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CHEMICAL HYDROLYSIS OF CELLULOSIC BIOMASS FOR THE PRODUCTION OF SECOND GENERATION BIOETHANOL

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Abstract: **This study evaluates the yield and purity of second generation bioethanol from chemical hydrolysis of cellulosic content of biomass (sugarcane bagasse),at ambient temperature and atmospheric pressure, and the effect of yeast concentration on its subsequent fermentation to ethanol, it is important to evaluate the purity of bioethanol because it is required to determine the property of bioethanol that would be used as fuel in the transportation sector while the yield is evaluated to determine the quantity of bioethanol produced. The method used involves chemical hydrolysis of sugarcane bagasse, with varying acid molarities of 1M, 2M, 3M, and 4M. The product, which consists mainly of simple sugars like glucose, xylose was subsequently fermented with varied concentrations of yeast of 5g/250ml, 4g/250ml, 3g/250ml and 2g/250ml in order to obtain ethanol. The result obtained shows that there is a gradual increase in the ethanol yield with increasing acid molarity from 1M until a critical optimum point is obtained at a high acid concentration of 3M. Beyond the molarity of 3M up to the 4M limit, there exists a decline in the ethanol yield, from the optimum point. The evaluation of the concentration of yeast on the fermentation of hydrolyzed cellulosic contents shows that the optimum ethanol yield is obtained at a yeast concentration of 3.0g/250ml for all the varying acid concentrations. A combination of acid concentration of 3M and yeast concentration of 3g/250ml therefore gives the optimum conditions, at moderate temperature and pressure, for the chemical hydrolysis of bagasse's lignocellulosic content and the fermentation of the resulting product. On purity determination, sample"C" has shown the highest purity of 95% making it to be used as fuel additives or fuel itself.**

Keywords: **chemical hydrolysis, generation bioethanol, chemical hydrolysis.**

1. INTRODUCTION

1.1 Background

Energy availability has been an issue for many years. With the potential of fossil fuels, the most common energy source in use today, becoming depleted and particularly increasing greenhouse gas emissions, hence contributing to global climatic change, new sources of energy are being developed(Alexanderetal.,2009;Cheng,2009).These new forms of energy include solar, wind, geothermal ,nuclear ,and other forms of renewable energy. Included within the renewable energy field lies that of using bioethanol as either a fuel additive or as fuel itself and this has led to an extensive research in the field of alternative fuel. In this context, bioethanol has been reported as an alternative fuel because it is renewable, non-toxic and biodegradable (Harun etal.,2011; Borinesetal.,2013).Second generation bioethanol can be derived from biomass with many different varieties of feed stocks such as corn, sugarcane bagasse,wood,cotton stalk and wastes which are easily accessible and reliable and can help to clean the environment from the wastes (Patni*etal*., 2013;Suryaningsih*etal*., 2014).According to(Berg,2001), fuel ethanol, besides its environmental value, is and will remain first and foremost an instrument to support farmers, as they will profit from fuel ethanol programs. Biofuels give more benefit since it comes from renewable resources. Its sustainability reduces greenhouse gas emission (Demirbas, 2006).

