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Acid Hydrolysis of Waste Paper to Glucose

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Abstract:
Waste paper stands for the major biodegradable organic fraction of most municipal waste. The potential of acid hydrolysis of waste paper for glucose production was investigated in this current work. This was carried out in two stages which involved the pretreatment of two samples (Computer printout and Newspaper), which was accompanied by first shredding the paper into pulp. Acid hydrolysis of waste paper was optimized to maximum glucose conversion, with a nitric acid concentration of 5.0 mL at 121 °C in an autoclave. The obtained results showed maximum percentage reducing sugar yield for 5 % w/v waste paper with 1 % v/v nitric acid at 72 h was 24.93. The obtained result showed that the maximum percentage reducing sugar yield for 5 % w/v waste paper with 5 % nitric acid at 72 h was17.59. The obtained results showed that the maximum percentage reducing sugar yield for 5 % w/v waste paper with 10 % v/v nitric acid at 72 h was 18.1. This research of acid hydrolysis is a promising method to improve waste paper conversion to glucose in order to control environmental pollution.

Keywords: *Glucose, hydrolysis, waste paper, nitric acid*

1. Introduction

The growing awareness of environmental issues and resource scarcity explains the increased interest by industries in the reuse of the waste generated during production processes. (Vaisanen et al, 2016). In recent years, efforts have increased towards a more efficient utilization of renewable municipal solid waste including waste paper (Holtzapple et al, 1992; Lay, et al, 2007; Li et al, 2012). Furthermore, strict legislative policies have forced the industries to find ways to reuse residues that previously were incinerated or disposed in landfills. (Vaisanen et al, 2016).

Used paper which stands for the major biodegradable organic fraction of most municipal solid waste has always been considered a waste material in our homes and offices, recycled at a smaller rate into low-grade paper products, such as newsprint, paper towels, toilet paper and cardboard, suggesting that a significant part of municipal waste paper is not useful as recycled products or cannot be recycled due to destruction after is use (Park et al., 2004). When these papers are deposited, decomposers act on these papers and only absorb a small amount of the minerals and energy for their use while the rest is released into the atmosphere, soil and water. Products released during the decomposition are gases such as CO_2, NH_3 and H_2S (Roy, 2001).

Cellulose, a major building block of waste paper, can be converted enzymatically to reducing sugar including glucose; one use of glucose is fermentation into ethanol. Also paper sludge after deinking has been traditionally disposed of by burning or landfilling, but could be used as an organic amendment in agricultural soils and filler of erosion control (Chantigny et al, 1999). Basically, the recycling of waste paper can be done by reusing waste paper after pulping and followed by removal of printing ink, a treatment process called “deinking” (Holtzapple et al., 1992)

The shortening of cellulose fibres with repeated reutilization tends to decrease the quality of paper produced. Recycling of waste paper depends on the value of the final product and it has been applied to the greatest extent for most of materials i.e. 60% of copper waste are recycled. On the other hand, if these papers are collected and burnt, this will result in the release of carbon (IV) oxide into the atmosphere. They release carbon (iv) oxide which is toxically/poisonous to Human body system and animals. Human activities such as burning of fuels, agricultural products and oil have increased the concentration of CO_2 in the atmosphere. These human activities results in the progressive warming up of the earth’s surface due to the blanketing of man-made carbon (IV) oxide (Roy, 2001).

In other to break down holocellulose and hemicelluloses for conversion of waste paper to glucose, the cellulose and hemicelluloses must be broken down to corresponding monomers (sugars). The hydrolysis step may be carried out either enzymatically or by acid treatment (Romero, et al, 2010). Enzymatic hydrolysis is conducted at mild conditions but requires pretreatment of the raw material to improve the enzymatic digestibility (Sun and Cheng, 2005) and longer retention time (Ingram et al, 1999). Acid hydrolysis may be carried out either at diluted or concentrated acid conditions. Dilute acid hydrolysis attacks polysaccharides, especially those from the hemicelluloses fraction which is easier to hydrolyze than cellulose. In addition no acid recovery steps are required and acid losses are not important. On the negative side, the yield of glucose from cellulose is low. Concentrated acid hydrolysis enables high yield because of almost quantitative conversion of cellulose into glucose, although acid recovery is required as well (Jung et al, 2013).

