PRODUCTION AND CHARACTERISATION OF

ETHANOL FUEL FROM BIOMASS

BY

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DEPARTMENT OF CHEMICAL ENGINEERING,

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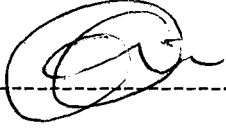
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FOR THE AWARD OF BACHELOR OF ENGINEERING

(B.ENG)

DEGREE IN CHEMICAL ENGINEERING.

NOVEMBER, 2005.

::

DECLARATION

I, EKWUEME UKAMAKA with registration number 99/8157EH Declare that this project report is my original work and has not been presented elsewhere to the best of my knowledge.

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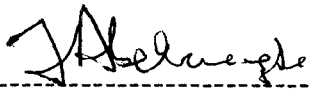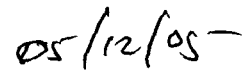Ekwueme. U.   Date

CERTIFICATION

This research project report by Ekwueme Ukamaka has been examined and certified under the supervision of ENGR A. S. KOVO to be adequate in scope and quality for the partial fulfillment of the requirement for the award of Bachelor of Engineering (B .Engr) in Chemical Engineering.

ENGR. A. S KOVO

DR. F. ABERUAGBA
HEAD OF DEPT.

EXTERNAL EXAMINER

DATE

05/12/05

DATE

DATE

DEDICATION

This project is dedicated to God Almighty whom by His grace I am still alive and also to my lovely parent Chief & Mrs. J .C Ekwueme.

ACKNOWLEDGEMENT

First and foremost my profound gratitude goes to the Almighty God of the universe whom by His grace and faithfulness kept me through my programme, may His name alone be praised forever and ever Amen.

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ABSTRACT

The production of ethanol fuel from Biomass (maize) was carried out. The work done includes, mashing, fermentation and distillation of the sample; All this processes are carried out at various pH and temperatures. The experimental production of the fuel from maize starch required the use of amylase to hydrolyze the complex starch to simple sugar, and the subsequent fermentation of the sample (wort) by the yeast to produce the ethanol in addiction to some CO_2, the bi-product of the reaction.

The production of the sample was successfully carried out to give a yield of 87% ethanol per gram of starch hydrolyzed. The sample was subsequently characterized to test for some propertied that are required of a fuel, such as the Latent Heat of Vaporization with a value of 950.8kj\kg, heat of combustion of 22133.7kJ/kg, flash point of $17-20^0C$, viscosity of 1.32 centipoises, and relative density of 0.805 were obtained respectively.

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CHAPTER ONE

1.0   INTRODUCTION

The concept of ethanol as a fuel began as early as the first model T car Design (Henry, 1980). American usage of ethanol gasoline began in the late 1970s. Environmentally, the use of ethanol blend has assisted in reducing carbon monoxide emissions mandated by the United State Clear Air Act of 1990. In addition, as corn prices declined, ethanol production using corn as a feed stock, came to be seen as a way of expanding the domestic market of grain helping to stabilize farmer's income (Smith, 1980). Fuel ethanol is generally produced by fermenting sugar, corn or other agricultural products into alcohol, Ethanol, C_2H_5OH is the second member of the aliphatic alcohol series, it is clear colourless liquid with a pleasant smell; except for alcoholic beverages, nearly all the ethanol used industrially is a mixture of 95% ethanol and 5% water which is known simply as 95% alcohol. Although pure ethyl alcohol otherwise known as absolute alcohol (Leary 2000). Ethanol is prepared by fermentation of sugar and starch or synthetically. Ethanol has boiling point 78^0C, melting point of -115^0C and specific gravity of 0.79 (Leary, 2000).

Ethanol, used as a source of fuel is better than fossil fuel, because during the production of fuel ethanol, no much harm is done to human and it's environment, the by-product of ethanol are mostly carbon dioxide, water vapour and heat energy, all these can be taken care of by trapping them during production process. The production process is much easier. The CO_2 produced could cause green house effect, but the growing plant uses them up, and that leads to less carbon dioxide emission. But in the case of fossil fuel

exploration and usage, which has much environmental hazards such as air pollution, oil spillage on water bodies leading to the death of aquatic life and oil spillage on land which affect the availability of agricultural products (Abdul Kareem 2005).

As in the case of energy efficiency, ethanol contains 22,400BTU/Litre. The energy content however, may not be as important as energy replaced. Due to the higher combustion efficiency of ethanol and it's octane credit at the refinery, for instance, ethanol can replace 26,57BTU of gasoline (Level Ton Engineering LTD, 1999). Combustion of ethanol is a complete one, which is the complete burning of carbon, leading to less emission of carbon dioxide, which is dangerous to human and it's environment. In-complete combustion of fossil fuel cause Ozone layer depletion and many dangerous air pollutants including carbon dioxide and air toxins.

Ethanol, as an alternative source of energy, makes an excellent motor fuel; it has a motor octane number which exceeds that of gasoline and has a lower vapour pressure than gasoline which results in lower evaporative emission. Ethanol's flammability in air is also much lower than that of gasoline which reduces the number and severity of vehicle fires. Anhydrous ethanol has low and high heating values of 21.2 mega joules per liter and 23.4 mega joules per liter, respectively; for gasoline, the values are 30.1 and 34.9 mega joules per liter. Ethanol fuel used in areas such as in automobiles, generation of power, cooking and for source of light for vision.

However, relating ethanol fuel use to present trends in the direction of alternative use in our present world, ethanol fuel are in automobile engines, it

keeps the burning engines cleaner and efficient, unlike the fossil fuel. Ethanol fuel use had led to market expansion for the farmers (Abdul Kareem 2005).

1.1 AIM AND OBJECTIVE

The aim of this project is to produce ethanol fuel as a source of energy from biomass (maize and sugar cane), this can be achieved via realization of the following objectives:

(i) Production of ethanol from biomass.

(ii) Conversion of ethanol produced to fuel.

(iii) Characterization of the ethanol fuel to determine it's suitability as an alternative source of energy.

(iv) Compared the production rate and activity of products obtained from different sources.

1.2 SCOPE OF PROJECT

This project is aimed at using biomass such as maize grain and sugar cane to produce ethanol, concentrating the ethanol by making it an absolute ethanol.

1.3 JUSTIFICATION OF PROJECT

The use of fossil fuel has led to air pollution, depletion of the Ozone layer and global warning and so many environmental effect. But in the production and use of ethanol fuel there are no much environmental effect involved, with this, the project on ethanol as a source of energy is justified.

1.4 LIMITATION

This project is limited to experimental result obtain from the biomass.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORY OF ETHANOL

Ethanol has been known to human from history as the active ingredient of alcoholic beverages. Its isolation as a relatively pure compound was probably achieved first, by an Islamic alchemist. Who develop the art of distillation (Al-Razi, 1815).

The name alcohol comes from the Arabic language al-kul. Alchemist used al-kul to refer to any of number of fine powder produced by chemical process. Alkul was also used for substances that were made by process of distillation, the earliest recorded English used for this meaning of the term is from 1672. "Alcohol of wine" was the term first used for fermented liquors that caused intoxication; originally referred to the process and distilled "essence", it was later referred to the "essence" which caused the effect of intoxication and later was used for liquid and in recent science contexts for the chemical known today (Smith, 1980).

Ethanol has also been described as one of the synthetic oxygen containing chemical; it is also known because of its unique properties as a solvent, germicide, beverages, an antifreeze, a combustible liquid and especially because of its versality as a building block or a chemical intermediate for other chemicals. It may also be called ethyl alcohol, it is a monohydric alkanol which form a homologous series with a general formular $C_nH_{2n+1}OH$. Ethanol is the second member of the series and by far the most important, the molecular formular is CH_3CH_2OH. The name was generally restricted to ethyl alcohol.

Ethyl alcohol is extremely well known as a constituent of alcoholic beverages, it has been produced and utilized unknowingly as far back as 400years ago by the Pharaoh's in Egypt as a beverage. An indication of the antiquity of knowledge of the effect of ethyl alcohol has been traced to Naoh who built for himself a vine yard and grew grapes which he fermented into a sort of alcoholic drink (beverages).

