Kurdistan Region

Salaheddin University – Erbil

College of Engineering

Chemical & Petrochemical Department

Bioethanol production from Sweet Potatoes

A project submitted to the chemical & petrochemical engineering Department University of Salaheddin – Erbil

In the partial fulfillment of the requirement for the degree of bachelor of Science in chemical & petrochemical engineering department

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ABSTRACT

This project was concerned with building a plant design for production of bio ethanol from 5tone/day of sweet potatoes.

Ethanol may be a renewable asset of vitality and is potentially cleaner elective to fossil powers. Generation of ethanol is developing day by day at an awesome degree for its flexible application and request. amid later a long time, generation of ethanol by maturation on an expansive scale Has been of considerable interest to meet to expanded request.

Ethanol has been portioned of alcoholic refreshments for long time, but its application has expanded much past that during the 20th Century. Much of the later intrigued is within the use of ethanol as fuel. Ethanol created by maturation, called bioethanol, account for around 98% of the ethanol production.

Production of bioethanol from sweet potatoes, where the analysis of the Project is started with material balance, then the heat is calculated in Each stream of the plant according to the energy balance, the design of Reactor and Distillation is accomplished and calculated the Cost of plant.

Bioethanol looks to have a bright future because there is a strong need for sustainable energy sources to decrease reliance on foreign oil.

ACKNOWLEDGEMENT

We are grateful to God for our well-being that was necessary to complete this project.

Also, we would like to convey our sincere gratitude to the project supervisor, [Mr. Ahmed Omer] for his continuous support, as well as head of department [Asst. Prof. Dr. Mohammed Barzanjy] , provides us with all the necessary facilities for the project.

We are also very thankful to our families and dear friends who have boosted our up morally with their support, and we would like to thank all our college faculty members and committee members .

SUPERVISOR'S CERTIFICATE

Supervisor

Signature:

Name:

Data: / /

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LIST OF ABREVATION

A_C	Area of column
A_d	Area of downcomer
A_h	Area of hole
A_n	Net Area
A_a	Active area
C_p	Specific heat capacity
dc	Column diameter
D_h	Hole diameter
H_c	Height of column (distillation tower)
H_s	Try spacing
h_w	Wier height
L_w	Wier length
N_{min}	Minimum number of plate
R	Gas constant
R	Actual Reflux ratio
R_{min}	Minimum reflux ratio
Q_L	Velocity of liquid
Q_V	Velocity of vapor
V_n	Vapor rate
V_{nf}	Capacity parameter
ε	Void fraction
ρ	Density
δ	Extent of reaction
μ	viscosity
α	Relative volatility

CHAPTER ONE
INTRODUCTION

CHAPTER ONE: INTRODUCTION

1.1GENERAL

Rising fossil fuel prices associated with growing demand for energy, and environment concerns are the key factors driving strong interest in renewable energy sources, particular in biofuels. Biofuel refers to any type of fuel whose energy is derived from plant materials. Biofuel which includes solid biomass, liquid fuels and various biogases is among the most rapidly growing renewable energy technologies in recently.

Biofuels can be divided into five categories: bioethanol, biodiesel, biogas, bio methanol, and biohydrogen. The different types of biofuels are sourced from starch-rich crops for bioethanol, vegetable oils for biodiesel, organic waste for biogas, cellulose for bio methanol, and steam reforming for biohydrogen. Bioethanol and biodiesel are the most common types of biofuels. The use of bioethanol and biodiesel as transport fuels is very attractive due to reduction of combustion emissions, accessibility from renewable resources, and biodegradability.

The term bioethanol is defined as an ethyl alcohol or ethanol (C_2H_6O). this can also be written as (CH_3CH_2OH) or (C_2H_5OH) produced from fermentation of fermentable sugars (i.e., glucose, sucrose, etc.) from plant sources using micro-organisms (yeasts or bacteria). Bioethanol is a clear colorless liquid, it is biodegradable, low in toxicity and causes little environmental pollution if spilt.

1.2 HISTORY

The rise of biofuels and bioethanol is tightly related to the industrial revolution in the 9th century.

Ethanol's first use was to power an engine in 1826, In the 1850s, ethanol was already being used as a fuel for street lighting and in 1876, Nicolaus Otto, the inventor of the four-stroke internal combustion engine, used ethanol to power his invention. In 1908, Henri Ford's Model T was the first industrially large-scale powered by ethanol vehicle. In the 1920s and 1930s, ethanol was blended with gasoline for the first time as an octane enhancer.

Today's ethanol industry began in 1970s when petroleum-based fuel expensive and environmental concerns involving leading gasoline created a need for an octane.

Ethanol's use as an oxygenate to control carbon monoxide emissions, encouraged increased production of the fuel through the decade and into the 1990s.

dramatically In 2005, the first Renewable Fuels Standard (RFS) became law as part of the United States' energy policy. It provided for ethanol production of four billion gallons in 2006 with an increase to seven and one-half billion gallons by 2012. Since that time, The Energy Independence and Security Act of 2007 requires renewable fuel usage to increase to 36 billion gallons annually by 2022.

The new RFS which currently guides national ethanol policy states that only 15 billion gallons of production should be produced from corn grain (starch) the remaining 22 billion should come from other advanced and cellulosic feedstock sources.

1.3 PHYSICAL AND CHEMICAL PROPERTIES OF ETHANOL

Bioethanol has physical and chemical properties that make it an attractive fuel source. Table 1.1 provides a summary of the physical and chemical properties of bioethanol.

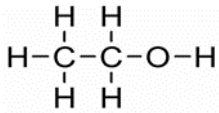
Property name	Value
Molecular formula	C_2H_5OH
Chemical structure	
Molecular weight	
Physical state	Clear liquid
Appearance	Colorless, volatile liquid
Odor	Mild, rather pleasant
Melting point	-130°C to -112°C
Boiling point	74°C-80°C
Flash point	12-17°C
Density	789 kg/m^3
Stability	Stable
Solubility -water	Full miscible with water
Solubility -solvent	Miscible with ether, methanol, chloroform and acetone
PH	Pure ethanol would have a PH reading about 7.9
Vapor pressure at (20°C)	59mmHg

Table 1.1physical and chemical properties of bioethanol

The physical and chemical properties of bioethanol are important for its storage, transportation, and use as a fuel. The low boiling point and high vapor pressure of ethanol make it more volatile than gasoline, which requires special handling and storage to prevent evaporation and fires.

1.4 APPLICATION OF BIOETHANOL

1.Transportation:

The primary application of bioethanol is as a fuel for transportation. The most cost-effective aid is the blending ethanol with a small proportion of volatile fuel such as gasoline. Thus, various mixture of bioethanol with gasoline or diesel Fuels have been used. The most well-known blends are (by volume):

- E85G (85% ethanol ,15% gasoline)
- E15D (15% ethanol, 85% diesel)
- E95D (95% ethanol,5% water, ignition improver)

2.Industry:

Bioethanol can be used as a feedstock for the production of chemicals, such as acetaldehyde, ethylene, and acetic acid, which are used in various industries.

Bioethanol can also be used as a solvent in the production of pharmaceuticals, cosmetics, and personal care products.

Another application of bioethanol in industry is as a fuel for combined heat and power (CHP) systems. CHP systems generate electricity and heat simultaneously, which can be used for industrial processes, heating, and cooling.

3. Agriculture:

Bioethanol can also be used in agriculture as a fuel for tractors, harvesters, and other farm equipment. The use of bioethanol in agriculture can reduce greenhouse gas emissions and support rural development by creating jobs and income opportunities for farmers. In addition, bioethanol can be used as a livestock feed additive. Ethanol production generates by-products such as distiller's grains, which are high in protein and fiber and can be used as a feed supplement for livestock.

More than 80% of US ethanol plants are now able to extract corn oil following the fermentation step, allowing the plants to sell into a wide variety of markets. This oil, known as distillers corn oil, maybe used as a feed ingredient or as a biodiesel feedstock.

1.5 BENIFATES OF USING BIO ETHANOL AS A FUEL

1. It reduces CO_2 emissions

Although it produces CO_2 when burned, it actually comes from the CO_2 absorbed by the plant as it grows, and it is also much lower than that generated by fossil fuels; the difference ranges from 19% (from corn crops) to 86% (from biomass residues).

2. It doesn't generate waste

Its combustion doesn't generate smells or waste, and the CO_2 generated can be captured and used in other industrial applications, such as the carbonation of drinks or freezing. For example, it allows the amount of rubbish generated in an urban center to be reduced.

1.3 It boosts the local economy

The increase in the demand of this fuel brings with it greater employment opportunities. As well as needing personnel to work at the bioethanol plants, jobs are created in the agricultural sector, to supply the raw materials and other related sectors.

1.6 METHODS AND RAW MATERIALS

Bioethanol is typically produced through a process known as fermentation, which converts sugars derived from biomass into ethanol. The process of manufacturing bioethanol involves several steps, including feedstock selection, preparation, fermentation, and distillation.

1.6.1 raw materials

The biomass feedstock can also be divided into three groups depending on the type of chemical structure of the raw material which as shown below:

Figure 1.1 biomass feedstocks for bioethanol production

Different types of biomasses have a potential as raw materials for bioethanol production. Because of their chemical composition, i.e., carbohydrate sources, they mostly form three groups: (i) sugar-containing raw materials: sugar beet, sugarcane, molasses, whey, sweet sorghum, (ii) starch-containing feedstocks: grains such as corn, potato, wheat, root crops such as cassava, and (iii) lignocellulosic biomass: straw, agricultural waste, crop and wood residues.