In line with the above, the study looks at the optimum conditions for glucose production from various types of paper after its treatment by optimum buffer, pH value, temperature, mass ratio and pre-treatment of wastes.The glucose content in waste paper can be used as a source of energy for man, improved feeds for livestock, raw materials and chemicals for our industries, thereby sustaining the economy.

2. Materials and Methods

2.1. Collection and Preparation of Samples

Old waste newspaper were collected from newspaper Vendor at Lafia junction, North Bank Makurdi and printout papers which was used as substrates, were collected from prince college Makurdi all from Benue State, Nigeria. The waste paper was cut into small rectangular shapes with a size less than 1cm^2. The cut material was kept at low temperature until the next stage of experiment. Reagent used for this experiment were Nitric acid, sodium hydroxide (NaOH), dinitrosalicylic acid, sodium sulphate (Na_2S), phenol, Glucose, potassium sodium tartrate (Rochelle salt) and distilled water.

2.2. Methods

2.2.1. Liquid Hot Water (LHW) Pre-Treatment of Waste Paper Material

Pre-treatment of waste paper material was carried out according to the method reported by Wang et al., (2012). Waste papers were cut into small rectangular shape using a pair of scissors. 30 g of the printout paper was weighed. The weighed paper was transfer into a 1000 mL beaker and 600 mL of distilled water was added. The Weighed mixture was then heated on a water bath at a high temperature (100 ˚C) with continuous stirring using a magnetic stirrer for 20 minutes. The mixture was allowed to cool in order to form the pulp.

2.2.2. Deinking

After pulping of waste paper, flotation deinking as reported by Dhermander et al., (2015) was adopted and used in deinking of the pulp. Octylphenolethoxy late (surfactant) was added to the pulp, the mixture was then heated at high temperature (120 ^{o}C) to ensure floatation of ink to the surface. A rubber scraper was then used to scrap off the ink as it reached the surface.

2.2.3. Bleaching of Deinked Pulp

After Deinking of pulp, bleaching as reported by Ingede, (2012) was adopted and used in bleaching the pulp by adding 0.6 mol of NaOH, 6ml of H_2O_2, to the pulp at 70°C and the mixture was allowed to stand for 1 hour. The goal is to make the pulp brighter.

2.2.4. Preparation of Dinitrosalicylic Acid Reagent

Dinitrosalicylic acid Reagent was prepared by weighing 1g of 3, 5 dinitrosalicylic acid, 0.2g of crystalline phenol and 0.05g of sodium sulfite in 100mL of 1% v/v NaOH into a beaker and stirred. Potassium sodium tartrate was added to maintain its color. A standard glucose solution was prepared by varying concentration from 0.1-0.5 (Lida and David, 1998)

2.2.5. Preparation of Glucose Standard.

Glucose standard used as the standard for the reduce able sugar was prepared in 250ml Erlernmeyer flask. 0.25g of glucose was dissolve in 250ml of water which form a glucose solution, the glucose solution was measured in test tube using 1mL, 2mL, 3mL, 4mL, 5mL with 9mL, 8mL, 7mL, 6mL and 5mL distilled water added respectively. 3mL of Dinitrosalicyclic acid (DNS) solution was added to each test tube the solution was then heated at temperature of 90 ˚C for 30min and allowed to cool. Each solution in the test tube was used to test for sugar absorbance in the calorimeter machine.

A calibration curve was drawn for absorbance Vs concentration. This was used to determine the amount of reducing sugars after hydrolysis.

