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EFFECT OF CATALYST CONCENTRATION AND THE MODELLING OF BIOETHANOL PRODUCTION FROM MANIHOT ESCULENTA TUBERS

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ABSTRACT

Bioethanol is a clear, colourless liquid that is biodegradable and can be used as fuel additive. In this work the effect of catalyst concentration on bio-ethanol production was studied in order to obtain optimal yield. The ethanol was produced from manihot esculenta (cassava) tubers using yeast-catalyzed fermentation process followed by distillation. The reaction conditions were maintained at a constant fermentation time of 5 days while varying the amount of yeast catalyst added. The results obtained show that the pre-treatment yield of bioethanol ranged from 6-12.5%. Maximum bioethanol yield of 12.5% occurred at 2.1g of catalyst being used. Furthermore, modelling the production process gives a second-order equation of the form: $Y = -2.392X^2 + 9.975X + 0.95$, where Y is the predicted yield of ethanol and X, the mass of yeast catalyst added.

KEYWORDS: Bioethanol; Catalyst; Modelling; Manihot Esculenta.

INTRODUCTION

Bioethanol is a typical bio-fuel that is capable of providing enough energy when burnt as fuel for transport. The use of ethanol as an alternative motor fuel has been steadily increasing around the World for a number of reasons. Domestic production and use of ethanol for fuel can decrease dependence on foreign oil (for countries that do not have petroleum and other fossil fuels). It can also reduce deficits, create jobs in rural areas, reduce atmospheric pollution and reduce global climate warning due to carbon dioxide build-up. Bioethanol, unlike gasoline, is an oxygenated fuel that contains 35% of oxygen, which reduces particulate matter and oxides of nitrogen (NOx) emissions (Farrell, 2006); Nguyen, 2007; Demirbas, 2009). The principal advantages of bio-ethanol over petro-fuels are its renewability, biodegradability and carbon neutrality (Lichts, 2010). Ethanol can be made synthetically from petroleum or by microbial conversion of biomass through fermentation (Nandy *et al*., 2002; Beltran *et al*., 2001; Finar, 1997; Ijayagopal and Balagopalan, 1989; Ijayagopal and Balagopalan, 1978; Badger, 2002). About 97% of ethanol in the world is produced by fermentation method. The basic chemical equations involved in enzymatic production of ethanol are shown in Eqn 1 and Eqn2.

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6 \quad \text{(Eqn 1)}$$

$$C_6H_{12}O_6 \rightarrow C_2H_5OH + 2CO_2 \quad \text{(Eqn 2)}$$

The steps involved in fermentation are i) formation of a solution of fermentable sugars, ii) the fermentation of these sugars to ethanol and iii) the separation and purification of ethanol, usually by distillation.

Several variable factors affect the fermentation process. These include catalysis (conditioning of the yeast) and processing parameters such as pH, fermentation time, reaction temperature, design of fermentation process reactor, etc (Lichts, 2010; Abara and Rakshit, 2004; Forgarthy and Kelly, 2006, Punchat, 1991, Ehiri *et al*, 2011). These

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conditions need to be adequately monitored to maintain an optimal substrate for fermentation. Yeast uses glucose to produce a high yield bio-ethanol provided the environment is ideal (Lichts, 2010). To avoid the yeast being exposed to extreme concentrations of sugar, the glucose level must be kept at an optimal level. A too high or too low pH will cause the yeast to use valuable energy to balance its own internal pH while not maximizing productivity (Lichts, 2010). High operating temperature will cause the yeast to die, while low operating temperature restrains the yeast and can make it inert. Hence, without active yeast sugar will not convert into ethanol and the potential for contamination grows, as the sugar is available for other micro-organisms (Lichts, 2010).

In this study, bio-ethanol was produced from cassava tubers using fermentation process. Yeast was used as the catalyst. The objective of the study was to investigate the effect of quantity of yeast catalyst used on bio-ethanol yield and to model the bio-ethanol production reaction.

MATERIALS AND METHOD

Materials: Fresh cassava tubers were obtained from Eke Amagu Market, Ikwo in Ebonyi State, Nigeria. Analar grade yeast powder was used. Other materials and instruments used were distilled water, conical flask, OGA DISIEL manual grater, distillation apparatus and KERN 770 Analytical weighing balance.

Preparation of Cassava for Fermentation: Fresh cassava tubers were peeled using kitchen knife and washed with distilled water. The starchy layer was pulverized using manual grater. Five litres of distilled water was added to the pulverized cassava tubers in a big bowl and were thoroughly mixed. The resulting mixture was allowed to settle for 24 h to yield enough starch. Later, it was filtered using a sieve cloth and allowed for 15 min to sediment; the top liquid layer was drained off, remaining only the starch that was eventually dried under the sun.

