Bio-ethanol production from waste paper

Thesis submitted in partial fulfillment of the

requirements for the award of degree of

Bachelor of Science in Chemical Engineering

by

Hawa Hayru	ENGR/570/07
Hiwot Assaf	ENGR/601/07
Ikram Mohammedamin	ENGR/614/07
Rezika Tofike	ENGR/934/07
Seniya Nuredin	ENGR/994/07

Department of Chemical Engineering

College of Engineering and Technology

Wolkite University

Wolkite, Ethiopia

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Approved by	**Signature**
Mr.temechachew.T	______________
Advisor	
Dr.Hanna Birhanu	______________
Mr.Tamrat Getachew	______________
Examiner	
1. ______________	______________
2. ______________	______________
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ACRONYMS

AOC	Annual Operating Cost
BFD	Block Flow Diagram
DFC	Direct Fixed Capital Cost
GHG	Green House Gas
IRR	Internal Rate of Return
LPG	Liquefied Petroleum Gas
MSW	Municipal Solid Waste
NPV	Net Present Value
ROI	Return on Investment
ROR	Rate of Return
TCI	Total Capital Investment
TPC	Total Plant Cost
TPDC	Total Plant Direct Cost
TPIC	Total Plant Indirect Cost
U.S	United States

ABSTRACT

Biomass energy is renewable energy source that comes from the material of plants and animals. Forms of biomass energy are bioethanol, bio methanol, and biodiesel. Bioethanol is one of the most important alternative energy sources that substitute the fossil fuels. The focus of this research is to produce bioethanol from waste office paper. Five laboratory experiments were conducted to produce bioethanol from wastepaper. The wastepaper was dried in oven and cut in to pieces. Then it passed through dilute acid hydrolysis, fermentation and distillation process respectively. High amount of ethanol was observed at 20 ml/g (liquid to solid ratio) and at the time of 2hr. Cost and economic analysis for ethanol production from wastepaper was performed. Results from the analysis indicated a paper to ethanol plant was feasible from the economic point of view with rate of return (RR) 38.61% and the payback period of 2.2 years.

Keywords: Wastepaper, Hydrolysis, Fermentation, Distillation and Bioethanol.

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Energy is the prosperity that must be transferred to an object in order to perform work on or to the object. It can be classified in to renewable and non-renewable energy resource .Non - renewable energy are any energy resource that cannot be replaced during the time of a human life span .It takes thousands of years to form and exist in fixed amount in the earth. They need to be conserved before they become depleted. Examples of Non-renewable energy resources are nuclear energy and fossil fuels (coal, oil, natural gas). Renewable energy is the term used to cover those energy flows that occur naturally and repeatedly in the environment and can be harnessed for human benefit [23]. Biomass energy is a renewable energy resource that comes from the material of plants and animals, including their wastes and residues. Forms of biomass energy are bioethanol, bio methanol, and biodiesel.

Bioethanol is one of the most important alternative renewable energy source that substitute the fossil fuels due to its potential to reduce negative environmental impacts such as air pollution and greenhouse gas emission. Conventionally, bioethanol is produced from the fermentation of starchy materials or sucrose-containing feed stocks, such as corn, sugar cane, and honey. The yield of bioethanol from corn and sugar are high and the techniques are mature, however, it increases the risk of causing global food shortage [2]. In this context, an alternative to starch and sucrose based biofuels has been the production of ethanol from lignocellulosic materials such as weed, grass, saw dust, municipal solid waste, woody biomass, and paper mill waste.

Wastepaper consists of a considerable share of municipal and industrial waste even though recycling efforts have been strengthened in recent years by legal provisions like the Packaging directive. However, the recycling rate of wastepaper is low and the recycled wastepaper has a low grade paper product because of shorted fiber length.

Since the shortening of paper fibers decreases the quality of paper, the maximum ratio of paper-to-paper recycling is said to be 65% [10]. This means that a certain fraction of paper would always be sent to disposal. Still, wastepaper is considered as one of the prospective and renewable biomass materials to produce bioethanol. The reasons for this include: Waste papers are relatively abundant, They are economically competitive with other biomass feed stocks as they are relatively low costs, They contain relatively high levels of carbohydrates that are potential convertible to bioethanol, They are likely to be easily digestible without aggressive physical or chemical pre-treatments, Utilization of waste papers for bioethanol production may offer a useful and valuable alternative route to managing these papers in addition to/as a complement to recycling. Furthermore, Paper recycling technology itself has limitations, for example, effective deinking technology is needed to produce high quality paper products and recycling to paper is very difficult for wastepaper that has been mixed with other organic' waste (kitchen/garden waste etc.). Moreover, this alternative outlet for waste papers could help reduce pressure on other waste management options (i.e. recycling, incineration and landfill) from the increasing waste generation due to rising population [10].

1.2. Statement of the Problem

Due to the increase in the price of petroleum, crude oil and environmental concerns about air pollution caused by the combustion of fossil fuels, the search for alternative fuels has gained importance. Bio-energy is an alternative renewable energy. The production of ethanol, a type of bio-energy, has already occurred all over the world. Ethiopian government is promoting ethanol-benzene blend currently. However, the conventional raw materials are high value products, such as corn, wheat, cellulose, potato, and sugarcane. Feedstock, which have already found, use as food.75% food-material inflation (worldwide) is attributed to using conventional feedstock for ethanol production. To alleviate such problems, alternative and non-edible agricultural products such as lignocellulosic material which includes weed, grass, saw dust, municipal solid waste, woody biomass, and paper mill waste must be investigated.

Moreover, this alternative outlet for waste papers could help reduce pressure on other waste management options (i.e. recycling, incineration and landfill) from the increasing waste generation due to rising population and ultimately we create aesthetically very attractive city.

Therefore, the aim of this work is to investigate the possibility of using and transforming different waste papers to ethanol by fermentation using Saccharomyces cereviciae there by contributing towards alternative energy supply.

1.3. Objectives

1.3.1. General Objective

The main objective of this research is to produce bioethanol from wastepaper.

1.3.2. Specific Objectives

The specific objectives of this research are:

- Production of bio-ethanol from waste paper.
- To correlate the hydrolysis parameter.
- To perform material and energy balance.
- To do cost analysis.
- Feasibility study of the project.

1.4. Significance of the research

- ✓ Decrease the impact of greenhouse effect comparatively to fossil fuels.
- ✓ Provide job opportunity.
- ✓ Helps to reduce foreign currency.
- ✓ For sustainable development.

1.5. Scope of the study

This proposal work involves the collection of waste paper from Wolkite University. The study was began from literature review, developing of methodology, performing experiment to produce bio ethanol, market study to decide the capacity of ethanol production and economic analysis.

CHAPTER TWO

2. LITERATURE REVIEW

Energy is the prosperity that must be transferred to an object in order to perform work on or to the object. It can be classified in to renewable and non-renewable energy resource .Non - renewable energy are any energy resource that cannot be replaced during the time of a human life span .It takes thousands of years to form and exist in fixed amount in the earth. They need to be conserved before they become depleted. Examples of Non-renewable energy resources are nuclear energy and fossil fuels (coal, oil, natural gas).Renewable energy is the term used to cover those energy flows that occur naturally and repeatedly in the environment and can be harnessed for human benefit. Or renewable energy resources are any resource that cycles or can be replaced within a human life span [23].Example of renewable energy resources are biomass, hydro power, solar and wind energy. Biomass energy is any energy that comes from the material of plants and animals, including their wastes and residues. Forms of biomass energy are bioethanol, bio methanol, and biodiesel.

2.1. Bio-ethanol

Bioethanol is a fuel derived from renewable sources of feedstock. It is a colorless, flammable, volatile liquid with a strong odor. Ethanol was first prepared synthetically in 1826, through the independent effort of Henry Hennel in Britain and S.G in France. Michael Faraday prepared ethanol by the acid-catalyzed hydration of ethylene in 1828, in a process similar to that used for industrial synthesis of ethanol today [13].

2.1.1. Properties of Ethanol

Ethanol or ethyl alcohol, CH_3CH_2OH, has been described as one of the most exotic synthetic oxygen-containing organic chemicals because of its unique combination of properties as a solvent, germicide, beverage, antifreeze, fuel, depressant, and especially because of its versatility as a chemical intermediate for other organic chemicals[7]. Ethanol under ordinary condition is a volatile, flammable, clear, colorless liquid. Its odor is pleasant, familiar, and characteristic, as is its taste when it is suitably diluted with water.

The physical and chemical properties of ethanol are primarily dependent upon the hydroxyl group. This group imparts polarity to the molecule and also gives rise to intermolecular hydrogen bonding.

The melting point of ethanol is –114.1°C, whereas it boils at 78.5°C. It is miscible with water in all proportions. Ethanol that is completely free of water is called absolute ethanol.

Ethanol forms a constant-boiling mixture, with water that contains 95 % ethanol and 5 % water and that boils at 78.15 °C [7].

Table 2.1.Physical and chemical properties of: - ethanol, methanol and gasoline Source :*(Stokes, 2005).*

Property	Methanol	Ethanol	Gasoline
Molecular weight (g/mol)	32	46	114
Specific gravity	0.789	0.788	0.739
Vapor density (rel. to air)	1.10	1.59	3-4
Liquid density(g/cm3)	0.79	0.79	0.74
Boiling Point(K)	338	351	300-518
Melting point(K)	175	129	-
Heat vaporization (btu/lb)	472	410	135
Heating value(kBTU /gal)			
Lower	58	74	111
Upper	65	85	122
Tank Design Pressure(Psig)	15	15	15
Viscosity (cp)	0.54	1.2	0.56
Flash point(K)	284	284	228
Flammability limits			
Lower	6.7	3.3	1.3
Upper	36	19	7.6
Auto ignition	733	636	523-733
Temperature(k)	None	95%EtOH	Immiscible
Peak flame temperature(k)	2143	2143	2303
Minimum ignition energy in air(mJ)	0.14	0.23	-

2.1.2. Uses of Ethanol

Bio-ethanol as a Sustainable Fuel

The alcohol molecule has one or more oxygen, which decreases to the combustion heat. Practically, any of the organic molecules of the alcohol family can be used as a fuel.

The alcohols that can be used for motor fuels are methanol (CH_3OH), bio-ethanol (C_2H_5OH), propanol (C_3H_7OH), butanol (C_4H_9OH). However, only methanol and bio-ethanol fuels are technically and economically suitable for internal combustion engines (ICEs).The main use of ethanol is as a motor fuel and fuel additive. Efficient method for conversion of biomass into fuel is by ethanol production because ethanol is an economical as well as environmentally friendly fuel. Ethanol has the advantages of being renewable, cleaner burning and produces no GHG. Bio-ethanol is appropriate for the mixed fuel in the gasoline engine due to its high octane number, and high heat of vaporization impede self-ignition in the diesel engine. So, ignition improver, glow-plug, surface ignition, and pilot injection are applied to promote self-ignition by using diesel–bio-ethanol blended fuel [7].

Ethanol blends are increasingly used in South Africa, while Brazil, the world leader, produces four billion gallons of ethanol a year: all Brazilian fuel contains at least 24% ethanol, and much of it is 100% ethanol (engines can be designed to run on 100% ethanol) [21].

Other Uses of Bio-ethanol

One of the major uses of ethanol is in alcoholic beverages. Alcoholic beverages vary considerably in their ethanol content and in the foodstuffs from which they are produced. Most alcoholic beverages can be broadly classified as fermented beverages, beverages made by the action of yeast on sugary foodstuffs, or as distilled beverages, beverages whose preparation involves concentrating the ethanol in fermented beverages by distillation. Fermented beverages may contain up to 15–20 % ethanol by volume, the upper limit being set by the yeast's tolerance for ethanol, or by the amount of sugar in the starting material [7].