On which he became drunk, which unfortunately resulted in his loss of self respect. Ethyl alcohol has a long and illustrious history of process, following the more interesting mile stone along the way (Smith, 2001).

Table 2.1.0

YEAR	SOURCE
1500	First comprehensive book on the art of separating alcohols from Fermentation process.
1790	First correlation between specific gravity and concentration of ethyl alcohol in mixture of ethyl alcohol and water.
1796	First preparation of anhydrous alcohol utilizing anhydrous potassium carbonate.
1811	First correlation between percent volumes of ethyl alcohol in spirit by tralles.
1825	First preparation of ethyl alcohol from ethylene and sulphuric acid.
1861	First patent issue covering the synthesis of ethyl alcohol from ethylene and sulphuric acid.
1862	First exhibit of one litre of ethyl alcohol obtained from ethylene and sulphuric acid at London exhibition.
1873	First Russian literature reference to ethyl alcohol
1902	First dehydration of azeotropic distillation of ethyl alcohol with benzene.
1903	First commercial development of dehydration by azeotropic distillation of ethyl alcohol with benzene
1906	First law to make industrial alcohol tax-free in USA.

Table 2:1:2

YEAR	SOURCE
1922	First British patent for the direct catalytic hydration of ethylene to ethyl alcohol.
1930	First commercial process for synthesizing ethyl alcohol from ethylene and sulphuric acid.
1943	First commercial production of ethyl alcohol from petroleum refining gases.
1943	Maximum annual production of about 580 million gallons of ethyl alcohol.
1951	First USA patent for direct catalytic hydration of ethylene to ethyl alcohol.
1954	First commercial production of ethyl alcohol direct hydration of ethylene.
1962	First in line blending of denatured ethyl alcohol directly into shipping vehicles.
1977	Fermentation capacity for fuel ethanol increased eight fold.
1989	Fermentation capacity was 20 billion litres per day world wide.
1995	Ethanol production rebounded from low levels.
1997	About 60 million bushel from corn were used for manufacturing of ethanol (Mathewson, 1980).

2:2   DEFINITION OF ETHANOL

ETHANOL: This is a colourless liquid, also know as ethyl ethanol which has a characteristic liquor and it is miscible in water and other organic solvents. It can be used industrially as fuel by mixing it with petrol and solvents (Ababio, 1986)

2.3   PROPERTIES OF ETHANOL

2.3.1 PHYSICAL PROPERTIES

Ethanol under normal condition is a volatile, flammable, clear, colorless liquid, with pleasant smell, familiar and characteristics, it taste suitably when diluted with water, otherwise, the taste may be pungent.

The physical and chemical properties of ethanol are primarily dependent on the hydroxyl group. This group impact polarity and give rise to hydrogen bounding. This two properties accounts for the abnormal physical behaviour of lower molecular weight. Infra-red spectrographic studies have shown that in the liquid state, hydrogen bonds are formed by the attraction of the hydroxyl hydrogen of one molecule and the hydroxyl oxygen of a second molecule. The net effect of this bonding is to make liquid alcohol behave as though it were largely demineralized, the behaviour is analogous to that of water, which however is more strongly bonded and appears to exist in liquid clusters for more than one molecules.

The association of ethyl alcohol is confirmed to the liquid state, in vapour phase, it is monomeric. The molecular Association of liquid ethyl alcohol gives rise to an abnormally high boiling point and a high heat of vapourisation.

Ethanol is very hydroscopic; it has a melting point of $-115^{\circ}C$, bonding point of $78\,^{\circ}C$ and specific gravity of 0.79 (Smith, 2001)

Ethanol has density of 0.78g/ml at 20 $^{\circ}C$. Ethanol has low freezing point, which has made it useful as a liquid in thermometer for temperature below $40^{\circ}C$.

The freezing of mercury and for other low temperature purposes, such as for antifreeze in automobile radiator. The atomic weight of ethanol is 46.07, the triple point of 159k and critical temperature of 514k (241). The acid base properties is 15.9. The liquid properties and heat change which is -277kj/mol, enthalpy change is 159.9j/mol.k, concentration in term of pressure cp is 112.45J/mol.k. It has a flash point of 17°C and explosive limit of 3.5 - 15% (Smith, 2001).

2.3.2 ETHANOL FUEL IN DIFFERENT APPLICATION

Ethanol makes an excellent motor fuel: it has a motor octane number which exceeds that of gasoline and has a lower vapour pressure than gasoline which results in lower evaporative emission, ethanol's flammability in air is also much lower than that of gasoline which reduces the number and severity of vehicle fires. Anhydrous ethanol has lower and higher heating value of 21.2 mega joules per litre and 23.4 mega joules per-litre, respectively; for gasoline the values are 30.1 and 34.9 mega joules per litres. (Workman, 2001) Ethanol fuel are also used or applied in generation of power in power stations. It could also be use in cooking as source of heat energy (Workman, 2001).

2.3.3 PRODUCTION OF ETHANOL

The production of ethanol involves several processes, the first process is the milling process whereby corn grain used in the research for the production of ethanol is milled. Milling is the process where the corn is passed through the hammer mill, which grinds it into a coarse particle size called the meal (Matthewson, 1980).

The processing following the milling process is called cooking, whereby all the meal, soluble starch are dissolve so as to gelatinize them.

`In commercial operations, cooking is always performed with steam, under pressure and it is usually a continuous process.

Conversion process is the next stage where the starch is converted to fermentable sugar and it can be accomplished either by the use of malt extracts of the enzymes contained in the malt or by treating the starch with acid in a process called acid hydrolysis. (Matthewson, 1980).

Malting is the next stage, and this involve the conversion of starch to a fermentable sugar by the action of the enzymes on the malt. When the seeds of any cereal is sprouted and moistened, certain enzymes (amylase) are produced which has the ability to convert starch to a fermentable sugar called the maltose. All grain produce this enzymes to a greater or lesser extent. However, barley produced by far the most, and is usually the most economical to use.

Fermentation is the next stage, and this involve mixing the activated yeast and the cooled PH adjusted mash in the fermentation vessel or tank. During fermentation, temperature is controlled. When fermentation begins, carbondoxide gas will be given off. At the height of fermentation, the reaction also produce some heat, the reaction equation is given as:

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2C_2H_5OH + 2CO_2 + \text{heat (Matthewson, 1980)}.$$
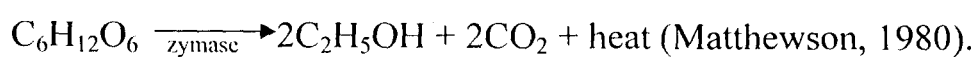
The optimum temperature for the fermentation process is between $70 - 80^oF$ and it is desirable not to let the temperature go much above $90\text{-}95\ ^oF$.

After fermentation and mash filtration, the next process is distillation of the product, which is a mixture of ethanol and other substances such as water.

In the production of fuel alcohol, it is necessary to get all the alcohol and water separated, if the alcohol is going to be mixed with gasoline or if the

alcohol is going to be burned in a converted engine. The separation of alcohol and water by distillation is made possible by the fact that alcohol boils at 173 °F and water boils at 212°F. When the mixture of water and alcohol boils, vapour with a greater concentration of alcohol will be formed and liquid with a lesser concentration of alcohol will remain behind. However, because water and alcohol do not form what is called ideal mixture, the separation cannot be done in one step (Olutoye, 2005).

In order to produce absolute ethanol, a small amount of benzene is added as an entrainer, and the mixture is again fractionally distilled. Benzene forms a trianary azeotrope with water and ethanol, to remove the last of water and a binary azeotrope with ethanol and most of the benzene, the resulting ethanol is water free (Williams, 2003).

