Bioethanol Production from Waste Paper: An Alternative Energy Source

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Abstract. Bioethanol is one of the best alternative form of energy source in place of fossil fuels. In this study, bioethanol was produced from waste paper following a pre-treatment. The isolates used were isolated from fresh palm wine and characterized via standard microbiological methods. The pre-treatment was done using 5%, 10% and 50% concentrations of sulphuric acid and sodium hydroxide respectively. Results obtained showed that the concentration of glucose from the substrates ranged between 0.2-0.8 ppm with 10% sulphuric acid giving the highest glucose yield. The fermentation of the sugar was carried out using *Saccharomyces cerevisiae* for the production of bioethanol, which was recovered by fractional distillation. From this study, the production of bioethanol from waste paper is a veritable means of shoring up energy deficit especially in the developing countries.

Keywords: Acid pre-treatment, Alkali pretreatment, Bioethanol, Waste paper, Saccharomyces

1. Introduction

Solid waste is regarded as resource in the wrong place. Nature gives off no solid waste because the waste of an organism becomes nutrients for another organism. Hence, man's activities will always produce solid waste directly or indirectly during the process of providing goods and services [1]. In metropolitan cities such as Lagos, over 23 million inhabitants can produce large amount of solid waste in the form of paper, cardboard, plastic, metal, food and other materials [2]. Thus recycling of waste rely on the worth of the final product.

Paper is produced from cellulose fibers, which can be found in wood and agricultural residues. Cellulose is a major constituent of the cell wall of plants. It is a polysaccharide that comprises linear glucan chains that are linked by β-1, 4-glycosidic bonds. These bonds are held together by intramolecular hydrogen bonds as well as intermolecular Van der Waals forces. Some characteristics of cellulose include its crystallite nature and its ability to resist degradation [3].

Biofuels are normally classified based on source and type. It can be obtained from municipal wastes, agricultural and forest products, food industry product and wastes. Secondary biofuels are usually processed and they can be in the form of solids, liquids or gases; examples include charcoal, ethanol and biogas respectively. Paper is used in large amounts daily. However, paper waste recycling is at a low rate due since it is destroyed after use. In addition, people are not aware of the value of the recycled product. Thus, an efficient disposal method of paper waste is necessary due to the huge benefits that are accruable from the products [4]. With the burgeoning rise in the human population, there is a huge demand on energy supply. It was reported that there would be decline from 25 billion barrels of oil production to 5 billion barrels [5]. Thus non-petroleum based energy is sought out worldwide especially in Nigeria where there is dearth of energy to sustain the country

Renewable form of energy (biofuel) has gained great interest all over the world. Biofuels-bioethanol are usually made from carbohydrates, agro-industrial wastes or lipids and oils; lignocellulose biomass including cellulosic plant biomass such as stems, wood, stalks [6]. Ethanol is an alcohol made from the fermentation of any biomass, which has high carbohydrate content such as starch, sugar, and

cellulose. Ethanol is mostly used as a fuel additive to reduce the amount of smog and carbon monoxide released into the environment by vehicles.

Ethanol combustion results in comparatively low emissions of volatile gas, carbon monoxide and nitrogen oxide. Biomass-based ethanol production has gained significant importance over the last few years but further cost reduction is essential for its development [7]. Innovation over the past few years in the production of ethanol has brought it on the verge of replacing the importation of fuels on a large scale. As a renewable fuel, bioethanol is doing a lot for the environment; it reduces greenhouse emission of gases up to 59 percent relative to gasoline. It also has a higher octane number, larger flammability limits, higher heats of vaporization, and flame speed which gives it a shorter burn time and higher compression ratio, which serves as advantages of bioethanol over gasoline in engines.

The use of bioethanol as a source of energy can curb the energy problems in Nigeria and drastically reduce the environmental pollution problems. In this study, the obtained sugar from the hydrolysis studies was incubated with *Saccharomyces cerevisiae* and the bioethanol produced was recovered.

