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ETHANOL EXTRACTION FROM WHEAT

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ABSTRACT

Current hike in the price of crude oil in the world market has produced ripples in the economy of nations. Research has therefore been in the area of renewable energy to break the monopoly of fossil fuel. One of such renewable fuels is ethanol. Ethanol has been produced from various feedstock. The objective of this project therefore is to produce ethanol using wheat as the feedstock. Fermentation was carried out to convert glucose ($C_6H_{12}O_6$) to ethanol (C_2H_5OH) and carbon dioxide gas (CO_2). 12 liters of fermented mash was heated in the boiler and the first condensate which was 60% water was collected in the receiver between 77^{0}C and 82^{0}C. After discarding the residue in the boiler, the first run distillation was reheated to 95.5^{0}C, when 70% ethanol plus by-products was obtained. This process was repeated a third time. The distillate collected was (E85) i.e. 85% ethanol which was about 170 proof. This ethanol was very flammable
Keywords: Renewable Energy, Hydrolysis, Fermentation, Distillation, Feedstock.

INTRODUCTION

Ethanol can be produced from a wide variety of plant-based feed stocks, most commonly grain or sugarcane crops. It is then blended with gasoline as an oxygenate or fuel extender for use in gasoline vehicles or it can be used alone in flexible fuel vehicles that can run on any blend of ethanol and gasoline. (Daniel, 2005) Ethanol dates back to the mid 19th century; it has been around as long as petroleum and was a popular illuminant for lamps. In 1861, two significant events affected the use of ethanol as an illuminant. First, kerosene came to the market and then, a $2.081 per gallon tax was imposed on alcohol (which affected ethanol) to assist in financing the Civil War in the U.S. Kerosene was quick to replace ethanol as the premier illuminant, due to its cheaper price. The tax on alcohol was lifted in 1906 thereby bringing about a renewed interest in ethanol and Henry Ford designed a model to run on ethanol in 1908. (Cliff and Ken, 1984). Also, the use of ethanol during World War I perpetuated a further increase in ethanol production to 50 million gallons annually (David, 1993). The use of ethanol declined again in 1919 because ethanol production was restricted and it could only be sold after it had been denatured (usually with petroleum). Consequently, in 1933, the use of ethanol rebounded when it was used during World War II for fuel and to make synthetic rubber. During this period about 600 million gallons of ethanol was produced annually in the U.S.A. (David, 1993). After the World War II, demand for ethanol reduced greatly due to importation of petroleum at cheap prices. Hence, ethanol was not used on a large scale again for about forty years. There were unsubstantiated claims that ethanol was used to power automobiles during the Nigerian civil war between 1967 and 1970. However, decades ago the versatility of ethanol was discovered. Its use as an ingredient in alcoholic beverage was well known. Medically, it was used as solvent for drugs, fluid in thermometers, preservation of biological specimens and as disinfectants in laboratory work surfaces. In addition, ethanol was used as intermediates in the manufacture of chemicals such as esters and halides. Some proportion of ethanol mixed with water or other solvents can be used as a solvent for paints and varnishes. It is also used in the manufacture of perfumes, paints, resins, dyes, soaps and tinctures. At present, ethanol has regained support for use in cars. It is used as a fuel by itself or blended with gasoline (which is known as gasohol). Brazil and Sweden use large quantities of ethanol as fuel. Some Canadian provinces promote ethanol use as a fuel by offering subsidies of up to 45 cents per gallon of ethanol. India initiated the use of ethanol as an automotive fuel (Christop, 2001) and a move has been made by distilleries in India to use surplus alcohol as a blending agent or an oxygenate in gasoline. Based on the experiments by the Indian Institute of petroleum, a 10 per cent ethanol blend with gasoline and a 15 per cent ethanol blend with diesel are being considered for use in vehicles in at least one state. France, produced ethanol from grapes that were of insufficient quality for wine production as a result of the increase in oil prices in the 1970s. Brazil introduced a programme to produce ethanol for use in automobiles in order to reduce oil imports. Brazilian ethanol is made mainly from sugarcane. Pure ethanol (100% ethanol) is used in approximately 40 per cent of automobiles in Brazil. The remaining vehicles use blends of 25 per cent ethanol with 75 per cent gasoline. Brazil consumes nearly 4 billion gallons of ethanol annually. In addition to consumption, Brazil also exports ethanol to other countries. Sweden has used ethanol in chemical production for many years; as a result, Sweden's crude oil

consumption has been cut in half since 1980. During the same time period; the use of gasoline and diesel for transportation also increased. Emissions have been reduced by placing catalytic converters in vehicle exhaust systems which decreased carbon monoxide, hydrocarbon and nitrogen oxide emissions. Ethanol blended gasoline and ethanol-blended diesel are being considered as viable alternatives to further lower emission levels because the amount of carbon-dioxide produced while burning fossil fuels must be reduced (Plinio, 2003).

