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Industrial ethanol from banana peels for developing countries: Response surface methodology

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ABSTRACT:

Energy plays a vital role in the development of any nation. However, that development increases pollution levels. Recycling and utilization have become major concerns of developing nations. The goal of this research is to utilize banana peels for the production of bioethanol by using the yeast *Saccharomyces cerevisiae*. The effects of hydrolysis factors were investigated, and the optimized combination of factors with response surface designs was found. The results show that 45.088% of ethanol was obtained at 1.50% v/v acid concentration, 91.02 °C temperature and 21.66 min retention time. Analysis of variance (ANOVA) correlation coefficients Pred $R^2 = 0.8650$ and Adj $R^2 = 0.9782$ indicates an excellent evaluation of the experimental data by a second-order polynomial regression model.

1. Introduction

The overall well-being of the world, industrial competitiveness, and the function of society are all dependent on safe, sustainable and affordable energy [1]. Energy provides essential power for almost all human activities. It provides services for cooking, heating, lighting, health, food production and storage, education, mineral extraction, industrial production and transportation [2,3]. Energy consumption has increased steadily over the last century as the world population has grown and as more countries have become industrialized. Crude oil has been the major resource required to meet this increased energy demand [4]. Different techniques have been used to estimate the current known crude oil reserves, and it has been concluded that the annual global oil production will decline from the current 25 billion barrels to approximately 5 billion barrels in 2050 [5].

Ethanol (ethyl alcohol, bioethanol) is the most employed liquid biofuel used as a fuel or as a gasoline enhancer. Given that ethanol has a higher oxygen content than other liquid biofuels, a smaller amount of the additive is required. The increased percentage of oxygen allows a better oxidation of the gasoline hydrocarbons with the consequent reduction in the emission of CO and aromatic compounds [6,7]. Biofuels are generally produced by fermentation of agricultural wastes, fruit wastes, municipal and industrial wastes using *Saccharomyces cerevisiae* (baker's yeast) as food for the microorganisms [8]. The complexity of the production process depends on the feedstock [9].

The recycling and utilization of solid wastes are currently major issues for environmental research. The treatment of solid waste goes as far back as the 18th century, when burying the waste was the best option for waste management. Inadequate municipal and industrial solid waste collection and disposal creates a range of environmental problems in Ethiopia. A considerable amount of waste ends up in open dumps or drainage systems, which threatens both surface water and ground water quality and causes serious environmental and health problems. The open air burning of waste, spontaneous combustion in landfills and incinerating plants lacking effective treatment for gas emissions are all causing air pollution [10,11]. The adverse effects of inadequate solid waste service create significant issues for productivity and economic development. Solid wastes, such as fruit peels, are largely obtained as a byproduct from food processing industries, juice processing plants, hotels and restaurants. These types of waste can cause serious environmental problems unless they are converted into a useful product or disposed of properly [12].

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Over time, the scarcity of resources and the soaring pollution level have necessitated the need for alternative treatment options. Recently, there are many treatment options for solid waste such as composting, incineration, land filling and production of different biofuels. The option chosen must be based on different technical and economic criteria of the particular situation [13]. In most developing African countries, municipal solid wastes are disposed of in non-engineered landfills, which are known to generate greenhouse gasses. In developed nations, however, municipal solid wastes are treated through advanced methods such as controlled incineration and production of biofuels both due to the increasing need to use the so called "waste" as a resource and due to stringent environmental regulations [14]. This research work focuses on the utilization of waste for energy generation (i.e., the possibility of converting waste fruit peels into valuable product (bioethanol) at optimum parameters).

The aim of this study is to optimize parameter conditions (acid concentration, temperature and time) for hydrolysing waste banana peels to obtain the maximum amount of fermentable sugars by conducting series of experimental analysis. The effect of benzyl penicillin is also studied during fermentation.