Bio-ethanol, is an alternative fuel derived from biologically renewable resources. It is a good substitute for gasoline in spark-ignition engines (Bioscience Biotechnology Research Asia, 2014). Second generation Bio-ethanol are produced from lignocellulosic materials, such as crop residues, municipal solid wastes. Production of fuel alcohol from biomass is of growing interest worldwide (Rodriguez*etal*, 2003).Biomass is the biological material derived from living, or recently living organisms. It mostly-often refers to plants or plant-based materials, which are simply called lignocellulosic biomass. Currently, this readily available biomass is in plenty and can be used in the production of bioethanol. The Lignocellulosic material is a complex mixture of cellulose, hemicellulose, and lignin that is tightly bonded by physical and chemical interactions. The chemical hydrolysis process can effectively breakdown its complex structure, fractionate its components, and convert its cellulose and hemicellulose to mono-sugars (hexoses and pentose), which can be converted to various biofuels and biochemical via biochemical and chemical methods. The Lignocellulosic material acid hydrolysis process can be an entry point into a Lignocellulosic Material bio refinery scheme(RinaldiandSchuth 2009).After hydrolysis, the obtained mono-sugars as carbon source can be fermented to many products including ethanol, butanol, organic acids, and solvent. They also can be chemically transformed into important bio refinery platform compounds such as xylose, furfural, 5-hydroxy methyl furfural, and levulinic acid, which can be further converted to a series of biofuels, valuable chemicals, and biomaterials. The obtained lignin can be used as cement additives, incinerated as fuel or electricity, or transformed into fine chemicals, for example, natural binders and adhesives. The concentrated acid hydrolysis process usually operates at room temperature with concentrated mineral acid. The Bergius process is a typical concentrated hydrolysis process. The concentrated hydrolysis process always has high yield of mono-sugars in the hydrolyzate. Its main problem is the strong equipment corrosion and the inadequate acid recovery (TaherdazehandKarimi, 2007).Although some measures have been taken to solve these problems, for example by use of gaseous hydrogen chloride or anhydrous Hydrogen fluoride to facilitate acid recovery (Wangetal, 2011).Recently studies on producing bio-ethanol from sugarcane bagasse are getting attraction especially in the developing countries of low income. The use of sugarcane bagasse as biomass would give great advantages considering the shortage of energy resources and increasing availability of bagasse.

1.1.1 Biofuel production from sugarcane bagasse

In the present study, cellulosic biomass such as sugarcane bagasse which are in abundance and do not interfere with food security can be subjected to simultaneous saccharification and fermentation by co–culture of Baker'syeast(Saccharomyces cerevisiae) for 5days and biomass yield, cell dry weight reducing sugar concentration and the ethanol yield can be determined.(FAO,2009).This study suggests that sugarcane bagasse contain fermentable sugars that can be converted to useful products like bio-ethanol and can serve as alternative fuel

1.1.2 Biomass:

An energy resource derived from organic matter. These include wood, agricultural waste, and other living-cell material that can be burned to produce heat energy. Plant biomass contains energy that can be used for food or fuel, depending on what part of the plant is used.

1.1.3 Cellulosic biomass refers to tough,fibrous,orwoody plant parts, such as grass, leaves, stems, flowers, corn stalks ,wood, or paper products. Although cellulosic biomass cannot be used for food, it contains a large amount of energy that can be used as fuel for transport. Cellulosic biomass is mostly made up of a molecule called cellulose, which is the primary component of plant cell walls. Without cellulose, plants would not be able to stand upright. This is one reason why cellulose is the most abundant molecule on earth and represents a huge potential pool of renewable energy if we could find a way to easily convert it into transportation fuel (http://www.glbrc.org/education)

1.2 Problem statement

In today's world, the greater percentage of energy being used is produced by the fossil fuels such as coals, crude oil and natural gas. Unfortunately there have been problems with the fact that these natural resources are diminishing and increasing greenhouse gas emissions, hence contributing to global climatic change that will continue to have a negative impact on the environment if not addressed well. It is therefore imperative to develop a renewable energy source with a lesser effect to the atmosphere which can also be used to fuel energy needs, such as for transportation fuel and other personal use. Bioethanol produced from biomass such as sugarcane bagasse is one such step.

1.3 Objectives

1.3.1 General objective

To produce second generation bioethanol using sugarcane bagasse

1.3.2 Specific objective

1. To vary the concentration of Sulphuric acid used in chemical hydrolysis
2. To determine the purity of bioethanol after distillation

1.4 Scope of the study

Sugarcane bagasse is obtained after milling sugar juice from crushed sugarcane. These bagasse materials contain cellulose, hemicellulose and lignin. The chemical hydrolysis will be done by mixing bagasse with concentrated Sulphuric acid, water, sodium hydroxide, heating and consequently fermentation of the sugar solution in the presence of *Saccharomycescerevisiae* enzyme for five days. The ethanol produced will then be purified by fractional distillation. The problems encountered in the course of this experiment will be noted.