CHARACTERISTICS OF ETHANOL

Ethanol (ethyl alcohol, grain alcohol, ETOH) is a clear colourless liquid with a characteristic, agreeable odour. In dilute aqueous solution, it has a sweet flavour, but in more concentrated solutions it has a burning taste. Ethanol - CH_3CH_2OH is an alcohol, a group of chemical compounds whose molecules contain a hydroxyl group –OH, bonded to a carbon atom. The word alcohol derives from Arabic al-kuhul, which denotes a fine powder of antimony produced by distilling antimony and used as an eye makeup. Alcohol originally referred to any fine powder, but medieval chemists later applied the term to the refined products of distillation, and this led to the current usage (Bright, 2003)

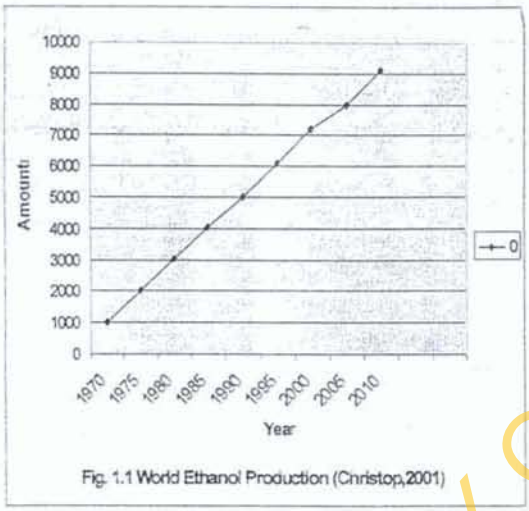

Fig. 1.1 World Ethanol Production (Cnristop,2001)

Ethanol melts at -114.1°C, boils at 78.5°C and has a density of 0.789g/ml at 20°C. Its low freezing point has made it useful as the fluid in thermometers for temperatures below -40°C, the freezing point of mercury, and for other low-temperature purposes such as for antifreeze in automobile radiators Ethanol has been made since ancient times by the fermentation of sugars. All beverage ethanol and more than half of industrial ethanol is still made by this process. Simple sugars are the raw material. Zymase, an enzyme from yeast, changes the simple sugars into ethanol and carbon dioxide. The fermentation reaction, represented by the simple equation:

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH+2CO_2$$

is actually very complex, and impure cultures of yeast produce varying amounts of other substances, including glycerine and various organic acids (Toru, 2003). There are wide varieties of feedstock that can be converted to ethanol. The feedstock will however dictate the exact nature of the milling process whether dry or wet. The feedstock that will be used is wheat because of its relative availability and efforts at local production in Nigeria. The objective of this project therefore is to produce ethanol using wheat as the feedstock.

REVIEW OF LITERATURE

The Brazilian government launched its National Fuel alcohol programme in the mid-1970's and by 1980 ethanol use had overtaken gasoline. Brazil is the world's leading ethanol producer and exporter, distilling 4 billion gallons in 2004. The Brazilian government extracts ethanol from sugarcane. United States of America extracts ethanol from corn. In 2004; 35 million tons of corn (12 percent of the U.S Corn Crop) was used to produce 3.4 billion gallons of ethanol. Capacity was expected to top 4.4 billion by late 2005 as 16 new plants came on line. Currently, there are 81 plants ranging in size from 1 to 300 million gallons annual capacity, half of which are farmer owned. The Australian government has supported ethanol since 2000 with a range of tax exemptions and production subsidies aimed at producing 92 million gallons of biofuel by 2010 - enough to replace one percent of total fuel supply. In 2004, production stood at 33 million gallons.