Absolute ethanol and 95 % ethanol are themselves good solvents, somewhat less polar than water and used in perfumes, paints and tinctures. Ethanol is used in medical wipes and in most common antibacterial hand sanitizer gels at a concentration of about 62 %.

Aside from fuel and beverage, ethanol has other applications in various industry branches such as: Personal care products, cleaning agents, as anti-freeze in automobile radiator, as raw material in the manufacturing of acetaldehyde, acetic acid, ethylene, glycol, dyes, detergents and cleaning solution, and pharmaceuticals(e.g. in the preparation of cough syrups and antiseptics).

2.4. Production of Bio-ethanol

Ethanol is produced from biomass both as petrochemical through the hydration of ethylene, and biologically, by fermenting sugars with yeast. Ethanol for use as industrial feedstock is most often made from petrochemical feedstock, typically by the acid-catalyzed hydration of ethylene, represented by the chemical equation:

$$C_2H_4 + H_2O \rightarrow CH_3CH_2OH$$

The catalyst is most commonly phosphoric acid, adsorbed onto a porous support such as diatomaceous earth or charcoal [7]. Ethanol for beverages, and fuel, is mainly produced by fermentation. The process of fermentation is carried out by certain species of yeast, (commonly, S. cerevisiae). When S. cerevisiae metabolizes sugar an-aerobically, they produce ethanol and carbon dioxide. The overall chemical reaction conducted by the yeast may be represented by equation below:

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

The process of culturing yeast under anaerobic conditions to produce alcohol is referred to as brewing. Brewing can only produce relatively dilute concentrations of ethanol in water since concentrated ethanol solutions are toxic to yeast. The most ethanol tolerant strains of yeast can survive up to about 25% ethanol (v/v) [7].

The three main groups of raw materials for production of ethanol by fermentation are: sucrose containing feedstock, starch materials, and lignocellulosic materials.

Sugar-containing raw materials: include sugarcane, sugar beets, fruits, sweet sorghum, and molasses. The advantage with the sugar-based raw materials is that they can be converted into ethanol directly without the use of hydrolysis. A disadvantage is that many of these raw materials are considered to be a human food resource and will therefore be too expensive to use for fuel ethanol production.

Starch-based materials: that commonly are used for ethanol production include corn, milo, wheat, rice, potatoes, cassava, sweet potatoes, barley, and various cereal grains. Prior to fermentation, the starch must be converted to sugars.

Starch hydrolysis is typically performed by cooking the starch at high and low temperatures. Dextrin oligosaccharides are generated by adding α-amylase and gluco-amylase is added to obtain glucose.

A disadvantage of using starch based materials for ethanol production is that the hydrolysis cost is high due to high energy costs of the cooking step and high costs for the amylolytic enzymes. These raw materials are also considered to be a human food resource. Moreover, the demand for these feed stocks impacts negatively on the production of other agricultural crops where, for example, prime agricultural land formerly used to cultivate wheat is converted to maize cultivation for bio-ethanol production, thereby directly decreasing the availability of wheat and indirectly increasing its price. Thus, for bio-ethanol to be economically sustainable on a global scale, biomass sources that are abundant in nature and do not compete as food or for agricultural land, must be explored [25].

Lignocellulose-based feed stocks: that can be considered for ethanol productions are wood residues, agricultural residues, and spent sulfite liquor from pulp and paper mills. The advantages of using lignocellulose as the raw material for ethanol production are their abundance and they are relatively cheap. A disadvantage is that lignocelluloses are relatively recalcitrant to hydrolysis. Production of ethanol from lignocellulosic waste materials, such as sawdust from the forestry industry, benefits from the fact that the energy input for the overall process can be kept low. Energy-related expenses for planting, fertilization and harvesting can be avoided if waste materials are used. If lignocellulosic waste materials are used, there will not be any competition for the limited agricultural land available, which instead might be needed for food production.

2.5. Lignocellulosic Feedstock for Ethanol Fermentation

2.5.1. Availability of Lignocellulosic Material

Lignocellulose is the most abundant renewable biomass; its annual production has been estimated in 1 × 1010 MT worldwide [3].The price of the raw materials is also highly volatile, which can highly affect the production costs of the bioethanol [29].

Lignocellulosic materials serve as a cheap and abundant feedstock, which is required to produce fuel bioethanol from renewable resources at reasonable costs. Lignocellulosic materials can be classified in four groups based on type of resource: forest residues, municipal solid waste, wastepaper, and crop residue resources. Literature reports several papers on utilization of various lignocellulosic waste materials such as rice straw , switch grass, palm bagasse, etc.[1].

Lignocellulosic materials could produce up to 442 billion liters per year of bioethanol. Rice straw is one of the abundant lignocellulosic waste materials in the world. It is annually produced about 731 million tons which is distributed in Africa (20.9 million tons), Asia (667.6 million tons), Europe (3.9 million tons), America (37.2 million tons) and Oceania (1.7 million tons). This amount of rice straw can potentially produce 205 billion liters bioethanol per year, which is the largest amount from a single biomass feedstock.

Lignocellulosic materials can be derived from wood, grasses, agricultural residues, and waste materials. The table 2.3 shows the contents of cellulose, hemicellulose and lignin for different lignocellulosic materials.

Table 2.2. Composition of Cellulose, Hemicellulose and Lignin for different Lignocellulosic materials Sources: *(Ye Sen et al, 2002).*

Lignocellulosic Materials	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Hard wood	40-55	24-40	18-25
Softwood stems	45-50	25-35	25-35
Switch grass	45	31.4	12-20
Coastal Bermuda grass	25	35.7	9-18
Wheat straw	30	50	15
Rice straw	36-47	19-25	10-24
Cotton seed hairs	80-95	5-20	0
Newspaper	40-55	25-40	18-30
White paper	85-99	0	0-15

2.5.2. Chemical Structure and Basic Components of Lignocellulosic Materials

Chemical composition of lignocellulosic materials is a key factor affecting efficiency of bio-fuel of lignocellulosic materials is highly variable because of genetic and environmental influences and their interactions. A typical chemical composition of lignocellulosic materials is 48 wt. % C, 6 wt. % H, and 45 wt. % O, the inorganic matter being a minor component [17].

The structural materials that plants produce to form the cell walls, leaves, stems, stalks, and woody portions of biomass are composed mainly of cellulose, hemicellulose, and lignin. Together, they are called lignocellulose, a composite material of rigid cellulose fibers embedded in a cross-linked matrix of lignin and hemicellulose that bind the fibers.

Except for the three major components above, lignocellulosic biomass also contains extractives, which refer to the organic substances which have low molecular weight and are soluble in neutral solvents. Resins, fats, waxes, fatty acids and alcohols, salts, minerals, and other compounds are categorized as extractives. Moreover, the residue remaining after ignition (dry oxidation at 575.25℃) of lignocellulosic biomass is ash, which is composed of minerals such as silicon, aluminum, calcium, potassium, and sodium [16].

i. **Cellulose:** the major component of plant biomass (30–60% of total feedstock dry matter), is a higher molecular weight linear polymer composed of D-glucose building blocks, joined by β1,4-glucosidic bonds. In native cellulose, each cellulose molecule is a long un-branched chain of D-glucose subunits with molecular weight ranging from 50,000 to over 1 million. These molecules, along with hemicellulose and lignin, are aggregated into long bundles called micro fibrils.

   Hydrogen bonding binds the cellulose molecules. As a result, these fibers are composed of a crystalline or highly-ordered region that protects the micro fibrils from hydrolytic degradation and a less ordered, amorphous region. The amorphous component is digested more easily by enzymatic attack than the crystalline component. This results in a difference in reactivity and adsorption that may result from variation in crystal structure, accessibility to the enzyme, and the degree of polymerization. In hydrolysis the polysaccharide is broken down to free sugar molecules by the addition of water. This process is also known as saccharification. The product, glucose, is a six-carbon sugar.

ii. **Hemicellulose** (20–40% of total feedstock dry matter) is a short, highly branched polymer of five-carbon (pentoses) and six-carbon (hexoses) sugars.
Specifically, hemicellulose contains Dxylose and L-arabinose (five-carbon sugars) and D-galactose, D-glucose, and D- mannose (sixcarbon sugars), and also of different uronicacids. The degree of polymerization of hemicellulose is on average about 100-200 and the molecules can be highly branched. Hemicellulose is more readily hydrolyzed compared to cellulose because of its branched, amorphous nature [12].

iii. **Lignin** (15–25% of total feedstock dry matter) is complex aromatic polymer consisting of phenylpropane units linked together by ether or carbon-carbon bonds. There are three main precursors of lignin biosynthesis; p-coumaryl alcohol, coniferyl alcohol and sinapyl alcohol. Lignins can be classified according to their structural elements. Guaiacyl lignin is to a high extent a polymer of coniferyl alcohol and is common in softwood. Guaiacyl-syringyl lignin is common in hardwood and is a polymer of coniferyl alcohol, and sinapyl alcohol. Lignin is one of the drawbacks of using lignocellulosic-biomass materials in fermentation, as it makes lignocellulose resistant to chemical and biological degradation.

iv. **Extractives** are a group of chemicals that can be extracted from wood by the use of various solvents. The extractives can be categorized as steroids, fats, waxes, and phenolic constituents.

2.5.3. Composition of Paper Samples

Table 2.3 presents composition of samples of newspaper, office paper, magazines, and cardboard analyzed by L. Wang et al [14]. Carbohydrates are expressed as a proportion of the oven dry weight of the wastepaper in their polymerized forms as glucan, xylan,galactan, mannan and arabinan. The concentration of the total carbohydrates as an available source for bio-ethanol production is in the range of 50.1–76.6%. The variations in composition of these types of paper are due to the different raw wood sources and paper making processes. With office paper as exception, newspaper, magazine and cardboard contain a considerable amount of xylan, galactan and mannan indicating the presence of hemicelluloses but in a lower fraction when compared with woody materials containing between 20% and 25% of hemicellulose [15].

The glucose is easily and efficiently converted into ethanol, while the xylose is more difficult to convert. The higher percentage of xylose in wood, approximately 25%, makes it worthwhile to include xylose fermentation in the process.

But because of the much lower amounts in wastepaper, it does not appear economical to include this step in the wastepaper process. Some of the xylose is consumed in the production of enzymes, but most of it and the other non-glucose sugars are an-aerobically digested to methane, which is burned for process energy.

Table 2.3. Compositions (weight percent [wt %] on dry basis) of wastepaper samples Source *(L. Wang et al., 2012).*

Composition	Newspaper	Office paper	Magazine	Cardboard
Glucan	47.26	64.49	35.91	52.61
Xylan	7.11	12.16	4.72	8.23
Galacta	1.9	0.0	1.98	1.89
Mannan	7.31	0.0	5.67	
Arabinan	1.86	0.0	1.82	1.55
Total carbohydrates	65.44	76.65	50.10	69.36
Lignin	18.14	9.76	14.83	15.77
Ash	16.42	13.59	35.07	14.88

2.5.4. Non-paper Components of Wastepaper

The fraction of wastepaper that is not paper, such as the ink, fillers, coatings, adhesives, and contaminants that may be present, may have a significant impact on process operation and cost. Printing inks are mixtures of three basic ingredients: a vehicle to carry and help bond the pigment to the paper, the pigment, and various additives. Petrochemical derivatives make up 80% of these materials. According to information from the American Newspaper Publishers Association [4], printing ink accounts for 1%-2% of the weight of newspapers and is composed of 55%-85% petroleum or vegetable oil, 6%-20% pigment, and 0%-20% resin.

