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Production of Bioethanol from Food Waste

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Abstract - *Enormous quantities of food wastes are being generated everyday and their handling can be quite challenging. On the other hand, they contain significant amounts of sugars and they can be used as raw material for the production of ethanol. The fermentation is carried out for different inoculum concentrations and different durations of fermentation so as to evaluate optimum dosage of inoculum and duration of fermentation considering capacity of container used for fermentation. From the results obtained during the study, conclusions drawn were, maximum ethanol concentrations in fermented broth were 8% v/v and 7% v/v after fermentation duration of 14 days and at 1% and 1.5% v/v inoculum concentrations respectively. The maximum quantity of fermented broth (undistilled ethanol) produced was 6.2 litres at inoculum concentration of 1.5% v/v after fermentation duration of 14 days. The maximum quantity of distilled ethanol after final distillation was found to be 496 millilitres after fermentation duration of 14 days at inoculums concentration of 1.5% v/v. The maximum volume reduction in biomass of food waste found to be 3.7 litres and 3.3 litres at 1% and 1.5% v/v inoculum concentrations respectively after fermentation duration of 14 days.*

Key Words: Food Waste, Ethanol, Fermentation, Fractional Distillation, Resource Recovery, Volume Reduction.

1. INTRODUCTION

Management of MSW in India has surfaced to be a severe problem not only because of the environmental and aesthetic concerns but also because of the enormous quantities generated every day. A major component of MSW in India is organic waste and most of it being food waste. On the other hand they contain significant amounts of sugars and they can be used as raw material for the production of ethanol. Ethanol also known as ethyl alcohol is manufactured by the fermentation of sugars in the presence of yeast. In ethanol fermentation, one glucose molecule is converted into two ethanol molecules and two carbon dioxide molecules.

In present study Food waste is used as a feedstock or substrate for production of bioethanol. The Food waste is collected from a restaurant in suitable cans and yeast is added to the collected food waste sample and is stored in three different containers of required capacity for Fermentation. The laboratory bench scale fermentation and distillation unit is set up for fermentation of food waste stored in containers of 10.0 litres capacity.

1.1 Objectives

- Production of Bioethanol from food waste via fermentation by yeast and multiple fractional distillation of fermented broth.
- Evaluate the volume reduction in biomass of food waste via fermentation by yeast.
- Evaluate the quantity of fermented broth produced and concentration of ethanol in fermented broth.
- Estimate the optimum duration of fermentation.
- Estimate the optimum inoculum concentration.
- To compare quantity of ethanol produced and volume reduction in biomass of food waste from different durations of fermentation and different inoculum concentrations.

1.2 Literature Review

Shilpa C., Girisha Malhotra and Chanchal, have worked on the project titled, **Alcohol Production from Fruit and Vegetable Waste,** Wastes from fruits, such as banana, orange, pineapple and pea peels were subjected to simultaneous saccharification and fermentation for 7 days by co-culture of Aspergillus niger and Saccharomyces cerevisiae. The results of the study showed that after 7 days of fermentation, pineapple peels had the highest biomass yield, followed by banana peels, orange peels, pea peels. The optimal ethanol yields were 8.34% v/v, 7.45 % v/v, 3.98 % v/v and 2.58 % v/v for pineapple, banana, orange and pea peels respectively.

Shafkat Shamim Rahman, Md. Mahboob Hossain, Naiyyum Choudhury, have worked on the project titled, **Bioethanol fermentation from kitchen waste using Saccharomyces cerevisiae,** Bioethanol obtained from microbial fermentation can replace conventional fossil fuels to satisfy energy demand. In this respect, of fermenting isolate of Saccharomyces cerevisiae, obtained from date juice, was grown in YEPD medium as a part of a previous research project. Fermentation in shaking condition resulted in 7.3% ethanol after 48hr, after which the pH of the medium increased slightly in response.

2. MATERIALS AND METHODOLOGY

2.1 Materials and Apparatus Required

Food waste collected from a restaurant, Inoculum - Saccharomyces cerevisiae, also known as Baker's Yeast, Plastic containers for storing Food waste for fermentation, Black garbage covers to cover the containers containing food waste sample, Cheese cloth to filter the fermented broth, Fractional distillation unit for distillation of Bioethanol, Hydrometer(alcoholometer) for estimation of ethanol concentration, Measuring cylinder and Measuring Jar to measure volume of food waste and quantity of ethanol produced, Plastic bottle containers to store bioethanol.

