



PRODUCTION OF BIOETHANOL USING PAPER WASTES AS SUBSTRATES

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Date Manuscript Received: 20/10/2016 Accepted: 03/01/2017 Published: March, 2017

ABSTRACT

An investigation was carried out on the production of ethanol from cellulosic material (paper and paper wastes) by acid hydrolysis and fermentation using locally isolated yeast (*Saccharomyces cerevisiae*). Specific weight (1.3Kg) of each sample was mixed with dilute hydrochloric acid and heated for complete hydrolysis. The content was filtered to remove solid and to recover the sugar/acid solution. The sugar/acid solution (wort) was fermented and distilled to obtain 96% ethanol. The results revealed that the quantity of sugar after conversion of newspaper, used A4 paper and unused A4 paper were 42%, 35% and 45%, respectively. The volume of ethanol produced from each paper samples were 250ml/L, 150ml/L, and 300ml/L respectively. The results obtained show clearly that paper wastes can be channelled towards production of ethanol which is of immense industrial and commercial value.

Keywords: *Paper wastes, hydrolysis, fermentation, bioethanol*

INTRODUCTION

Energy demand is predicted to grow more than 50% by 2025 because of the emerging demand from several rapidly developing nations (Ragauskas *et al.*, 2006). Today, the population growth and the need for energy together with the fossil fuel depletion and environmental pollutions have urged countries to seek for newer and cleaner sources of energy (Balat and Balat, 2009). Around 60 % of world's oil consumption and one-fifth of global CO₂ emissions are related to transportation sector (Kırtay, 2011). Hence, replacing fossil fuels by renewable energy sources, especially in developing countries where the rate of energy consumption is faster than industrial ones, is a must (Balat and Balat 2009). In 2012, the global petroleum consumption was estimated as 89 million barrels per day from which about a half was used for gasoline production. At this rate of consumption, the oil resources are predicted to run out within the next 50 years (Arifin *et al.*, 2014). Furthermore, fossil fuel usage can cause environmental problems such as air pollution, greenhouse gas emissions, and global warming, consequently, which makes the society worried. Thus, many countries are trying to find renewable resources as alternatives which are capable of balancing the Green House Gas (GHG) emissions. Biofuels seem a key solution for the present challenge since it is produced from renewable resources and have a great influence on Green House Gas mitigation (Fiorese *et al.*, 2013). Biofuels can be categorized into three main groups, first-, second-, and third- generation biofuels which can be obtained from food, non-food feedstocks, and microalgae, respectively. The biomass potential for supplying energy has been estimated as 1020 J/year of which 40 % is being utilized nowadays (Ragauskas *et al.*, 2006).

Bioethanol is currently the most common biofuel in terms of produced volume, which at present is industrially produced mainly from corn and sugarcane. For decades, it was used as a source of energy in a lamp oil, for cooking, or known as spirit oil before being applied in an internal motor combustion by Samuel Morey early in the nineteenth century. Later on, it was introduced to the automobile market and in agricultural machines. However, emergence of oil and its derivatives in twentieth century drove it aside until the Arab oil embargo of 1970s (Lee and Lavoie, 2013). Today, the depletion of fossil fuels and its environmental drawbacks have enforced the policy makers to focus on renewable sources of energy. Hence, many countries enacted several directions for enhancing the share of biofuels

in their energy basket (Zah *et al.*, 2010). The annual production of ethanol increased to more than 85.6 billion liter in 2010 worldwide (Carriquiry *et al.*, 2011) since it has some advantages over other fuel additives. Its high octane number and flexibility in blending with petrol have made it a well-suited additive in automobile's engines without almost any modification requirement. By blending ethanol with petrol, not only the emissions of GHG, unburned hydrocarbons, and carcinogens would be reduced but also the sulphur oxides which are the main cause of acid rains will be decreased significantly (Nigam and Singh, 2011). These features can make the ethanol as the best environmental-friendly candidate in the transportation sector. Bioethanol from biomass sources is the principal fuel used as a petrol substitute for road transport vehicles. The high price of crude oil makes biofuels attractive (Bryner and Scott, 2006).