The vegetable oil, e.g. soybean oil, now accounts for only 2% of the market. The resin component is almost exclusively man-made isoprene hydrocarbon condensation material. Coatings and fillers are used to provide the appropriate surface qualities for ink and to give the paper product the desired look. Newspaper is the lowest quality grade of paper and has the least content of coating and filler.

The amount of coating and filler varies considerably among the numerous grades of printing and writing paper, but can account for up to 30% of the weight of the paper [20]. Generally, the percent tends to increase as the quality and, therefore, the cost of the finished product increases. Coatings and fillers are composed mostly of benign materials such as clay, calcium carbonate, and titanium dioxide.

2.5.6. Estimates of Potential Ethanol Production from Wastepaper

Projections of how much wastepaper will ultimately be available for ethanol production depend on the total amount of wastepaper generated, the fraction of the total that can be economically recovered, and the competition for the recoverable portion-factors .Overall, the amount generated depends directly on the amount of paper and paperboard products consumed, and reasonably accurate predictions of this are easily obtained. The economically recoverable fraction and the competition for that fraction are less easily predicted. The paper and paperboard industry, domestic and foreign, is by far the largest consumer of wastepaper and because of its potential appetite the prices it is willing to pay should determine wastepaper prices for much of the wastepaper supply.

The world in the 21st century is facing a dual crisis of increasing waste and global climate change. Substituting fossil fuels with waste biomass-derived cellulosic ethanol is a promising strategy to simultaneously meet part of our energy needs, mitigate GHG emissions, and manage municipal solid waste (MSW). However, the global potential of MSW as an energy source is as yet un-quantified. Riley and Bergeron (1991) reported increasing trends of MSW generation, and waste biomass-derived cellulosic ethanol potentials in relation to socio-economic development across 173 countries, and show that globally, up to 82.9 billion liters of wastepaper-derived cellulosic ethanol can be produced worldwide, replacing 5.36% of gasoline consumption, with accompanying GHG emissions savings of between 29.2% and 86.1%.

2.6. Pathways of Bioethanol Production from Cellulosic Feedstock

The basic process steps in producing bioethanol from lignocellulosic materials are pretreatment to enhance biomass digestibility, hydrolysis of cellulose to sugar monomers, fermentation of sugars to ethanol, and recovery of ethanol by distillation/evaporation from process stream.

Bioconversion of lignocellosics to bioethanol is difficult due to: the resistant nature of biomass to breakdown, the variety of sugars which are released when the hemicellulose and cellulose polymers are broken and the need to find or genetically engineer organisms to efficiently ferment these sugars, costs for collection and storage of low density lignocellosic materials [2].

2.6.1. Pretreatment of Lignocellulosic Materials

The recalcitrance of lignocellulose is one of the major barriers to the economical production of bioethanol. The technical approach to overcome recalcitrance has been pretreatment of biomass feedstock to remove lignin and hemicellulose, reduce cellulose crystallinity, and increase the porosity of the materials. Pretreatment is crucial for ensuring good ultimate yields of sugars from both polysaccharides. [5].

Since lignocellulosic materials have complex structures, their pretreatment is not simple. Pretreatment can be the most expensive stage in the biomass- to-ethanol process. However, there is potential for improvements in the areas of efficiency and cost reduction through further research and development. Several methods have been introduced for pretreatment of lignocellulosic materials prior to enzymatic hydrolysis or digestion. These methods are classified into Physical pretreatment, Chemical pretreatment, and Biological pretreatment.

2.6.1.1. Physical Pretreatment

Physical pretreatment can increase the accessible surface area and size of pores, and decrease the crystallinity and degrees of polymerization of cellulose. Several mechanical and non-mechanical methods can be used for the physical pretreatment of biomass.

Mechanical methods involve biomass comminution by a combination of chipping, grinding and milling to reduce biomass size and cellulose crystalline. The energy required for mechanical pretreatment depends on the final particle size and biomass characteristics. Power requirements increase rapidly with decreasing particle size.

Non-mechanical methods such as irradiation have also been tested. Irradiation of the cellulose by gamma-rays results in the cleavage of β-1,4- glycosidic bonds, giving a larger surface area and lower crystallinity. This method is, however, far too expensive to be used in a full-scale process and doubts remain about its feasibility [5].

2.6.1.2. Chemical Pretreatment

Acid Pretreatment

Concentrated acids such as H_2SO_4 and HCl have been used to treat lignocellulosic materials. Although they are powerful agents for cellulose hydrolysis, concentrated acids are toxic, corrosive and hazardous and require reactors that are resistant to corrosion. In addition, the concentrated acid must be recovered after hydrolysis to make the process economically feasible. Dilute acid hydrolysis has been successfully developed for pretreatment of lignocellulosic materials. The dilute sulfuric acid pretreatment can achieve high reaction rates and significantly improve cellulose hydrolysis.

Alkaline Pretreatment

Some bases can also be used for pretreatment of lignocellulosic materials and the effect of alkaline pretreatment depends on the lignin content of the materials. The mechanism of alkaline hydrolysis is believed to be saponification of intermolecular ester bonds crosslinking xylan hemicelluloses and other components, for example, lignin and other hemicelluloses. Dilute NaOH treatment of lignocellulosic materials caused swelling, leading to an increase in internal surface area, a decrease in the degree of polymerization, a decrease in crystallinity, separation of structural linkages between lignin and carbohydrates, and disruption of the lignin structure.

2.6.1.3. Biological Pretreatment

Microorganisms can also be used to treat the lignocelluloses and enhance enzymatic hydrolysis. The applied microorganisms usually degrade lignin and hemicellulose but very little part of cellulose, since cellulose is more resistance than the other parts of lignocelluloses to the biological attack. Several fungi, e.g. brown-, white- and soft-rot fungi, have been used for this purpose. White-rot fungi are among the most effective microorganisms for biological pretreatment of lignocelluloses.

In general, biological treatment offer advantages such as low-capital cost, low energy, no chemicals requirement, and mild environmental conditions. However, the main drawback to develop biological methods is the low hydrolysis rate obtained in most biological materials compared to other technologies.

2.6.2. Hydrolysis (Saccharification) Techniques

Cellulose hydrolysis (saccharification) is the process of turning polymeric lignocellulosic materials into fermentable sugars. Acid hydrolysis and enzymatic hydrolysis are currently the main two processes used to create fermentable sugars from cellulosic biomass. Several products can result from hydrolysis of lignocellulosic material. When hemicelluloses are hydrolyzed to xylose, mannose, acetic acid, galactose, and glucose are liberated.

Degradation of xylan yields eight main products: water, methanol, formic, acetic, and propionic acids, hydroxy-1-propanone, hydroxy-1-butanone and 2-furfuraldeyde.Under high temperature and pressure xylose is further degraded to furfural. Similarly, 5-hydroxymethyl furfural is formed from hexose degradation. Cellulose is hydrolyzed to glucose [1].

2.6.2.1. Chemical Hydrolysis

Chemical hydrolysis involves exposure of lignocelluloses materials to a chemical for a period of time at a specific temperature, and results in sugar monomers from cellulose and hemicelluloses polymers. In the chemical hydrolysis, the pretreatment and the hydrolysis may be carried out in a single step. Acids are predominantly applied in chemical hydrolysis. There are two basic types of acid hydrolysis processes: dilute acid and concentrated acid, each with variations.

Dilute Acid Hydrolysis

Dilute acid hydrolysis is the oldest technology for converting cellulose biomass to bioethanol. The dilute acid process is conducted under high temperature and pressure, and has a reaction time in the range of seconds or minutes, which facilitates continuous processing. Dilute acid process involves a solution of about 1% H_2SO_4 concentration in a continuous flow reactor at a high temperature (about 488K). The combination of acid and high temperature and pressure dictate special reactor materials, which can make the reactor expensive. The biggest advantage of dilute acid processes is their fast rate of reaction, which facilitates continuous processing [5].

The primary challenge for dilute acid hydrolysis processes is how to raise glucose yields higher than 70% in an economically viable industrial process while maintaining a high cellulose hydrolysis rate and minimizing glucose decomposition. For rapid continuous processes, in order to allow adequate acid penetration, feed stocks must also be reduced in size so that the maximum particle dimension is in the range of a few millimeters [2].

Concentrated Acid Hydrolysis

Hydrolysis of cellulosic materials by concentrated sulfuric or hydrochloric acids is a relatively old process. The concentrated acid process uses relatively mild temperatures, and the only pressures involved are those created by pumping materials from vessel to vessel. Reaction times are typically much longer than for dilute acid [5]. This method generally uses concentrated sulfuric acid followed by a dilution with water to dissolve and hydrolyze or convert the substrate into sugar. Strong acid hydrolysis usually separates and recycles the acid catalyst, limiting the total acid losses to approximately 3%, or the same as the dilute process. Use of the concentrated acid, however, allows lower temperature and pressure hydrolysis with fewer byproducts produced. Concentrated hydrochloric acid at a concentration of about 47 % is sometimes used for strong acid hydrolysis because it is relatively easy to recover.

2.6.2.2. Enzymatic Hydrolysis

Acid hydrolysis has a major disadvantage where the sugars are converted to degradation products like tars. This degradation can be prevented by using enzymes favoring 100% selective conversion of cellulose to glucose.

When hydrolysis is catalyzed by such enzymes, the process is known as enzymatic hydrolysis. Enzymatic hydrolysis is an environmentally friendly alternative that involves using carbohydrate degrading enzymes (cellulases and hemicellulases) to hydrolyze lignocelluloses into fermentable sugars.

The products of the hydrolysis are usually reducing sugars including glucose. Enzymatic hydrolysis of natural lignocellulosic materials is a very slow process because cellulose hydrolysis is hindered by structural parameters of the substrate, such as lignin and hemicellulose content, surface area, and cellulose crystallinity.

2.6.3. Fermentation

Fermentation is a metabolic process of microorganisms to obtain energy by breaking down organic compounds. While microorganisms derive their energy, some byproducts are: lactic acid, butane, carbon dioxide, ethanol, cellulose.

Lignocellulose is often hydrolyzed by acid treatment. The hydrolysate obtained is then used for bioethanol fermentation by microorganisms such as yeast. Because such lignocellulose hydrolysate contains not only glucose, but also various monosaccharaides, such as xylose, mannose, galactose, arabinose, and oligosaccharides, microorganisms should be required to efficiently ferment these sugars for the successful industrial production of bioethanol. In general, the conversion of lignocellulosic material to sugar and then ethanol is governed by equation below: $(C_6H_{10}O_5)_n + nH2O \rightarrow nC_6H_{12}O_6 + \text{yeast} \rightarrow 2nC_2H_5OH + 2nCO_2$

2.6.3.1. Microorganisms Suitable for Bioethanol Production

Microorganisms meet their energy demand by converting the carbon sources to by-products such as: carbon dioxide, lactic acid, ethanol, cellulose. Ethanol is one of the end products of fermentation, which can be performed by either bacteria or yeasts.

Saccharomyces cerevisiae (baker‘s yeast) is the preferred choice due to its ability to produce ethanol up to concentrations reaching 18% (w/v) and its high tolerance of up to 150 g ethanol. However, S. cerevisiae is unable to ferment the hemicellulose-derived pentoses such as xylose and arabinose and is, therefore, of limited use for lignocellulose substrates with a high content of such sugars [5].

2.6.4. Product and Solids Recovery

Distillation technologies that will allow the economic recovery of dilute volatile products from streams containing a variety of impurities have been developed and commercially demonstrated [18].A distillation system separates the bioethanol from water in the liquid mixture.

Water content of the fermentation product is generally higher than 80%. Large quantities of energy are required to concentrate the ethanol to 95% [11]. The maximum concentration of bioethanol tolerated by the microorganisms is about 10 wt. % at 303 K but decreases with increasing temperature [8].