However, these sugar- and starch-containing feedstocks (first generation) compete with their use as food or feed, thus influencing their supply.

Therefore, lignocellulosic biomass (second generation) represents an alternative feedstock for bioethanol production due to its low cost, availability, wide distribution and it is not competitive with food and feed crops.

Sugar cane and beet are the most important sugar-producing plants in the world. Two-thirds of the world sugar production are from sugar cane and one-third is from sugar beet. Sugarcane production requires a tropical climate and Brazil has the largest sugarcane cultivation (about 27% of global production) and was the first and biggest producer of bioethanol in the world for many years. Sugarcane contains about 15% sucrose (saccharose) which is a (one molecule of glucose and one molecule of fructose) The chemical bonds can be broken relatively easily (e.g., by *yeast Saccharomyces cerevisiae*) resulting in glucose which is free and available for fermentation in the ethanol production process, the pretreatment is not required for bioethanol production from the feedstocks containing sugar (sucrose), which makes this bioprocess more feasible than from feedstocks containing starch.

The second largest feedstock for bioethanol production is corn. Grain crops (e.g., corn, barley, wheat or grain sorghum) and root/tubular crops (e.g., cassava, potato, sweet potato, Jerusalem artichoke, cactus or arrowroot) contain large quantities of starch. The biggest corn starch production is in the USA and it represents more than 80% of the worldwide market. In the USA,

corn is a source of over 95% of bioethanol production and the rest is produced from barley, wheat, whey and beverage residues.

Production of bioethanol from the raw materials that contain lignocellulose is attractive and sustainable because lignocellulosic biomass is renewable and non-competitive with food crops. Furthermore, the use of bioethanol obtained from lignocellulosic biomass is related to the considerable reduction of greenhouse gas emission.

saccharomyces cerevisiae

Yeast called *saccharomyces cerevisiae*. (S. cerevisiae) is known as (brewer's yeast) or (baker's yeast), the yeast contains an enzyme called invertase, which acts as a catalyst which help to convert the sugar to ethanol.

1.6.2 Processing technology

There are some differences in the processing technology between first generation feedstocks (sugar feedstock, starchy feedstock) and second-generation feedstocks (lignocellulosic feedstock). Generally, commercial bioethanol production requires several steps:

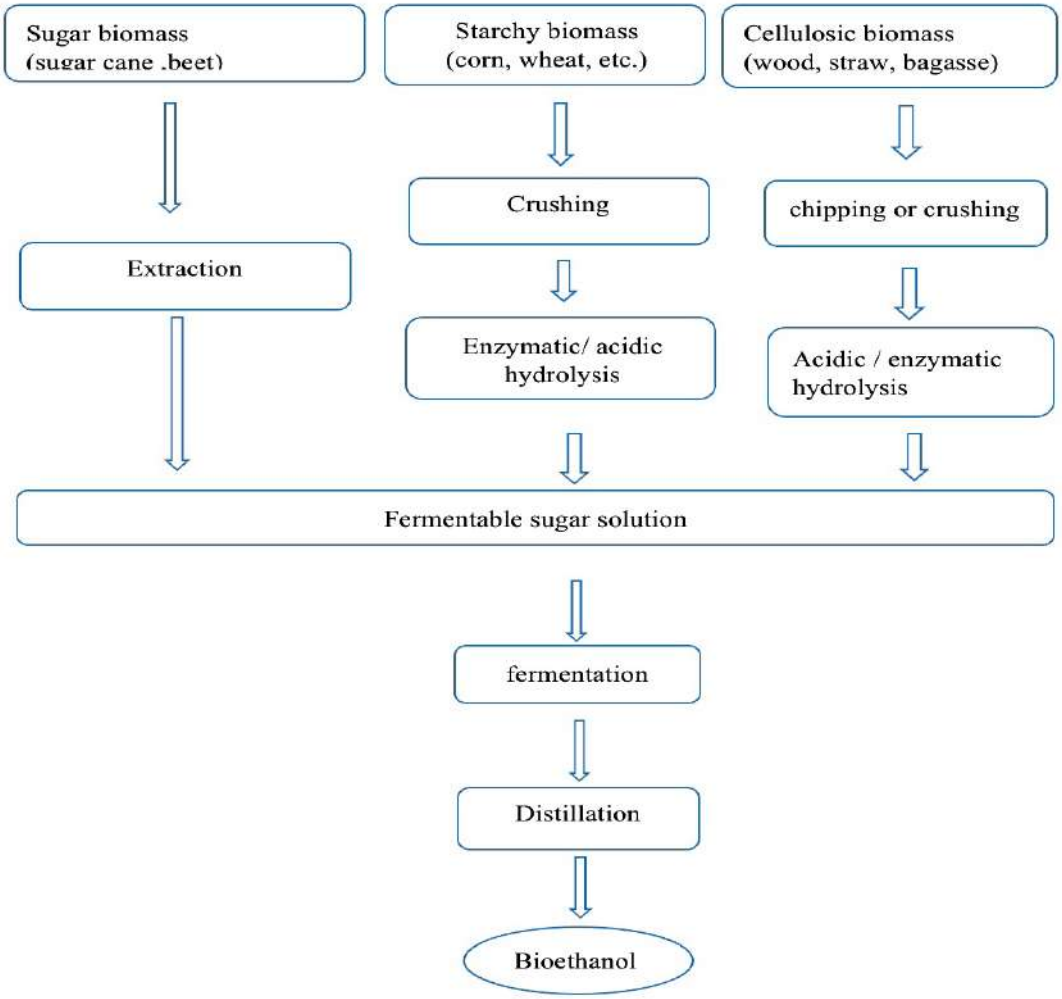


Fig1.2Scheme of different steps in bioethanol production from different feedstocks

1.7 BIOETHANOL PRODUCTION FROM SWEET POTATO

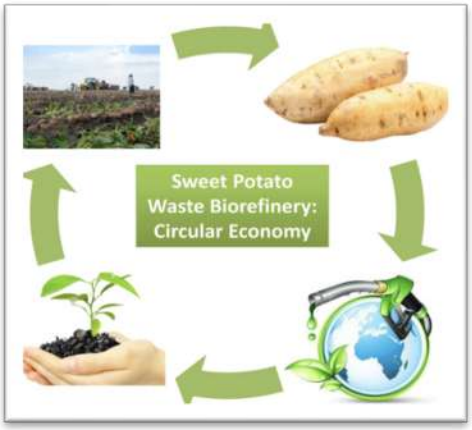


Figure1.3 sweet potato waste biorefinery

Here, we tried using sweet potato as a substrate for bioethanol production, because it can produces high amount of ethanol and sweet potatoes contain a high percentage of starch and available in many areas where it is the sixth most cultivated crop in the world. Its global production in 2016 was 105 million tons. Also, the characteristics of sweet potatoes are a permanent crop that is more adaptive to the environmental conditions, grows easily, has high drought resistance and is easily harvested.

Bioethanol is produced from the potato where the source of energy is starch. The process of converting starch into bioethanol is carried out in three main steps: hydrolysis (acidic or enzymatic), fermentation and distillation.

1.7.1 Process sequence to produce bioethanol from sweet potato

1. Milling

At this stage the peels of washed potatoes are removed, which is rich in carbon could be used as fertilizer or fuel for biomass boilers. Then the potato is milled to be turned into a kind of mashed potatoes, in such a way that it facilitates the action of the enzymes in the starch in the following stages. As mentioned above to convert potato starch into sugars that can be fermented, it is necessary to use enzymes.

2.Hydrolysis process

Hydrolysis is a common form of a chemical reaction where water is mostly used to break down the chemical bonds that exists between a particular substance and by adding enzyme or acid.

The commonly used enzyme for hydrolysis is (α-Amylase). And Starchy materials require a reaction of starch with water (hydrolysis) to break down the starch into fermentable sugars (saccharification). Enzymatic Hydrolysis usually is carried out at temperature (30°C).

Another method is acidic hydrolysis instead of using enzyme to hydrolyze the biomass into sugar, we can use acid as sulfuric acid, hydrochloric acid in a similar way with a higher temperature.

In this project we use the enzymatic hydrolysis by alpha amalyse

$$C_6H_{10}O_5 + H_2O \xrightarrow{\alpha-amalyse} C_6H_{12}O_6$$

3.Fermentation

is a process of bioconversion of sugars into ethanol, by adding yeast to the solution, which is then heated. Yeast called *saccharomyces cerevisiae*.(S. cerevisiae) the yeast contains an enzyme , which acts as a catalyst which help to convert the sugar to ethanol.

$$C_6H_{21}O_6 \xrightarrow{yeast} 2C_2H_5OH + 2CO_2$$

4.Fractional Distillation Process

The ethanol, which is produced from the fermentation process, still contains a significant quantity of water, which must be removed. This is achieved by using the fractional distillation process. The distillation process works by boiling the water and ethanol mixture. Since ethanol has a lower boiling point (78.3C) compared to that of water (100C), the ethanol turns into the vapor state before the water and can be condensed and separated.

1.7.2 Operating conditions

The temperature of the hydrolysis is 30℃ and its duration usually 1hour.