2.2 Methodology

The laboratory bench scale fermentation and distillation unit is set up for fermentation of food waste stored in containers of 10.0 litres capacity. The sample was collected from the kitchen of Atharva Hotel and Restaurant, located near Ram Mandir, Kalaburagi. The fermentation was carried out for different durations and different inoculum concentrations. The fermented broth is subjected to multiple distillation and the concentration of Ethanol in the distilled sample is estimated and further the quantity of ethanol produced post-distillation is estimated. The study was conducted at ambient temperature in a laboratory located in an Ethanol plant at Bhalkeshwar Sugars Ltd, Bhalki.

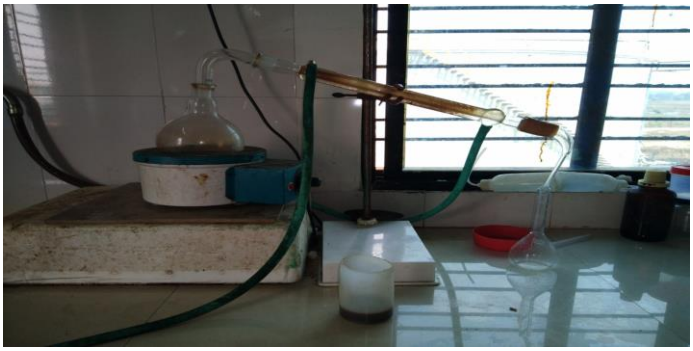
Fermentation Process

$$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$$

glucose — ethanol — carbon dioxide

Fermentation is a metabolic process that produces chemical changes in organic substrates through the action of enzymes. In biochemistry, it is narrowly defined as the extraction of energy from carbohydrates in the absence of oxygen. Yeast, a form of fungus, occurs in almost any environment capable of supporting microbes. Yeasts convert (break down) sugar-rich molecules to produce ethanol and carbon dioxide.

Fractional Distillation



Fractional distillation in a laboratory makes use of common laboratory glassware and apparatuses, typically including a Bunsen burner, a round-bottomed flask and a condenser, as well as the single-purpose fractionating column. Ethanol boils at 78.4 °C (173.1 °F) while water boils at 100 °C (212 °F). So, by heating the mixture, the most volatile component (ethanol) will concentrate to a greater degree in the vapour leaving the liquid.

3. RESULTS AND DISCUSSION

The results obtained during the study have been discussed in the following sections.

3.1 Effect of Duration of Fermentation

Duration of fermentation plays a major role in the production of ethanol since it is important to know at what rate alcoholic fermentation is optimum. The food waste after being collected from the restaurant is measured using a measuring jar by volume and 5 litres of food waste is mixed with 2.5 litres of water, making a diluted food waste sample of 7.5 litres, at this stage 0.5% (of sample) inoculum is added to the sample and mixed well. This sample with inoculum thoroughly mixed in it, is stored in plastic container of 10 litres storage capacity, similarly same volume of sample is stored in another two containers of similar capacities. A pipe is connected to the top of the container and is dipped in a

bottle containing water, so that gases formed in the container during fermentation pass through the pipe while maintaining anaerobic condition. All three containers are covered properly with black garbage covers and kept for fermentation for 7 days, 14 days and 21 days respectively.

Table -1: Effect of Duration of Fermentation

FERMENTATION DURATION	7 DAYS	14 DAYS	21 DAYS
INOCULUM (%) CONCENTRATION	0.5%	0.5%	0.5%
ETHANOL CONCENTRATION IN FERMENTED BROTH	4.5%	6.5%	6.5%
QUANTITY OF UNDISTILLED ETHANOL PRODUCED	4.3 LITRES	5.1 LITRES	5.12 LITRES
QUANTITY OF ETHANOL POST DISTILLATION	205 ML	360 ML	365 ML
VOLUME OF FOOD WASTE POST-FERMENTATION	3.2 LITRES	2.4 LITRES	2.35 LITRES
REDUCTION IN VOLUME OF FOOD WASTE	1.8 LITRES	2.6 LITRES	2.65 LITRES

3.2 Effect of Inoculum Concentration

The food waste after being collected from the restaurant is measured using a measuring jar by volume and 5 litres of food waste is mixed with 2.5 litres of water, making a diluted food waste sample of 7.5 litres, at this stage 0.5% (of sample) inoculum is added to the sample and mixed well. This sample with inoculum thoroughly mixed in it, is stored in one plastic container of 10 litres storage capacity, similarly same volume of sample is stored in another two containers of similar capacities with different inoculum concentrations such as 1% and 2% respectively in another two containers. A pipe is connected to the top of the container and is dipped in a bottle containing water, so that gases formed in the container during fermentation pass through the pipe while maintaining anaerobic condition. All three containers are covered properly with black garbage covers and kept for fermentation for 14 days.