2.3.4 ALCOHOL AS FUEL

The alcohols are fuel family of the oxygenates; as it is known the alcohol molecules has one or more oxygen which contribute to the combustion. The alcohols are named according to the basic molecules of hydrocarbons which is derive from: methanol (CH_3OH), ethanol (C_2H_5OH), Propane (C_3H_7OH), Butanol (C_4H_9OH). Theoretically, any of the organic molecules of the alcohol family can be used as fuel. Only two of the alcohols are technically and economically suitable as fuels for internal combustion engines.

These alcohols are those of the simplest molecular structure, that is methanol and ethanol. In this project, ethanol is considered to be used as fuel. It is produced mainly from biomass transformation or bioconversion. Economic reasons dictate however, the process which can produce the alcohol at the minimum cost. Each country around the world has found the best compromise

in the production of an alternative fuel to replace petrol, especially for countries with large area of land. The method of production of ethanol from biomass, is said to be solar energy stored in plants by photosynthesis process. Therefore ethanol from biomass conversion is called "Solar energy in a liquid state" (Mathewson, 2003).

The increasing cost of gasoline, and the new laws requiring alternative fuels have turned the attention of car and truck designers to substitutes, chief among alternative fuel is alcohol, considerable research has been done, and is still carried out for alcohol in spark ignition engines. (Leary, 2000).

Alcohol fuels were used extensively in developed countries and alcohol blend are used in many vehicles at the present time. Both alcohols (ethanol and methanol) have a higher octane number than gasoline (Leary, 2000).

2.3.5 FUEL PROPERTIES OF ETHANOL

Alcohol has characteristic that make it a natural engine fuel: it has a high octane rating which prevent engine detonation (knock) under load. It burn so clean, in fact that net only are noxious emission drastically reduced, but the internal parts of the engine are purged of carbon and gum deposits, which of course do not build up as long as alcohol is used as fuel. An alcohol burning engine tends to run cooler than gasoline power counterpart, thus extending engine life and reducing the chance of over heating. At this, it is detailed, exactly how these and other characteristics of alcohol affect engine performance (Matthewson, 1980).

2.3.6 OCTANE RATING

When referring to alcohol fuels the word "Octane" does not apply, since octane (in its pure form) is merely hydrocarbon in gasoline which is assigned

the numerical value of one hundred for fuel rating purpose. The octane number given automotive fuel is really an indication of the ability of the fuel to resist premature detonation within the combustion chamber (premature detonation or engine knock), came about when fuel / air mixture ignites spontaneously toward the end of the compression stroke, because of intense heat and pressure within the combustion chamber since the spark plug is supposed to ignite the mixture at a slightly later point in the engine cycle, pre-ignition is undesirable, and can actually damage or even ruin an engine (Mattewson, 1980).

High compression ration in an engine lead to more power per stroke, greater efficiency and better economy, it's easy to see why a fuel that resist pre-ignition even under high compression condition is especially desirable, and alcohol is on the average, about sixteen points high on the research octane scale than premium gasoline (Mattewson, 1980).

2.3.7 HEAT VALUE

The heat value of a fuel is a measure of how much energy that can be obtained from its per unit basis, be it in pounds or in gallons. When comparing alcohol and gasoline, using this measuring stick, it is obvious that ethanol contains only about 63% of the energy that gasoline does, mainly because of the presence of oxygen in the alcohol's structure. But since alcohol undergoes different changes, it is vapourised and compressed in an engine, the out right heating value of the ethanol is not as important when it is used as a motor fuel.

The fact that there is oxygen in the alcohol's structure also means that this fuel will naturally be "leaner" in comparism to gasoline fuel without

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making any changes to the jets in the carburetor. This is one reason why the air-fuel mixture must be enriched, when burning alcohol by increasing the size of the jet (Mattewson, 1980).

2.3.8 VOLATILITY

The volatility of a fuel refers to its ability to be vapourised. This is an important factor, because if vapourization does not occur readily, the fuel can not be evenly mixed with air and would be of little value in the engine. Some substance that are highly volatile can not easily be used as a motor fuel, and others, which have excellent heating value, are not volatile enough to be used in an engine (tars and waxes) (Mattewson, 1980).

Another point to be considered is that a very volatile fuel is potentially dangerous, because of the chance of explosion from heat or sparks. This is one reason why alcohol with a higher flash point than gasoline is a much safer automotive fuel and quite vulnerable (Mattewson, 1980).

2.3.9 LATENT HEAT OF VAPORISATION

Latent heat of vapourisation is the phenomena that results in an alcohol powered engine's running cooler than that of gasoline. When a substance is about to undergo a change in form (from a liquid to a vapour, in this case), it must be absorbed in a certain amount of additional heat from its surroundings in order for the change to take place. Since alcohol must absorb roughly 2 - 1/2 times the amount of heat that gasoline does, and the heat naturally is taken from the engine block, the engine should operate at a much lower temperature. (Mattewson, 1980).

2.4.0 EXHAUST EMISSION

When gasoline burned in an engine, it produces carbon monoxides and other poisonous fumes, mostly because of the fact that the fuel never combusts completely and also because its subjected to extreme temperature and pressures. In addition, as earlier mentioned, gasoline is a complex mixture of many substances and some of these substances are lead, sulphur and other noxious materials. These, too, add to the contaminative effect of the engines exhaust fumes.

Alcohol on the other hand, burns much cleaner, even though it never combusts completely, the volume of noxious fumes is drastically reduced in an alcohol burning engine because alcohol contains oxygen in its structure (which means thorough combustion) but does not contain all the other pollutant necessary as additives in gasoline (William, 2003).

2.4.1 ALCOHOL-WATER MIXTURE

It has been observed from experiments and studies that gasoline and water don't mix. The gasoline tends to floats to the top of the mixture, leaving the water to settle below it, in a car's fuel tank, this can be disastrous, particularly during the dry seasons

Alcohol, however, mixes quite well with water: The water particles distribute evenly within the mixture. As a result, not only is the winter freezing problem solved but pure alcohol is not necessary for fuel purposes. This is very important to the small scale alcohol fuel producer, since non-industrial still are generally not capable of producing more than 96% pure alcohol. As far as its use in an engine is concerned, researchers have had

excellence result with various strength of alcohol. Addition water added beyond the 20% limit cause the engine to hesitate and idle roughly, hence, that practice is not recommended. As an extra benefit, the water in the fuel helps cleanse and "lubricate" the internal part of the engine, including the valve sit, piston, head surface, and combustion chamber. (Smith 2001) which means a need for a larger fuel tank and larger jet size in the carburetor it requires less air for combustion, which compensates for high calorific values. In proportion, this could result in practically the same air fuel ratio for all.

Experimental tests have shown that alcohol fuel spark ignition engines can produce as much or slightly higher power than gasoline. Alcohol fuels have a higher self-ignition temperature than gasoline, which rates them better from a safety stand point, but this same quantity bans them from use in diesel engine which depends on the heat of compression to ignite the fuel. At the present time only ethanol can be blended in small concentration (10%) with gasoline. Because of the high octane rating, alcohols can be used in relatively high compression ratios, experiments indicates that emissions from engines fueled by alcohol would require the use of exhaust gas recirculation controls. (Leary, 2000)

Ethyl alcohol, or ethanol has been used in Germany and France as early as 1894, by the incipient industry of internal combustion engines. Brazil has utilized ethanol as fuel since 1925 by that time, the production of ethanol was 70 times bigger than the production and consumption of petrol. (Matthewson 1980).

2.4.2 ENGINE ECONOMY

The fuel economy of an engine is directly proportional to how rich the air/fuel mixture is, and that of course is dependent upon how large the main jet in the carburetor is. Alcohol requires a richer air-fuel mix than those of gasoline, but that difference is not reflected proportionately with respect to economy partial due to the fact that alcohol has a higher "octane" rating and can be utilized more efficiently.

By experimenting with orifice size (diameter) of the carburetors main jet. It is possible to reach a happy medium between power and economy in a standard auto engine using alcohol.

