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Effect of Temperature Variation on the Production of Ethanol from Sawdust

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Abstract: The conversion of sawdust to ethanol to determine the conditions of temperature and other variables that maximize the yield of ethanol. The effect of temperature variation on the fermentation step was analyzed. The method employed here was to use decrystallization, acid hydrolysis, neutralization, fermentation of reducing sugars using yeast, distillation and finally analysis to determine the percentage concentration of ethanol. It was observed that at moderately high temperature and enzyme loading of 30%, the yield of ethanol was appreciably high for the batch process fermentation.

Key words: Ethanol, sawdust, conversion, acid hydrolysis, fermentation, temperature

INTRODUCTION

Ethanol has been in existence many years ago. It was one of the first fuels used in automobile engines. It was used extensively in Germany during World War II and also in Brazil, the Philippines and the United states. During the post-war period as petroleum supplies became cheap and abundant, gasoline largely replaced ethanol as an automobile fuel (Wyman and Hinman, 1990). Not until the 1970s when the supply of oil was restricted, did ethanol re-emerge as an alternative to or extender for petroleum based liquid fuels (ethanol as an extender to petroleum products is added to these fuels to increase their volume) (Anusiem, 2004; Baxendell, 1981). Today, 12 countries produce and use a significant amount of ethanol. In Brazil, for example one third of that country's automobile uses pure ethanol as fuel, the remaining two thirds uses a mixture of gasoline and ethanol is called gasohol. France, the United States, Indonesia, the Philippines, Guatemala, Costa Rica, Argentina, the Republic of South Africa, Kenya, Thailand and Sudan are other countries with government or private ethanol fuel program (Atkinson, 1994). Rostrup-Nielsen stated that rising fuel prices and increasing environmental concerns in conjunction with the depletion in crude oil reserves will see the search for alternative transportation fuels intensify.

The Nigerian Yeast and Alcohol Manufacturing Company (NIYAMCO) located in Kwara state is the only company presently involved in ethanol production using molasses as starting material.

Sawdust is the major waste from the furniture industry. It is primarily fine chippings of wood produced during sawing or cutting. It contains lignocelluloses and certain amount of moisture. Besides being a source of silvichemicals the term silvichemicals refers to wood-derived chemicals analogous to petrochemicals. It can be used as a source of energy and also to produce ethanol or methanol and other organic compounds (Opara, 2002; Weil *et al*., 2002).

Fong provided a perspective on the relative costs of producing ethanol from a wide range of possible biomass feedstock using conventional plants and processes being developed. At present, many of these waste materials have a negative value or impact on the ecosystem or at the most have a very low grade fuel value. Since these waste raw materials do not compete with human food stuffs or fossil fuels, there is a real advantage in utilizing these wastes instead of grains or sugarcane as source of alcohol (Von Sivers *et al*., 1994).

Biomass ethanol production also produces valuable by-products such as acetic acid which can be used as a food additive as a photographic chemical and in the manufacture of plastics. Other by products such as distillers dried grains are obtained. Distiller's grain are solids that are separated from the spent stillage (removed prior to or right after fermentation). The major advantage of using the stillage is the elimination of the costs for the equipment and energy used to process DDGS (Distillers Dried grain soluble). Adeyinka (1993) observed that the yield of ethanol was affected by the medium s acidity, enzyme loading, temperature and the homogeneity of the medium. Also, retention time employed affected product distribution due to agitation.

Since yeast, a bioenzyme otherwise called *Saccharomyces cerevisiae*-thrives optimally in certain physical conditions and pH (at 50°C and 4.8 pH), the effect of temperature on the fermentation medium cannot

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be overemphasized. As a rule of thumb, the rate of reaction is doubled for every 10°C increase in temperature (Anusiem, 2004). But for a complex reaction like the one we are dealing with temperature variation affects a host of factors like yield of ethanol, retention time, product distribution and so on.

Also, sugarcane residues and spent wood spillage could be burnt as fuel for the distillation process. The utilization of even the seemingly waste products of the ethanol production process makes it a very lucrative project both economically and environmentally.

MATERIALS AND METHODS

Pretreatment and decrystallization procedure: The sawdust is first cleared of impurities and coarse chippings. About 263.3 g of sawdust is placed in a vessel and concentrated sulfuric acid (1 L) is then poured into the vessel. The sawdust turns black on contact with the acid. The reaction is almost spontaneous but the vessel should be left for 48 h to allow for complete reaction, after vigorous stirring of the mixture. A plastic stirrer is used for mixing.

Acid hydrolysis procedure: After 48 h, boiling water of about 1 L is added into vessel containing the acid-sawdust mixture. Care should be taken when adding the hot water to the vessel as the reaction is strongly exothermic. Pour the boiling water into the vessel along its sides with escape of fumes from the vessel. A pH of 0.8 was recorded.

Lignin removal and filtration procedure: Place the net filter over a bucket and clip on the sides. The acid hydrolyzed sample (black) is then poured on the filter to remove the lignin from the sample. Care should be taken as both the lignin and filtrate as very corrosive. Mash or squeeze the lignin to extract as much of the acid solution as possible. This is to ensure that as much of the acidic solution is recovered as possible. The clear filtrate is then sent to the refractometer. The refractometer was used to determine the sugar content (concentration) to be 46%. Although, the above procedure could be deferred until after fermentation, we carried this out to compare the yields of ethanol when this procedure is carried out before fermentation.