2. Material and methods

2.1. Material

2.1.1. Raw material

Banana peels (Royal red and Lacatan) were collected in plastic bags from a juicing plant near the MIT campus and were washed before use. Analytical grade chemical, sulfuric acid (H_2SO_4), sodium hydroxide (NaOH), yeast extracts agar, urea, dextrose sugar (Mg $SO_4.7H_2O$), baker's yeast/yeast (*Saccharomyces cerevisiae* maintained on YEPDA (1% yeast extract, 2% peptone, 2% agar) slant stored at 4 °C), distilled water, and benzathine penicillin G were used in the experiment. The physicochemical characteristics of the banana peel are listed in Table 1.

2.1.2. Experimental design

The Box-Behnken method has been selected for the optimization of three variables (acid concentration (% v/v), temperature (°C) and time (min)). The variables, factors and level are referenced in Table 2. For the three variables, 17 runs were conducted to produce fermentable sugar which is referenced in Table 3. The design summary for acid hydrolysis with three levels and three factors is presented in Table 4. The central composite design has mostly been used for fitting the second-order model. The second-order model is defined as follows to facilitate calculations:

Table 1
Physicochemical characteristic of banana peel.

S. no	Component	% w/w
1	Cellulose	9.00
2	Crude fat	6.00
3	Dietary fiber	19.00
4	Glucose	2.00
5	Hemicellulose	8.00
6	Lignin	9.00
7	Other solids	6.00
8	Pectin	11.00
9	Proteins	6.00
10	Starch	3.00
11	Water	20.00
12	Xylose	1.00

Table 2
Process parameter for hydrolysis.

Variable unite	Factors (X)	Levels		
		−1	0	1
Acid Conc. (%v/v)	A	0.5	1.5	2.5
Temp. (°C)	B	70	90	110
Time (min)	C	10	20	30

$$Y = b_0 = \sum_{i=1}^{n} b_i x_i + \sum_{i=1}^{n} b_{ii} x_i^2 + \sum_{i=1}^{n} \sum_{j>1}^{n} b_{ij} x_i x_j \quad (1)$$

where Y is the predicted response, b_0 the constant coefficient, b_i the linear coefficients, b_{ii} the quadratic coefficients, b_{ij} the interaction coefficients, and x_i, x_j are the coded values of the adsorption variables [15].

2.2. Methods

2.2.1. Feed material

The gathered peels were chopped into small pieces approximately 2–4 cm in length using a knife. The pieces were then sun dried under mild sunlight for two days and then dried at 60 °C in an oven for one day. Next, the samples were taken out of the drier once they were dry enough to be crushed. The cut pieces were then crushed in the grinder. The ground sample was divided proportionally into seventeen separate samples of 10 g of ground banana peels and another two separate samples of 20 g of ground banana peels. A juice was prepared for each sample by adding 10:1 (v/w) ratio of distilled water to the sample in separate flasks [16]. The lignocelluloses molecules must be broken down into free sugars before the fermentation required for alcohol production [17].

2.2.2. Steam treatment

The separate samples capped with aluminum foil were autoclaved at 15psi pressure for 30 min. After autoclaving the samples were allowed to cool and the soluble portion was separated from the insoluble using filtration. The insoluble portion was then allowed to hydrolyse, and the amount of sugar produced was measured for each sample.

Table 3
Experimental design formulation for acid hydrolysis.

Experimental run	Acid concentration (%v/v)	Temperature (°C)	Time (min)	Percent weight of ethanol content (%w/w to original sample)
1	2.5	90	30	43.56
2	1.5	90	20	45.10
3	2.5	70	20	44.01
4	1.5	90	20	45.00
5	0.5	110	20	44.27
6	2.5	90	10	42.40
7	1.5	90	20	45.00
8	2.5	110	20	42.98
9	1.5	90	20	45.00
10	1.5	90	20	45.15
11	1.5	110	10	42.96
12	0.5	70	20	43.21
13	0.5	90	30	43.00
14	0.5	90	10	42.56
15	1.5	70	10	42.20
16	1.5	70	30	43.85
17	1.5	110	30	43.40

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