2.4.3 ENGINE PERFORMANCE

An engine powered by alcohol, if converted correctly, will have performance equivalent to if not greater than, the same power plant burning gasoline. This is because of the fact that alcohol has a higher octane rating (hence the timing can be advanced slightly) and it can stand much greater compression ratios.

Even without changing the compression ratio, an alcohol powered engine with fairly low compression still holds its own against its gasoline burning counterpart and if the timing is advanced safely short of the "knock" limit, the top range is broadened, considerably allowing the vehicle to put under load exceptionally well in fact it does much better under such conditions than the gasoline version does (Mattewson, 1980).

2.4.4 FUEL PROPERTIES OF ETHANOL

TABLE 2.4.7

TERM	ETHANOL
1. Formula	C_2H_5OH
2. Molecular weight	46.07
3. Carbon/hydrogen (w)	4.00
4. % Carbon (w)	4.00
5. % hydrogen (w)	52.17
6. % Oxygen (w)	13.40
7. Boiling point at 1 atm $^{\circ}C$	34.78
8. Freezing at 1 atm $^{\circ}C$	78.40
9. Density at 15.5 $^{\circ}$lb/gal	-80.00
10. Viscosity at 20 $^{\circ}C$ C/1atm, centipoises	6.63
11. Specific heat at 25/1atm BTU/lb	1.20
12 Heat of vaporization at boiling point/1atm, BTU/lb	0.60
13. Heat of vaporization, at 25 $^{\circ}C$ /1atm, BTU/lb	
14. Heat of combustion at 25 $^{\circ}C$, BTU/lb	
15. Stoichiometric lb air \lb fuel	9.0
16. Research octane number	105
17. Flash point temperature $^{\circ}C$	12.778
18. Auto ignition temperature $^{\circ}C$	422.778
19. Flammability limits	lower 4.30
	higher 19.0
20. Latent heat of vaporization at 20 $^{\circ}C$ KJ/kg	921.36
21. Octane number	8.00

2.4.5 NET ENERGY BALANCE IN ETHANOL FUEL PRODUCTION

An alcohol based fuel economy should have positive net fuel energy balance for viability. The total fuel energy expended in producing the alcohol including fertilizing, farming, harvesting, transportation, fermentation, distillation and distribution, as well as the fuel used in building the farm and fuel plant equipment should not exceed the energy content of the product.

Switching to a system with negative fuel energy balance would only increase the consumption of non- alcohol fuels such a system would only be worth considering as a way of exploiting non- alcohol fuels that may not be suitable for transportation use, such as coal, natural gas or bio-fuel from crop residue.

However, many of the expected environmental and sustain ability advantages of alcohol fuel would not be realized in a system with negative fuel balance (Smith, 2001).

Even a positive but small energy balance would be problematic: if the net fuel energy balance is 50%, then in order to eliminate the use of non-alcohol fuels, it would be necessary to produce two gallons of alcohol for each gallon of alcohol delivered to the consumer. In this regard, geography is the decision factor. In tropical regions with abundant water and land resources such as Brazil, the viability of production of alcohol from sugar cane is no longer in question. In fact the burning of sugar cane residue generates far more energy than needed to operate the ethanol plants and many of them are now selling electricity to the utilities.

Also in countries with abundant hydroelectric power, the net fuel energy balance of the cycle would be improved to some extent by using electricity in the production, example for milling and distillation (Workman, 2001).

However, continuous refinements of ethanol production procedures have much improved the benefit/cost ration and most studies of the model system indicate that they now have a positive net energy balance. Many other studies of corn ethanol production have been conducted, with greatly varied net energy estimates. Most indicate that production requires energy equivalent to ½, $^2/_3$ or more of the fuel produced is require to run the process. A 2002 report by the United State department of Agriculture concluded that corn ethanol production in the Untied State, has a net energy value of 1.34 meaning 34% more energy was produced than what went in. This means that 75% ($^1/_1.34$) of each unit produce is required to replace the energy used in production. Michigan State University (MSU) ethanol energy balance, May 2002. This comprehensive independent study founded by MSU shows that there are 56% more energy in a gallon of ethanol than it takes to produce it (Workman, 2001).

2.4.6 ENVIRONMENTAL EFFECT OF ETHANOL FUEL USE

2.4.7 NET REDUCTION IN GROUND LEVEL OZONE FORMING EMISSIONS

Ground level ozone cause human respiratory problems and damages many plant, but does nothing to increase ozone concentration in the stratosphere that protect the earth from the sun's ultraviolet radiation. The volatility of ethanol blends must match with normal gasoline, the ozone

forming potential of ethanol blends is even lower in the United State where ethanol blends are allowed to have increase volatility. The emission produced by burning ethanol are less reactive with sunlight than those produced by burning ethanol are less reactive with sun light than those produced by burning gasoline, this results in a lower potential for forming the damaging ozone (Workman, 2002).

2.4.8 THE GREEN HOUSE EFFECT

The green house effect refers to the earth atmosphere trapping the sun's radiation. It is a term often used synonymously with global warming, which refers to the increasing average global temperature arising from an increase in green house gases from industrial activity and population growth. Green house gases contributing to the green house effect includes carbon dioxide, methane and nitrous oxides.

The term climate change refers to a wide range of changes in weather patterns that result from global warming. A substantial increase in the earth average temperature could result in a change in Agricultural patterns and melting of the polar ice caps, raising in sea level and cause flooding of low lying coastal areas.

Under current conditions, use of ethanol blended fuel as (85% ethanol and 15% gasoline) can reduce the net emissions of green house gases by as much as 37.1% ethanol-blended fuel as (10% ethanol and 90% gasoline) reduce green house gases by up to 3.9%.

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Carbon dioxide is a normal product of burning fuels that contribute to global warming. More CO_2 is absorbed by crop growth than is released by manufacturing and using ethanol (William, 2003).

2.4.9 30% REDUCTION IN CARBON MONOXIDE (CO) EMISSIONS.

Carbon monoxide is a toxic gas that contributes to air pollution. It is of particular concern when vehicles operating at low temperature. Oxygenated gasoline, such as ethanol blends lower the level of CO_2 emitted by promoting a more complete combustion of fuel (William, 2003).

2.5.0 ENVIRONMENTAL IMPLICATION OF FEEDSTOCK ASSOCIATED WITH THE PRODUCTION OF ETHANOL FOR FUEL.

(a) **BIOLOGICAL RENEWABILITY:** - Fuel ethanol is produced from biologically renewable sources, such as grains or wood products.

(b) **SUSTAINABLE AGRICULTURE:** - With the development of sustainable and environmentally sensitive production methods in the agricultural sector, the impact of farming practice is very minimal. The demands for grain to produce fuel ethanol has not resulted in an increased corn or wheat acreage, in Canada (Workman, 2001).

2.5.1 PRODUCTION OF ETHANOL

2.5.2 PROCESS

2.5.3 MILLING: - The corn will first pass through hammer mills, which grind it into a fine powder called meal.

2.5.4 COOKING: - Cooking is necessary for all starchy materials. The objective was to dissolve all the meal which is water soluble starch and

then as much as possible, gelatinizes them. In commercial operations, cooking is almost always done with steam under pressure and usually in a continuous process. Water boils at 212^OF at sea level and at a lower temperature as attitude increases. By using pressure cooking equipment, higher temperatures and shorter cooking times can be obtained. At 150 pounds pressure, for example, grain starches can be cooked in six minutes or less, large scale pressure cooking equipment is expensive and in this manual, the cooking times for various materials are listed under the individual feed stocks such as corn, with 66% convertible starch should produce 660 pounds or 100 gallons.

Because a lot of energy is needed to boil the water used in the cooking process, it is best to cook with as little water as possible then, after cooking, additional water may be added to dilute the mash to optimum concentration for fermentation. If the additional water is added at a time when it is desirable to cool the mash, for example after cooking and prior to conversion, cooling time is saved. Most grains can be cooked with as little as 15-20 gallons of water per bushel. Note that when cooking with minimum water, special attention must be given to stirring the mash. Otherwise lumping and burning may occur.