When fully combusted, the products are only carbon dioxide and water, which are also by-products of regular cellulose waste decomposition. For this reason, it is favoured for environmentally conscious transport scheme (Laaly, 2000). Ethanol appears to be less of a fire hazard than gasoline. Since ethanol dissolves in water rather than floating on it like gasoline, ethanol fires can be extinguished with ordinary water. The types of crops from which the ethanol was produced would absorb all the CO_2 that is liberated in the manufacture and consumption of ethanol. This results in decreased net output of the green house gas carbon dioxide (Radulich and Beetle 1991). In contrast, the burning of fossil fuel injects massive amounts of poisonous fumes and volatile organic compound into the atmosphere without creating a corresponding sink.

Distillation

The purpose of distillation section of the separation process is to affect the bulk of the binary ethanol-water mixture separation and increase the concentration of ethanol in the distillate stream (tops product) to 90% by mass. It is critical to reach this alcohol concentration via distillation to ensure the final 99.8% ethanol by mass concentration. This separation cannot be achieved solely with standard distillation due to the existence of a minimum boiling azeotrope, 95.5% ethanol by mass with a boiling point of 78.15°C (Perry 1998) in the vapour liquid equilibrium characteristic of an ethanol-water mixture. Fig.3 shows the schematic diagram of a distillation column. One option for the separation is to use a benzene entrainer to form a ternary azeotrope allowing the ethanol-water mixture to be separated. Questionable sustainability of the use of benzene that is highly flammable presents a risk to the environment. A suitable alternative is to distil the ethanol-water mixture to a point close to the azeotrope and then use pervaperation to complete the dehydration.

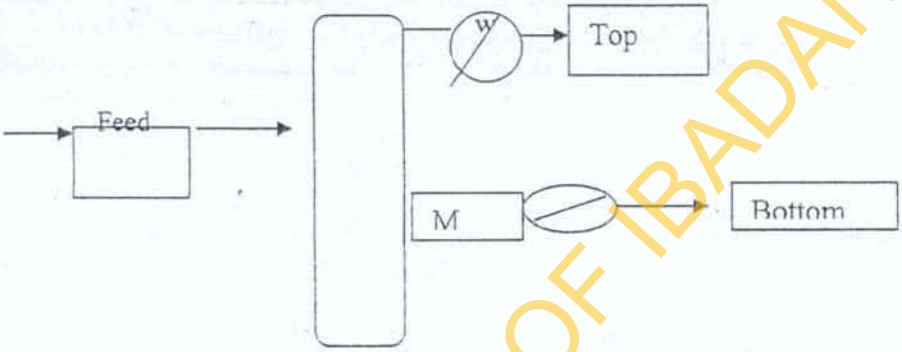

Fig. 3: Schematic diagram of a distillation column

Denaturing

The ethanol to be used for fuel is then denatured with a small amount (0 – 5%) of some product, such as gasoline, to make it unfit for human consumption. Through the process of denaturing, different percentage of gasohol can be obtained. A mixture containing gasoline with approximately 10% ethanol is known as gasohol. It was introduced nationwide in Denmark and in 1989 Brazil produced 12 Million litres of fuel ethanol from sugarcane, which was used to power 9.2 million cars (Berkely, 2006). Other gasohols that can be obtained from denaturing are:

- E_5: this contains 5% alcohol and 95% gasoline
- E_{20}: this contains 20% alcohol and 80% gasoline
- E_{85}: this contains 85% alcohol and 15% gasoline
- E_{95}: this contains 95% alcohol and 5% gasoline

ETHANOL AND OTHER LIQUID FUELS

Ethanol is a clear colourless liquid and is as clear as water. Ethanol is flammable and pure ethanol burns more clearly than many other fuels. When fully combusted, its combustion products are only carbon dioxide and water. For this reason, it is favoured for environmentally conscious transport schemes and can be used to fuel cars. The 113 octane rating for pure ethanol is much higher than ordinary gasoline. To change a gasoline-fuelled car into an ethanol-fuelled car, larger carburettor jets (about 30-40% larger by area) are needed. A mixture of gasoline with approximately 10% ethanol is known as gasohol. It was introduced nationwide in Denmark, and in 1989 Brazil produced 12 billion litres of fuel ethanol which was used to power 9.2 million cars.

MATERIALS AND METHODS

The methodology for a batch ethanol production from wheat is as follows.