1.5 Justification of the study

An important driver for bioethanol promotion is the potential to reduce life cycle carbon dioxide emissions by replacing fossil fuels. The current International Energy Agency see rapid increasing biofuel demand, in particular for second generation biofuels, in an energy sector that aims on stabilizing atmospheric carbon dioxide concentration at 450 parts per million (ppm)and this research will provide the source of biofuel

1.6 Significance of the study

This research is very important because it reduces the strain put on the food industry from other forms of bioethanol production. Instead of utilizing food crops to produce fuels, other forms of organic matter containing cellulose can be used and it is also an instrument to support farmers, as they will profit from fuel ethanol programs. There are a variety of uses for the sugars produced from this reaction; ethanol, acetic acid, amino acids, antibiotics, and other chemicals.

2. LITERACTURE REVIEW

Globally, the world is facing the crisis of depletion of fossils fuels as well as the problem of environmental degradation. The rapid depletion of fossil fuel reserves with increasing demand and uncertainty in their supply, as well as the rapid rise in petroleum prices, has stimulated the search for other alternatives to fossil fuels. In view of this, there is an urgent need to explore new alternatives, which are likely to reduce our dependency on oil imports as well as can help in protecting the environment for sustainable development (International Journal of Biological science, 2012).

2.1 Ethanol

What is Ethanol?

Ethanol is an alcohol originally referred to any fine powder, but medieval alchemists later applied the term to the fined products of distillation, and this has led to the current usage. Ethanol is a clear liquid alcohol that is made by the fermentation of different biological materials. This alcohol is known to have many uses, but one in particular is becoming more popular. Ethanol, the most widely used biofuel, is made in a process similar to brewing beer. The ethanol in the end is blended with gasoline to improve vehicle performance and reduce air pollution (American coalition for ethanol, 2016).

2.2 Bioethanol

Bio-ethanol; bioethanol emerges as the most energy efficient environmentally friendly options in recent times to fulfill the future energy needs. Bio-ethanol is a renewable fuel substitute that can be produced from biomass. During the last 15years bio-ethanol has progressed from the research stage to a large-scale production in many developing countries. In context, non-edible oils are emerging as a preferred feed stock and several field trials have also been made for the production of biodiesel (DOE’s Biomass power, 1997).

Many traditional biomass like sugarcane bagasse, cotton stalk, and millet straw etc. are available in our country in abundance, which can be exploited for production purpose. Bio-ethanol can be used neat or as additive in compression Ignition engines.

The ancient Egyptians produced bio-ethanol by naturally fermenting vegetative materials. also, in ancient times, the Chinese discovered the art of distillation which increases the concentration of alcohol in fermented solutions. Ethanol was first prepared synthetically by HenryHennel (2014). Michael Faraday prepared ethanol by acid catalyzed hydration of ethylene in 1828, in a process similar, to the one used in the industrial synthesis of ethanol today. Ethanol was used as a lamp fuel in (1840) but a tax levied on industrial alcohol during the civil war made this use uneconomical. In (1907), Henry Ford reintroduced ethanol to the American motoring public by producing his first vehicle to run on ethanol (Chemical Engineering Communications, 1990).

2.3 Generation of bioethanol

2.3.1 First generation bioethanol

First generation bioethanol is a liquid biofuel designed for road vehicles, generated from food crops with high levels of starch and sugar(GuoW,2014).Production of first generation bioethanol uses food feedstock, mainly starchy materials (*e.g.* corn, maize, wheat, barley, cassava, potato) and sucrose-containing feedstock (*e.g.* sugarcane, sugarbeet, sweetsorghum). This has led to serious concerns regarding the socio-economic and environmental consequences of large-scale production(BuijsNA,SiewersV,NielsenJ,2013).First generation biofuel production competes with food production for water and arable land ,and may also contribute to resource depletion such as water shortages, and soil and water degradation due to over-fertilization(JamboSA,AbdullaR,2016).It may push up the price of food commodities such as cereals, crops and vegetable oils and livestock feed.