Table -2: Effect of Inoculum Concentration

FERMENTATION DURATION	14 DAYS	14 DAYS	14 DAYS
INOCULUM (%) CONCENTRATION	0.5%	1%	1.5%
ETHANOL CONCENTRATION IN FERMENTED BROTH	6.5%	7.5%	8%
QUANTITY OF UNDISTILLED ETHANOL PRODUCED	5.1 LITRES	5.8 LITRES	6.2 LITRES
QUANTITY OF ETHANOL POST DISTILLATION	360 ML	435 ML	496 ML
VOLUME OF FOOD WASTE POST-FERMENTATION	2.4 LITRES	1.7 LITRES	1.3 LITRES
REDUCTION IN VOLUME OF FOOD WASTE	2.6 LITRES	3.3 LITRES	3.7 LITRES

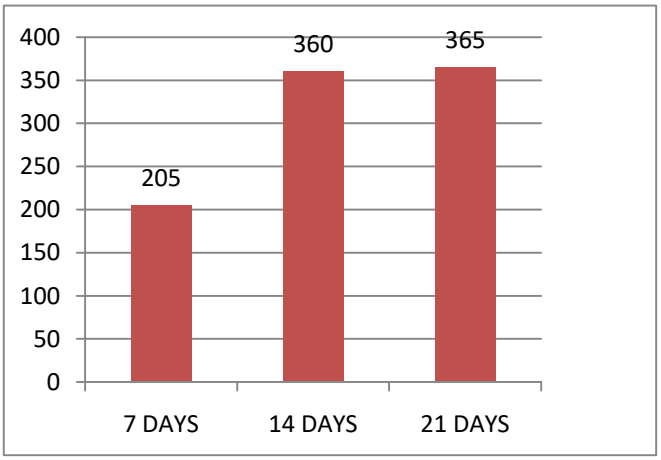


Chart -1: Quantity of Ethanol Produced Post Distillation in millitres V/S Duration of Fermentation in days

The graph was plotted using data obtained after the fermentation and distillation process were carried out. The graph was drawn by plotting Quantity of ethanol produced post fermentation in millilitres on Y-axis and Duration of fermentation in days on X-axis. By results obtained and the graph plotted, it is clear that the ethanol quantity post distillation was found to be increased at fermentation duration of 14 days compared to quantity of ethanol produced at fermentation duration of 7 days, where as there no significant increase in ethanol production at 21 days fermentation duration though there was increase of 5ml in quantity of ethanol produced. Thus, 14 days can be considered as optimum fermentation duration.

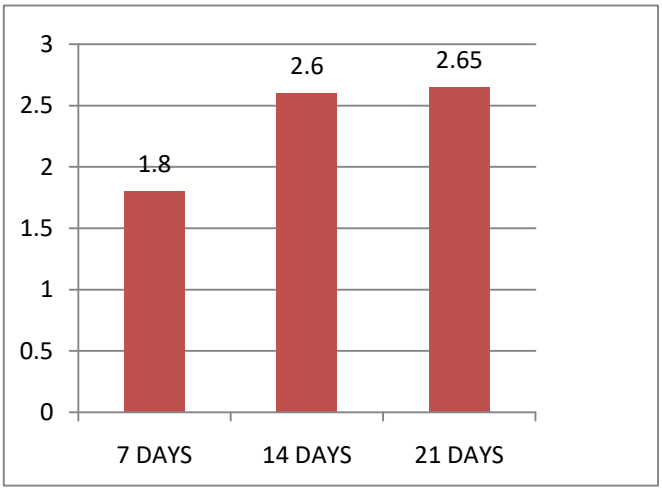


Chart -2: Reduction in Volume of Food waste Post-Fermentation in litres V/S Duration of Fermentation in days

The graph was plotted using data obtained after the fermentation and distillation process were carried out. The graph was drawn by plotting Reduction in volume of food waste post fermentation in litres on Y-axis and Duration of fermentation in days on X-axis. By results obtained and the graph plotted, it is clear that the reduction in volume of food waste post fermentation was found to be increased at fermentation duration of 14 days compared to reduction in volume of food waste post fermentation at duration of 7 days, where as there no major increase in reduction in volume of food waste at 21 days fermentation duration though there was increase of 500ml in reduction in volume of food waste. Thus, 14 days and 21 days, both can be considered as optimum fermentation duration.