New methods of cooking are being developed that help to conserve energy. The most interesting is the method that combines milling and cooking into one operation without the use of water. The process use heat generated by friction in the milling process to simultaneously cook the grain. It is all done in a specially design grain mill.

2.5.5 CONVERSION

Conversion is the process of converting starch to fermentable sugars. It can be accomplished either by the use of malt, extract of the enzymes contained in malt, or by the treatment of the starch (or cellulose) with acid in a process called "acid hydrolysis". Each method is discussed separately.

2.5.6 MALTING

Starch can be converted to fermentable sugars by the action of enzymes in malt. When the seeds of any cereal grain are moistened and allowed to sprout, certain enzymes (amylases) are produced which have the ability to convert starch to a form of fermentable sugar called maltose. All cereal grain produces these enzymes to a greater or lesser degree. However barley produce by far the most and is usually the most economical to use.

In converting starch to sugar, malt enzymes exert two forms of chemical activity: liquefaction and saccharification. The intensities of these two activities depend on the temperature of the mash. The liquefying power is greater at about $158^{O}F$. It begins to weaken at $175\ ^{O}F$ and ceases at about 200 ^{O}F. The saccharifying (sugar making) power is strongest between 120-130 ^{O}F and is destroyed completely at $175\ ^{O}F$

Both of these actions are desirable. Therefore a compromise must be made. The conversion process is therefore usually begin after the cooked mash is allowed to cool to about 150 ^{O}F. The material is held at this temperature for a certain length of time (depending on the material) and then allowed to cool to the optimum fermenting temperature.

The average malting recipe for the use of between half to 1 pound of dried malt for each 10 pound of grain. Again specific recipes are covered later. The dried malt is usually mixed with warm water at a ratio of about 2.5 pounds per gallon to form slurry.

This slurry should be mixed about an hour ahead of time and added to the mash when it cools to the proper temperature.

Because barley malt is expensive, usually more expensive than the material it is used to convert, it is best to be used as little as possible. The minimum amount can be determined after several trial conversions.

Take a little of the converted mash and filter it in a filter cloth, place a little of the filtrate on a white dish and add several drops of solution composed of 5 grams potassium iodide and 5 grams of iodide crystals in one quart of (distilled) water. Any blue colour produced indicated the presence of unconverted starch. Naturally, if the test indicates no blue colour, the next trial should be run with less malt and vice-versa. The test solution can be compound by your local druggist or the chemical can be purchased from any laboratory supply house.

2.5.7 PREMALTING

During the cooking process, the starch in the grain is gelatinized. When the mash is cooled, it may become too thick to be stirred and handled effectively during the malting operation. The technique of premalting cures the problem by taking advantage of the liquefying properties of malt prior to conversion. To premalt, simply add about 10% of the total malt weight to the mash prior to cooking. These causes sufficient liquefaction to facilitate

handing the mash during subsequent operations. It also helps to prevent thermal destruction of the malt enzyme later on and so reduces the production of undesirable by-products. After cooking, the remaining 90% of the slurring is added and conversion is continued as usual.

2.5.8 PREPARATION OF MALT

The following is a basic process for making malt, for those who prefer to prepare their own, any grain can be used to make malt but as stated before, barley is the best.

However, if corn is used, for example for this project, it involves simply setting a side about 20% of the grain, prepare a malt as described below and use it in the same way as barley malt. The same is true of similar materials.

Malt is simply sprouted grain. The basic requirements for sprouting are moisture, warmth and darkness. Grain can be sprouted in anything from a five gallon plastic pail to a 55gallons drum. The container should either have small holes poked in the bottom or with larger containers, a value protected by a screen or mash that allow water to drain but retain the material being sprouted.

Begin by soaking the grain until the kernels can be crushed between the fingers and the inside is soft. This takes about 12-18hours for barley and considerably longer for corn. Then drain the water. Thereafter, sprinkle the grain several times a day with warm water. The objectives is to keep the grin moist but not wet, the grain will rot. After a watering, the water will work its way down through the grain and out of the holes (or valve) in the container.

The sprouting will generate some heat. The optimum temperature for sprouting is about 80^0F. But most enzymes seem to produced at 60^0F.

When sprouting in large containers, carefulness is being applied so that the grain does not get too warm. If it does, it can be spread out on a concrete floor in a dark place and the sprouting continued. Small container will not have the problem of too much heat. Sprouting will take about 4days, the malt is ready when the sprout is about a half inch long. Prior to use, the malt will have to be crushed. This can be done in a mill or on a small scale; a heavy duty garbage disposal can be adapted. Ordinary blender or food processor can be used for milling.

2.5.9 ENZYME CONVERSION

The enzymes contained in malt are available commercially from several manufacturers. The procedures for using them are very similar to malt conversion. In addition, the use of enzyme extract is usually superior to malt. The enzyme extracts are usually cheaper. They are also specifically designed for the job at hand, and they generally produce more predictable result and higher yields. The three basic types of commercially available enzymes are alpha, beta and gluco amylase. Alpha amylase randomly split the starch molecules to produce a type of sugar called dextrose. Beta amylase act similarly to produce maltose. Together, this two enzymes can convert about 85% of starch to fermentable sugar. Gluco amylase can reduce the remaining starches and the use of all the three can achieve almost total conversion of the starch. Enzymes are used in much the same manner as malt.

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2.6.0 ACID HYDROLYSIS

Starch and (cellulose) may also be converted to fermentable sugars by the action of acid. This process is relatively simple but it requires acid proof equipment, high temperatures and the handling of acid. For these reasons, it is not really recommended for small scale production. Basically, dilute mineral acid (usually sulphoric) is added to the grain slurry prior to cooking at a concentration of 1-4% as calculated on weight per weight basis.

The mash is then cooked at a temperature of $350^{\circ}F$. Cooking and conversion of the starch take place simultaneously. The mash is then immediately neutralized with calcium hydroxide (lime) or some other base and fermented in the usual manner.

The high temperatures essential in this process are obtained by the use of pressure cooking. The steam pressure required is about 15pounds per square inch. This together with the necessity for acid proof equipment makes this process unsuitable for small scale use. However it is an excellent process for large operations because cooking and fermentation times are short and the method is readily adaptable to continuous operation.

2.6.1 MASH COOLING

Malting is conducted at a temperature of about $145-1500^{\circ}F$, fermentation is commenced at an optimum temperature of $70-80^{0}F$ between the two steps the mash must be cooled.

One of the biggest problems affecting alcohol yield is bacterial contamination of mash either before or during fermentation. The chief protection against this is the PH or acidity control of the mashing and fermentation operations. However, even with perfect PH control bacterial

infections can come in. This happen mostly during the cooling stage between mashing and fermentation.

If bacterial contamination becomes a problem, the only solution (other than the obvious need for cleanness) is to shorten the cooling time as much as possible. The less time at the temperature conductive to bacterial growth the better. Therefore, it might become necessary to make a cooling coil. The cooling coil is the best long term solution but if the problem only occur occasionally during summer months, a plastic bag full of the ice and suspended in the mash might do the trick. Precautions should be taken to ensure the plastic bag doesn't teak and dilute the mash.

2.6.2 YEAST AND FERMENTATION

2.6.3 YEAST

Yeast is an organism belonging to the vegetable family. The yeast itself does not take a direct part in the fermentation process but it secretes a complex of enzymes that act upon the sugar and convert it to alcohol and carbon dioxide gas.

The yeast used in alcoholic fermentation is a special strain bred to be tolerant to variation in PH and resistance to alcohol.

In the past distillers bred and propagated their own yeast strains. The yeast was kept alive in culture and grow in batches of ever increasing size to be used in the fermentations keeping yeast alive and growing cultures is a trickily business that require precise control of temperature and nutrients, special active dry yeast is available. To use it, warm water is merely added to

reactive it and then and then add it to the mashing fermenter.two pounds is sufficient for 1000 gallons of mash..