There are three main sources of biomass that can be used as a feedstock for bioethanol production: sucrose-based sources (sugarcane, sugar beet, and sweet sorghum), starchy biomass (wheat, corn, and barley), and lignocellulose materials (wood, straw, and grass) [Soccol *et al.*, 2010]. Although the first two (first and second generations) benefit a highly simple and mature technology in converting the sugars to ethanol, they suffer the controversy of food versus energy as well (Lee and Lavoie 2013). Thus, lignocellulose-based material can be a better replacement for them. However, more complex processes are required to convert them to ethanol. In most countries, there is a good potential for bioethanol production from various wastes and residues including forestry and agricultural residues (forest woody feedstocks, corn stovers, cornstalks, rapeseed residue, sugarcane bagasse, citrus peels, empty bunches of fruits, straws, etc), water hyacinth and seaweeds as well as industrial or municipal solid wastes (such as paper wastes, newspapers, household food and kitchen wastes, coffee residue and waste textiles) [Avami 2013].

Dubey *et al.*, (2012) produced ethanol from paper wastes through dilute acid (0.5 N H₂SO₄) treatment at 120°C for 2h and obtained 3.73 g/L ethanol. Their novelty took the possibility of xylose fermentation as well as glucose with the aid of *Pichia stipitis* into account. Economic feasibility and sensitivity analysis of ethanol production from various paper wastes (newspaper, office paper, cardboard, and magazines) were investigated by Wang *et al.*, (2013) with the aid of *Zymomonas mobilis*. They suggested that separation of papers from other municipal wastes and recycling it into new

papers is nearly harder than converting its cellulose to ethanol. They concluded that paper wastes can economically be used for ethanol production if the office papers and newspapers receive only dilute acid and oxidative lime pretreatment, respectively. The maximum glucose and xylose yield was related to office papers, whereas the minimum quantity was obtained from magazines.

Ethanol is traditionally produced from a liquid or a fluid mash via submerged microbial fermentation (Hang *et al.*, 1981). *Saccharomyces cerevisiae* which is also known as brewer's yeast is the most widely used fermentation microorganism for ethanol production (Roehr, 2001) besides *Kluveromyces marxianus* (Lark *et al.*, 1997) and *Zymomonas mobilis* (Pranavya *et al.*, 2015).

This study aimed at using paper wastes (Old news papers, Used A4 papers and Unused A4 papers) as feedstock for the production of bioethanol. The utilization of bioethanol for transportation among others has the potential to contribute to the national economy as alternative energy fuel.

MATERIALS AND METHODS

Study area

The paper samples were collected within Keffi metropolis. Keffi is a fast growing town that is about 68km from Abuja, the federal capital of Nigeria and 128km from Lafia, the capital of Nasarawa State. Keffi located on latitude 8° 5' N and longitude 7°50'E and it is situated on an altitude 850 metres above sea level (Akwa *et al.*, 2007). Keffi is situated the North-West of Lafia, the capital city of Nasarawa state.

Collection of paper wastes

The methods employed by Uduak *et al.*, (2009) were used for the collection of paper wastes. New black polythene bags were used to collect Old newspapers from various disposal points in Keffi, while Used A4 paper wastes were collected from Photocopying Business Centres in different locations in the Nasarawa state University campus, Keffi. Unused A4 papers were however, purchased from the market and used in the experiment as the control. The categories of papers were taken to the laboratory for analyses.

Pre-treatment of waste paper substrates

The methods of Uduak *et al.*, (2009) were adopted for the preparation of the papers for hydrolysis. The paper samples were cut into smaller pieces using a pair of scissors, and these were sun dried. A quantity of 1.3Kg (1300g) of each paper sample was mixed with diluted hydrochloric acid, and was heated at

100°C for 6hours. Each of the hydrolysed material was soaked in distilled water and drained several times in order to wash of the acid; the solid residues was then dewatered and soaked in 40% hydrochloric acid for 4hours. Each of the hydrolysed material was again dewatered, dried and remixed with 40% hydrochloric acid and maintained at 100°C for 3hours. The content was filtered to remove solid and to recover the sugar/acid solution. The sugar/acid solution was neutralised using sodium hydroxide (NaOH).