2.3.2 Second generation bioethanol

Generally, second and subsequent generations of biofuels including bioethanol do not compete against food supplies as they are based on non-food raw material (Thompson, Meyer, 2013). Second generation bioethanol is typically produced from lignocellulosic biomass, but it is also possible to use industrial byproducts, such as whey (BalatM, BalatH, 2008) or crude glycerol, as feed stock. Such biomass is usually relatively inexpensive as well as readily and locally available. Lignocellulose is considered a renewable and sustainable carbon source, and occurs in many plant raw materials

2.3.3 Third generation bioethanol

The third generation of biofuels is based on the cultivation of microalgae or unicellular microorganisms derived from eukaryotes and prokaryotes(cyanobacteria,suchas*Cyanidiumcaldarium*or*Synechococcus*)(KollerM,SalernoA,2012).Live biocatalysts in the form of active micro algal biomass are able to use nutrients(carbon,nitrogen,phosphateorsulfur) from industrial waste streams as substrates to create high concentrations of biomass. These waste streams include effluent gases from industrial power plants, waste water, products of hydrolysis of organic waste and digest ate(waste from biogas production).Producing third generation biofuels can therefore help minimize waste streams from many industries. Biological sequestering of CO_2 from the combustion of fossil resources by microalgae and conversion of CO_2 to biofuels contributes to the reduction of levels of GHGs in the atmosphere, helping to meet global targets for preventing climate change (KollerM, SalernoA, 2012)

2.4 Fuel Ethanol

Although ethanol has been traditionally thought of as a beverage product for use in spirits, beer and wine, ethanol is an important, viable alternative to unleaded gasoline fuel. Ethanol is used as an automotive fuel; it can be used alone in specially designed engines, or blended with gasoline and used without any engine modifications, motor cycles, lawn mowers, chain saws etc. can all utilize the cleaner gasoline/ethanol fuel (World Academy of Science, Engineering and Technology, 2011)

Most importantly, the millions of automobiles on the road today can use this improved fuel. Farmers, cities, counties, and rural electric co-op fleets, plus snow mobile racers and fishing guides in the U.S. use ethanol blends exclusively with no performance problems. Adjustments maybe required for air intake (Engineering Technology (IJRAET) V-4I-1, 1992).It is important to consult your owner's manual. Fuel ethanol what has been called"gasohol"-the most common blends contain 10% ethanol mixed with 90% gasoline (E10). Because the ethanol is a high-octane fuel (2.5-3points above the octane of the blending gasoline) with high oxygen content (35% oxygen by weight), it allows the engine to more completely combust the fuel, resulting in fewer emissions. Since ethanol is produced from plants that harness the power of the sun, ethanol is also considered a renewable fuel. Therefore, ethanol has many advantages as an auto motive fuel. (*Biosciences Biotechnology Research Asia*, 2014).

2.5 Using Ethanol in Engine

When the use of ethanol began in1979 most automobile manufacturers did not even address alcohol fuels. As soon as each manufacturer tested their vehicles, they approved the use of a 10% ethanol blend. Today, all manufacturers approve the use of ethanol and some even recommend ethanol use for environmental reasons. A number of tests have been done with ethanol in small engines as well. One of them was done at the Lake AreaVo-Techat Watertown, South Dakota, where they put a life time of use on seven different models of small utility equipment. They acquired matched sets of each of the seven models, and ran one on an ethanol blend and the other on an unleaded gasoline. After each test, each motor was torn down for laboratory analysis. The most significant difference was that the ethanol blend engines had slightly fewer carbon deposits. The Detroit Lakes Technical College at Detroit Lakes, Minnesota studied the “Hydroscopic effects of a marine environment on ethanol blended gasoline", and concluded that the amount of water an ethanol blend will absorb from the atmosphere is minimal, and should not be a concern. (SBaier, 2009).