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Equipment and Chemicals

Equipment used

- ✓ Autoclave
- ✓ Centrifuge
- ✓ Digital Balance
- ✓ Digital PH meter
- ✓ Flasks of different volumes
- ✓ Graduated cylinders of different volumes
- ✓ Incubator
- ✓ Rotary evaporator
- ✓ Scissor

Chemicals

- ✓ 5M sodium hydroxide (NaOH) solution
- ✓ 98% sulfuric acid (H_2SO_4)
- ✓ Distilled water
- ✓ Dry instant yeast (saccharomyces cerevisiae)
- ✓ Potassium dichromate

Raw Material Preparation

- ✓ Waste paper which was collected from Wolkite University.

3.2. Methods

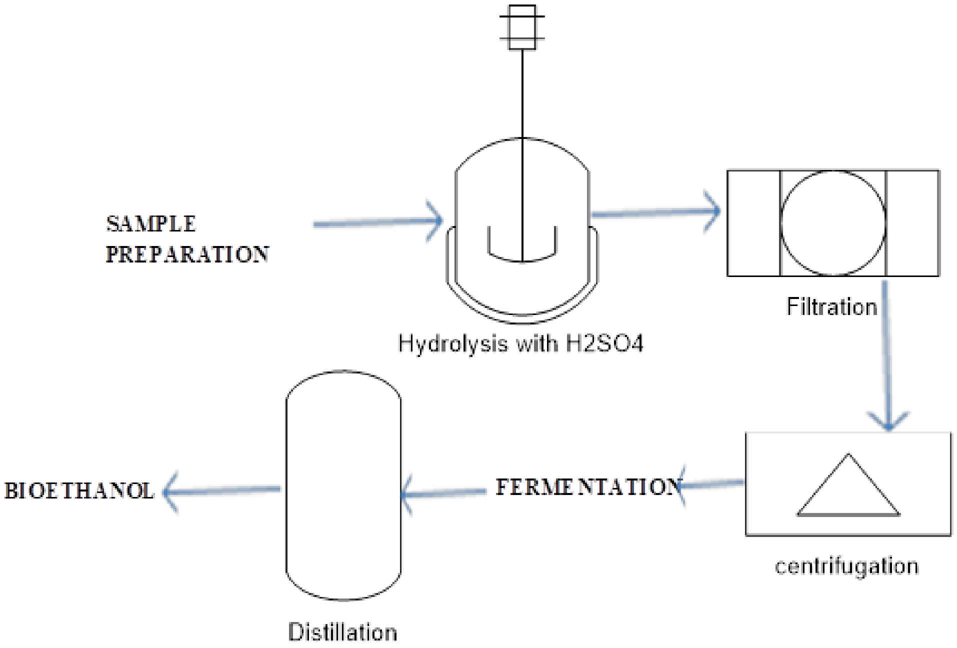


Figure3.1.Block Flow Diagram for Production of Bio-ethanol from waste paper

3.2.1. Sample Preparation

Waste office papers were collected locally in Wolkite university. The wastepaper was dried in tray dryer (60 ^{0}C for 48hr). The sample was cut in to pieces by using scissor. The cut material was kept at desiccator until the next stage of experiment in order to remove contact with the atmosphere. Cutting of the sample wastepaper into pieces increases the surface area of the sample which enhances the contact between hemicellulose and cellulose with dilute acid.

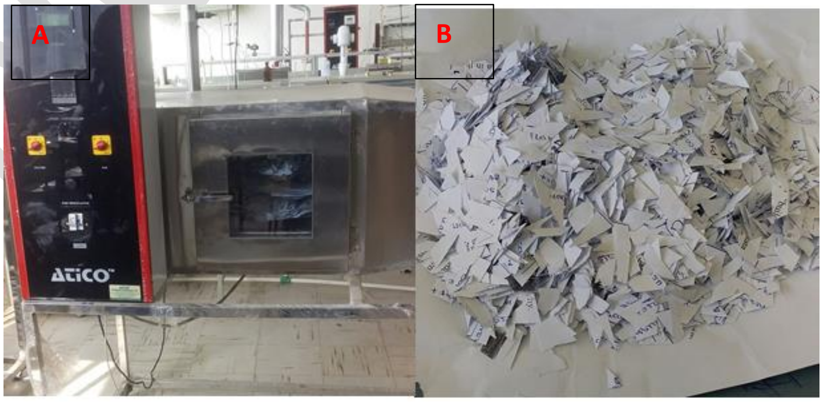


Figure 3.2.Sample preparation, (A) Sample on tray dryer, (B) Sample cutting.

3.2.2. Dilute Acid Hydrolysis

The carbohydrate polymers in lignocellulosic materials need to be converted to simple sugars before fermentation, through a process called hydrolysis. Even though there are many types of hydrolysis types, dilute acid hydrolysis is an easy and productive process and the amount of alcohol produced in case of acid hydrolysis is more than that of alkaline hydrolysis.

This process is conducted under high temperature and pressure, and has a reaction time in the range of seconds or minutes, which facilitates continuous processing. The experimental conditions of the different test carried out and the observed hydrolysis time and acid volume in each experiment was shown by table 3.1.

Table 3.1. Experimental hydrolysis parameters

Test	Liquid to solid ratio(ml/gm)	Time(min)
1	20	60
2	20	120
3	20	180
4	10	120
5	30	120

Acid hydrolysis was done to break down cellulose into glucose units. Experiments were carried out by using different volume of flasks. For that, 10 g of paper was soaked in different amounts of H_2SO_4 (5% weight): 200 and 300 mL [98% sulfuric acid (by volume to water) was diluted to 5% concentration]. The mixture was placed in an autoclave at 121 ºC. The influence of time on the process was determined in the rage of 60-180 min. After hydrolysis, the samples were filtered and centrifuged to separate the solid particles from the liquid in the hydrolyzate (remove the non-fermentable lignin portion) and to obtain the hydrolyzate product as shown in the figure below. After that, the pH of the obtained product was adjusted at 4.5-5.5 by adding sodium hydroxide solution 5M.

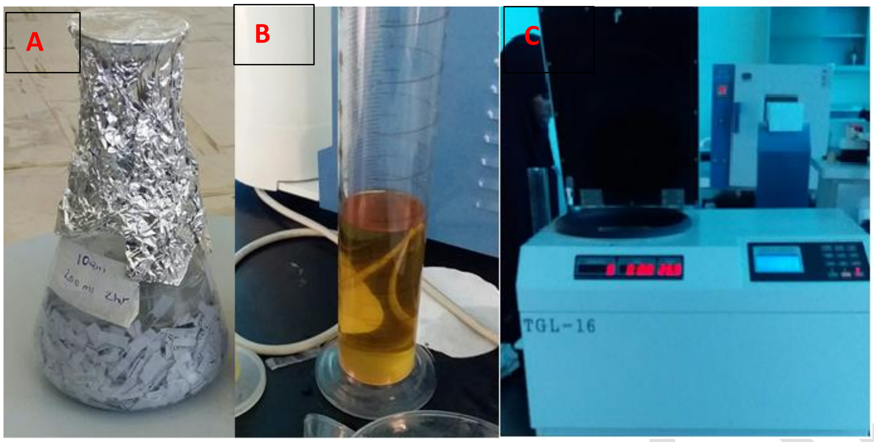


Figure 3.3. Acid hydrolysis (A), Sample ready for Dilute Acid Hydrolysis, (B), after filtration and (C) Centrifugation

3.2.3. Adjustment of pH

Before addition of any microorganism to the diluted hydrolyzed sample, pH of these samples had to be adjusted. Otherwise the microorganism will die in hyper acidic or basic state. A pH of around 4.5 - 5.5 was maintained. The hydrolyzed samples were primarily checked for pH using a digital pH meter. The pH then was adjusted to 4.5 - 5.5. If the pH went below 4.5 - 5.5, sodium hydroxide solution was added drop wise to the flask with constant stirring until the pH reaches to a range of 4.5 - 5.5. When the pH went beyond 4.5 - 5.5, concentrated sulfuric was added drop wise to maintain the pH in the range.

Figure 3.4 PH Adjustment, (A) before PH is adjusted, (B) after PH is adjusted

3.2.4. Fermentation

The yeast Saccharomyces cerevisiae was added to the hydrolyzed sample. The fermentation of all the samples was done in the incubator at 30 °C for 72 hours. After 72 hours of fermentation, the sample was taken out and distilled in order to get the bioethanol.

3.2.5. Distillation

All distillation experiments were carried out at a temperature of 90°C and a distillation time of 6 hours by rotary evaporator to separates the bioethanol from water in the liquid mixture.

Figure 3.5. rotary evaporator

3.2.6. Identification of Bioethanol

About 5 ml fermented sample was taken and pinch of potassium dichromate and a few drops of H_2SO_4 were added. Color change from orange to green indicated the presence of bioethanol.

Figure 3.6. Identification of bioethanol, (A) before adding H_2SO_4, (B).After adding H_2SO_4.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

The focus of this research is to produce bioethanol from waste office paper by acid hydrolysis and subsequent fermentation. The Table below shows the value of hydrolysis parameter and the corresponding amount of ethanol of this research.

Table 4.1. Values of Hydrolysis Parameters and the corresponding result of the research.

Test	Liquid to solid ratio(ml/g)	Time(min)	Amount of ethanol (ml/10g)
1	20	60	1.7
2	20	120	4
3	20	180	2.2
4	10	120	0.8
5	30	120	2

High amount of ethanol was observed at 20 Liquid to solid ratio (ml/g) and at the time of 2hr.

By varying time and taking constant liquid to solid ratio (ml/g) the obtained amount of bio-ethanol is described in the Table below.

Table 4.2. Amount of bio ethanol at constant liquid to volume ratio

Time (min)	Amount of ethanol(ml/10g)
60	1.7
120	4
180	2.2

The graphical representation of the obtained results is shown in the Figure below.

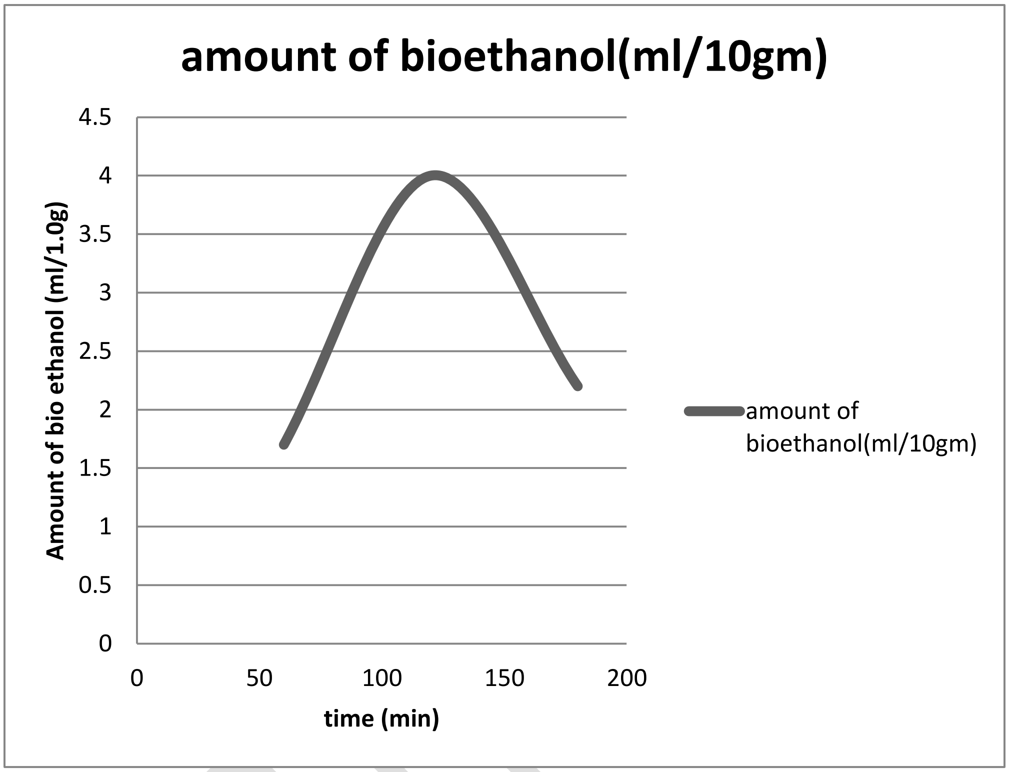


Figure 4.1. Influence of hydrolysis time on the amount of bioethanol

The results showed that maximum ethanol amount is achieved at 120 min. Therefore, time taken is 120 min for further study.

