Bread Yeast Fermentation Method Production of Papaya Fruit Bioethanol

Authors: I Nengah Muliarta et al.

This research focused on the production of bioethanol from papaya waste using bread yeast fermentation. The authors studied the effect of yeast dosage and fermentation duration on ethanol concentration. The maximum ethanol concentration was obtained using optimized yeast concentration and fermentation conditions. The study demonstrated that papaya waste can serve as an effective raw material for sustainable bioethanol production.

E. Production of Bioethanol from Rotten Watermelon and Banana Using Enzymatic Approach

Authors: Amina Saad Bala et al.

In this work, rotten watermelon and banana wastes were utilized for ethanol production using an enzymatic hydrolysis method. The substrates were pretreated and fermented for several days before distillation. The results showed that banana waste produced a higher ethanol yield compared to watermelon waste because of its higher sugar content. The study emphasized the role of enzymatic treatment in enhancing fermentation efficiency and ethanol recovery.

F. Stress Tolerance Yeast Strain from Papaya Waste for Bioethanol Production

Authors: Gemilang Lara Utama et al.

This paper investigated stress-tolerant yeast strains isolated from papaya waste for ethanol production. The study focused on improving microbial resistance under fermentation conditions to achieve better ethanol yield. The results indicated that optimized fermentation parameters and suitable yeast strains significantly improved ethanol production efficiency. The research contributed toward developing efficient microbial systems for bioethanol production from fruit waste.

G. Summary of Literature Review

Based on the above literature review, it is observed that many researchers have successfully produced bioethanol from various fruit wastes such as papaya, watermelon, banana, pineapple, and mixed fruit residues using fermentation techniques. Different microorganisms including Saccharomyces cerevisiae, Zymomonas mobilis, and Aspergillus niger were used to improve ethanol yield and fermentation efficiency. Recent studies mainly focused on optimizing fermentation parameters, sugar concentration, yeast dosage, and pretreatment methods to enhance bioethanol production.

Based on these advancements, the present project focuses on the preparation of ethanol from mixed fruit waste using Saccharomyces cerevisiae fermentation followed by distillation. The study aims to convert biodegradable fruit waste into renewable bioethanol while reducing environmental pollution and promoting sustainable waste management practices.

OBJECTIVES

The main objective of this project is to produce ethanol from fruit waste using fermentation and distillation processes. The specific objectives of the work are as follows:

1. To collect and pretreat watermelon, papaya, pineapple, and pomegranate waste for ethanol production.
2. To prepare fruit waste mixtures suitable for fermentation.
3. To carry out fermentation using Saccharomyces cerevisiae yeast culture under controlled conditions.
4. To perform distillation for separating ethanol from the fermented mixture.
5. To analyse the sugar content and physical properties of the produced ethanol.
6. To study the effect of different fruit waste combinations on ethanol yield and production efficiency.

III. METHODOLOGY

The production of ethanol from fruit waste was carried out through a sequence of biochemical and physical processes including collection of fruit waste, pretreatment, fermentation, and distillation. The methodology adopted in this work was designed to convert fermentable sugars present in fruit waste into ethanol using yeast fermentation under controlled conditions.

3.1 Materials Required

3.1.1 Raw Materials

The following fruit wastes were used as substrates for ethanol production:

- Watermelon waste
- Papaya waste
- Pineapple waste

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- Pomegranate waste
- Water – 1 litre for every 1 kg of fruit waste mixture

The fruit wastes were selected because of their high sugar content and suitability for microbial fermentation.

3.1.2 Chemicals Used

The chemicals used during the experiment are listed below:

- Sodium metabisulfite – 2 to 3 g
- Sodium hydroxide (NaOH) – for pH adjustment
- Sugar – 5 g for yeast activation

Sodium metabisulfite was used as a sterilizing agent to eliminate unwanted microorganisms, while sodium hydroxide was used to maintain the optimum pH for yeast activity.

3.1.3 Microorganism

The yeast culture used for fermentation was:

- Saccharomyces cerevisiae – 50 g

Saccharomyces cerevisiae was selected because of its high ethanol production efficiency and rapid fermentation characteristics.