2.6 Bioethanol and Environment

Increasing industrial activity and population growth has resulted in arising concentration of 'greenhouse gases’ in the atmosphere that contribute to the ‘Greenhouse Effect’. These gases include carbon dioxide, methane, and nitrous oxide. The term 'Greenhouse Effect’ refers to the Earth's trapping of the sun's incoming solar radiation, causing warming of the Earth's atmosphere. This offsets the Earth's natural climatic equilibrium, and results in a net increase in global temperatures. 'Global Warming' is a term used to describe the increasing average global temperature. (RI Canada, 2010).

2.7 Environmentalbenefits of bio ethanol fuel

Carbon dioxide; Carbon dioxide from the burning of fossil fuels is the largest single source of greenhouse gases from human activities, representing about half of all greenhouse gas emissions. Use of 10%ethanol-blended fuels results in a 6-10% CO_2 reduction and higher levels of ethanol can further reduce the net quantity of CO_2 emitted into the atmosphere (RICanada,2010).More CO_2 is absorbed by crop growth than is released by manufacturing and using ethanol. The carbondioxide produced during ethanol production and gasoline combustion is extracted from the atmosphere by plants for starch and sugar formation during photosynthesis. It is assimilated by the crop in its roots, stalk sand leaves, which usually return to the soil to maintain organic matter, or to the grain, the portion currently used to produce ethanol by(Gurgaon Institute of Technology and Management,2016).Only about 40 percent or less of the organic matter is actually removed from farm fields for ethanol production. The rest is returned to the soil as organic matter, increasing fertility and reducing soil erosion. With modern conservation farming practices, this soil organic- matter will build up, representing a net removal of carbon dioxide from the atmosphere. An increase of only 1%in the soil organic matter level means an atmospheric reduction of over40 tonnes of CO2 per hectare of farmland (journal of World Academy of Science, Engineering and Technology, 2009)

2.8 Socio-economic benefits of bioethanol fuel

Bioethanol gives more benefits since it comes from renewable sources. According to (Berg, 2001), bioethanol fuel besides its environmental value, is and will remain first and foremost an instrument to support farmers, as they will profit from bioethanol fuel programs.

Its sustainability will improves regional development, social structure, agriculture and food security supply (Demirbas, 2006)

2.8.1 Occupational health and safety of bioethanol production

According to the Biotechnology Innovation Organization(BIO),the direct job creation from advanced biofuel production could reach 190,000 units by 2022.This context generates attention too occupational safety, which has to take into account all actions aimed at protecting the safety, health, and welfare of people engaged in such industrial sector. This can include safety assessments, accident investigations, training programs, and other activities, which can reduce or eliminate work place injuries and illnesses. In the face of growing development of the bioethanol industry and the consequent increase in employed workforce, there are still limited data, which are referred to the occupational health and safety of these production processes.

2.9 Sugarcane bagasse

Sugarcane bagasse is the fraction of biomass resulting from the cleaning, preparation and extraction of sugarcanejuice.it is heterogeneous in terms of size and particle format and regarding the three predominant components of the polymers: cellulose, hemicellulose and lignin (Rabelo and Carlos Eduardo, in sugarcane, 2015)

2.9.1 Several factors influence sugarcane bagasse composition

The use of fire or another method for straw removal before cutting.

Harvesting and loading methods resulting in greater or lesser dragging of dirt, sand and vegetable residue, i.e., manual, mechanical cutting, chopped cane, cutting to include the tip, etc.

The type of soil where sugar cane was planted (lato sols, sandy soils, and other types of soils).

2.9.2 Theoretical scope.

There are three methods of extraction of bioethanol; pretreatment, hydrolysis and fermentation. The three methods are followed by distillation of fermented solution to extract pure bio-ethanol thus step by step production is pretreatment, hydrolysis, fermentation and distillation.