The three experiments were carried out by varying the Liquid to solid ratio (ml/g) and with constant time.

Table 4.3. Amount of bioethanol at constant time (120 min)

Liquid to solid ratio(ml/g)	Amount of bioethanol(ml/10g)
10	0.8
20	4
30	2

The graphical representation of the obtained results is shown in the Figure below.

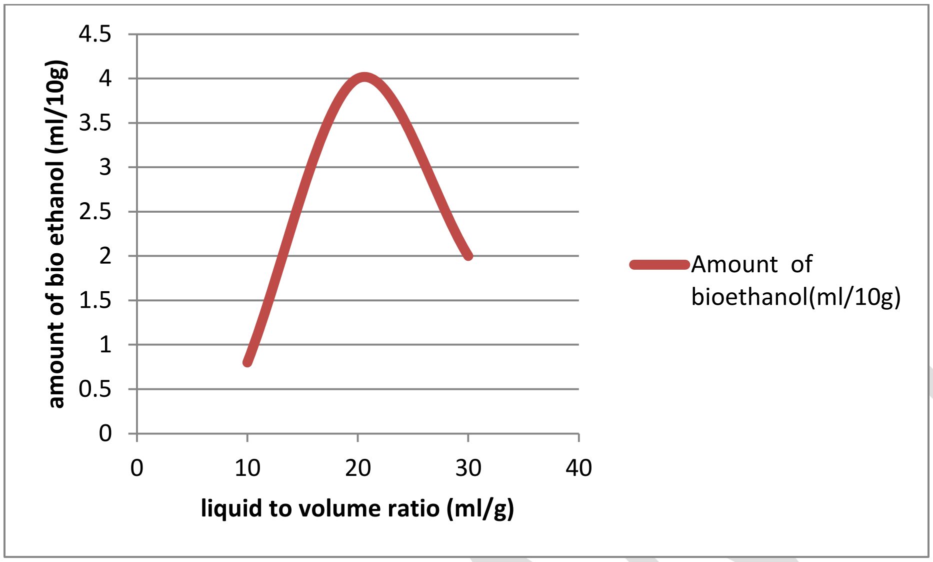


Figure 4.2. Influence of hydrolysis liquid to solid ratio on the amount of bioethanol

The data revel that there was substantial decreases in the amount of bio ethanol when waste office paper was treated with 10 and 30 ml/g. While when treated at 20 ml/g high amount of bio ethanol was obtained.

Table 4.4. Amount of bioethanol at various time intervals (at 20ml/g and for 120 min)

Time (hr)	Amount of bioethanol(ml/10g)
2:00	0.8
2:30	1.4
3:00	2.6
3:30	3.1
4:00	3.4
4:30	3.6
5:00	3.8
5:30	3.9
6:00	4
6:30	4

The above table shows the value of evaporation time and the corresponding ethanol amount that was collected in every 30 minutes in rotary evaporator (For the sample in which high amount of bio ethanol was obtained).

The graphical representation of the obtained result is shown in the Figure 4.3 below

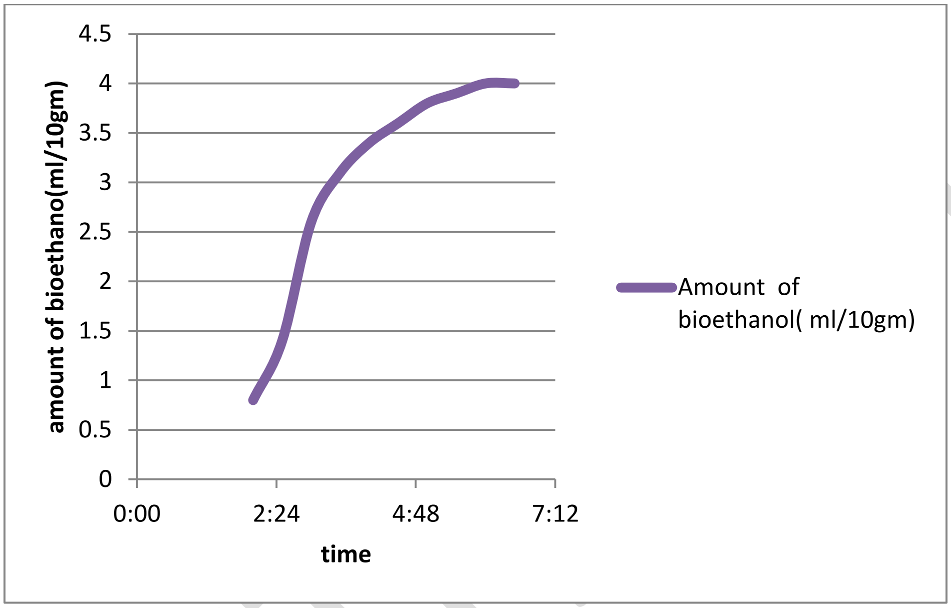


Figure 4.3. Amount of bioethanol at various time intervals (20ml/g for 120 min)

High bio ethanol amount was obtained at 20ml/g for 120 min which is 4ml/10g. So, this condition became preferable for the production of bio ethanol from waste paper.

- **Bioethanol Characterization**

Table 4.5. Characterization of the product

Characteristics	Standard value	Product value
Color	Colorless	Colorless
Odor	Strong odor	Strong odor
Volatility	Volatile	Volatile
Bulk density(g/cm^3)	0.79	0.76

CHAPTER FIVE

5. MATERIAL AND ENERGY BALANCE

When we are dealing with chemical engineering, it's mandatory to perform material balance and energy balance on selected areas. Material balances are fundamental to the control of processing, particularly in the control of yields of the products. The first material balances are determined in the exploratory stages of a new process, improved during pilot plant experiments when the process is being planned and tested, checked out when the plant is commissioned and then refined and maintained as a control instrument as production continues. When any changes occur in the process the material balances need to be determined again.

The increasing cost of energy has caused the industries to examine means of reducing energy consumption in processing. Energy balances are used in the examination of the various stages of a process, over the whole process and even extending over the total production system from the raw material to the finished product. The energy balance determinations are also made to determine the energy requirements of the process, the heating, cooling and power required. In this plant operation it is thought that an energy balance (energy audit) on the plant will show the pattern of energy usage and suggest areas for conservation and savings.In this chapter, description of the basic steps of ethanol production process and detailed mass and energy balance for each unit operations is presented.

5.1. Material Balance

5.1.1. Conservation Of Mass

Material balances are based on a conservation law which is stated generally in the form:

In put + generation - output - consumption = Accumulation …………………1

Where: Input = enters through system boundaries

Generation = is producing within the system

Output = Exist through system boundaries

Consumption = is a soul within the system

Accumulation is built up within the system

The term that is added in a chemical process is known as generation and the term that is subtracted in a chemical process is known as consumption.

If there is some sort of chemical reaction entire the general equation for material balances,

Input + generation – consumption – output = accumulation

If there is no chemical reaction the process is at steady state (when there is no change) which means there is no generation and consumption. This implies accumulation is zero.

Accumulations are time rates of change of the amount of the entities within the boundary. For example, in the absence of sources and sinks, an accumulation occurs when the input and output rates are different.

Input – output = 0, i.e. input = output [at steady state –accumulation is zero]

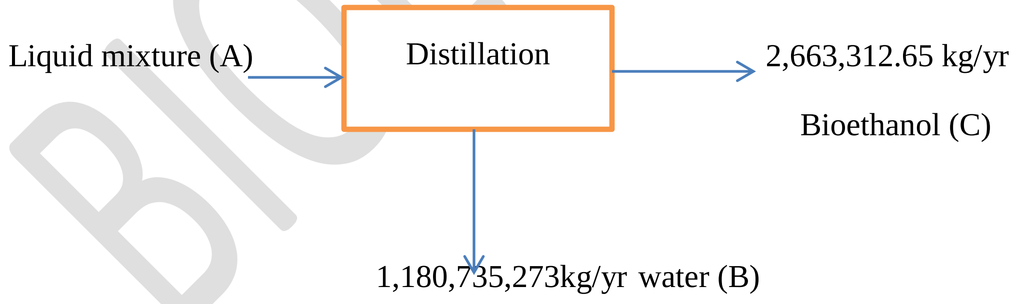
Except in nuclear processes, mass is neither generated nor consumed; but if a chemical reaction takes place a particular chemical species may be formed or consumed in the process.

5.1.2. Calculation

The total material balance is written as: Material in = Material out Or Mi = Mo (i = input; o = output).The mass balance calculation starts with wastepaper inputs. The wastepaper to ethanol conversion process can be divided into five basic steps [Sample Preparation (drying), acid hydrolysis, Filtration, centrifugation and Distillation].

Assume Production capacity of 3,000,000 gal/yr of ethanol with plant operation of 300 days/yr.

I. Distillation



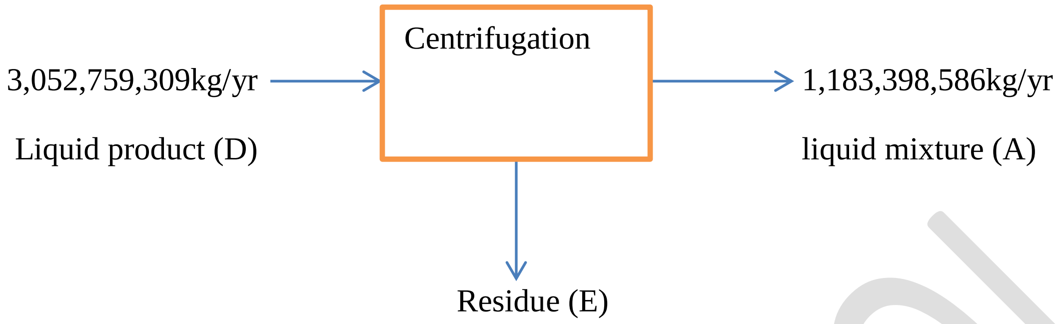
- If there is no chemical reaction the steady-state balance reduces to

Material in= Material out

A = B+C = 1,180,735,273kg/yr +2,663,312.65 kg/yr =1,183,398,586kg/yr

A=1,183,398,586kg/yr

II. Centrifugation



<u>Overall material balance</u>

- no chemical reaction so, the steady-state balance reduces to: material in= Material out