3.1.4 Equipment Used

The major equipment used in the experiment includes:

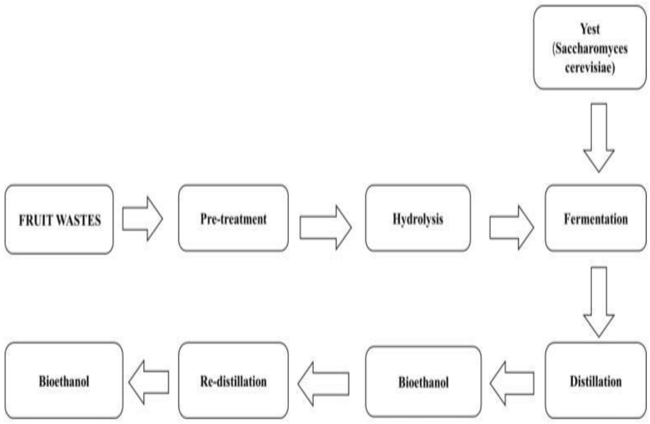
- Grinder or mixer
- Heating mantle
- Thermometer
- pH meter
- Refractometer
- Fermentation containers
- Distillation apparatus
- Condenser and receiver flask

These instruments were used for pretreatment, fermentation monitoring, and ethanol separation through distillation.

3.2 Experimental Procedure

3.2.1 Collection and Preparation of Fruit Waste

Approximately 1 kg of fruit waste was collected and washed thoroughly to remove dust and impurities. The cleaned fruit waste was mixed with 1 litre of water and ground into a fine pulp using a mixer grinder. The proportion of fruit waste to water was maintained at 1:1. The grinding process increased the surface area of the substrate, enabling efficient release of sugars during fermentation.



3.2.2 Refractometer Analysis

A Brix refractometer was used to determine the sugar concentration of the fruit waste mixture before fermentation. The refractometer works on the principle of light refraction and measures the refractive index of the solution, which is converted into percentage Brix value representing sugar concentration.

3.2.3 Boiling Process

The prepared fruit pulp was transferred into a heating vessel and heated at 80°C for 30 minutes using a heating mantle. Boiling was performed to:

- Break down complex sugars into simpler fermentable sugars
- Eliminate unwanted microorganisms
- Sterilize the substrate mixture

After boiling, the mixture was allowed to cool to room temperature before further processing.

3.2.4 Sterilization

To avoid contamination during fermentation, 2–3 g of sodium metabisulfite was added to the cooled fruit mash. The mixture was stirred thoroughly and left undisturbed for about 10–15 minutes. Sodium metabisulfite acted as a sterilizing and preserving agent by suppressing unwanted microbial growth.

3.2.5 pH Adjustment

The pH of the fruit mash was measured using a pH meter. For efficient yeast activity, the pH value was maintained at 5. If the mixture was highly acidic, sodium hydroxide solution was added gradually until the desired pH value was obtained. The

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pH adjustment is essential because yeast fermentation occurs effectively only within a suitable acidic range.

3.2.6 Preparation of Yeast Culture

The yeast culture was prepared by mixing:

- 50 g yeast
- 5 g sugar
- 100 ml water

The mixture was stirred thoroughly and kept in a warm place for 24 hours for activation of yeast cells. Activated yeast culture improves fermentation efficiency and ethanol production rate.

3.2.7 Fermentation

The prepared yeast culture was added to the fruit mash and mixed thoroughly. The mixture was then transferred into airtight fermentation containers and kept undisturbed for 48 hours under anaerobic conditions. During fermentation, Saccharomyces cerevisiae converted the sugars present in the fruit waste into ethanol and carbon dioxide. The biochemical reaction involved in fermentation is where glucose is converted into ethanol and carbon dioxide by yeast action.

3.2.8Distillation Process

The fermented mixture was subjected to fractional distillation to separate ethanol from water and other impurities. The mixture was heated gradually, and ethanol vapours were collected through condensation. Since ethanol has a lower boiling point than water, it vaporizes first and gets separated effectively. The experimental boiling point observed during the study was approximately 78.35°C, which closely matched the standard value.

Apparatus Used for Distillation

- Boiling flask
- Claisen adapter
- Thermometer
- Liebig condenser
- Receiver flask
- Heating mantle
- Ring clamp and support stand

IV. RESULTS AND DISCUSSION

The experiment was successfully carried out for the production of ethanol from fruit waste through pretreatment, fermentation, and distillation processes. Different combinations of fruit waste including watermelon, papaya, pineapple, and pomegranate were analyzed to study their sugar content and ethanol yield. The obtained results confirmed that fruit waste can be effectively utilized as a raw material for bioethanol production.