Fermentation of Starch: 100g of the dried starch was weighed in a watch glass and transferred into a conical flask. Next 0.5g of yeast powder was added as catalyst followed by 200cm^3 of distilled water. The resulting mixture was stirred thoroughly for homogeneity using a stirring rod. The conical flask containing the mixture was covered with a light tissue paper and masking tape so as to create a little vent for optimum performance of the yeast.

Distillation of Fermented Cassava Broth: The fermented cassava broth was filtered using a cloth sieve and was allowed to settle for 15mins in a beaker. Next 200cm^3 of the supernatant liquid (filtrate) was put in the round-bottomed flask of the distillation apparatus fitted with a thermometer. Anti-bumping chips were also added into the flask for even distribution of heat. Thereafter, the mixture in the flask was heated and the distillate collected at temperature between 70 and 90^{o}C. The volume of the ethanol distillate was measured and recorded. The same procedure outlined above was repeated for 1.0g, 1.5g, 2.0g, 2.5g and 3.0g of yeast catalyst. The pretreatment yield of ethanol was calculated using Eqn 3:

$$Y = (V_e/V_m) \times 100\% \qquad \text{(Eqn 3)}$$

where Y is the yield of ethanol, V_e and V_m are the volumes of bioethanol distillate and fermented mixture distilled respectively.

RESULTS AND DISCUSSION

Table 1 gives the reaction conditions and the pretreatment yield of bioethanol from the fermented cassava tubers. The data indicate that the pre-treatment yield of bioethanol ranged from 6 – 12.5% in all the reaction conditions studied.

Table 1: Reaction Conditions and Yield of Bioethanol

Sample No.	Quantity of yeast added/g	Fermentation time/day	Volume of fermented mixture distilled/cm^3	Volume of ethanol distillate/cm^3	Bioethanol yield/cm^3
1.	0.5	5	200	12	6
2.	1.0	5	200	16	8
3.	1.5	5	200	18	9
4.	2.0	5	200	25	12.5
5.	2.5	5	200	24	12
6.	3.0	5	200	17	8.5

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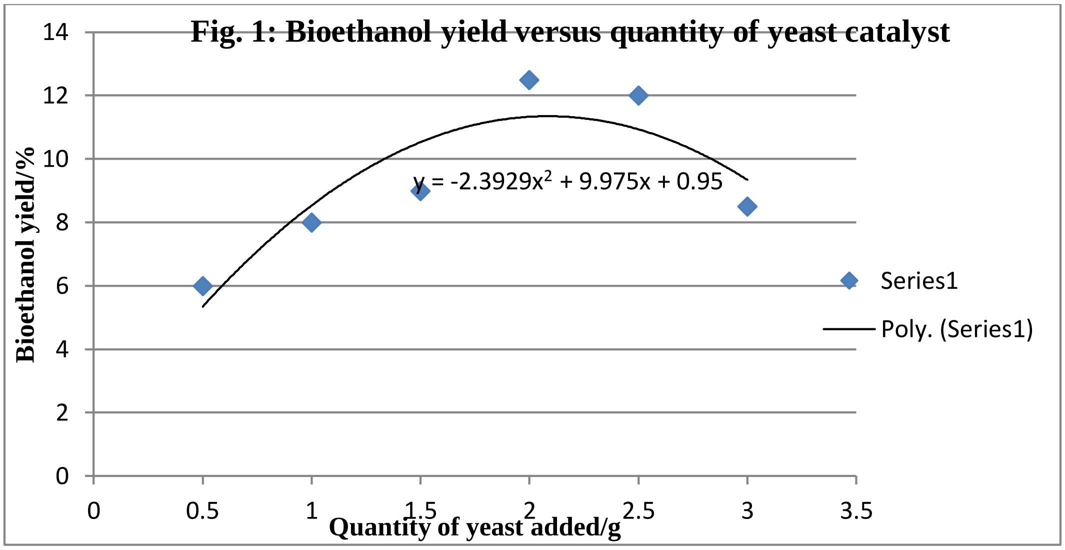

Effect of Quantity of Yeast Catalyst on Yield

The effect of quantity of yeast catalyst added during fermentation on the yield of bioethanol is shown in Fig. 1. Modeling the yield of ethanol as a function of fermentation time by taking all data points on Fig. 1 gives a quadratic equation of the form: $Y = -2.392X^2 + 9.975X + 0.95$ where Y is the yield of bioethanol and X is the quantity of yeast catalyst added . Optimization gives an optimum yeast catalyst mass of 2.1g giving an optimal bioethanol yield of 11.35%.

CONCLUSION

In this work, bioethanol was prepared from cassava tubers using yeast-catalyzed fermentation process followed by distillation. Catalysis was vital in the fermentation process. An optimal catalyst concentration of 2.1g with a corresponding maximum bioethanol yield of 11.35% was established while the production model followed the quadratic type.

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