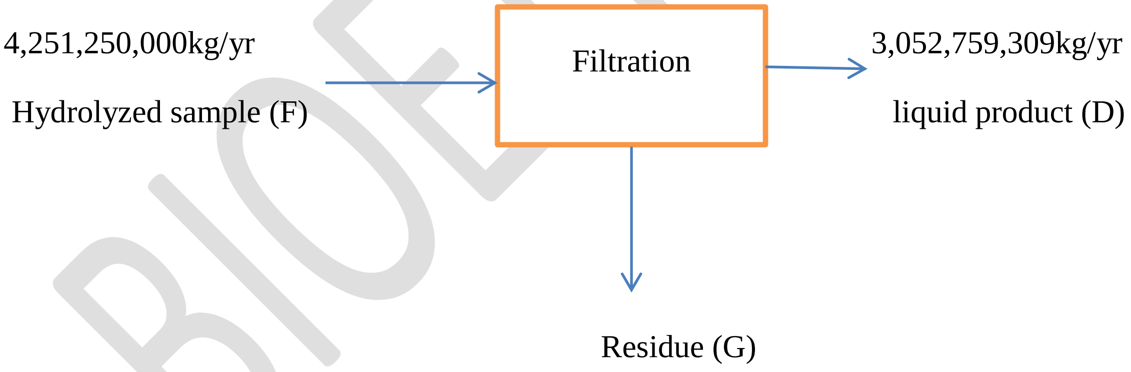
  D = E+A

  E=A-D

  E= 3,052,759,309kg/yr -1,183,398,586kg/yr=1,869,360,723kg/yr

  <u>E=1,869,360,723kg/yr</u>

III. Filtration



<u>Overall material balance</u>

- no chemical reaction so, the steady-state balance reduces to: material in= Material out

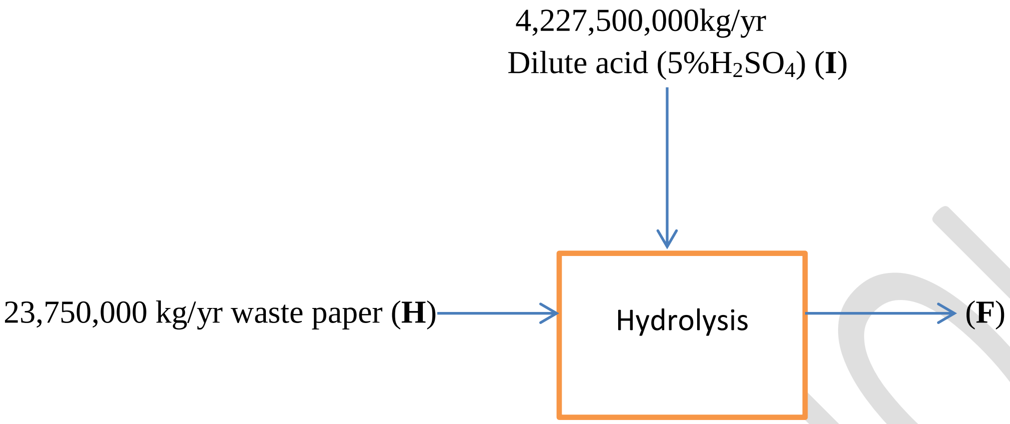
  F = D+G

  G=F-D

  G=4,251,250,000kg/yr -3,052,759,309kg/yr =1,198,490,691kg/yr

  <u>G=1,198,490,691kg/yr</u>

IV. Acid hydrolysis



Overall material balance

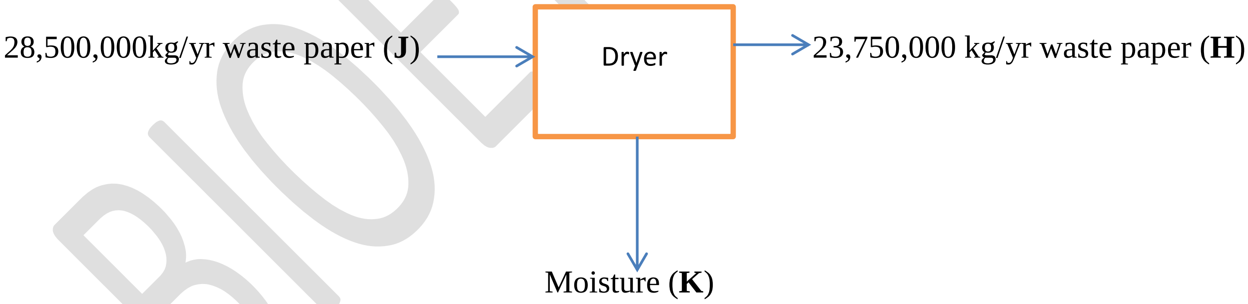
- no chemical reaction so, the steady-state balance reduces to: material in= Material out

  H+I=F

  F=23,750,000 kg/yr +4,227,500,000kg/yr =4,251,250,000kg/yr

  F=4,251,250,000kg/yr

V. Dryer



Overall material balance

- no chemical reaction so, the steady-state balance reduces to: material in= Material out

  J= K+H

  K=J-H=28,500,000kg/yr -23,750,000 kg/yr =4,750,000kg/yr

  K=4,750,000kg/yr

5.2. ENERGY BALANCE

5.2.1. Introduction

As with mass, energy can be considered to be separately conserved in all but nuclear processes. The conservation of energy, however, differs from that of mass in that energy can be generated (or consumed) in a chemical process.

5.2.2. Conservation Of Energy

As for material a general equation can be written for the conservation of energy:

Accumulation = Energy in + generation — consumption — Energy out

An energy balance can be written for any process step. Chemical reaction will evolve energy (exothermic) or consume energy (endothermic). For steady-state processes the accumulation of both mass and energy will be zero.

So for unit mass of material:

$$U_1 + P_1V_1 + 0.5\ U_1^2 + Z_1\ g + Q = U_2 + P_2V_2 + 0.5\ U_2^2 + Z_2\ g + W \text{ …………… } 2$$

It is convenient and useful, to take the terms U and PV together; defining the term enthalpy, usually symbol H, as:

$$H = U + PV \text{ ………………………………………………………………….}3$$

In chemical processes, the kinetic and potential energy terms are usually small compared with the heat and work terms, and can normally be neglected. So if the kinetic and potential energy terms are neglected equation 2 simplifies to;

$$H_2 – H_1 = Q – W \text{ ……………………………………………………………..}4$$

For many processes the work term will be zero, or negligibly small, and equation 2 reduces to the simple heat balance equation:

$$H_2 – H_1 = Q \text{ …………………………………………………………………….}5$$

Where heat is generated in the system; for example, in a chemical reactor:

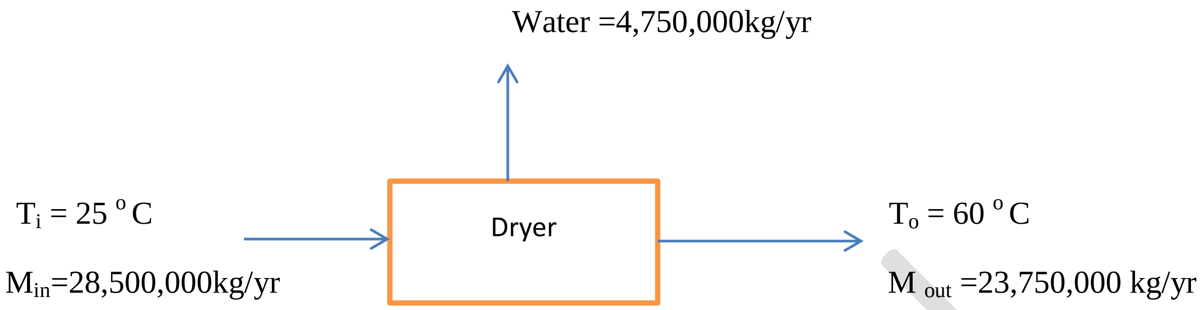
$$Q = Q_p + Q_s \text{ ………………………………………………………………………..}6$$

Where: Q_s = heat generated in the system

Q_p = process heat added to the system to maintain required system temperature.

If heat is evolved (exothermic processes) Q_s is taken as positive, and if heat is absorbed (endothermic processes) it is taken as negative

I. Dryer



M = 23,750,000 kg/yr

$\Delta T = 35\,^{o}C = 308$ K

Cp = 1.4 J/g*K

$Q = M*Cp*\Delta T$

Q = 23,750,000 kg/yr *308 K *1.4 J/g*K

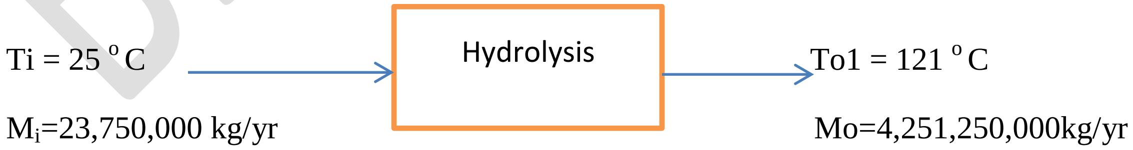
$Q=1.0241*10^{10}$KJ/yr

$P=Q*T = 1.0241*10^{10}$KJ/yr*(1yr/300day)*(1day/16hr)*(1hr/3600s) = P = 592.65 KW

E=P*T = 592.65 KW*16hr= 9,482.4 KWh

The quantity of energy required for the dryer per year is: 9,482.4 KWh.

II. Acid hydrolysis



M = 4,251,250,000kg/yr

$\Delta T = 96\ ^{o}C = 369\ K$

Cp = 2.79 J/g*K

$Q = M*Cp*\Delta T$

Q=4,251,250,000kg/yr*2.79 kJ/kg*K*369 K

$Q=4.37*10^{12}KJ/Kg$

$P=Q*T = 4.37*10^{12}KJ /Kg *(1yr/300day)*(1day/16hr)*(1hr/3600s) = 253,281KW$

E=P*T = 253,281KW *16hr= 4,052,504 KWh

The quantity of energy required for the hydrolysis per year is: 4,052,504 KWh

III. Distillation

M =1,180,735,273kg/yr

$\Delta T = 65\ ^{o}C = 338K$

Cp = 4.18 J/g*K

$Q = M*Cp*\Delta T$

Q=1,180,735,273kg/yr *4.18 J/g*K * 338K

$Q=1.67*10^{12}KJ/Kg$

$P=Q*T = 1.67*10^{12}KJ/Kg *(1yr/300day)*(1day/16hr)*(1hr/3600s) = 96,539KW$

E=P*T = 96,539KW *16hr= 1,544,620 KWh

The quantity of energy required for the distillation per year is: 1,544,620 KWh

CHAPTER SIX

6. COST AND ECONOMIC ANALYSIS

An acceptable plant design must present a process that is capable of operating under conditions which will yield a profit. Since net profit equals total income minus all expenses, it is essential that the chemical engineer be aware of the many different types of costs involved in manufacturing processes. Capital must be allocated for direct plant expenses, such as those for raw materials, labor, and equipment. Besides direct expenses, many other indirect expenses are incurred, and these must be included if a complete analysis of the total cost is to be obtained. Some examples of these indirect expenses are administrative salaries, product-distribution costs, and costs for interplant communications. A capital investment is required for any industrial process, and determination of the necessary investment is an important part of a plant-design project. The total investment for any process consists of fixed-capital investment for physical equipment and facilities in the plant plus working capital which must be available to pay salaries, keep raw materials and products on hand, and handle other special items requiring a direct cash outlay. Thus, in an analysis of costs in industrial processes, capital-investment costs, manufacturing costs, and general expenses including income taxes must be taken into consideration.

For small projects, and for simple choices between alternative processing schemes and equipment, the decisions can usually be made by comparing the capital and operating costs. More sophisticated evaluation techniques and economic criteria are needed when decisions have to be made between large, complex projects, particularly when the projects differ widely in scope, time scale and type of product. Even if insufficient technical information is available to design a plant completely, we must still make an economic evaluation to determine if it is economically and financially feasible. A project is economically feasible when it is more profitable than other competing project and financially feasible when management can raise the capital for its implementation.