2.6.4 YEAST PROPAGATION

Yeast is propagated by observing some certain precaution. Above all, the conditions must be absolutely sterile ordinary boiling water does not kill all the bacteria present. It is necessary to use a pressure cooker. Make a solution of (proportionately) one cup sugar, one cup flour and two quarts water. Place the solution in a pressure cooker and boil at elevated pressure for at least 45 minutes.

Without opening the pressure cooker, cool the solution to about room temperature. Then open the container and add a cake of baker's or distiller's yeast. Close the container and keep it in the refrigerator.

The yeast will slowly grow. Some carbon dioxide will be given off, so be sure to leave the vent open. It desired, the yeast slurry can be transferred to jars. To use the yeast culture, merely remove a teaspoon or soon, place it in another (sterile) container feed in some sugar warm it to room temperature. When it becomes active, it is ready for the fermented.

2.6.5 FERMENTATION

All that is necessary to begin fermentation is to mix the activated yeast and the cooled, P^{H} adjusted mash in the fermentation tank. Aside from consideration of P^{H} as discussed earlier, the most important thing during the fermentation is temperature control. When the fermentation begins, carbon

dioxide gas will be given off. At the height of fermentation, the mash will literally "boil" from the carbon dioxide produced.

The reaction produces some heat. The optimum temperature for the fermentation process is between 70-85^{0}F and it is desirable not to let the temperature go much above 90-95^{0}F. Cooling is readily done with the use of ice bags or by the use of cooling coil. A less desirable method of control temperature is to dilute the mash. The fermentation equation is

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2C_2H_5OH + 2CO_2 + heat$$
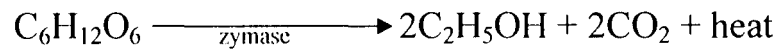
The actual time required to ferment a mash varies with the material being fermented, the P^{11}, temperature and several other factors. It can take from one to four days. It will be observed that the fermentation is complete when the mash ceases bubbling and the yeast cake which forms on top. Sink to the bottom.

At this point, the fermented liquor is known as "beer" and it is readily to be distilled. It is to distill the beer as soon as possible. Occasionally, If it is allowed to sit, it will turn to vinegar. Vinegar is alcohol that has been oxidized to acetic acid. Certain enzymes present after fermentation acts as catalysts and allow any air present in the mash solution to react with the alcohol to form acetic acid. Infact, if vinegar is to be produced, air is bubbled through the fermented mash. Once this vinegar reaction has set in, the mash is lost. There is no cure. The only prevention is to separate the beer from the mash sediment and distill it as soon as possible.

2.6.6 FERMENTATION BI-PRODUCT

The principle products of fermentation are alcohol, carbon dioxide and fermentation residue. The alcohol is distilled from the beer are used as fuel. The Carbon dioxide gas in large distilleries is usually compressed or made into dry ice. Another use for the gas would be to pipe it into a green house. The plants will the use it in the photosynthesis cycle, removing the carbon and giving off oxygen. Lacking a use for the carbon dioxide, it can be simply vented into the air as it is totally non-polluting and non toxic. What will be left is a lot of water and solids. A portion of the water can be used for back slopping. The remaining solids contain proteins, vitamins, minerals, fat and oil and yeast cells. All the nutrition value of the original feedstock, except the starch or sugar that has been turned into alcohol, survives intact. It may be fed to cattle or if suitably process it can be used for human consumption.

However, in the wet state, it will keep for a maximum of 3.5 days depending on conditions, after this it will begin to rot. Therefore, for long term storage this residue (spillage) must be dried. This can be done by straining and the solids and spreading them in a thin layer to dry in the sun by the use of rotary grain dryers or similar equipment.

2.6.7 STARCHY MATERIAL

Starchy materials generally require milling, cooking and conversion prior to fermentation. Exceptions are materials, such as potatoes and sweet potatoes that do not required milling and materials such as artichokes, which do not require conversion, sugar cane do not require conversion. Relatively

high alcohol yields often affect the necessary additional manufacturing steps and most starchy materials are good alcohol sources.

2.6.8 GRAIN

Grains must be milled, diluted, cooked and converted prior to fermentation .However, they contain large amount of potentially fermentable materials. The average content of convertible starch and sugar in some typical grams are: Barley, 50% Maize (Indian corn), 66%; Oats, 50%; rye 59%; sorghum seed 67%; wheat 65%. Alcohol yield per tone is dependent on how completely the starches are converted to fermentable sugar, but should be between 70 – 100 gallons.

After milling, the grain must be diluted prior to cooking and fermentation. The average dilution is between 56 – 64 gallons per 100 pounds of grain, depending on moisture and starch content. The method of cooking with minimal water and adding the balance prior to conversion, as described previously, has the dual advantage of reducing the energy needed for cooking and shortening the cooling time.

2.6.9 DISTILLATION THEORY

The object of distillation is the separation of the alcohol from the other ingredient in the beer, mostly water. In making fuel alcohol it is necessary to get all of the alcohol and water separated if the alcohol is going to be mixed with gasoline, and most of the alcohol and water separated if the alcohol is going to be burned in a converted engine. The separation of alcohol and water by distillation is made possible by the fact that alcohol boils at 173°F and

water at 212°F. When the mixture of water and alcohol boils, vapour with a greater concentration of alcohol will be formed and liquid with a lesser concentration of alcohol will remain behind. However, because water and alcohol do not form what is called an "ideal mixture", the separation cannot be done in one step.

To produce absolute ethanol, a small amount of benzene is added, and the mixture is again fractionally distilled. Benzene forms a trinary azoetrope with water and ethanol to remove the cast of water, and a binary azeotrope with ethanol removes most of the benzene. The resulting ethanol is water free, for processes that requires it.

2.6.0 DRYING THE ALCOHOL

2.7.1 GENERAL DESCRIPTION

As stated earlier, if the ethanol (alcohol) to be produced is going to be burned in an engine modified to burn "pure" alcohol, water content of 5, 10 or 15% is not objectionable. However, if the alcohol is going to be mixed with gasoline, the water will either have to be removed or neutralized. Drying the alcohol is a separate manufacturing step requiring additional labour, energy and or expense. It would be wise to consider all factors before deciding whether this procedure is necessary.

2.7.2 ABSORPTION METHODS

If alcohol obtained from the still is close to 190 proofs (95%), the easiest method of producing "gasohol" is to mix sufficient benzene (benzyl) with the alcohol to keep the water from separating. Usually, benzene in a ratio

of about 2-3 times the amount of water in the alcohol is sufficient. For example, to prepare 100 gallons of 10% gasohol mixes 10 gallons of 95% alcohol with 2 gallons of benzene. Then add 88 gallons of gasoline. Note that water percentage greater than 5% require the addition of much larger amount of benzene. It is suggested that experiments on a small scale be done before attempting to mix large quantities of gasohol. Prepare a mixture according to the above preparation and see if it separates.

A second method take advantage of the fact that water will dissolve in most salts, but ethanol will not. Therefore, water can be removed (although not entirely) by filtering the alcohol water through any salt. Almost any hygroscopic (water absorbing) material such as calcium salt, various sulphates, phosphate and smaller material will work. However, common rock salt, such as used in water softeners is cheap and available. An apparatus for sprouting malt can be used. Fill the drum or the container with rock salt. The alcohol and water is poured in at the top and filter down through the salt. Relatively, water-free alcohol is collected through holes or a valve at the bottom of the container. The salt must be dried. After absorbing water from a certain amount of alcohol, the salt must be re-dried either in an oven or by spreading it out in the sun.

A good system might be so use both of the method described above. First, most of the water in the alcohol is removed by the salt method, and then the blend is prepared with benzene. The more water that can be removed from the alcohol, the less benzene will be needed. Benzene will have to be purchased and can be used only once.

CHAPTER THREE

3.0 EXPERIMENTAL PROCEDURES

The experimental procedure was divided into two parts, which includes the production of ethanol and the characterization of the ethanol in order to obtain its fuel properties.