Concentration of Glucose (gL)	Time (min)	Volume (mL)
0.1	30	1
0.2	30	2
0.3	30	3
0.4	30	4
0.5	30	5

Table 1: Shows the Experimental Conditions of the Different Tests Carried Out

2.3. Acid Hydrolysis

Acid hydrolysis was done to break down cellulose into glucose unit Experiments were carryout in 600mL in conical flask. For that, 5g of waste paper was dissolve in different amount of nitric acid (5% weight): 1.0, 5.0, and 10 mL. The mixture was then place in an autoclave at temperature of 100 ^{0}C for 1 hour to 48 hours. The influence of time on the process was determined in the range of 40min. After hydrolysis, the supernatant was used to determine reducing sugar concentration by using dinitrosalicylic method at each time interval from 1hr, 3hr, 5hr, 12hr, 24hr,48hr and 72 hrs.

Test	Weight of Sample(G)	Volume of Acid Use (Ml)
1	30	1.0
2	30	5.0
3	30	10

Table 2: Shows the Experimental Conditions of the Different Tests Carried Out

2.3.1. Hydrolysis Procedure

The pulp was weighed into a beaker (5g) and filled up 100mL with distilled water. Pretreatment was done by heating to 100^{0}C for 40 mins, after the water lost during heating was replace and allow to cool before hydrolysis ,1% v/v of nitric acid was added and to stand for one hour. After that 1mL of the mixture was transfer into a test tube where by 3mL of distilled water and 3mL of the Dinitrosalicylic reagent were added to the dilute solution this was then heated with a magnetic stirrer at 100 °C for period of 15mins. The mixture was allowed to cool. After cooling, calorimetric test was carryout on the solution. This procedure was repeated for 5% v/v and 10% v/v of nitric acid at the time interval of 1hrs, 3hrs, 5hrs, 24hrs, 48hrs, and 72hrs respectively.

3. Results and Discussions

3.1. Table 3 Show the Glucose Standard Absorbance for Each Concentration of 0.1-0.5g/L.

Concentration of Glucose (g/L)	Absorbance
0.1	0.16
0.2	0.29
0.3	0.63
0.4	0.80
0.5	1.10

Table 3: Glucose Standard Absorbance

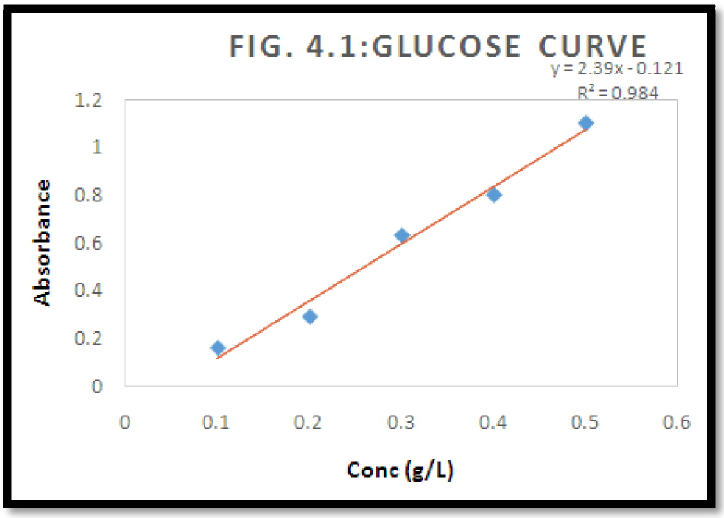

Figure 1: Glucose Standard Absorbance

3.2. Hydrolysis Condition of the Waste Paper

Result for experiment 1, 2 and 3 are given in the table below with their corresponding graph (graph of reducing sugar concentration versus time taken to hydrolyze the wastepaper in hours).