The fermentation temperature is 70 ℃ for 72 hours.

The distillation temperature is 80℃ and takes 1.5 hours.

Concentration of α-amalyse enzyme (700ml/t $_{\text{sweet potatoes}}$).

Yeast concentration of S. cerevisiae (3.3 kg/t $_{\text{sweet potato}}$).

Conversion of both bioreactors 95%.

-The production of bioethanol in this way is more common and its materials are readily available.

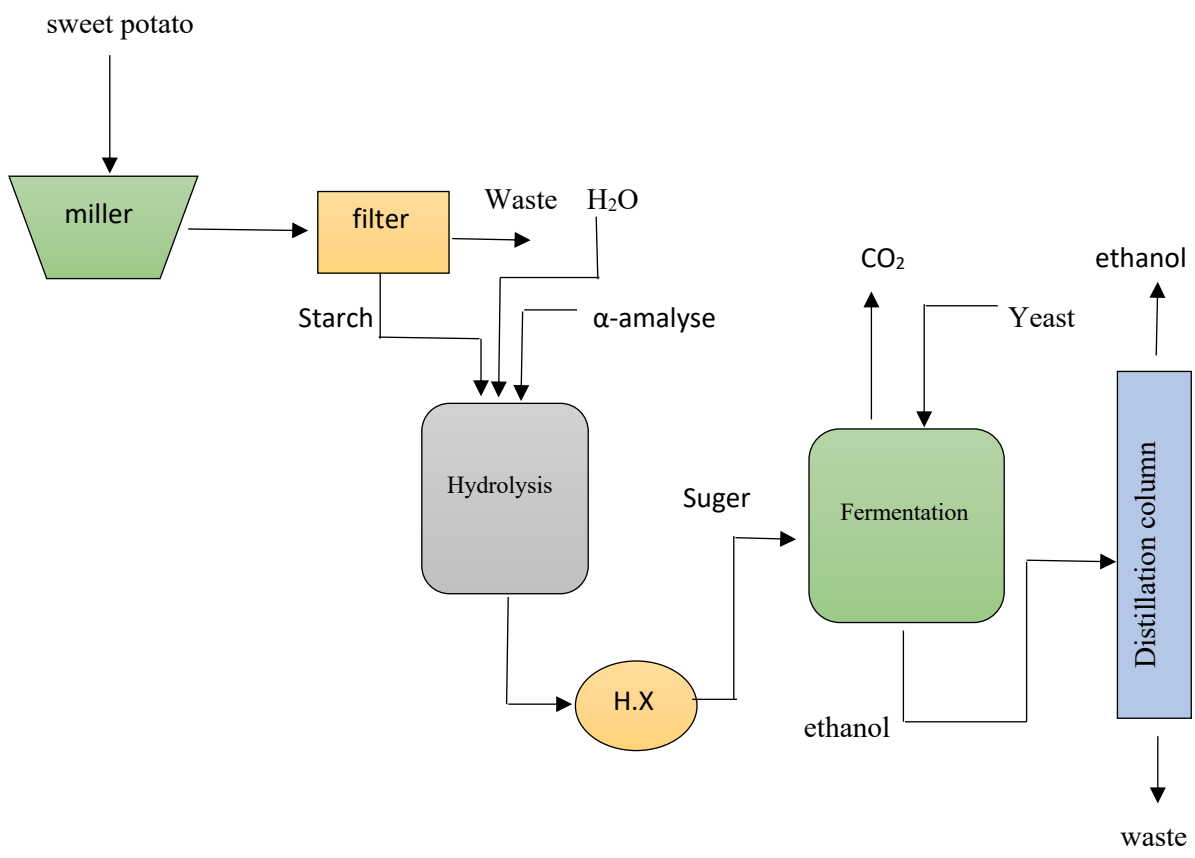


figure1.4 PFD of bioethanol production from sweet potato

CHAPTER TWO

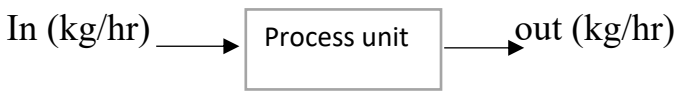
MATERIAL BALANCE

CHAPTER TWO: MATERIAL BALANCE

Material balance are the basis of process design, a material balance taken over the complete process will determine the quantities of raw materials required and products produced. Balances over individual process units set the process stream flows and compositions, and provide the basic equations for sizing equipment.

Material balance is nothing more than the application of the law of the conservation of mass:'' mater is neither created or destroyed''.

The general balance equation



Input + Generation – Output – Consumption = Accumulation

assuming, 5tone/day of Sweet Potato is on processing.

Amount of Sweet Potatoes = 5 tone/day

= 208.33 kg/hr

The process is the continuous process, a plant is operated for 24 hours per day. The conversion of both Reactors is 95%.

Starch	73%
Moisture	8.12%
Total Protein	10.86%
Fiber	1.65%
Ash	2.15%
Others	4.22%

Table 2.1 composition of sweet potatoes

The amount of Starch(cellulose) from 5 tone of sweet potatoes per day

= 0.73 × 208.33 =152.08 kg/hr

Compound	Molecular Formula	Molecular weight (kg/kmole)
Cellulose	$C_5H_{10}O_6$	162
Water	H_2O	18
Glucose	$C_6H_{10}O_6$	180
Carbon dioxide	CO_2	44
Ethanol	C_2H_5OH	46

Table 2.2 Molecular Formula and molecular weight of Compounds

2.1 Over All Material Balance on Miller and Filter

IN=OUT

S1 = 208.33 kg/hr [Sweet potatoes]

S3 = S1- S4 = 208.33 -152.08 = 56.25 [Waste]

S1 = S3 + S4

kg/hr = 208.33 kg/hr

-Assuming fulling starch extraction.

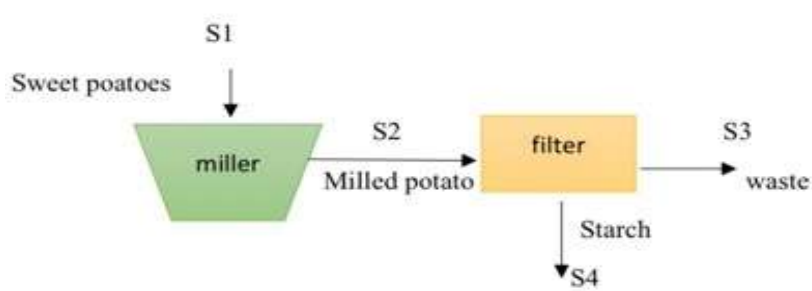


Figure 2.1 over all material balance on miller and filter

2.2 Material Balance on Reactor one

The Reaction occur in this Reactor is:

$$C_6H_{10}O_5 + H_2O \rightarrow C_6H_{12}O_6$$

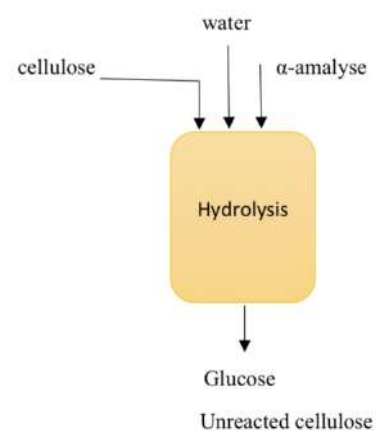
Cellulose amount =152.08 kg/hr

Cellulose amount for Conversion 95% (Reacted):

$152.08 \times 0.95 = 144.476$ kg/hr

Glucose amount Produced:

$\frac{144.476}{162} \times 180 = 160.52$ kg/hr



Amount of H_2O (Reacted):

1mol H_2O = 1mol $C_6H_{12}O_6$

$\frac{160.52}{180} \times 18 = 16.05$ kg/hr

figure 2.2 M.B on R1

Cellulose unreacted = total cellulose amount in feed – Cellulose Reacted

$= 152.08 - 144.476 = 7.604$ kg/hr

(α-Amylase) is (0.7 kg/1tone$_{\text{sweet potato}}$) from reference, For 5tone of

Sweet potatoes= 3.5×10^{-3}kg/hr

Compound	IN(kg/hr)	OUT(kg/hr)
Cellulose	152.08	7.604
Glucose	--------	160.52
Water	16.05	---------
α-Amylase	0.0035	0.0035
Total	168.13	168.13

Table 2.3 all components flowrate based on material balance over reactor1

2.3 Material Balance on Reactor 2 (Fermentation)

The Reaction occur in R2 (Fermentation) is:

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$$

Glucose amount that entered the Reactor = 160.52 kg/hr

Glucose amount for Conversion 95% (Reacted): 160.52 × 0.95 = 152.503 kg/hr

Ethanol amount Produced:

$$\frac{152.503}{180} \times 46 \times 2 = 77.94 \text{ kg/hr}$$

CO_2 amount Produced:

2mol CO_2 = 2mol C_2H_5OH

$$\frac{77.94}{46} \times 44 = 74.55 \text{ kg/hr}$$

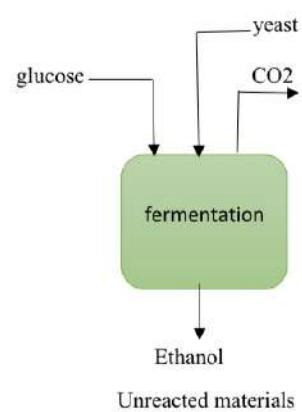


Figure 2.3 M.B on R2

Unreacted Glucose = Glucose amount in feed – Glucose Reacted

= 160.52 - 152.503 = 8.026 kg/hr

Yeast amount is (3.3 kg/1 tone $_{\text{of sweet potato}}$) depend on the amount of starch in potatoes from reference, For 5 tone of sweet potatoes = 0.52 kg/hr. This amount of yeast entered with water as a slurry, the ratio of yeast to water [1:10].