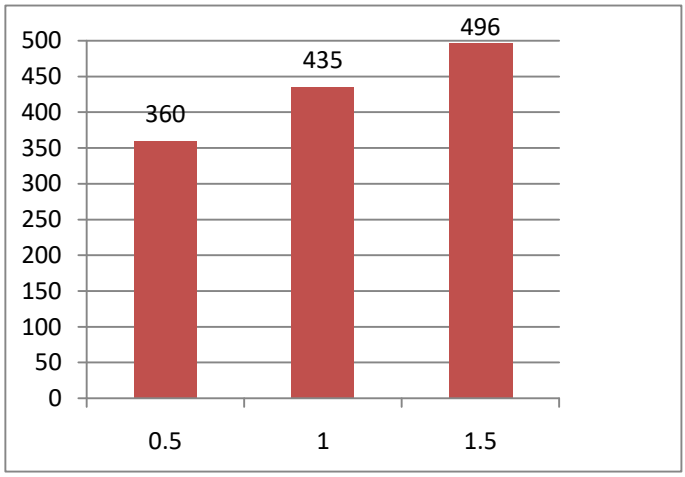


Chart -3: Quantity of Ethanol Produced Post Distillation in millitres V/S Inoculum Concentration in percentage v/v

The graph was plotted using data obtained after the fermentation and distillation process were carried out. The graph was drawn by plotting Ethanol concentration in fermented broth in % v/v on Y-axis and Inoculum concentration in days on X-axis. By results obtained and the graph plotted, it is clear that the Quantity of ethanol produced post multiple distillation was found to be increased at inoculum concentration of 1% compared to quantity of ethanol produced post distillation at inoculum concentration of 0.5%, further at inoculums concentration of 1.5% distilled ethanol quantity was found to be increased further. Thus, 14 days can be considered as optimum fermentation duration and 1.5% can be considered as optimum inoculum concentration.

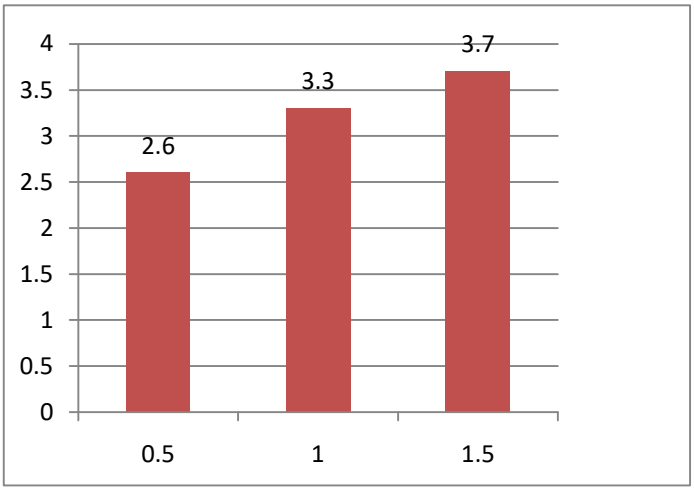


Chart -4: Reduction in Volume of Food waste Post-Fermentation in litres V/S Inoculum Concentration in percentage v/v

The graph was plotted using data obtained after the fermentation and distillation process were carried out. The graph was drawn by plotting Reduction in volume of food waste post fermentation in litres on Y-axis and Inoculum concentration in % on X-axis. By results obtained and the graph plotted, it is clear that the reduction in volume of food waste post fermentation at inoculum concentration of 1% was found to be increased compared to reduction in volume of food waste post fermentation at inoculum concentration of 0.5%, where as there no major increase in reduction in volume of food waste at inoculums concentration of 1.5% though there was increase of 400ml in reduction in volume of food waste. Thus, 1% and 1.5% inoculum concentrations both can be considered as optimum concentrations, considering volume reduction of food waste.

3. CONCLUSIONS

- Food Waste can be used as a valuable substrate for production of Ethanol.
- The maximum ethanol concentrations in fermented broth were 8% v/v and 7% v/v after fermentation duration of 14 days and at 1% and 1.5% v/v inoculum concentrations respectively.
- The maximum quantity of fermented broth (undistilled ethanol) produced was 6.2 litres at inoculum concentration of 1.5% v/v after fermentation duration of 14 days.
- The maximum quantity of distilled ethanol after final distillation was found to be 496 millilitres after fermentation duration of 14 days at inoculums concentration of 1.5% v/v.
- The maximum volume reduction in biomass of food waste was found to be 3.7 litres and 3.3 litres at 1% and 1.5% v/v inoculum concentrations respectively after fermentation duration of 14 days.

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