Time (hrs.)	Absorbance	Reducing sugar Concentration (g/L)	% Reducing Sugar Yield
0	0.00	0.00	0.00
2	0.12	0.1008	6.25
3	0.16	0.1178	7.29
5	0.20	0.1346	8.33
24	0.41	0.2222	13.78
48	0.62	0.3100	19.22
72	0.82	0.4021	24.93

Table 4: Result of the Reaction of 5% W/V Waste Paper with 1% V/V Nitric Acid from 0hour to 72hour

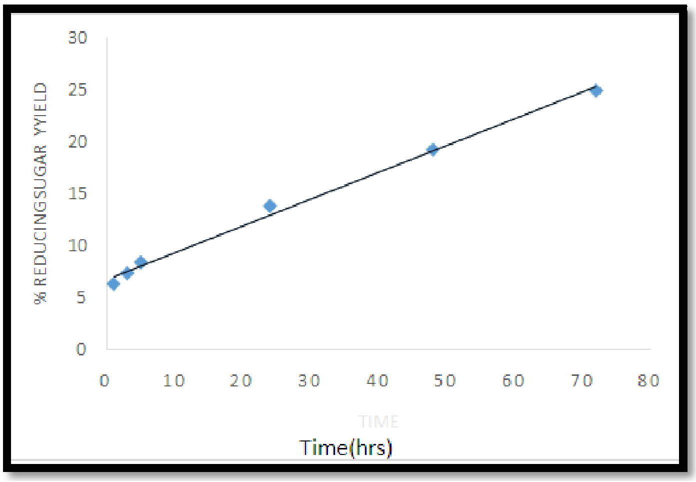

Figure 2: Progress Chart of the Reaction of 5% W/V Sample with 1.0%V/V Nitric Acid

Time (hrs.)	Absorbance	Reducing Sugar Concentration (g/L)	% Reducing Sugar Yield
0	0.00	0.00	0.00
1	0.15	0.1139	4.78
3	0.17	0.1218	5.12
5	0.23	00.1469	6.16
24	0.45	0.2389	10.03
48	0.66	0.3268	13.73
72	0.88	0.4188	17.59

Table 5: Result of the Reaction of 5% W/V Waste Paper With 5% V/V Nitric Acid From 0hour to 72hour

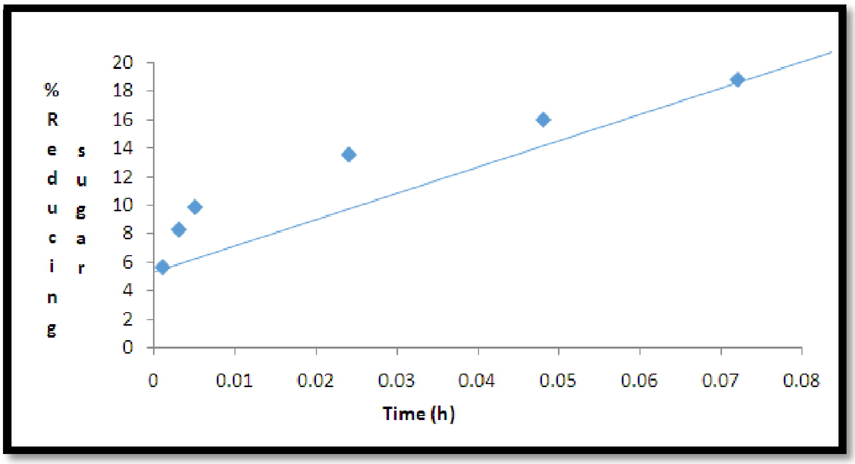

Figure 3: Progress Chart of the Reaction of 5% W/V Sample With 5% V/V of Nitric Acid

Time (hrs.)	Absorbance	Reducing Sugar Concentration (g/L)	% Reducing Sugar Yield
0	0.00	0.00	0.00
1	0.20	0.1343	5.64
3	0.35	0.1971	8.28
5	0.44	0.2347	9.86
24	0.65	0.3226	13.55
48	0.79	0.3812	16.01
72	0.95	0.4481	18.82

Table 6: Result of the Reaction of 5% W/V Waste Paper with10% V/V Nitric Acid from 0hour To72hour