Compound	IN(kg/hr)	OUT(kg/hr)
Cellulose	7.604	7.604
Glucose	160.52	8.026
Ethanol	--------	77.94
Carbon dioxide	--------	74.55
Yeast+water	0.52+5.2	0.52+5.2
Total	173.2	173.2

Table 2.4 all components flowrate based on material balance on reactor 2

2.4 Material Balance on Distillation

We have separation of (ethanol as overhead) and

(Waste as a bottom), Separation process such as total ethanol 98% to

Overhead of the (inlet feed) and 2% to Bottom of (inlet feed)

(Rule of thumb).

Feed stream (F) = 99.29 kg/hr

Ethanol amount = 77.94 kg/hr

Glucose amount = 8.026 kg/hr

Cellulose amount = 7.604 kg/hr

Water amount = 5.2 kg/hr

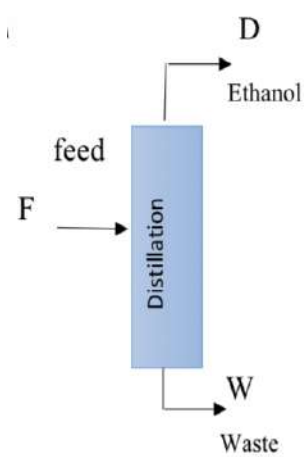


Figure 2.4 M.B on distillation

Overhead stream (D):

Ethanol amount = 77.94 × 0.98 = 76.3812 kg/hr

Water amount = 5.2 × 0.02 = 0.104 kg/hr

Cellulose amount = 0 kg/hr

Glucose amount = 0 kg/hr

Bottom stream (B):

Ethanol amount = 77.94 × 0.02 = 1.55 kg/hr

Water amount = 5.2 × 0.98 = 5.096 kg/hr

Cellulose amount = 7.604 kg/hr

Glucose amount = 8.026 kg/hr

Compounds	IN (F) (Kg/hr)	OUT(D) (Kg/hr)	OUT(B) (Kg/hr)
Ethanol	77.94	76.3812	1.55
Cellulose	7.604	0	7.604
Glucose	8.026	0	8.026
Water	5.2	0.104	5.096
Total	99.29	99.29	

Table 2.5 all components flowrate based on material balance on distillation

2.5 Overall material balance

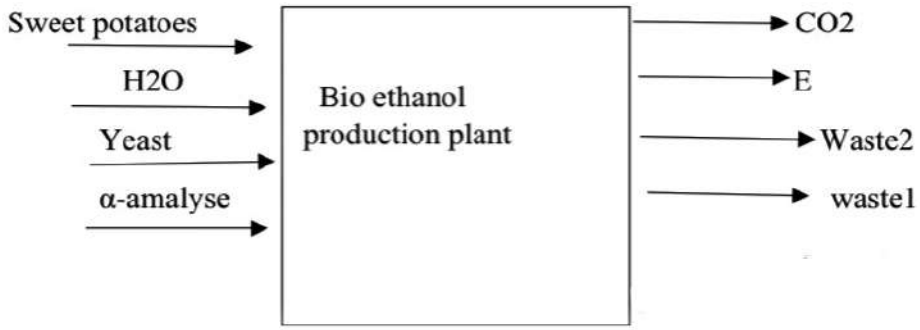


figure 2.5 over all material balance

Input (kg/hr)	Output (kg/hr)
Sweet potatoes = 208.33	CO_2 = 74.55
H_2O =16.05	Ethanol = 77.94
Yeast + water = 5.72	Waste 2(distillation) = 22.276
α-amalyse = 0.0035	Waste 1(filter) = 56.25
Total = 230	Total = 230

Table 2.6 all components flowrate based on overall material balance

CHAPTER THREE
ENERGY BALANCE

CHAPTER THREE:ENERGY BALANCE

Energy balance is defined as the state achieved when the energy intake equals energy expenditure. This concept maybe used to demonstrate how bodyweight will change over time in response to changes in energy intake and expenditure. When the body is in energy balance, body weight is stable

The general energy balance equation will be:

$$\Delta KE + \Delta PE + \Delta H = Q - W$$

In this project we don't have velocity or height or movement parts, so:

$$\Delta KE = \Delta PE = W = 0$$

So that the general equation will be:

$Q = \Delta H$

$\Delta H = H_2 - H_1$

$Q = \Delta H = m\int_{Tref}^{T} Cp\, \Delta T$

$Q = m\, Cp\, (T - T_{ref})$

The reference Temperature for calculation is taken as:

$T_{ref} = 298$ K

ΔH = Enthalpy change ($\frac{KJ}{Kg}$)

ΔT = Temperature change (K)

Cp = Specific heat ($\frac{KJ}{Kg.K}$)

	Molecular Formula	Cp $(\frac{KJ}{Kg.K})$	Hf ° $(\frac{KJ}{Kg})$
Cellulose	$C_6H_{10}O_5$	1.23	-963
Water	H_2O	4.18	-285.8
Glucose	$C_6H_{12}O_6$	1.21	-1271
Carbon dioxide	CO_2	0.82	-393.5
Ethanol	C_2H_5OH	2.44	-277

Table 3.1 Specific heat capacity and heat formation of compounds

3.1 Energy balance on reactor one

The input temperature of both Cellulose and Water are at 25°C

The input temperature of the enzyme used is 25°C

The operating temperature of Reactor is 30°C

The reaction product leave Reactor at 30°C

T = 30 + 273 = 303 k

$\Delta H = \Delta H_{Product} - \Delta H_{Reactant} + \Delta H_{Reaction}$

$\Delta H_{Product} = m\ Cp\ (T-T_{ref})$

$\Delta H_{Reactant} = m\ Cp\ (T-T_{ref})$

$\Delta H_{Reaction} = \Delta Hf°_{Products} - \Delta Hf°_{Reactants}$

Reactants				
Compound	T (k)	T_{ref} (k)	M (kg/hr)	ΔH (kJ/hr)
Cellulose	298	298	152.08	0
Water	298	298	16.05	0
α-amalyse	298	298	0.0035	0

Products				
Compound	T (k)	T_{ref} (k)	M (kg/hr)	ΔH (kJ/hr)
Glucose	303	298	160.53	974.77
Cellulose	303	298	7.6	46.74
Total				1021.51

The reaction occur in this reactor is:

$$C_6H_{10}O_5 + H_2O \rightarrow C_6H_{12}O_6$$

$\Delta H_{Reaction} = 1\times \Delta Hf°_{Product} - 1\times \Delta Hf°_{Reactant}$

$= -22.2$ kJ/kg

$Q = \Delta H_{Product} - \Delta H_{Reactant} + \Delta H_{Reaction}$

$= 998.8$ kJ/hr

3.2 Energy balance on Heat Exchanger

(Heat exchanger for heating)

Temperature in K

$T_{In} = 30 + 273 = 303$ k

$T_{out} = 50 + 273 = 323$ k

$\Delta H_{In} = 1021.51$ kJ/hr

$Q = \Delta H = \Delta H_{out} - \Delta H_{in}$

ΔH_{out}				
Compound	T_2 (k)	T_1(k)	M (kg/hr)	ΔH (kJ/hr)
Glucose	323	303	160.53	3884.826
Cellulose	323	303	7.6	186.96
Total				4071.286

ΔH_{out} = 4071.286 (kJ/hr)

$Q_T = \Delta H_{out} - \Delta H_{in}$

= 3049.776 kJ/hr

Water used for heating

T_{in} = 50 +273 = 323 k

T_{out} = 20 + 273 = 293 k

$Q_{water} = Q_T = m_{water} \times Cp_{water}(T_1 - T_2)$

$3049.776 = m_{water} \times 4.18 \times (50-20)$

m_{water}=24.32kg/hr

3.3 Energy balance on Reactor 2

The input temperature of the compounds inter the Reactor are 50°C.

The input temperature of the yeast inters the reactor is 25°C.

The operating temperature of Reactor is 70°C.

The reaction products leave the Reactor at 70°C.