2. Materials and Methods

2.1. Chemical and Reagents

All chemical and reagents used in this study were of analytical grade. These include sulphuric acid (H_2SO_4), Potato dextrose agar and Basal salt medium. The media were prepared according to the manufacturer's instruction following aseptic techniques**.**

2.2. Isolation of fungal isolate

The *Saccharomyces cerevisiae* used in this study was obtained from palm wine using the pour plate method on potato dextrose agar [8].

2.3. Waste paper collection

Waste papers were gathered from different places around the College of Science and Technology (CST) building. These include used student attendance papers, envelopes for packing exam scripts and Old papers. Forty (40) grams of paper were soaked under alkali and acidic pre-treatment. The combination of the two pre-treatment methods is a way of optimization the production [9]. For the acid pre-treatment about 5%,10% and 50% sulphuric acid (v/v) were added to 40grams of paper and left to stand for 6 hours. The same quantities 5%, 10% and 50% sodium hydroxide w/v were used for alkali pre-treatment using 40grams of paper for 6 hours.

2.4. Identification and purification of isolate

Standard morphological and physiological tests, were used for the fungal identification. The tests include morphology, surface characteristics, ascospore formation, and vegetative reproduction. The fungi colonies were further purified by successive subculturing on potato dextrose agar until pure cultures were obtained. The pure culture was then subcultured on PDA slants, incubated for 24 hours, and stored at a temperature of 8 °C [10].

2.5. Waste paper hydrolysate

In a 250ml Erlenmeyer flask, forty grams (40g) of already pre-treated paper (both acid and alkaline) were added and left to stand at room temperature for 5-7 days [11].

2.6. Determination of reducing sugar concentration (DNS) using 3, 5-dinitrosalicyclic acid method

The pre-treated substrate 0.5mL of the sample was placed in a test tube and 2.5mL of distilled water and 3mL of DNS were added. The mixture was placed in a water bath at increased temperature for 5 minutes. One (1) ml of 40% Rochelles salt was added to the test tubes and left to cool. The UV analysis was carried out using a spectrophotometer at a wavelength of 540 nm.

2.7. Production of Bioethanol

The fermentation of the sugar was carried out using *Saccharomyces cerevisiae*, which produced the bioethanol that was recovered by fractional distillation at 78^0C. For this, the *Saccharomyces cerevisiae* was stored in slant was used for this process. The inoculating loop was used to inoculate the yeast cells into the Erlenmeyer flask containing the hydrolyzed sugar. Thereafter flask containing the substrate and the yeast was placed in a shaker with revolving speed at 800rmp. This was for an hour every day for 3 days. After the third day the mixture was filtered. The residue was discarded while the filtrate was used for distillation. A distillation column was set up and the filtrate was allowed to heat to 78^oC which is the boiling point of ethanol [12]

3. Results

3.1. Reducing sugar concentration

The release of sugar from the pre-treated substrate varied because of the ability of the pre-treatment material to break up the lignocellulosic structure of the paper, which enabled the enzyme released by the microorganism to break down cellulose to give glucose**.**

Table 1: Concentration of reducing sugars released from different concentrations of acid and alkali pre-treatment

CONCENTRATION (ppm)	ABSORBANCE (540nm)	ACID AND ALKALINE CONCENTRATIONS
0	0	Blank
0.2	0.13	5% Sodium Hydroxide
0.2	0.14	10% Sodium Hydroxide
0.2	0.11	50% Sodium Hydroxide
0.2	0.14	5% Sulphuric Acid
0.8	0.41	10% Sulphuric Acid
0.3	0.17	50% Sulphuric Acid

The different acid and alkaline concentrations, the concentration (ppm) and absorbance (540 nm) of released sugars ranged from 0.2 to 0.8 ppm. The concentration of released sugar (0.8ppm) had the highest yield from the 10% sulphuric acid pre-treatment. The use of acid to break up the lignocellulosic structure of the paper was more efficient than using alkaline. The 10% sulphuric acid concentration was mild to avoid the formation of inhibitory compounds, which can cause the action of the enzyme to be hindered. Alkali pre-treatment yielded low sugar concentrations as the effect of the alkali on the paper was not strong enough to fully break up the structure, which would have made cellulose easily susceptible to the work of the enzyme

3.2. Alcohol yield

The percentage yield of the alcohol obtained from distillation was calculated and the 10% acid pre-treatment yielded the most ethanol.