2.9.3 Fermentation

This is the chemical transformation of organic substance to simpler compounds by the action of enzymes. In industrial practice, fermentation refers to any process by which raw materials are transformed by the controlled action of carefully selected strains of organisms into definite products. For this research, it will be a biological method for ethanol production. The fermentation reaction is caused by yeast which feed on simple sugars. The glucose produced from acid hydrolysis is fermented with yeast to produce ethanol. Carbon dioxide is also produced as glucose is consumed. The simplified reaction equation is

$$\mathbf{CHO \rightarrow CHOH + CO}$$

This is by Bioethanol production from corn meal by simultaneous enzymatic saccharification and fermentation (Fuel,vol.88,pp. 1602–1607, 2009).

2.9.4 Distillation

This is a separation of mixtures based on volatilities (boiling points of the individual components that make up the mixture).Distillation is often used if one product is required, in this case ethanol is required

3. MATERIALS AND METHOD

Bioethanol can be produced through the microbial conversion of biomass by fermentation of the sugars contained in it, the principle steps are the formation of the fermentable sugars, fermentation of these sugars to ethanol and finally the purification of the ethanol by distillation

However, there are step to step procedures that are necessary for effective production of bioethanol from this feedstock and they include pretreatment, chemical hydrolysis, fermentation of the sugar solution, and purification of the ethanol by distillation

3.1 The materials used in the production of bio-ethanol from bagasse are

120g Sugarcane Bagasse, Condenser, Baker's yeast, Funnel,

Stove for heating, Reagent bottles, Retort stand fitted with a clump

Weighing scale, 500ml Round bottom flask, Wine hydrometer

1000 ml conical flask, glass beaker

3.2 Pretreatment

120g sugarcane bagasse used as the feed stock for bioethanol production was collected and pretreated mechanically with the use of a high-speed multi-function comminutor in order to reduce the size of the bagasse and ultimately, the surface area of the material and then immediately sieved in order to obtain fine particles of the material

3.3 Chemical hydrolysis

30g of sugarcane bagasse was weighed using weighing scale. 100mLof1M sulfuric acid was then added to the bagasse in the glass beaker. It was ensured that the bagasse was thoroughly (not excessively) covered by the acid. Afterwards, 400ml of distilled water was added to a1000ml conical flask. The bagasse with acid mixture was then poured into the 1000ml conical flask with the distilled water. Following this, the pH of the bagasse, acid and water mixture was taken with the pH meter. Water was then added to the mixture to increase the pH to a value between5.0and6.0 (which is conducive for yeast) without exceeding the 800ml mark of the conical flask. Since the water could not increase the pH to a value between 5.0and6.0, 2N of NaOH solution was added to the solution with a dropper bottle until the pH was in the desired range. The same procedure was repeated for every acid concentrations of 2M, 3M, and 4M

3.4 Microbial fermentation

After the pH of the mixture was regulated to be between 5.0 and 6.0 which is conducive for the yeast.250ml of the mixture was poured into a bottle and 5.0g of yeast was added on the mixture and then the bottle was closed tightly. The whole mixture was left for five days to ferment. The same procedure was repeated with4.0g, 3.0g and 2.0g of yeast for 2M, 3M, and 4M Acid concentrations respectively

3.5 Distillation

After the five days, the mixtures were removed and filtered. The filtrate contains ethanol and some other impurities.

200ml of the mixture was then distilled for 2hours and the purity of the ethanol was determined.

The same procedure was repeated with other variations

Table 1: variation of acid Conc used, amount of yeast added, NaOH Conc used, quantity of mixtures used in fermentation and quantity of filtrate used in distillation.