T = 50 + 273 = 323 k

T = 70 + 273 = 343 k

Reactants				
Compound	T (k)	T_{ref} (k)	M (kg/hr)	ΔH (kJ/hr)
Glucose	323	298	160.53	3884.826
Cellulose	323	298	7.6	186.96
Yeast +water	298	298	5.72	0
Total				1021.51

Products				
Compound	T (k)	T_{ref} (k)	M (kg/hr)	ΔH (kJ/hr)
Ethanol	343	298	77.94	8557.812
Glucose	343	298	8.026	437.0157
Cellulose	343	298	7.6	420.66
Carbon dioxide	343	298	74.55	2750.895
Total				12166.382

The reaction is:

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$$

$\Delta H_{reaction} = (2 \times \Delta Hf^{\circ}_{Carbon\ Dioxide} + 2\times \Delta Hf^{\circ}_{Ethanol}) - \Delta Hf^{\circ}_{Glucose}$

$= -71.2$ kJ/hr

$Q= \Delta H_{Product} - \Delta H_{Reactant} + \Delta H_{Reaction}$

$= 11073.67$ kJ/hr

3.4 Energy balance on distillation

Feed Temperature = 70 + 273 = 343 k

Overhead (D) Temperature = 80 + 273 = 353 k

Bottom temperature (B) =85+273 = 358 k

ΔH (Feed) = 9415.48 KJ/hr

$\Delta H (D) = m\ Cp\ \Delta T$

m = 76.4852 kg/hr

$Cp_{mix} = (X \times Cp)_{Ethanol} + (X \times Cp)_{water}$

$= (0.98 \times 2.44) + (0.02 \times 4.18)$

$= 2.474$ kJ/kg. k

$\Delta H_D = 76.4852 \times 2.474(353 - 303)$

$= 10407.84$ kJ/hr

ΔH (bottom)

$\Delta H_B = m\ Cp\ \Delta T$

m= 22.276 kg/hr

$Cp_{mix} = [(X \times Cp)_{Ethanol} + (X \times Cp)_{Cellulose} + (X \times Cp)_{Glucose} + (X \times Cp)_{water}$

$= 4.1452$ kJ/kg. K

$\Delta H_B = 22.276 \times 4.14(358 - 298)$

$= 5533.3584$ kJ/hr

$\Delta H_{Reboiler} = m\ Cp\ \Delta T$, m = 20 kg (assumption)

$= 20 \times 4.18(358 - 303) = 4598$ kJ/hr

$\Delta H_{Heat} = \Delta H_B - \Delta H_{Reboiler}$

$= 5533.3584 - 4598 = 935.3548$ kJ/hr

$\Delta H_{Feed} + \Delta H_{Heat} = \Delta H_D + \Delta H_B + \Delta H_{Cool}$

$\Delta H_{Cool} = (9415.48 + 935.3548) - (10407.814 + 5533.3548) = -5590$ kJ/hr

ΔH In kJ/hr	ΔH Out kJ/hr
9415.48	10407.814
935.3584	5533.3548
----------	-5590
T= 10350.71	T= 10350.71

CHAPTER FOUR
EQUIPMENT DESING

CHAPTER FOUR :EQUIPMRNT DESIGN

4.1 Design of reactor

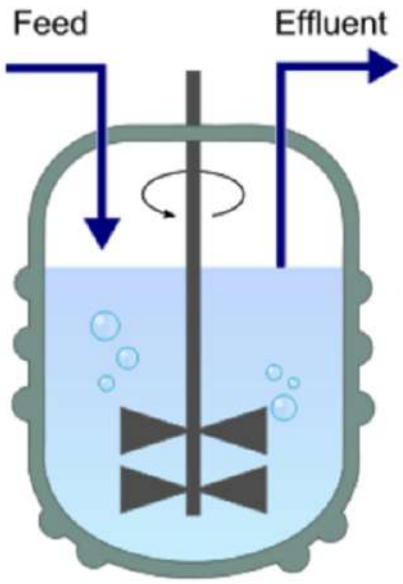


Figure 4.1.batch reactor

A bioreactor may refer to any manufactured or engineered device or system that supports a biologically active environment .

In one case , a bioreactor is a vessel in which a chemical process is carried out which involves organisms or biochemically active substances derived from such organisms. This process can either be aerobic or anaerobic. These bioreactors are commonly cylindrical, ranging in size from liters to cubic meters , and are often made of stainless steel.

Conversion =95%

Working pressure of vessel (p) =1.1bar

Temperature of reaction = 30°C

Batch time = 5 hr

4.1.1 Determine the rate of reaction

the rate equation becomes:

$$-r_A = K\, C_{A_o} \left[\frac{1-XA}{1+(\varepsilon A \times XA)}\right]$$

the Arrhenius equation:

$$k = A \times e^{-Ea/RT}$$

From the reference

$$k = 0.028\, min^{-1}$$

Y_{A0} = 0.90 mole fraction of cellulose

Total volumetric flowrate is

$$C_T = \frac{P}{RT}$$

$$C_T = \frac{1.86}{0.082 \times 303}$$

$$C_T = 0.043$$

Volumetric flowrate is

$$C_{A0} = C_T \times Y_{A0}$$

$C_{A0} = 0.90 \times 0.043$

$C_{A0} = 0.0387$

$\delta = 1-2 = -1$

$\varepsilon = Y_{A0}\,\delta$

$= 0.90 \times -1$

$= -0.90$

$-r_A = 0.028 \times 0.0387[\frac{1-0.90}{1+(-0.90\times0.95)}]$

$= 3.73 \times 10\text{-}4\ \text{min}^{-1}$

$1/-r_A = 2676.26$ min

4.1.2 Determine the time

$t = \frac{NA}{v}\int_0^x \frac{dx}{-rA}$

$t = 0.0387\int_0^{0.95} \frac{dx}{3.73*10^{-4}}$

t = 98.6 min = 5913.95sec

4.1.3 Determine the volume of reactor

$$V_r = \frac{m * batch\ time}{\rho_{cellulose}}$$

$$V_r = \frac{152.08 * 5hr}{80\ kg/m^3}$$

$$V_r = 8m^3$$

Assuming 30% volume of fluid as free space

$$V_f = 0.30 * Vr$$

$$V_f = 10.4\ m^3$$

we assume that, $\frac{L}{D} = 1.5$

$$V_f = \frac{\pi}{4} D^2 L$$

$$10.4 = \frac{\pi}{4} D^2 1.5D$$

$$D = 2.06m$$

$$L = 3.1m$$

4.1.4 determine vessel wall thickness

$$t = \frac{PR}{SE - 0.6P} + t_c + t_d$$

$$t = 0.21\ in$$

D = 2.06m, L = 3.1m, R = 1.03m = 40.551in

t_c = 0.125in t_d = 0.0394 in, E = 0.9, S = 1100bar

When T is equal to 30°C maximum allowable stress is found by the below figure which is S=1100 (Jasbir S. Arora (2012), Introduction to Optimum Design, Third Edition).