During pretreatment, the fruit wastes were processed to release fermentable sugars suitable for microbial fermentation. Saccharomyces cerevisiae efficiently converted these sugars into ethanol under anaerobic conditions. After fermentation, distillation was performed to separate ethanol from the fermented mixture based on boiling point differences. Approximately 150 ml of ethanol was obtained from 1 kg of fruit waste, indicating the effectiveness of the adopted process.

The ethanol obtained after distillation appeared as a clear and colourless liquid with a characteristic alcoholic odour, confirming the formation of ethanol. The presence of ethanol was further verified through Gas Chromatography analysis.

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4.1 Gas Chromatography Analysis

Gas Chromatography analysis was carried out to confirm the presence of ethanol in the distilled sample. The chromatographic report indicated a positive ethanol peak, demonstrating successful fermentation and ethanol recovery from fruit waste.

4.2 Refractometer Analysis

The sugar content of different fruit waste samples was measured using a refractometer before fermentation. The Brix value indicated the amount of fermentable sugars present in the substrate, which directly influenced ethanol production.

Papaya showed the highest sugar concentration of 6%, whereas watermelon showed the lowest sugar concentration of 3%. Mixed fruit samples exhibited intermediate sugar concentrations ranging from 4% to 5%. Higher sugar concentration generally resulted in higher ethanol yield after fermentation.

Table 4.1 Refractometer Results

Sl.no	Fruits	Proportion	Percentage
1	Watermelon	1	3%
2	Papaya	1	6%
3	Watermelon and papaya	1:1	4%
4	Watermelon and papaya	3:1	5%
5	Pineapple and pomegranate	1	5%

4.3 Physical Properties of Ethanol

The physical properties of the produced ethanol samples such as density, specific gravity, viscosity, and ethanol yield were evaluated. The results indicated variation in ethanol quality depending on the fruit waste composition.

Papaya waste and pineapple–pomegranate mixture showed comparatively higher ethanol yields of 19%, while watermelon produced the lowest yield of 14%. Mixed fruit combinations produced moderate ethanol yields between 16% and 17%. These variations were mainly due to differences in sugar concentration and fermentable carbohydrate content of the fruit wastes.

Table 4.2 Physical Properties of Produced Ethanol

Sl. no	1	2	3	4	5
Fruits	Water melon	Papaya	Watermelon and papaya	Watermelon and papaya	Pineapple and pomegranate
Proporation	1	1	1:1	3:1	1:1
Density	0.9123 g/ml	0.9335 g/ml	0.9536 g/ml	0.9556 g/ml	0.9432 g/ml
Specific Gravity	0.9123	0.957	0.966	0.9789	0.9089
Viscosity	1.27mpa	1.273 mpa	1.291 mpa	1.148 mpa	1.138 mpa
Results	14%	19%	16%	17%	19%

V. CONCLUSION

The present study successfully demonstrated the production of ethanol from fruit waste through the processes of pretreatment, fermentation, and distillation. The experimental results confirmed that fruit waste is a suitable raw material for bioethanol production because of its high fermentable sugar content and biodegradability. Saccharomyces cerevisiae effectively converted the sugars present in the fruit waste into ethanol under anaerobic fermentation conditions.

Different fruit waste samples including watermelon, papaya, pineapple, and pomegranate were utilized in the study. Among the tested samples, papaya waste and pineapple–pomegranate mixtures produced higher ethanol yields due to their greater sugar concentration and favourable fermentation properties. Watermelon waste showed comparatively lower ethanol yield because of its low sugar content and higher moisture level. Mixed fruit waste combinations resulted in moderate ethanol production, indicating that the composition of the substrate significantly influences fermentation efficiency and ethanol yield.

The refractometer analysis revealed that papaya waste had the highest sugar concentration of 6%, while watermelon waste showed the lowest sugar concentration of 3%. The ethanol obtained after distillation was clear, colourless, and possessed a characteristic alcoholic odour. Gas Chromatography analysis further confirmed the successful production of ethanol. Approximately 150 ml of ethanol was obtained from 1 kg of fruit waste, demonstrating the feasibility of producing bioethanol from biodegradable waste materials.

The study highlights the potential of fruit waste as an economical and sustainable feedstock for renewable energy production. Utilization of fruit waste for ethanol production not only reduces environmental pollution caused by improper waste disposal but also contributes to energy recovery and sustainable waste management practices. This method can be

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further developed for large-scale bioethanol production and can support future renewable energy requirements.

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