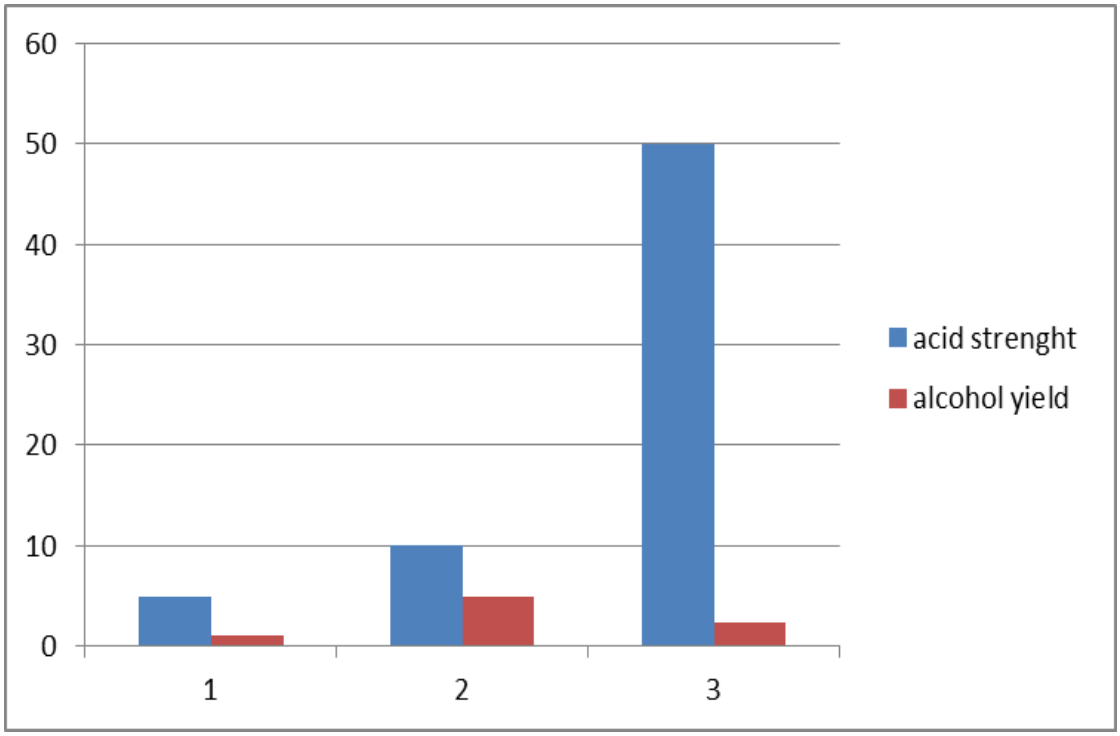

Figure 1a. Alcohol yield obtained from acid pre-treatment. Data represent different concentrations of the sulphuric acid in 5, 10 and 50% concentrations and their glucose yield