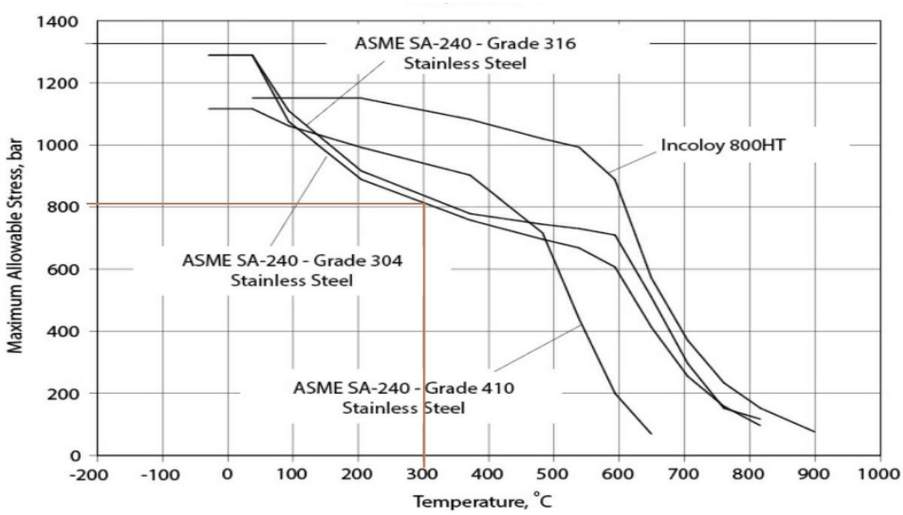


Figure 4.2 maximum allowable stress

4.2 Design of distillation column

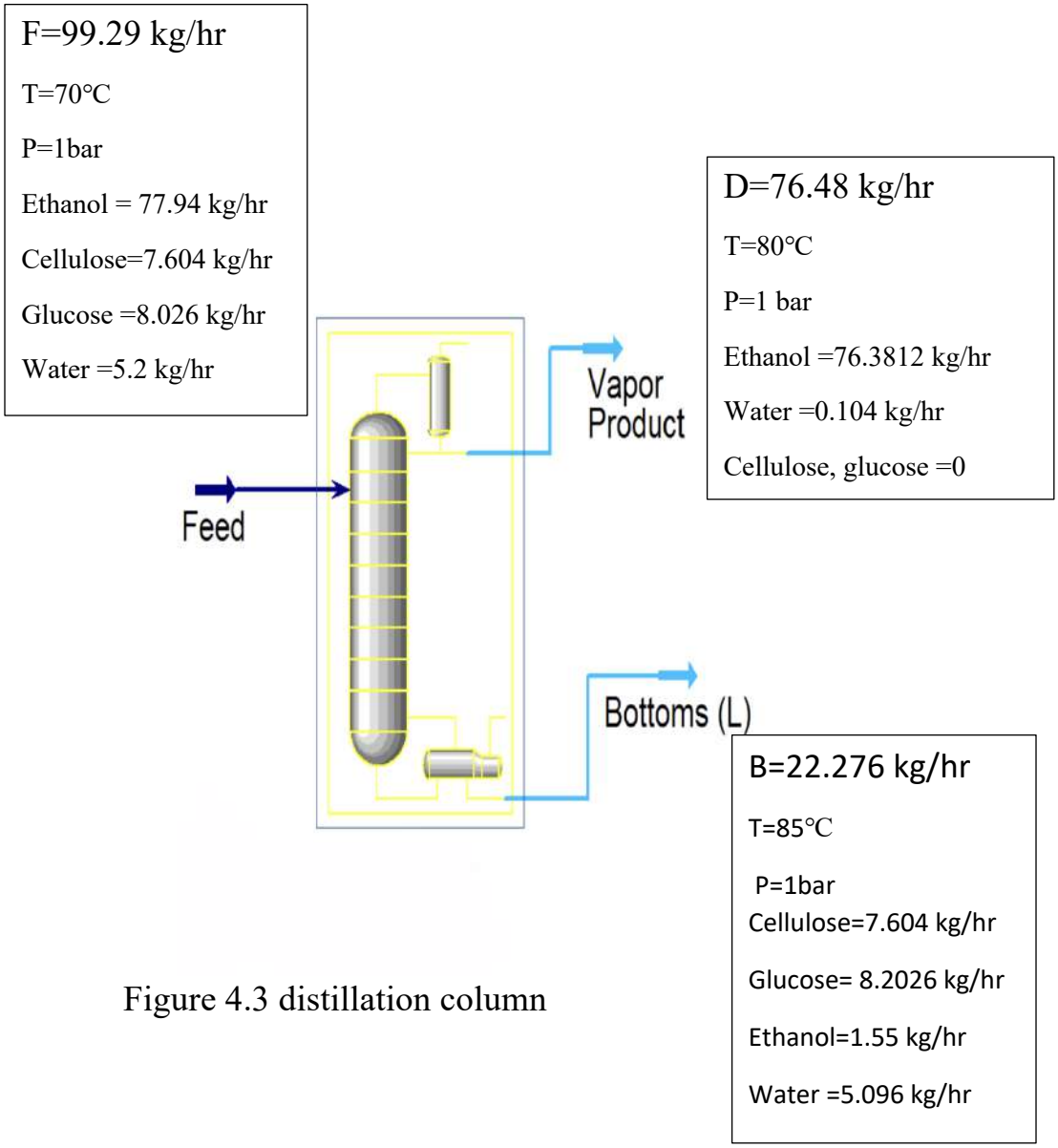


Figure 4.3 distillation column

components	Feed fraction (x_f)	Bottom fraction (x_f)	Top fraction (x_f)
Ethanol	0.784	0.069	0.98
Water	0.0523	0.22	0.0013
Glucose	0.08	0.36	0
Cellulose	0.076	0.34	0

Table 4.1 mass fraction of the materials

Heavy key component HKC= ethanol

Light key component LKC= water

4.2.1 Volatility calculations:

To calculate relative volatility, we need some data

First step we need bubble point and dew point of feed, top product, bottom product, for this we need K-values of all components, to determine the K-values we need vapor pressure data for all feed components, which taken from Antoine equation:

$$\text{Log pi} = A - \frac{B}{T+C}$$

$$k_i = pi/p \text{ or } pj/p$$

T=temperature, °C

P_i= vapor pressure of component i.

P= operating pressure of column

A, B, C = the Antoine coefficients from reference:

Compound	A	B	C
ethanol	8.2133	1652.03	231.48
water	8.0713	1730.63	233.426

Table 4.2 Antoine coefficients of materials

Relative volatility (α) equation:

$$\alpha = K_i/K_j$$

Where

i=light key

j= heavy key

Adopting this procedure, relative volatility of each of components in feed, top product and bottom product is computed at their respective temperatures.

Average volatility equation:

$$\alpha_{avg} = (\alpha_{feed} * \alpha_{top} * \alpha_{bottom})^{1/3}$$

Feed (P=1atm)	B (P=1.2atm)	D (P=1 atm)
$P_{ethanol}$= 541.37mmHg	$P_{ethanol}$= 984.51mmHg	$P_{ethanol}$= 811.76mmHg
P_{water}= 233.17mmHg	P_{water}= 432.870mmHg	P_{water}= 354.53mmHg

Table 4.3 Vapor pressure of each materials

Feed (P=1.1bar)	B (P=1.2bar)	D (P=1.1bar)
$K_{ethanol}$= 0.72	$K_{ethanol}$= 1.09	$K_{ethanol}$= 1.08
k_{water}= 0.31	k_{water}= 0.48	k_{water}= 0.47

Table 4.4 (K) for each materials

Feed	B	D	Average
$\alpha_{ethanol}$= 1	$\alpha_{ethanol}$ =1	$\alpha_{ethanol}$= 1	α_{avg}= 1
α_{water}= 0.43	α_{water}= 0.44	α_{water}=0.435	α_{avg} = 0.43

Table 4.5 (Relative volatility) for each materials

$$\alpha_{avg} = 0.433$$

4.2.2 Calculation of minimum No. of plate

$$N_{min} = \frac{\ln\left[\left(X_{LK}/X_{HK}\right)_D \times \left(X_{HK}/X_{Lk}\right)_B\right]}{\ln\left(a_{\frac{LK}{HK}}\right)}$$

$$N_{min} = \frac{\ln\left[\left(0.0013/0.98\right)_D \times \left(0.069/0.22\right)_B\right]}{\ln\left(0.433\right)}$$

$$N_{min} = 5$$

4.2.3 Calculate minimum Reflux Ratio:

$$R_m = \frac{1}{\alpha - 1}\left[\frac{\alpha * x_D}{x_F} - \frac{1 - x_D}{1 - x_F}\right] - 1$$

$$R_m = \frac{1}{0.43-1}\left[\frac{0.43*0.0013}{0.0523} - \frac{1-0.0013}{1-0.22}\right] - 1$$

$$R_m = 1.24$$

Actual reflux ratio:

The rule of thumb is:

R= (1.2 ------- 1.5) R_{min}

R = 1.24 *1.5

R= 1.86

4.2.4 Calculate the theoretical number of stages

$$\frac{N_T - N_m}{N_T + 1} = 0.75[1 - \left(\frac{R - R_m}{R + 1}\right)^{0.566}]$$

$$\frac{N_T - 7}{N_T + 1} = 0.75[1 - \left(\frac{1.86 - 1.24}{1.86 + 1}\right)^{0.566}]$$

$$N_T = 10$$

4.2.5 Calculate the actual number of stages

Column Efficiency: E_o

Average temperature of column = 78.33 °C

Feed viscosity at average temperature =μ_{avg} = 0.359 mPa.s

$$E_o = 51 - 32.5\log(\mu_{avg} * a_{avg})$$

$$E_o = 51 - 32.5\log(0.359 * 0.43)$$

$$E_o = 77.37\%$$

$$\text{No. of actual trays} = \frac{10}{0.774} = 13$$

4.2.6 Calculation of Location feed

$$\log\left(\frac{N_D}{N_B}\right) = 0.206\log\left[\frac{B}{D}\left(\frac{X_{HK}}{X_{LK}}\right)\left(\frac{X_{LKB}}{X_{HKD}}\right)^2\right]$$

$$\log\left(\frac{N_D}{N_B}\right) = 0.206\log\left[\frac{0.784}{0.0523}\left(\frac{0.22}{0.98}\right)^2\right]$$

$$N_D + N_B = 13$$

$N_D = 6$

$N_B = 7$

Vapor rate = D(1+R) = 76.48 (1+1.68) =204.96 kg/hr

Liquid flow above the feed, L = R×D = 1.68×76.48=128.4864 kg/hr

Liquid flow below the feed, L_o = (R×D) +F = (1.68×76.48) + 99.29

= 229.456 kg/hr

$$\rho_v = 1.53\frac{kg}{m^3} \ , \ \rho_L = 774.52 kg/m^3$$

$$F_{LV} = \left(\frac{L_n}{V_n}\right)\left(\frac{\rho_v}{\rho_L}\right)^{0.5}$$

$$F_{LV} = 0.05$$

Capacity parameter:

Assumed tray spacing H_s = 18in = 0.45m

From figure4.5, Csb (20) = 0.08 m/s (J.F. Richardson (2002), Particle Technology and Separation; Vol 2, Fifth edition)

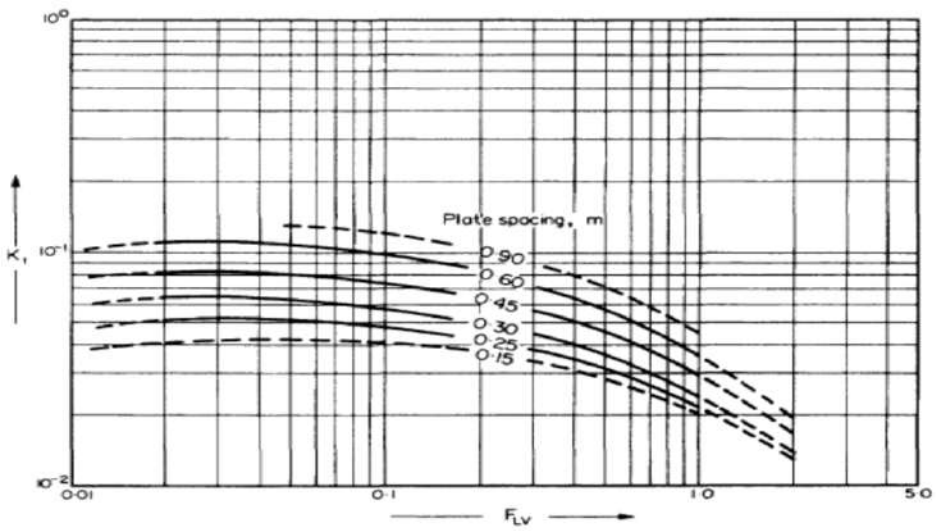


Figure 4.4 Correlation of flooding velocities for sieve trays.