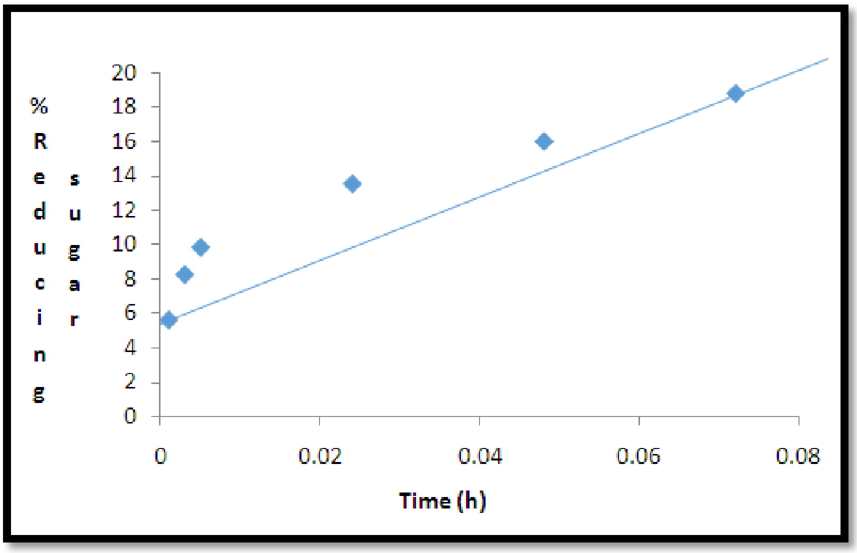

Figure 4: Progress Chart of the Reaction of 5% W/V Sample with 10% V/V of Nitric Acid

4. Discussion

The focus of this research was to produce glucose from waste paper by acid hydrolysis. Acid hydrolysis needs the optimization of process parameters, including amount and concentration of nitric acid, reaction time, and reaction temperature. The analysis of time and amount of acid concentration of obtained % reducing sugar was carried out. The hydrolysis consists of the conversion of cellulose present in the paper into glucose unit. Hydrolysis was carried out using a solution of nitric acid of 5 % weight at different reaction time.

The result showed that maximum % reducing sugar yield is achieved at 72 hrs. This is in agreement results obtained by Kumal et al, (2012).

Another important parameter on the process is the amount of acid. Consequently, three experiments were carried out varying the acid volume with the same concentration and 100 min at 40 °C in an autoclave. The data review that the percentage sugar yield was high for 1 mL followed by 10 mL. This is in agreement with work earlier reported by Young et al, (2011) and Mezule et al (2015)

From the result tabulated in table 4.0, the maximum absorbance of reducing sugar for glucose standard obtained, is 1.10. This was however different from the result presented in table 4.1. The maximum percentage reducing sugar yield for 5%w/v wastepaper with 1%v/v nitric acid at 72hrs was recorded as24.93. Result tabulated in table 4.2 from the study show that maximum percentage reducing sugar yield for 5%w/v waste paper with 5%v/v nitric acid at 72hrs is 17.59. The Result tabulated in table 4.3 from the study showed that maximum percentage reducing sugar yield for 5%w/v of waste paper with 10%v/v nitric acid at 72hrs. was obtained as 18.82.From figure 4.2, it was observed from the progress curve that 1%v/v of nitric acid has a faster reaction at the beginning and a higher yield at the end followed by 10% and 5%v/v respectively. However for the rest time within an hour of 1, 3, 5, 24,48,72hour, 1%v/v with 5%v/v and 10%v/v nitric acid had higher yield at the end of the reaction. Therefore percentage reducing sugar yield for 1%w/v waste paper was higher than 5%w/v after 72hour, hydrolysis and absorbance of reducing sugar for 5%w/v sample is higher and closer to the glucose standard value than 1%w/v sample time taken for hydrolysis of waste paper which is dependent on the concentration of the acid. This was evidently shown in the absorbance, concentration and percentage reducing sugar of 5%w/vand 1% sample with 10% of nitric acid after 72hours hydrolysis. Therefore shorter time for complete hydrolysis will be require for higher volume and concentration of acid and vice versa.