Neutralization procedure: Since the yeast thrives optimally at a pH range of 4-5, the pH of the solution must be raised to that favorable for yeast survival. Dissolve the pellets of NaOH in distilled water which is exothermic. Careful pour the NaOH solution into the vessel containing the acidic sample along its sides. Ensure that the cover of the vessel is in place as the reaction is very hazardous and particles out of the vessel adding the NaOH solution until the pH get to about 4.5 is achieved.

Fermentation procedure: Pour 100 g of the neutralized sample (although still slightly acidic) into four reactors (conical flasks). Measure about 30 g of yeast (30% enzyme loading) and add to the various flasks. Ensure that the vessels are very clean now, measure in acetaldehyde (1% catalyst loading) and add into the fermentation vessels. Place a corker over the vessels an insert a thermometer into the vessels. Place the vessels into water bath and regulate the temperature at 20, 30, 40, 50°C. Leave for 4 days for fermentation to occur.

Distillation procedure: Decant the solution on top of the yeast (in the sample) and filter. Then setup the arrangement shown below and carryout a simple distillation. The distillation should be done twice. A first run at 100°C should be done. A second distillation process where the temperature range should be about 78-85°C (boiling point of ethanol) should be used.

Procedure: After distillation, the distillate should be weighed and its volume measured.

Alternative routes: In order to explore the various possibilities available, the researchers considered several alternatives:

- Deferring the separation of lignin until after fermentation, sample 5
- Excluding acetaldehyde addition from the above, sample 6. These were done to observe their various effects on ethanol yield

In other words, the researcher prepared two additional samples (i.e., sample 5 and sample 6). Sample 5 is a fermented sample in which all the steps of pretreatment, decrystallization, hydrolysis, neutralization, catalyst addition, fermentation and then lignin removal before distillation. Sample 6 is also a fermented sample in which the steps of pretreatment decrystallization to fermentation and lignin removal occurred excluding catalyst addition.

RESULTS AND DISCUSSION

The fermented samples in the experiment gave the following results. The fermented samples were analyzed for ethanol after 4 days. The densities and percentage

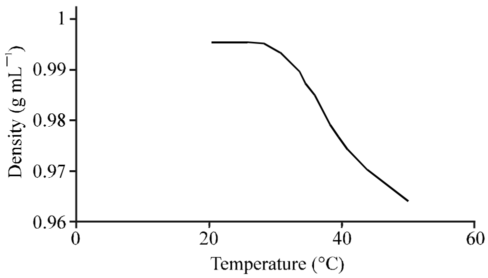

Fig. 1: Density against temperature

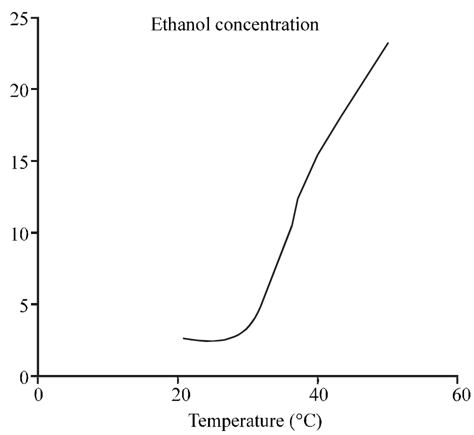

Fig. 2: Ethanol concentrations against temperature

ethanol were analyzed. From Fig. 1, the density decreases as the temperature increases. The rate of decrease of density with temperature is nonlinear. The rate of increase of ethanol concentration with temperature is nonlinear.

From the experiment the ethanol yield was found to be affected by fermentation conditions, acidity and enzyme loading. The reaction vessel and retention time also affected the yield. Other factors like temperature if not controlled also affect the yield as observed by Adeyinka (1993).

The ethanol concentration of the sample increases as the density increases. The variation of ethanol concentration with temperature is nonlinear from Fig. 1 and 2.

The density of the distillate should not be greater than one. Between 20 and 30°C, the density of the distillate was about 0.99 (g mL^{-1}). However, at higher temperatures, the density drops sharply.

The rate of increase of ethanol concentration is quite low between 20 and 30°C. This is because yeast does not survive well at low temperatures. The ethanol concentration increases sharply after 30°C.

From Fig. 2 at temperature of about 20 and 30°C, the yield of ethanol was about 2.6 and 3.6%, respectively. This is quite low, better yields of about 15.6 and 23.4% were obtained at higher temperatures of about 40 and 50°C, respectively. All these results were obtained when lignin was absent in the fermentation steps.

However, fermentation was done in the presence of lignin, better yields were obtained. This is because the yeast enzyme also acts on the lignin residue to produce ethanol thereby leading to better yield of ethanol. Acetaldehyde was also used in the fermentation step (about 1% acetaldehyde). Without acetaldehyde temperature and enzyme loading of about 50°C and 30% respectively, a relatively high yield of 40% was obtained.

The best results were obtained in sample 6 of the experiment. In the presence of acetaldehyde and lignin during fermentation and at the conditions of temperature and enzyme loading just considered, a high yield of 52.1% was realized.

Other possible variables that affect the yield may include sanitary conditions, level of agitation, pH, percentage acetaldehyde, geometry of vessel, residence time product inhibition, etc.

CONCLUSION

The yield of ethanol from sawdust is affected by a host of factors which include temperature, pH value, enzyme loading, catalyst, sanitary conditions and so on. However, it was observed that the yield of ethanol increases as temperature increases. This is not to say that this holds for very high temperature since we know from literature that most enzymes (including yeast) cannot survive at extreme temperature and very acidic conditions. The range of temperature considered had ethanol yield increasing with temperature.

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