$$V_{nf} = c_{sb}\left(\frac{\sigma}{20}\right)^{0.2}\left(\frac{\rho_l-\rho_v}{\rho_v}\right)^{0.5}$$

$$V_{nf} = 0.08\left(\frac{774.52 - 1.53}{1.53}\right)^{0.5}$$

$$V_{nf} = 1.79 \text{ m/s}$$

Assuming %90 flooding

$$V_n = 0.9 \times V_{nf}$$

$$V_n = 1.62 \text{ m/s}$$

$$Q_v = \frac{\text{vapor rate}}{\rho_v \times 3600} = 0.82 m^3/s$$

$$Q_L = \frac{L}{\rho_l \times 3600} = 0.08 \ m^3/s$$

4.2.7 Column diameter:

$$A_n = \frac{Qv}{Vn}$$

$$A_n = 0.6\ m^2$$

$$A_c = A_n + A_d$$

$$A_c = A_n + 0.15\ A_c$$

$$A_c = 0.717\ m^2$$

$$A_d = 0.107\ m$$

$$A_c = \frac{\pi}{4} d^2$$

$$d_c = 0.95\ m = 3\ ft$$

$$A_a = A_c - 2A_d$$

$$A_a = 0.503m$$

$$A_h = 10\%\ A_a$$

$$A_h = 0.0503m^2$$

$$\text{Wierr length} = \frac{Ad}{Ac}$$

$$\text{Wier length} = 0.149$$

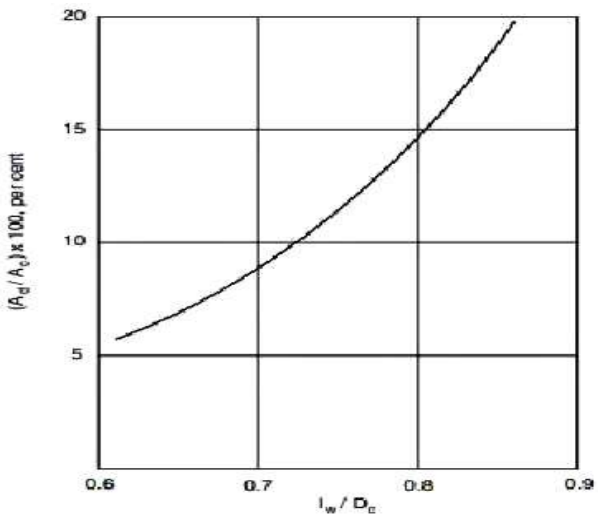


Figure 4.5 pitch (Sinnott R K,2005b)

From figure 4.5

$L_w/d_c = 0.77$

$L_w = 0.77*0.95 = 0.7315m$

$h_w = 50mm$

$d_h = 5mm$

Plate thickness = 5 mm

4.2.8 No. of holes

Area of 1hole = $\frac{\pi}{4} d_h^2$

Area of 1hole = 1.96×10^{-5} m^2

$$\text{N hole} = \frac{Ah}{Area\ of\ one\ hole}$$

N hole =2570

4.2.9 Height of distillation:

$$H_c = (N_{act} - 1)H_s + \Delta H + plate\ thickness$$

$$plate\ thickness = 0.005\ \times 13 = 0.065\ m$$

$$H_c = (13 - 1)0.5 + 1 + 0.065$$

$$H_c = 7m = 23\ ft$$

CHAPTER FIVE
ECONOMY

CHAPTER 5: ECONOMY

The economic analysis for fuel production from Sweet Potatoes will be Discussed in this chapter. The economic analysis's main goal is to find the Profitability of a process, that will decide if this process is economically favorable or not. The design engineer needs to be able to make quick, rough, cost estimates to decide between alternative designs and for project evaluation. the cost of production is needed before the profitability of a project can be assessed.

5.1 Reactor cost:

our reactor is Batch reactor, because of the high acidity and corrosivity materials we have to use stainless steel material for reactor interior. And for pressure

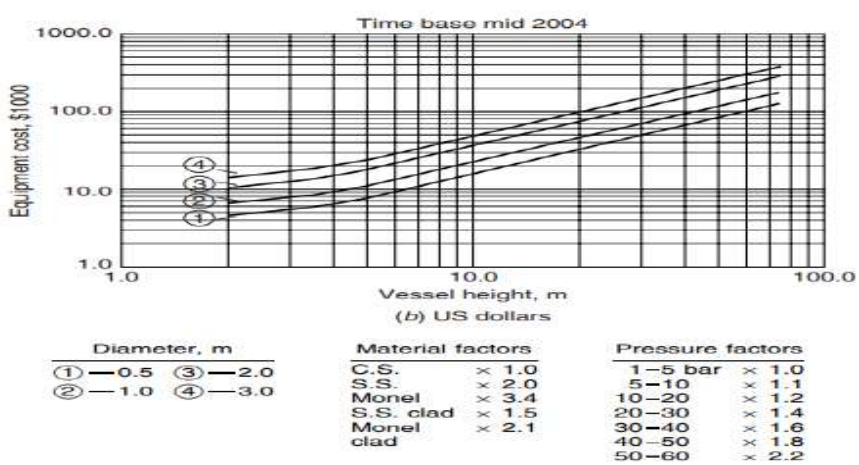


Figure 6.5*a*, *b*. Vertical pressure vessels. Time base mid-2004.
Purchased cost = (bare cost from figure) × Material factor × Pressure factor

figure 5.1 vertical pressure vessels

From (Figure 5.1) By height (1.3m) and diameter (2.06m)

We compute that equipment cost in 2004 is nearly 15000$

material factor stainless steel = 2

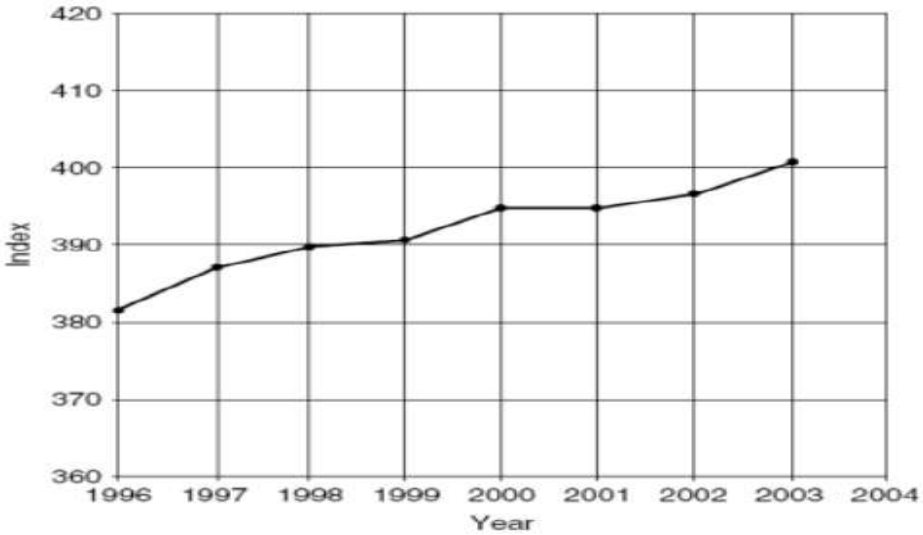


Figure 5.2 CPE Index

pressure factor (1 – 5 bar) = 1 bar

Vessel cost = 15000$ × 2 × 1 =30000$

From CPE Index figure (5.2):

Index in 1996 = 382

Index in 2004 = 401

The average increase in costs = $index\ in$ (2004−1996)/ $nYears$

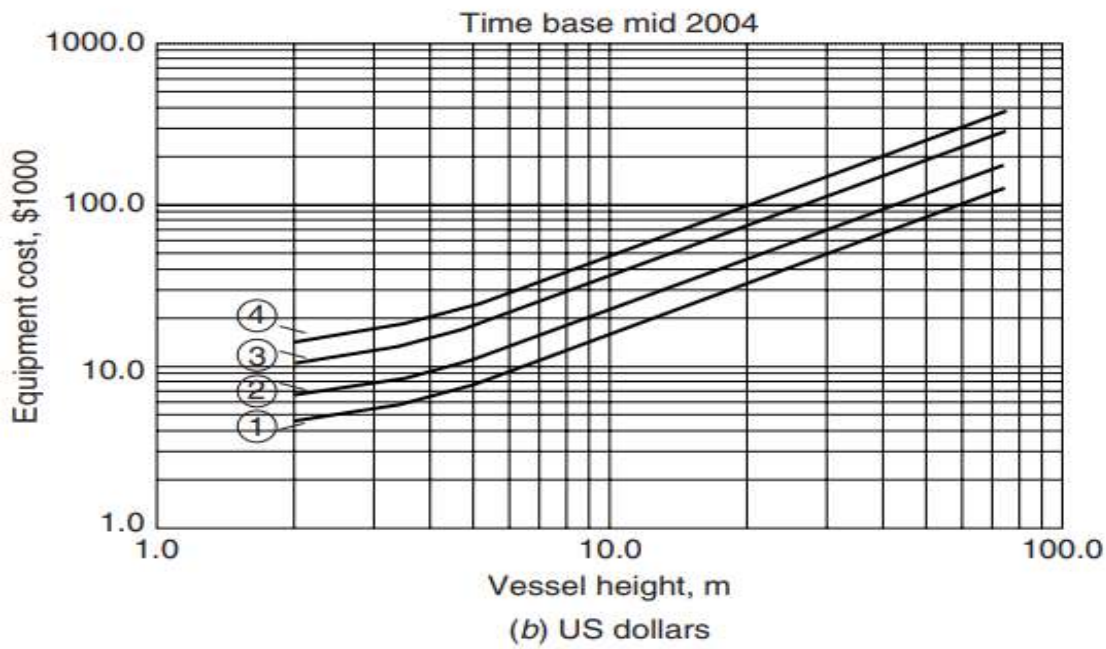
= (401−382) /7 = 2.71 per year

The cost index in 2023 = [19× 2.71] + 401 = 453.2

Cost of 2023 = 30000$ × [453.2/401] =33905$

5.2 Distillation Column cost

cost our distillation column which is a simple distillation , we use carbon steel material, and for pressure factor we use 1 bar.