Samples	Acid Conc used(M)	Amount of yeast added(g)	NaOH Conc used(N)	Qty used in fermentation(mls)	Qty used in distillation(mls)
A	1	5.0	2	250	200
B	2	4.0	2	250	200
C	3	3.0	2	250	200
D	4	2.0	2	250	200

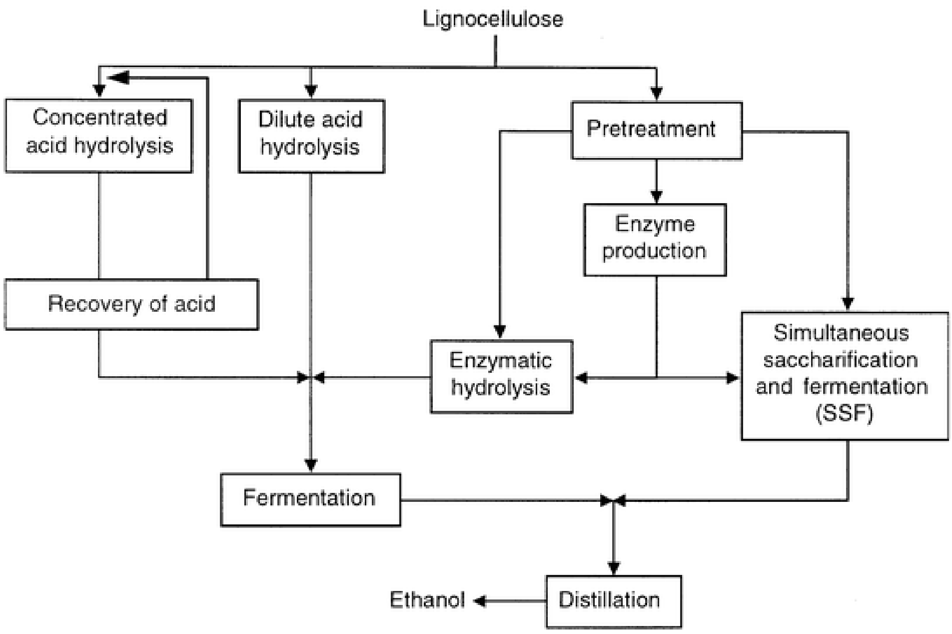

Figure 1: cellulosic ethanol production process (Zacchi, 2002)

4. DISCUSSION AND RESULTS

Table 2: Variations of Acid Conc, Yeast Conc, Ethanol Qty obtained and Ethanol purity

Samples	Acid Conc(M)	Yeast Conc(g/250ml)	Ethanol Qty(mls)	Ethanol Purity (%)
A	1	5.0	2	45
B	2	4.0	5	50
C	3	3.0	20	95
D	4	2.0	10	60