5. Conclusion

In this study it can be concluded that since the yield was gotten to be 13.73%, the waste paper can be said to be a good source for glucose production. It is less expensive and therefore should be used as an alternative raw material for producing glucose and also ethanol.

This contributes to minimizing environmental pollution by these papers which are either littered in the environment /burnt, resulting to land and air pollution. The steps/processes involved in the conversion were also environmentally friendly therefore adequate arrangements and provision of collection centers of used papers should be provided by the government and organizations or well spirited individuals, so that these papers can be collected and thereafter used, instead of littering them around, thereby reducing environmental litter.

6. References

i. Chutigny, M. H., Angers, D. A., and Beauchamps, C. J. (1999) Agregation and organic matter decomposition in soils amended with de-inking paper sludge. Soil science Society of America Journal, 63: 1214-1221
ii. Dhermander, K., Rakesh, K, J., and Neelem, G. (2015) Enzymatic Deinking of ONP- An effective way of producing quality
iii. Newsprint. Oct. Journal Env. Res 3(4) 332-337
iv. Holtapple. M. T., Lundeen, J. E., and Sturgis, R (1992) Pretreatment of lignocellulosic Municipal solid waste by ammonia fibre explosion (AFEX) Appl. Biochem. Biotechnol 34 (35): 5-21 http// dx. Doi. Org: 001:105658/WOOD.2013.41.2.87
v. Ingede, E. V. (2012) Assessment of Print product recyclability; Method 11. International Association of De – inking Industry.
vi. 74321m Bietgheim- Bissingen, Germany Pg 1-13
vii. Ingram, L. O., Aldrich, H. C., Borgas, C. C., Causey, T. B. Martinez, A and Morales, F (1999) Enteric Bacteria Catalyst for fuel ethanol production. Biotechnol, prog. 15(5): 855-866
viii. Jung, Y. J., Choi, S. M., and Yang, J. (2013) Optimization of concentrated Acid Hydrolysis of Waste paper using Response
ix. Surface Methodology. J. Korean Wood Sci and Tech 41 (2): 87-99
x. Kumar, A. P., Gupta, N. G., and Naithani, S. (2012) "Bioethanol Production from Waste paper Acid pretreatment hydrolyzate with xylose". Carbohydr. Polym. 88: 825-829
xi. Lay, J. T., Lee, Y. J., and Noike, T. (1999) Feasibility of Biological hydrogen production from organic fraction of municipal solid waste. Water RRes. 33(11): 2579-2586
xii. Li, A., Antizar-Ladislao, B., and Khraisheh, M (2007) Biocoversion of Municipal solid waste to glucose for Bioethanol production. Bioprocess. Bio syst. Eng. 30: 189-196
xiii. Park, E. Y., Anh, P. N., Okuda, N. (2004) Bioconversion of waste office paper to L (+) – Lactic acid by Filamentuos fungus
xiv. Rhizopus oryzae. Biorsour. Technol. 93:77-83
xv. Romero, L. E., Ruiz, E.., and Moya, M. (2010) Acid hydrolysis of olive tree biomass. Chemical Engineering Research and Design 88: 633-640
xvi. Roy, M. H. (2001) Pollution, Causes, Effects and Control. 4th Edition, Press Ltd UK. Pg 354
xvii. Sun, Y., and Cheng, J. J. (2005) Dilute acid Pretreatment of Rye straw and Bermuda grass for ethanol production. Bioresour.
xviii. Technol 96:1599-1606
xix. Vaisanen, T., Haapala, A., Lappalainen, R., Tomppo, L. (2016) Utilization of Forest and Waste residues in natural Fiber-
xx. Polymer Composites: A review. Waste Management. 54: 62-73
xxi. Wang, W., Yaun, T., Wang, K., Ciu, B., Dai, Y. (2012) Combination of Biological pretreatment with liquid hot water to enhance enzymatic hydrolysis of Populus tomentosa. Biosour Technol. 107: 282-286