Diameter, m	
① —0.5	③ —2.0
② —1.0	④ —3.0

Material factors	
C.S.	× 1.0
S.S.	× 2.0
Monel	× 3.4
S.S. clad	× 1.5
Monel clad	× 2.1

Pressure factors	
1–5 bar	× 1.0
5–10	× 1.1
10–20	× 1.2
20–30	× 1.4
30–40	× 1.6
40–50	× 1.8
50–60	× 2.2

Figure 6.5*a*, *b*. Vertical pressure vessels. Time base mid-2004.
Purchased cost = (bare cost from figure) × Material factor × Pressure factor

Figure (5.3) vertical pressure vessels.

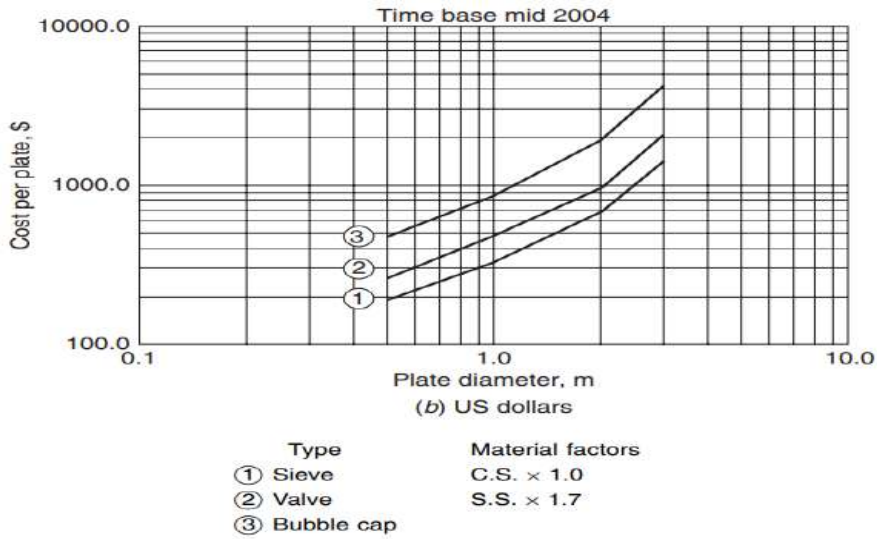


Figure 6.7*a*, *b*. Column plates. Time base mid-2004 (for column costs see Figure 6.4)
Installed cost = (cost from figure) × Material factor

Figure (5.4) column plates time base mid-2004

From (Figure 5.3) By height (7m) and diameter (0.95m)

We compute that equipment cost in 2004 is nearly 15000$

Material factor carbon steel = 1

Pressure factor (1 – 5 bar) = 1 bar

Vessel cost = 15000$× 1 × 1 =15000$

Cost of vessel in 2023 is nearly 16952$

From (Figure 5.4)

We compute that equipment cost in 2004 is nearly 400$

Material factor carbon steel = 1

Plate cost = 400$ × 1 =400 $

Plates cost = 400$×17 =6800 $

Plate cost in 2023 is nearly 7685$

Total Cost in 2023 = 7685$ +16952$ = 24637$

Total cost of equipment = 24637$+33905$

Final coast = 58542$

CHAPTER SIX
SAFETY AND HAZARD

CHAPTER SIX: SAFETY AND HAZARD

Ethanol can be harmful if inhaled or ingested, so it is important to handle it with care. If you are working with ethanol in a poorly ventilated area, use a fume hood or other ventilation system to help reduce your exposure to the substance.

When working with ethanol, it is important to follow all safety procedures and protocols. This includes reading and understanding the Material Safety Data Sheet (MSDS) and (NFPA Code) for the substance, as well as any other safety information provided by your employer or supervisor.

Diamond	Hazard	Value	Description
	Health	2	Can cause temporary incapacitation or residual injury.
	Flammability	3	Can be ignited under almost all ambient temperature conditions.
	Instability	0	Normally stable, even under fire conditions.
	Special		

Table 6.1 NFPA Code of Ethanol

6.1 POTENTIAL HAZARDS

Methods of extracting, transporting, processing, and refining gas and oil are complicated, often pose a great risk to both workers and assets. One common hazard is that of fire or explosion, resulting from the presence of flammable liquids and gases.

Fire or Explosion:

Flammable! Combustible material; may be ignited by heat, sparks or flames. Vapors may travel to a source of Ignition and flash back. Container may explode in heat of fire Vapor explosion hazard indoors, outdoors or in sewers Runoff to sewer may create fire or explosion hazard.

Health Hazards:

May be poisonous if inhaled or absorbed through skin. Vapors may cause dizziness or suffocation. Contact may irritate or burn skin and eyes. Fire may produce irritating or poisonous gases. Runoff from fire control or dilution water may cause pollution.

GHS Sign:

Globally Harmonized System is an identification of the product; a signal word – either Danger or Warning – where necessary · hazard statements, indicating the nature and degree of the risks.

Figure 6.1 GHS Sign

6.2 GHS chemical labels-Ethanol

Protect workers from potential chemical hazards with GHS signs Chemical safety signs help you comply with new GHS requirements Includes everything you need to know about chemical properties and potential harmful effects for both compliance and added workplace safety.

The sign ward is danger:

Figure 6.2 GHS chemical labels-Ethanol

6.3 Prevention

Keep away from heat / sparks / open flames / hot surfaces – No smoking. Keep container tightly closed. P240 Ground/bond container and receiving equipment.

Use explosion-proof electrical / ventilating / lighting equipment. Use only non-sparking tools. take precautionary measures against static discharge. Wear protective gloves / protective clothing /eye protection. Wash skin thoroughly after handling.

If on skin or hair remove/ take off immediately all contaminated clothing. Rinse skin with water.

If in Eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If eye irritation persists Get medical advice/attention.

In case of fire: Use powder, alcohol-resistant foam, lots of water, carbon dioxide for extinction. Store in a well-ventilated place. Keep cool.

Disposal: Dispose of contents / container to a specialized waste disposal plant in accordance with local / regional regulations

Main Hazard: Harmful if swallowed or inhaled. Possible aspiration hazard if swallowed (can enter lungs and cause damage). May be irritating to the skin, eyes and respiratory tract. Over exposure may cause CNS depression. Possible reproductive hazard.

Flammability: Flash Point 12ºC

6.4 Storge and Handling of Ethanol

Here is some additional information on the safety and health considerations when handling ethanol:

Ethanol is a highly flammable substance that can easily ignite if exposed to heat, sparks, or flames. It should be stored in a cool, dry place away from any sources of ignition such as open flames, electrical equipment, or hot surfaces**.**

Ethanol is not corrosive to metals and may be stored in stainless steel, mild steel or Aluminum containers. Ethanol may also be stored in HDPE containers.

First – Aid Measures:

Product in eyes: Flush immediately with water or neutral saline solution for at least 15 minutes. Seek medical attention.

Product on Skin: Remove contaminated clothing and rinse contaminated area with soap and water. If skin irritation persists, seek medical attention.

Product Ingested: If victim is conscious, give 1-3 glasses of water or milk to dilute stomach contents. If spontaneous vomiting occurs, or when vomiting is induced, monitor for breathing difficulty. Do not make an unconscious or semi – conscious person vomit. Keep affected person warm at rest. Get medical attention for substantial ingestions and/or gastrointestinal symptoms.

Product Inhaled: Remove the victim to fresh air. If not breathing, ensure open airway and institute cardiopulmonary resuscitation (CPR). If breathing is weak, irregular or has stopped apply artificial respiration. Oxygen may be beneficial. Keep affected person warm and at rest. Get immediate medical attention.

CONCLUSION:

This method is considered one of the best methods and its cost is low. We Recommend this method to investors because ethanol fuel saves us from fossil Fuels (petroleum) because it is environmentally friendly and can be used Easily. it seems like this process could be a promising alternative to traditional ethanol production methods. However, it will be important to continue researching and developing more efficient and cost-effective ways to produce bioethanol from sweet potatoes in order to make it a viable option for widespread use.

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