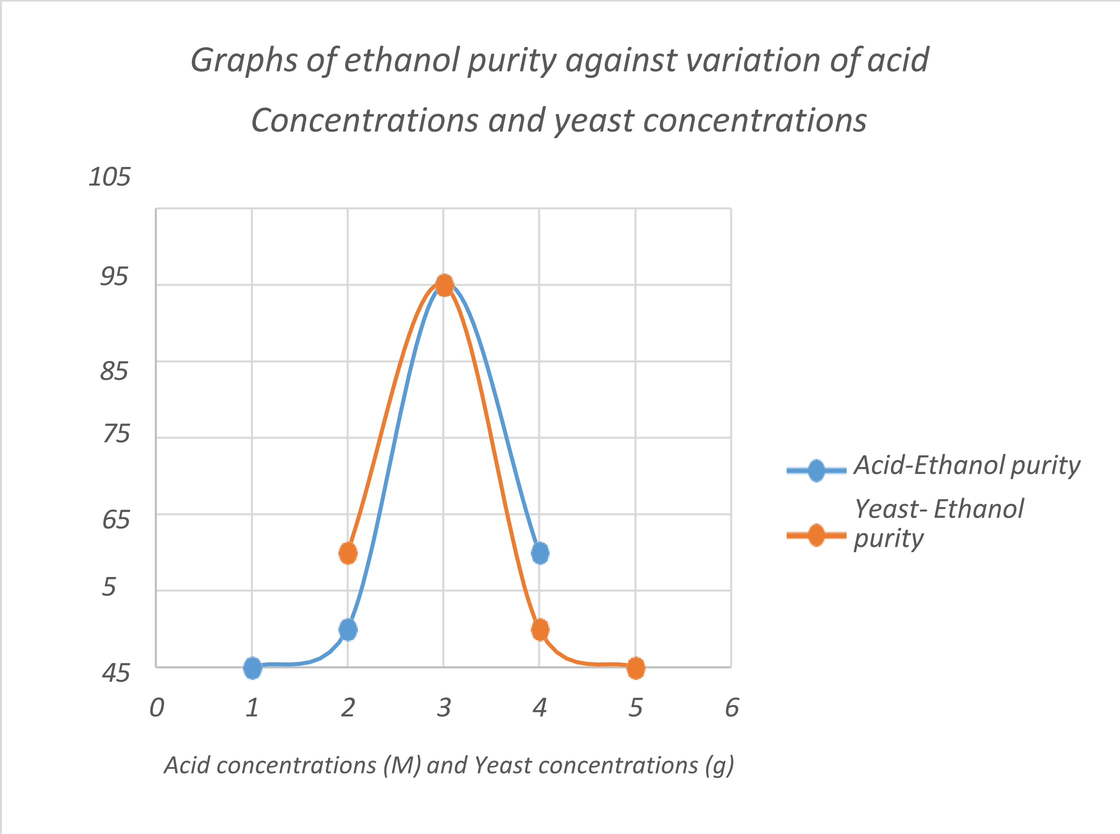

Figure 2: Graph of ethanol purity against variation of acid concentrations and yeast concentrations

4.1 Discussion of results

From the results, it is observed that the two varied factors, acid concentration and yeast concentration, affect the yield and purity of bioethanol. The acid is used to break down the cellulose bonds. Afterwards, the water added causes the broken chains to form glucose and other fermentable sugars that can easily be fermented.

There is gradual increase in the yield of ethanol with increasing acid concentrations from1M upto3M which is the optimum critical point. The reason for the low yield of bioethanol at low concentration of bioethanol is that the low concentration of acid is unable to effectively remove lignin and break down the cellulose bond at atmospheric pressure and room temperature. Beyond the optimum critical point, there is a decline in the yield of ethanol. This is because at higher concentration of acid beyond the optimum critical point of 3M, the high concentration of acids leads to break down of part of fermentable sugars that are formed as a result of the hydrolysis of cellulosic content of the bagasse

The yield of ethanol also increases with increase of yeast up to the critical point and then it declines. This is because beyond the optimum critical point, higher concentration of yeast inhibits fermentation process ,hence a decline in ethanol yield.

Finally bioethanol produced with the highest purity can be used as fuel additives or fuel itself in the transportation sector

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study shows that chemical hydrolysis, at room temperature and atmospheric pressure, may be used for the hydrolysis of cellulosic content of bagasse, thus producing bioethanol that could be used as biofuel and could help in Shifting the transport sector from petroleum and gasoline towards more sustainable, renewable and environmentally friendly energy source. “Environment free from negative emission of greenhouse gases is the best environment for humanity”

The optimum conditions for maximum yield of bioethanol occurs at a combination of acid concentration of 3M and yeast concentration of 3g/200ml.Any deviation from this critical concentrations give gradual declining bioethanol yield. On purity determination, sample”C”has shown the highest purity 0f 95% making it to be used as fuel additives or fuel itself

5.2 Recommendations

This research has the possibility of converting sugarcane bagasse into bioethanol

Globally also, bioethanol is being used as fuel in the transportation sector and it is safe for the environment compared to fossil fuel

Therefore I recommend sugarcane bagasse to be used to produce bioethanol as it is always in plenty from sugar factories.

5.3 Limitations

Covid-19 affected the research study especially when I couldn’t get accessed to laboratory over the lock down period and as a result some of my samples got sploilt.This has made me to restart the whole experiment again when the university was reopened

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APPENDICES

Figure 3: showing pretreatment process being done using high speed multi-function comminutor

Figure 4: purified bioethanol of sample"A"

Figure 5: purified bioethanol of sample"B"

Figure 6: purified bioethanol of sample"C"

Figure 7: purified bioethanol of sample"D"