1. Milling: The Feedstock was passed through a hammer mill which grinds it into a fine powder.
2. Liquefaction: The meal (3600ml) was mixed with water (12000ml) and it was passed through a cooker and galantines of 85°C for 30 minutes a continuous stirring process. Alpha Amylase (60ml) was added
3. Saccharification: The mash from the cooker was put in a water bath and stirred continuously for 1 hour. Gluco-amylase (60ml) was added and was left for 4 hours, to cool down. The hydrolysed solution was then passed through a Muslin Cloth
4. Addition of supplement: Growth factors were added as follows:

10g	of	NH_4SO_4
3g	of	$MgSO_4.7H_2O$
2g	of	NH_4Cl.
1g	of	Yeast Extract
6g	of	KH_2PO_4

The growth factors (Supplements) mixed in 20ml of water and autoclaved for 5 minutes at 110°C. It was then allowed to cool to room temperature

5. Fermentation: Saccharomyces Cerevisae "Yeast" (24%V/W) was added. The mash was allowed to stay in the reactor for 48 hours at 30°C.
6. Distillation: The fermented mash was later allowed to flow into the boiler. The mash was boiled and ethanol came out at its boiling point which is 78.5°C and was collected in a glass because plastics, rubber and metals cannot be used as ethanol receiver.

DENATURING PROCESS FOR ETHANOL

Reagents and equipment used

- Ethanol (Colurless solution)
- Petrol (Amber colour)
- Generator (2 Stroke engine)
- Measuring cylinder

Procedures for denaturing are shown below:

E_{20}: 20ml of ethanol was measured using a measuring cylinder and it was added to 80ml of Petrol. The amber colour of petrol turns to deep pink when in contact with ethanol.

E_{40}: 40ml of ethanol was measured and added to 60ml of petrol. Each drop of petrol turns pink when in contact with alcohol.

E_{60}: 60ml of ethanol was measured and added to 40ml of petrol. The colour of the solution became light pink.

E_{80}: 80ml of ethanol was added to 20ml of petrol. The colour changed to a very faint pink colour.

E_{90}: 90ml of ethanol was measured and added to 10ml of petrol. On contact, the colour turned to lilac

E_{95}: 95ml of ethanol was measured and added to 5ml of petrol. On contact, the colour turned lilac.

CONCLUSION

The ethanol (E85) produced was highly flammable and was extracted from the hydrolysis of wheat. The process of using wheat as the source had not been seriously explored in Nigeria. Strange enough wheat is available in the local markets and the cost of the produced ethanol is comparative. The combustion tests carried out showed that gasohol (blend of gasoline and ethanol) burns more slowly, effectively and with clear emissions than gasoline.

REFERENCE

Afolayan, L.A. (1995), "Organic Chemistry" Macmillan Education Ltd., Nigeria, vol.6. Pp 18-88.

Berkely, C. A. (2006), ''Ethanol can replace Gasoline with Big Energy Savings'' vol.1 University of California

Bright, L.k. (2003), ''Renewable Energy report'' vol. 52, Pp 42-43 London retrieved intermediate Tech. London

David, M.A., (1993) "A 150 year struggle," Michigan Old line series,. U.S.A. Econfine Distillation System Molecular Sieve Dehydrating Plant, Colorado

Honlon, P.O. (2003) "Renewable Energy report" Pp 12-15, Longman U.S.A

Karen Pulp-Macel Dekkar (2000) ' Handbook of Cereal and Technology.''

Laaly, H.O.(2000), "Global Warming and Third World". 4th Edition, Adams, Betteworth series, New York,

Perry Robert (1998) ''Perry's Chemical Engineers Handbook'' 7th Ed. McGraw Hill, New York

Plinio M. Natari, (2001) "Brazils strategy of Globalization for fuel ethanol" Presentation at the American council on Renewable Energy's second Annual Conference, Renewable Energy in America. Building a National Strategy on State Local Success, Washington, DC.

Smith.C.Wayne,(1995)''Crop production'' John Wiley and Sons Pp.60-62

Toru, I. D. (2003) "Drastic Improvement of bio-ethanol recovery using a pervaporation separation technique employing a silocone rubber coated silicate membrane" Journal of Chemical Engineering and Biotechnology fuel.