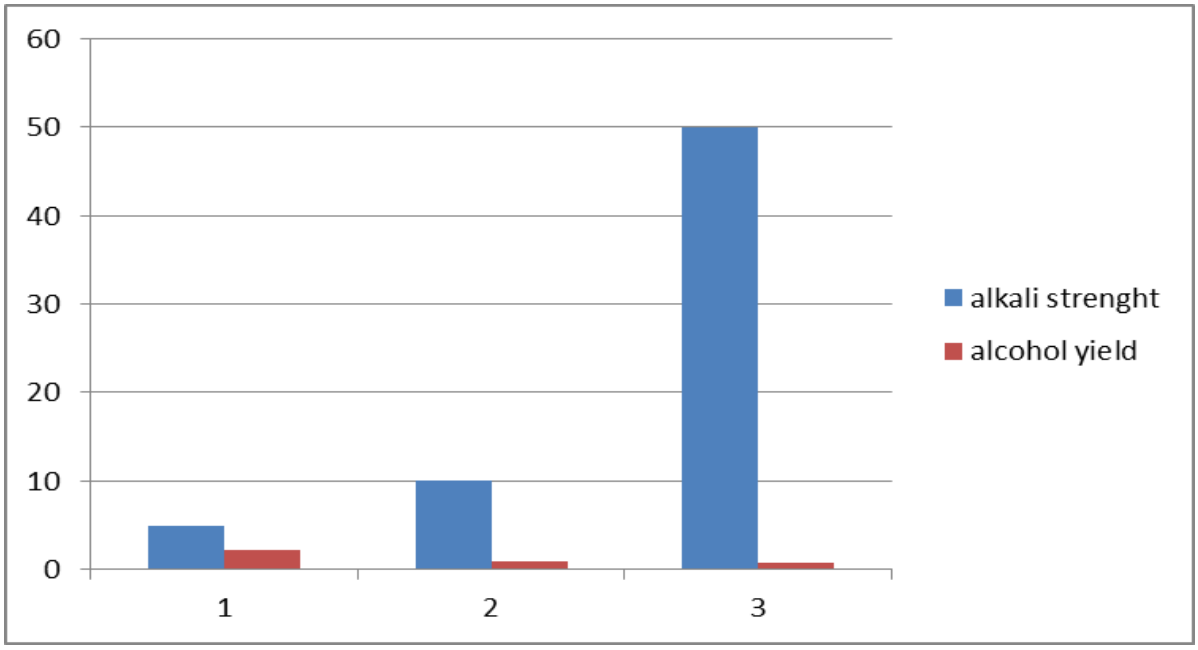

Figure 1b. Alcohol yield from alkali pre-treatment Data represent different concentrations of the sodium hydroxide in 5, 10 and 50% concentrations and their glucose yield.

4. Discussion

Many filamentous fungi secrete cellulase [13]. The carboxymethyl-cellulase breaks the β-1,4-glucosidic bonds in the cellulose chain leading to the release of glucose and cellooligosaccharides of different

lengths. Some fungal species such as *Chaetomium, Fusarium, Myrothecium, Trichoderma, Penicillium, Aspergillus* and bacterial species which include: *Trichonympha, Clostridium, Actinomycetes, Bacteroides succinogenes, Butyrivibrio fibrisolvens, Ruminococcus albus, and Methanobrevibacter ruminantium* have been used [14]. The pre-treatment involves the conversion of cellulose and hemicellulose into forms that can occur swiftly and increase productivity (see Fig1a, b). The pre-treatment removes lignin and distorts the crystalline structure of cellulose. The pre-treatment using the various concentrations of sodium hydroxide and sulphuric acid yielded different substrates (See Table 1.0).

5. Conclusion

From the result obtained, the 10% sulphuric acid yielded more glucose with a concentration of 0.8ppm obtained for the production of the bioethanol. The hydrolysis of the paper releases monomeric sugars and soluble oligomers that can be used by the fungi for bioethanol production [15]. The use of dilute acid is commonly used in industrial processes and brings about an effective release of glucose while alkali pre-treatment is not as efficient in glucose release but helps in avoiding inhibitory products formation [16]. The released glucose is then catabolized by the yeast through the glycolytic or Embdem Meyerhof-Parnas pathway to give pyruvate, which undergoes decarboxylation by pyruvate decarboxylase and the forming of aldehyde and CO_2. Ethanol is formed when acetaldehyde acts as an electron acceptor and is used to oxidize NADH that is observed by the release of bubbles upon fermentation with *Saccharomyces cerevisiae* [7].

In conclusion, the production of biofuels can be easily carried out without the need for high capital. This study serves as a means of curbing pollution, which arises from the inefficient methods used for waste paper disposal. This process not only brings about a cheaper and environmentally friendly method of energy production, but it also makes the disposal of waste paper easier and useful.

6. Acknowledgements

The authors are most grateful to Covenant University research, Innovation and Discovery (CURCID) for defraying the cost of the publication. **NOC** designed/supervised this study, corrected the second draft manuscript, **AEF and GDZ** drafted the first manuscript **EZM,** did the laboratory experiments.

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