3.1 EQUIPMENT USED

TABLE 3.1 LIST OF EQUIPMENT USED

NAME	MODEL/MANUFACTURER	COMMENT
Filter cloth	UNTL Textile	
Milling Machine	Duran Schott	
Cooking Pot	Tower brand	
Magnetic stirrer	PC 220/corning	
Retort stand/clamp		
Beakers	Duran Schott	
Electric heater	Phillips Co.	
Digital weigh balance	CT 1200/OHAUS	
P^{H} Meter	3071/Jenway	
Thermometer	SEDIM	
Electric water Bath	WE 4105/Clifton	

Table 3.2 CHEMICAL AND REAGENTS

NAME	FORMULAR	COMMENT
Sodium hydroxide	NaOH	Prepared in the laboratory
Phosphoric acid	H_3PSO_4	Prepared in the Laboratory
Iodine solution	$I_2(aq)$	Prepared in the Laboratory
Buffer solution	-	Prepared in the Laboratory
Distilled water	H_2O	Prepared in the Laboratory

3.3 PRODUCTION PROCEDURE

The procedures for ethanol fuel production from corn starch comprise of five stages names;

1. Cleaning

2. Milling

3. Mashing

4. Fermentation

5. Distillation

3.3.1 CLEANING

The maize grain was cleaned by removing the dirt and impurities in it, with the aid of a blower.

3.3.2. MILLING

The maize was grinded using a milling machine and a coarse particles size was obtain with size range of 4μm.

3.3.2 MASHING

A mixture of 315.0g of maize, 12g of malted barley and 4.73 litres of water were added to the mashing vessel. The mixture was then transferred into water bath and the mixture was heated to 550C and maintained for 60 minutes. The mixture was stirred continuously by the use of mechanical stirrer, clamped to the retort stand, while the pH of the mash (mixture) was measured using the pH ter, some drops of caustic soda was added when pH drop than the expected value of 6 $\pm$ 0.1. The temperature of $55^{o}C$ was

necessary to breakdown the complex proteins in to simple amino acid that would be utilized by the yeast cells and also to gelatinize the corn starch.

The temperature of the mash was then raise to $75^{0}C$ for 40 minutes, at this period liquefaction of the starch takes place, 5ML of the enzyme term amyl was added. The mash temperature is increased to $93^{0}C$ for 40 minuites and later cools from $93^{0}C$ to $59^{0}C$ which is the saccharification temperature. The pH of the mash was checked which must be in the range of 5.5 $\pm$ 0.1.

Another 5ML of the enzyme fungamyl was added and saccharification rest was observed for 45 minutes at $59^{0}C$. The mash was cooled and filtration was carried out and the filtrate (wort) was then heated for 60 minutes at $80^{0}C$ in order to destroy the enzyme remnant and to kill off unwanted micro organism.

3.3.5 FERMENTATION

20g of bakers yeast was mixed with the cooled wort so that they yeast cell can grow, the yeast then added to the wort in a transparent vessel that

made air tight. A flexible tube was connected to the vessel and then to a plastic container, containing water to collect the CO_2 produced during the process of fermentation. The whole set up was kept in a cupboard at room temperature on constant observation, the fermentation process essentially completed after about 16 days as the mash surface ceased to bubble.

3.3.5 DISTILLATION

The fermented wort was transferred to the conical flask of the distillation apparatus were it was heated to 78^0C, (the boiling point of pure ethanol) and the first drop of ethanol was observed, the temperature was maintained for 20 minutes to obtain the production of the first run. The distillate recovered was again heated to 78^0C to obtain product of the second run. The process was repeated for two consecutive times, maintaining distillation temperature in order to obtain the fuel for characterization.

4.0 RESULTS and DISCUSSION of RESULT

4.1 RESULTS

The mouths for the production of the ethanol after a 16 days fermentation period is summarized the tables below:

Table 4.1.0

ITEMS	QUANTITY
Maize Starch	315.0g
Water	4.73liters
Malt	12.0g
Termamyl	5.0ml
Fungamyl	5.0ml
Yeast	20.0g

Table 4.1.1

pH	Observed	Expected
Mashing	4.3 – 4.7	5.5 – 6.0
Fermentation	4.6 – 4.8	5.5 – 6.0

Table 4.1.2

Runs	1	2	3	4	5	6
Initial Vol. (liters)	1.6	1.28	0.98	0.76	0.64	0.51
Final Vol. (liters)	1.28	0.98	0.76	0.64	0.51	0.43
Temperature (^{o}C)	85	82	79	78	78	78
R.D	38	52	64	75	83	87
Refractive index	11.5	13.7	15.9	18.8	19.1	20

Table 4.1.3

Sample of Known Conc(%)	Refractive Index on arbitrary Scale	Ethanol	Water
33	9.3	1	2
40	13.3	2	3
50	15.5	1	1
60	16.0	3	2
80	18.5	4	1

Table 4.2.1

Temperature (^{0}C)	Volume Collected (liters)
76	10
76	20
76	30
76	40
76	50
76	60
76	70
76	80
76	90
76	100

Table 4.2.2

Experiment	Experiment Values (Sample)	Standard Values (Ethanol)	Gasoline
Sulphur Content	0.0367	-	0.5
Relative Density	0.8050	0.79	0.69
Vapour pressure(Kpa)	13.20	16.0	48 – 108
Flash point	17 – 20	12.8	-42.8
Heat of Combustion (KJ/Kg)	22133.7	25120	43961
Latent Heat of Vaporization(KJ/Kg)	950.8	921.4	349.0

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4.2 DISCUSSION OF RESULT

The important operation during the production of the ethanol were mashing and fermentation. The principle, the process appear relatively simple but actually, they are a bit more complex not all of this reactions taking place have been fully understood till date. During mashing however, interest is in the hydrolysis reactions involving the conversion of the complex network of glucose in starch to simple sugars and also, the conversion of proteins present to amino acid that can all be metabolized by the yeast cells while the reaction of interest during fermentation is the synthesis of ethanol by the breaking down of the yeast cells on the substrate or simple sugars and amino acid formed during mashing. But in all, like all biological reactions, the two are strongly dependent on medium temperature and ph since the amylases, protease and invertase and diastase have particular values of this parameters at which they exhibit optimum performance. Table 4.1.2 and 4.1.4 shows the temperature and the ph regime that is required when mashing and fermenting during the production.

Effectiveness of mashing was checked by the response of the sample to test for sample sugars and unhydrolyzed starch. Feeling's solution was used and the mashed sample gave a brick red colour which was indicative of a considerable level of conversion of the starch to simple sugars. However, the sample still gave a blue colour (though a faint one) on addition of iodine solution showing the presence of unconverted starch even after mashing incomplete conversion of the starch is an aftermath of in balance in ph

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requirement during mashing and may also have resulted from the use of incorrect proportions of the enzyme for the 315.0g of starch used.

Fermentation was run for 16 days and the ph measured before the start was 4.7. At the end of the 16days period, the total volume was taken as 1.6 litters and the relative density (R.D) measured with hydrometer give 0.9. From table, its corresponded to a maximum concentration of 9% ethanol in the sample after the 16 days fermentation period.

Distillation of the sample was carried out to separate the liquor from spent material using the difference boiling point between ethanol and water as the driving force and to convert to concentrates the ethanol in the liquor. Total of (6) runs were carried out and after each run, the condensate was observed richer in ethanol than the initial starting material and the residue in the flask. Literature gives the boiling point of ethanol at standard pressure of 1 atmosphere as 78^0C while for water is 100^0C.The temperature during the first run was maintained at 85^0C so that appreciable quantity of water in addition to ethanol is vaporized from them both. Thereafter, temperature was successively decreased and then maintained at the boiling point of the pure ethanol for the last three – distillation runs. This was done to bring about a progressive change in the ethanol content as the distillate will be richer in ethanol and of higher content than when the distillation is continuously maintained and the boiling point. It is important to note that ethanol forms an azeotropic mixture with water which makes it difficult for the mixture to be completely separated by ordinary means. This was evident during the distillation. A careful look at the table – 4.1.3 shows that the concentration increased significantly during the initial runs but during the last three

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distillation runs, the concentration change was slight and it was maintained at near 87%. Literature value for the maximum concentration of ethanol distilled from water is 90 – 95%. 87% obtained on the experiment was close though the difference may have been due to

      i Non consideration of the pressure of the atmosphere on the laboratory environment

      ii Incorrect R.D readings from the hydrometer.

      iii Difference of chart reading from reality during actual distillation.