Source of Organisms:

Saccharomyces cerevisiae was isolated from palm wine locally obtained from Keffi using Yeast-Peptide-Dextrose (YPD) agar and stock cultures of the organism were maintained on slants of the same agar medium. Identification of the organism was done on the basis of morphological, cultural and biochemical characteristics as described by Olutiola *et al.*, (2000).

Fermentation and Distillation:

The hydrolyzed and filtered extracts of the paper wastes including the control were fermented using *Saccharomyces cerevisiae* for seven days of incubation at room temperature (28±2°C) on a rotary shaker. A 3% inoculum of the yeast was added to each pre-treated waste paper substrate for fermentation to convert simple sugars to alcohol. After fermentation the content was filtered and primary distillation was carried out in vacuum flask at 78.5°C (boiling point of ethanol) and fractions were collected. Ethanol concentration was then determined by specific gravity method and potassium dichromate method (Prasad, 2014).

Determination of Total sugar

The total sugar content of the samples was determined by Phenol sulphuric acid method with glucose as standard (Pranavya *et al.*, 2015).

RESULTS AND DISCUSSION

Table 1 shows the results of the qualitative analysis of the three different substrate (Old newspapers, Used A4 papers and Unused A4 papers), while Table 2 shows the sugar and ethanol content produced from each of the three substrates (Old news papers, Used A4 papers and Unused A4 papers).

The results demonstrate that Unused A4 paper yielded the highest sugar content which was reflected on the amount of ethanol produced. The high yield of sugar and ethanol in the Unused A4 papers may be due to the fact Unused A4 papers is pure cellulose and also due to the absence of some interference like

ink, dirt and exposure. The lower volumes of ethanol produced from Used A4 papers and Old newspaper may be as results of some level of interfering factors such as ink, dirt and other environmental elements. Thus, the results from the production of sugar from hydrolysed wort revealed that old newspaper produced 42%, Used A4 paper produced 35% and Unused A4 paper produced 45%. These results agree with those of Boulton (1996) and Uduak *et al.* (2009).

Bioethanol is likely to play a big part in the fuel system of the near future. Although there are several controversies associated with some fermentation substrates, development is likely to continue. Paper wastes provide a somewhat untapped resource of cellulosic materials that could be harnessed by the bioethanol industry. The utilization of bioethanol for transportation among others has the potential to contribute to a cleaner environment. It is expected that the bioethanol industry will benefit from the efficient utilization of paper wastes if fully harnessed.

Table 1: Results of qualitative analysis for the presence of reducing sugar in pre-treated paper wastes

Substrate	Substrate waste (Kg)	Reducing Sugar
Old news paper	1.3	+
Used A4 paper	1.3	+
Unused A4 paper	1.3	+

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Table 2: Yield of total reducing sugar and ethanol from waste paper substrates

Substrate	Total Reducing Sugar (%)	Ethanol produced (ml/L)	Specific gravity
Old news paper	42	250±0.04	1.889
Used A4 paper	35	150±0.02	1.986
Unused A4 paper	45	300±0.05	1.528

CONCLUSION

The hydrolysis of paper wastes into fermentable sugar and the subsequent fermentation of the sugar into ethanol has provided a feasible approach for the use of paper wastes as feedstock for bioethanol production. The maximum fermentable sugar and ethanol yield was obtained with Unused A4 papers, followed by old newspaper and the Used A4 papers. This investigation showed that waste paper can be utilized as source of fermentable sugar for the production of ethanol.

ACKNOWLEDGEMENTS

The authors are grateful to the Microbiology Unit, Department of Biological Sciences, Nasarawa State University, Keffi, Nigeria, for providing the laboratory materials and facilities used in this investigation.

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