The ultimate purpose for developing such a detailed process design and cost estimate is to determine the economics of ethanol production from wastepaper.

Table 6.1.purchased equipment cost

Name	Type	Units	Size (Capacity)	Purchase Cost ($/Unit	Total Purchase cost
SC-101	Screw Conveyor	4	15.00 m	183,000	732,000
GR-101	Grinder	2	48,870.00 kg/h	339,000	678,000
HX-102	Heat Exchanger	2	63.48 m2	181,000	362,000
V-101	Stirred Reactor	2	75.82 m3	584,000	1,168,000
PM-102	Centrifugal Pump	1	0.65 kW	20,000	20,000
T-101	Multi-Stage Steam Turbine	1	7,138.59 kW	1,432,000	1,432,000
EV-101	Evaporator	1	254.33 m2	746,000	746,000
BF-101	Belt Filter	8	3.47 m	326,000	2,608,000
DDR-101	Drum Dryer	3	18.83 m2	244,000	732,000
FR-101	Fermenter	3	2,636.03 m3	665,000	1,995,000
SG-101	Steam Generator	2	91,507.31 kg/h	901,000	1,802,000
C-101	Distillation Column	1	67,138.38 L	552,000	552,000
V-107	Flat Bottom Tank	4	1,382.17 m3	1,210,000	4,840,000
GP-101	Gear Pump	1	58.44 Kw	171,000	171,000
HX-103	Heat Exchanger	1	100.00 m2	206,000	206,000
HX-104	Heat Exchanger	1	66.08 m2	183,000	183,000
GAC-101	GAC Column	4	27,147.35 L	390,000	1,560,000
Total birr					19,487,000

Assume delivery cost = 10 % purchasing equipment cost

So equipment purchasing cost = 1.1 (19,487,000) = 21,435,700birr

6.1. Estimating Capital Investment

Before an industrial plant can be put into operation, a large sum of money must be supplied to purchase and install the necessary machinery and equipment. Land and service facilities must be obtained, and the plant must be erected complete with all piping, controls, and services.

In addition, it is necessary to have money available for the payment of expenses involved in the plant operation. The capital needed to supply the necessary manufacturing and plant facilities is called the fixed-capital investment, while that necessary for the operation of the plant is termed the working capital. The sum of the fixed-capital investment and the working capital is known as the total capital investment. The fixed-capital portion may be further subdivided into manufacturing-capital investment and nonmanufacturing-capital investment.

6.1.1. Fixed Capital Investment (FCI):

Manufacturing fixed-capital investment represents the capital necessary for the installed process equipment with all auxiliaries that are needed for complete process operation. Expenses for piping, instruments, insulation, foundations, and site preparation are typical examples of costs included in the manufacturing fixed-capital investment.it Can be categorized in to

a. Direct cost and
b. Indirect cost

Direct Fixed Capital (DFC): refers to the fixed assets of an investment, such as plant and equipment. It is calculated as the sum of direct, indirect and miscellaneous costs that are associated with a plant‘s capital investment. The direct costs include cost elements that are directly related to an investment, such as the cost of equipment, process piping, instrumentation, buildings, facilities, etc.

The indirect costs include costs that are indirectly related to an investment, such as the costs of engineering and construction. Additional costs such as the contractor‘s fee and contingencies are included in miscellaneous costs. Table 6.2 shows the fixed capital estimate summary.

Table 6.2. fixed capital investment

Component’s	Assumed % of total	Cost (birr)	Rationed % of total
Total Plant Direct Cost (TPDC) (physical cost)			
Purchased equipment	27	21,435,700	23.7
Purchased equipment installation	10	19,678,000	8.7
Instrumentation & control (installed)	5	16,568,000	4.43
Piping (installed)	5	14,643,000	4.43
Electrical (installed)	6	4,255,000	5.2
Building (including service)	10	6,333,000	8.7
Yard improvement	3	6,333,000	2.63
Service facilities (installed)	14	8,258,000	12.3
Land	1	15,904,666	0.88
TPDC		113,408,366	
Total Plant Indirect Cost (TPIC)			
Engineering and supervision	12	29,642,000	10.6
Construction expense	8	41,459,000	7
Contractors fee	3	2,941,399	2.63
Contingency	10	9,804,666	8.7
TPIC	114	83,847,065	100
Direct Fixed Capital Cost (DFCC = TPDC+TPIC=121,792,431			

6.1.2. Working Capital Investment (WCI)

Working capital : is the amount of capital required to start up the plant and finance ordinarily amounts to the production cost for 1 month of operation before revenues from the process start. In general it will be found to be amount equal to **10 to 20%** of the total capital investment.

So working capital investment (take average value) = 15 % TCI

- TCI = WCI + FCI = 0.15 TCI + FCI

  0.85 TCI = FCI =121,792,431birr

  TCI=**<u>143,285,212.9birr</u>**

  WC = 0.15 (143,285,212.9birr) = **<u>21,492,781.8birr</u>**

6.1.3. Startup and Validation Cost: includes pre-opening, one-time expenditures incurred to prepare a new plant for operation.

6.1.4. Up-Front Research & Development Cost: accounts for the cost of research & development required before a product is manufactured.

6.1.5. Up-Front Royalties: for the payments made for use of assets, resources, patents, etc. prior to the initiation of a project.

6.2 Estimating Total Product Cost

Total product cost can be categorized in two branches:

a. Manufacturing cost
b. General expense

a. Manufacturing Cost (MC)

All expenses directly connected with the manufacturing operation or the physical equipment of a process plant itself is included in the manufacturing costs.

These expenses, as considered here, are divided into three classifications as follows:

(1) **Direct production costs: -** Vary with production rate but not necessarily directly proportional.
(2) **Fixed charges: -**Do not vary with production rate but relate "directly" to production function.
(3) **Plant-overhead costs: -**Functions to which operations must contribute – overhead burden.

1. **Direct Production Costs(DPC)**
   i. Raw material (RM): It also includes transportation, unloading, etc.,)

Raw material cost (yeast+H_2SO_4+NaOH) =4,115,000 birr Assume transportation and unloading cost = 10 % raw material cost

So raw material cost = 1.1 (4,115,000 birr / year) =**4,526,500 birr / year**

ii. Operating labor (OL)

Table 6.3 operating labor cost

No	Position	Req. No	Monthly (birr) salary/unit	Total month (birr) salary	Annual salary (Birr)
1	Plant Manager	1	18,000	18,000	216,000
2	Technical Manager	1	7,000	7,000	84,000
3	Administrative and financial officer	1	6,000	6,000	72,000
4	Secretary	5	2,500	12,500	150,000
5	Accountant	5	3,000	15,000	180,000
6	Guard	12	1,200	14,400	172,800
7	Store Man	3	1,500	4500	54,000
8	Mechanical Engineer	4	6,000	24,000	288,000
9	Chemical Engineer	4	6,000	24,000	288,000
10	Electrical Engineer	4	6,000	24,000	288,000
11	Operators	9	5,000	45,000	540,000
12	Chemist	9	3,000	27,000	324,000
13	Seller and marketing	6	3,600	21,600	259,200
14	Labor force	100	1,200	120,000	1,440,000
	Total labor cost				4,356,000

iii. Utility (U)

The utilities required for the electricity, paper and water but paper is raw material that we use.

Electricity cost = cost consumed for [crusher + pump + fan]

Table 6.4 utility cost

No	Item	Quantity (year)	Purchasing cost/unit	Total purchasing cost (Birr)
1	Electricity	30,365,714.29KWh	0.35	10,628,000

iv. Maintenance and repair (MR**)** = 6 % FCI = 0.06 (121,792,431birr)

=**7,307,545.86 birr**

v. Direct supervisory and clerical labor (DSCL) = 17.5 % OL

= 0.175 OL = 0.175 (4,356,000) = **762,300 birr**

vi. Operating suppliers (OS) = 15 % MR = 0.15 MR = 0.15 (7,307,545.86)

= **1,096,132 birr**

vii. Laboratory charges (LC) = 15 % OL = 0.15 OL = 0.15 (4,356,000) = 653,400 birr

DPC = OL + OS +DSCL + MR + U + LC +RM

=4,356,000+1,096,132 +762,300+7,307,545.86 +10,628,000+653,400 +4,115,000

=**28,918,377 birr**

2. Fixed Charges (FC)

A. Depreciation (D) = 10 % FCI + 2.3 % building cost, But building cost = 10 % FCI

= 0.1 FCI + 0.023 (0.1) FCI = 0.1023 FCI = 0.1023 (121,792,431)

= **12,459,365.69** birr

B. local tax (LT) = 2.5 % FCI = 0.025 FCI = 0.025 (121,792,431) =**3,044,810.8 birr**

C. insurance (I) = 0.7 % FCI = 0.007 FCI = 0.007 (121,792,431) =**852,547 birr**

- Fixed charges = LT + I +D

= (3,044,810.8 +852,547 +12,459,365.69) birr

= **16,356,723.5 birr**

3. Plant Overhead Cost (POH)

Plant overhead cost (POH) = 60 % (OL + DSCL + MR) = 0.6 (OL + DSCL + MR)

= 0.6 [4,356,000 + 762,300 + 7,307,545.86] birr = **7,455,507.5 birr**

- MC = DPC + FC + POH

= 28,918,377 + 12,459,365.69 + 7,455,507.5 birr = **48,833,250.2 birr**

b. General Expense (GE)

- Costs in addition to the manufacturing costs, other general expenses are involved in any company's operations. These general expenses may be classified as: Administrative expenses and other costs.

1. **Administrative Expense**(AE)

   Administrative expense = 15 % (OL + DSCL + MR) = 0.15 (OL + DSCL + MR)

   = 0.15 (4,356,000 + 762,300 + 7,307,545.86) = **1,863,877 birr**

2. **Other Costs** (OC)

a. Distribution and selling cost (DSC) = 11 % TPC = 0.11 TPC

b. Research and development (RD) = 5 % TPC = 0.05 TPC

c. Interest (I) = 5 % TCI = 0.05 TCI =0.05 (143,285,212.9birr) = **7,164,260.645 birr**

- OC = DSC + RD + I = [0.11 TPC + 0.05 TPC + 7,164,260.645] birr

  = 0.16 TPC + 78,964,331.25

- General expense = AE + OC = 1,863,877 + 0.16 TPC + 7,164,260.645

  = 0.16 TPC + 8,028,137.645

  - TPC = MC + general expense = 48,833,250.2 + 0.16 TPC + 8,028,137.645

    TPC = 56,861,387.85+ 0.16 TPC

    0.84 TPC = 56,861,387.85

    TPC = **67,692,128.39birr**

So DSC = 0.11 *67,692,128.39birr = **7,446,134.birr**

RD = 0.05 TPC = 0.05 × 67,692,128.39birr = **3,384,606.42birr**

But for easy calculation, we have to calculate TPC by leaving cost of depreciation.

TPC = 67,692,128.39birr - 12,459,365.69 birr = **55,232,762.7birr**

CHAPTER SEVEN

7. PROFITABILITY ANALYSIS

7.1. Gross and Net Profit

Average unit production cost = total production cost / capacity of plant

Average unit Production Cost = [55,232,762.7 birr /year]/ [3,000,000 gal/year] = 18$birr$/gal

- Unit Product Selling Price = 35 birr/gal
- Plant Capacity = 3,000,000 gal/year

Sales (total income) = 3,000,000 gal/year $*$ 57 birr/gal = 105,000,000$per\ year$

The factory has designed for 15 year service time and no salvage value so average depreciation will be:

$$\text{average depreciation} = \frac{\text{depriciable fixed capital investment} - \text{salvage value}}{\text{service tme}}$$

$$\text{average dep.} = \frac{121{,}792{,}431\text{birr} - 0}{15}$$

$$= 811{,}949.4\ \frac{\text{birr}}{\text{year}}$$

- Gross profit per year = annual sales - (TPC+ depreciation)
- Annual sale = capacity of plant * unit cost

= 3,000,000 gal/year $*$ 57 birr/gal = 105,000,000$per\ year$

Considering production efficiency the following costs vary with production but others are fixed.