In all, 0.9litres of the final 87% ethanol was collected at the end of distillation. This corresponds to a volume of 0.783litres of absolute ethanol and it gives a yield of 1.12cm3 of ethanol per gram of maize starch.

For any material to be capable of functioning as a fuel, it must have certain properties that are associated with all fuels. Fuels irrespective of the use for which they are intended for basically are rated from the stand-point of the amount of energy that it can produce and also, from the perspective of safety during handling. A step further for fuels for automobile use must be flexible and should be able to offer good engine performance. Presently, gasoline is the primary fuel for SI (spark ignition) engines but the potential of ethanol as a good substitute or replacement for gasoline is becoming feasible as time rolls out. Gasoline offers relatively good engine performance but concerns about its use stems from the fact that the natural environment is becoming distorted by the day and if concerted efforts are not taken to curtail its widespread use, then some few years from now, the earth would be exposed to severe and extreme environmental conditions.

In looking at the fuel potential of ethanol, it was necessary for carry out the fuel test on it especially those more associated with gasoline required for SI engines the properties were shown on table 4.1.6

The distillation ranges experiment was carried out to ascertain the boiling point range of the ethanol fuel sample and to determine the volatility based on the temperature at which 10% and 90% respectively of a measured sample are distilled. The results showed that the some temperature was maintained for different fractions of the sample distilled. Thus for all functions (both 10% and 90%) of initial sample, the temperature of 76^0C was maintained. The significance of the single temperature boiling point of 76^0C is that the sample is a pure compound of ethanol as against gasoline that is from $30^0C - 200^0C$, which signifies that it is a relatively impure sample and obviously is made up of a mixture of hydrocarbons. The lower boiling temperature interval of gasoline means that it is more volatile than ethanol which means that it will give off enough vapour to mix with air in an engine but the higher volatility makes it less safe as it will be more prone to explosion than lower volatile ethanol.

Literature gives the standard boiling point of ethanol as 78^0C (workman, 2001) but the sample boiled at 76^0C. The difference was due to deviation of laboratory conditions from that of the standard. Atmospheric pressure of the laboratory was 714mmHg and the use of the boiling point correction index to obtain the corresponding temperature of normal atmospheric pressure gave the normal temperature of 78^0C.

Relative density of materials varies with temperature and for comparison with that of others, it is common practice to take a particular

that during handling at temperature higher or close to room temperature, the vapour formed can be a source of uncontrollable run away reactions. Consequently, it is unsafe and must be handled with care. Flash point obtained for ethanol from experiment was in the range of 17-20 and it is quite close to literature value. Although it is also lower than room temperature, it would give off only a small amount of vapour compared to that of gasoline. It is safer to handle than gasoline.

Ethanol fuel is also a good source of chemical energy yielding heat energy of 22133.7kj/kg during combustion. However, its value is less than that of gasoline but as earlier stated in chapter two, in an engine so many things are required that the difference in the heat of combustion is not too important. One of such requirements and obviously, a due out edge for ethanol over gasoline, is the latent heat of vaporization of ethanol is responsible for simple. The higher latent heat of vaporization of ethanol is responsible for the greater effect of change cooling during its use in an engine. On vaporization, ethanol draws some heat from the incoming air/fuel mix and the engine environment and the resultant decreases in temperature of the mixture increases the mass flow rate into the cylinder with corresponding increase in power output. The result is that engines running on ethanol will always be cooler than its gasoline fueled counterpart with a higher thermal efficiency.

At the end of the experiment the various properties of the ethanol obtained from the laboratory compared favorably with those of literature. In most of the characterization, the value were not exactly the same but the slight deviation of experimental readings from literature values are a

testimony to the reliability of the experimental results and the methods employed in carrying out the experiments of typical example is the determination of the concentration of distillates at the end of each distillation. Values determined from the chart using the relative density were very close to readings from the graph of concentration versus arbitrarily determined refractive index.

CHAPTER FIVE

5.1 CONCLUSION

The project was successfully carried out as the aims and objectives were achieved. At the end of the experiment, the yield of the ethanol produced shows that maize is actually a viable source of ethanol fuel that can effectively serve as an alternative or substitute for the conventional fossil fuels. This was attested to by the good comparison of the sample characteristics with that of gasoline which in some instances, even measured more than the hydrocarbon. The closeness of the experimental and literature values of the characterization are an indication of the reliability of the whole experimental efforts.

5.2 RECOMMENDATIONS

The successful attainment of the aims and objectives of the experiment was not without its own share of difficulties. In view of experimental method carried out in the production of ethanol from cassava starch carried out in this project, the following points are recommended.

1. Alternative to the exogenous enzymes (both termamyl & fungamyl) should be sought after and used. Difficulty in obtaining the enzymes, especially in small quantity, was a major constraint duri the experiment and when it is found, it is always very exorbitant.

2. The use of bakers yeast should be avoided if possible. Specially formulated brewers yeast are well suited for ethanol production since they can survive in higher concentrations of the compound during fermentation and should be integrated into the production program.

3. Calcium hydroxide should be used instead of sodium hydroxide (NAOH) in the experiment to control the pH of the mashing system. The Ca^{2+} serves as a co-factor for amylase performance (Richardson and cousin)

4. The experiment should be carried out at different conditions to obtain the condition that gives the best yield of the fuel.

5. The octane rating is a very important characteristic of fuels. However, for the sample, the value was not determined as the facilities to carry-out the test were not available. In subsequent work in this research, efforts should be made to determine the octane value of ethanol to serve as an indication of the burn efficiency of the fuel before it is tested in an automobile engine.

In all, the prospects in the use of ethanol as a renewable fuel for the future lie basically in its potential as an excellent fuel for internal combustion engines. Its lower heating value technically rules it out for use, solely as a heating fuel as the heat of combustion is the main parameter when considering fuels for that purpose. Automobile fuels require some other properties inherent in the fuels of which ethanol readily meets.

It is important to stress at that point that this write-up does not aim at making ethanol a total replacement for gasoline because if this is done, over time, the fuel would generate its own share of environmental problems as is being experienced presently and if possible, some others not even envisaged at this point. The suggestion is that of alternation or a blend of the two fuels with more emphasis, in the direction of the renewable ethanol fuel so that the natural reserves of the fossil fuel is not depleted and the environment is not starved of natural flora and food for the sake of fuel.

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APPENDIX

Calculation of viscosity: The viscosity value of the sample is determine from the experiment using the viscometer was calculated according to the equation below, viscosity = Stokes constant X Time of travel of the sample.

Time of travel = 16.5 seconds

Stokes constant for viscometer = 0.08

Viscosity = 16x0.08 = 1.32 centipose.

HEAT OF COMBUSTION; Heat of combustion of the sample for experiment is equal to the amount of heat librated during the combustion of the sample per unit weight of the sample combusted.

Heat librated on joule meter

Weight of sample = $M_2 - M_1$

$$= 105 - 100 = 5g$$

Thus heat of combustion = x/5 = 22133.7

$$= 25x22133.7$$

Temperature Correct

Tactual = t + 0.00012 (760-P) (273+T)

P = ambient pressure of laboratory environment

T – Boiling point of sample recorded in the laboratory

P = 7.4 MMHG

T = 760+0.00012 (760-714) (273+76)

$$= 16+1.92648$$

$$= 77.93^0c$$

$$= 78^0c$$

Graph of conc. of ethanol vs.refractive index of sample on arbitrary scale.