- Raw material (RM)=4,526,500 birr
- Local tax (LT) = 3,044,810.8 birr and Utility (U) = 10,628,000 birr
- Distribution and selling (DS) = 93,945,368.27 birr

- RM + LC + LT + DS + U = 54,563,821.8 birr

- TPC = 55,232,762.7birr birr – ([1- ε][54,563,821.8 birr]) where ε = efficiency

So we have to calculate total product cost by considering costs listed above with respect to efficiency. Take tax = 34 %

Income tax value = 0.34 (gross profit)

Net profit = Gross profit – Income tax = Gross profit – 0.34 gross profit= 0.66 gross profit

Table 7.1.gross and net profit

Year	ε (%)	Annual sale birr ($\varepsilon * 105{,}000{,}000$)	Depreciation birr	TPC birr	Gross profit birr /yr.	Net profit birr/yr.
1	75	78,750,000	811,949.4	41,591,807.25	36,346,243.4	23,988,520.6
2	85	89,250,000	811,949.4	47,048,189.43	41,389,861.2	27,317,308.4
3	95	97,750,000	811,949.4	52,504,571.6	44,433,479	29,326,096.1
4	98	102,900,000	811,949.4	54,141,486.26	47,946,564.34	31,644,732.5
5- 15	100	105,000,000	811,949.4	55,232,762.7	104,132,817.8	68,727,659.7
Average profit						55,174,827.9

7.2. Rate of Investment (ROI)

$$\%rate\ of\ return = \frac{net\ profit}{total\ capital\ investment} * 100\%$$

- Here only cost working capital investment vary: WCI = [ε][21,492,781.8birr]

Table 7.2 rate of return

Year	Net profit birr	ε	FCI birr	WCI birr	TCI birr	% rate of return
1	23,988,520.6	0.75	121,792,431	16,119,585.7	137,912,316.7	17.39
2	27,317,308.4	0.85	121,792,431	18,268,864.5	140,061,295.5	19.5
3	29,326,096.1	0.95	121,792,431	20,418,142.7	142,210,573.7	20.6
4	31,644,732.5	0.98	121,792,431	21,062,926.2	142,855,357.2	22.15
5-15	68,727,659.7	1	121,792,431	21,492,781.8	143,285,212.8	47.96
Average rate of return						38.61

7.3. Payback Period

$$PBP = \frac{depriciable\ fixed\ capital\ investment}{annual\ net\ profit}$$

Where annual net profit =average profit per year + average depreciation per year

Annual net profit =55,174,827.9+ 811,949.4 = 55,986,777.3

$$PBP = \frac{121{,}792{,}431}{55{,}986{,}777.3}$$
$$= \mathbf{2.17 \sim \textit{about}\ 2.2\ \textit{years}}$$

7.4. Break Even Analysis (X)

Breakeven is the point of zero loss or profit. At breakeven point, the revenue of the business is equal to its total cost.

- Fixed costs are costs that do not change with the level of sale. They exist regardless of how much you sell or do not sell.

So fixed costs = fixed charges + POH + administrative + interest + research and development

= [16,356,723.5 + 7,455,507.5 + 1,863,877 + 7,164,260.645 + 3,384,606.42birr]

Fixed cost = **36, 224, 974.42 birr**

- Variable cost = DPC / capacity = 28,918,377 birr / 3,000,000 gal = 9.64birr / gal

$$X = \frac{fixed\ costs}{selling\ price\ per\ Kg - unit\ variable\ cost}$$

$$X = \frac{36,224,974.42\ \text{birr}}{3{,}000{,}000\ \text{gal}(35 - 9.64)\text{birr/kg}} \times 100\%$$
$$= 47.6\ \%$$

Or

$$X = \frac{36,224,974.42}{35 - 9.64} = 1{,}428{,}429.59\ units$$

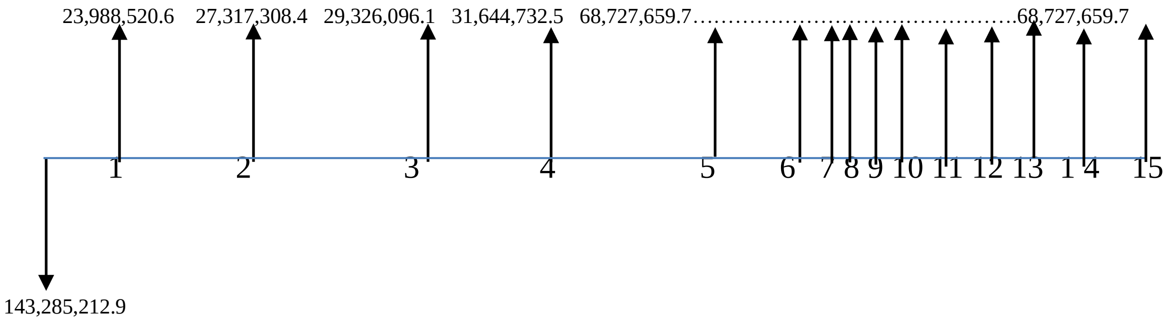
- Implies that the company should sale this amount of units to cover its expense without profit. If it sales more, then it makes a profit.

7.5. Net Present Value / Worth

NPV compares the value of the birr today versus the value of the money birr in the future:

$$NPV = \frac{CFn}{(1+r)^n}, n = 1,2,3, \ldots .number\ of\ years$$

$$NPV = -CFo + \frac{CF1}{(1+r)^1} + \frac{CF2}{(1+r)^2} + \frac{CF3}{(1+r)^3} + \frac{CF4}{(1+r)^4} + \frac{CF5}{(1+r)^5} + \frac{CF6}{(1+r)^6} + \frac{CF7}{(1+7)^7} + - - - - - - - \frac{CF12}{(1+r)^{15}}$$



Taking interest (r) = 10%

NPV = PV cash inflow – PV cash out flow

PV cash inflow = $\frac{23,988,520.6}{(1+0.1)^1} + \frac{27,317,308.4}{(1+0.1)^2} + \frac{29,326,096.1}{(1+0.1)^3} + \frac{31,644,732.5}{(1+0.1)^4} + \frac{68,727,659.7}{(1+0.1)^5} + \frac{68,727,659}{(1+0.1)^6} + \frac{68,727,659}{(1+0.1)^7} + \frac{68,727,659}{(1+0.1)^8} + \frac{68,727,659}{(1+0.1)^9} + \frac{68,727,659}{(1+0.1)^{10}} + \frac{68,727,659}{(1+0.1)^{11}} + \frac{68,727,659}{(1+0.1)^{12}} + \frac{68,727,659}{(1+0.1)^{13}} + \frac{68,727,659}{(1+0.1)^{14}} + \frac{68,727,659}{(1+0.1)^{15}}$

$= \frac{23,988,520.6}{1.1} + \frac{27,317,308.44}{1.21} + \frac{29,326,096.1}{1.33} + \frac{31,644,732.5}{1.46} + \frac{68,727,659}{1.61} + \frac{68,727,659}{1.77} + \frac{68,727,659}{1.95} + \frac{68,727,659}{2.14} + \frac{68,727,659}{2.36} + \frac{68,727,659}{2.59} + \frac{68,727,659}{2.85} + \frac{68,727,6599}{3.14} + \frac{68,727,6599}{3.45} + \frac{68,727,6599}{3.79} + \frac{68,727,6599}{4.18}$

$= 21,807,746 + 22,576,287.9 + 22,049,696,.32 + 21,674,474.32 + 42,687,987.4 + 38,829,186.27 + 35,244,953.7 + 32,115,728.8 + 29,121,889.7 + 26,535,775.95 + 24,114,968.32 + 21,887,789.7 + 19,921,060.78 + 18,133,947.15 + 16,442,023.85$

= 393,143,516.2

PV cash in flow = 393,143,516.2birr

PV cash out flow =143,285,212.9 birr

- NPV = PV cash inflow – PV cash out flow

  = 393,143,516.2birr – 143,285,212.9 birr = 249,855,303.3 birr

NPV is positive (i.e. NPV > 0) project is accepted

7.6. Profitability Index

Profitability index is the ratio of the PV of future cash inflows by the PV of cash out flows.

$$PI = \frac{PV\ of\ cash\ inflows}{PV\ of\ cash\ out\ flows}$$

$PI = \frac{393,143,516.2}{143,285,212.9}$= 2.74

PI >0, so the project is still accepted

SUMMARY

Table 7.3 ESTIMATED CAPITAL INVESTMENT STATEMENTS

Fixed capital investment (FCI)	121,792,431birr
Working capital (WC)	21,492,781.8birr
Total capital investment (TCI)	143,285,212.9birr

Table 7.4 ESTIMATED PRODUCTION COST STATEMENTS

	Manufacturing capital	
Direct production cost	Raw material cost	4,526,500 birr/year
	Operating labor cost	4,356,000 birr/year
	Utilities	10,628,000 birr/year
	Operating supplies	1,096,132 birr/year
	Laboratory charge	653,400birr/year
	Plant Maintenance and repair	7,307,545.86 birr /year
	Direct supervisory and clerical labor	762,300birr / year 28,918,377 birr / year
	Total	58,248,254.86 birr/year
Fixed charges	Depreciation	12,459,365.69 birr /year
	Insurance	852,547 birr /year
	Taxes	3,044,810.8birr/year
	Total	16,356,722.69 birr/year
Plant overhead		7,455,507.5 birr/year
	General expenses	
Administrative		1,906,487 birr /year
Other costs	Distribution and selling price	38,604,802 birr /year
	Research and development	17,547,637birr / year
	Interest	7,442,760 birr / year
	Total	63,595,199birr /year
		65,501,687 birr/year
Total production cost (TPC)		338,009,046 birr /year

Table 7.5 ESTIMATED INCOME AND RETURN STATEMENTS

Total capital investment	143,285,212.9birr
Total production cost	338,009,046
Total income	105,000,000birr/year
Net profit	55,174,827.9birr/year
Rate of return	38.61%
Payback period	2.2 year
Break even analysis	1,428,429 units or 47.6 %
Net present worth	249,855,303

Profitability index	2.74

CHAPTER EIGHT

8. Plant Location

Plant location refers to the choice of region and the selection of a particular site for setting up a business or factory. It means deciding a suitable location where the plant or factory will start functioning.

General Consideration for the Selection of Plant locations are:-

- Availability of raw materials
- Transport facility
- Availability of land
- Availability of water
- Market etc.

8.1. Site Selection

The environmental location of the final plant can have strong influence on the success of the industrial venture. Considerable care should be exercised in selecting the plant site, and many different factors should be considered. Primarily the plant must be located where the minimum cost of production and distribution can be obtained, the sufficient Raw material supply, Transport facilities from the plant to the market, minimum labor cost with respect to other towns, availability of utilities in continuous way, land for plant which means free from any natural disaster, environmental impacts of the production process in the society, culture, including effluent disposal and Climate.

Based on the above Consideration wolkite which is found in the southern region is selected as the best place.

CHAPTER NINE

9. ENVIRONMENTAL IMPACT OF BIOETHANOL PRODUCTION FROM WASTEPAPER

9.1. Water Issues

Water issues are an important concern of both, ethanol processing and use of ethanol. The water consumption for the production of bioethanol is considerable high. Thereby, much water is used for feedstock production. The quantity of water needed for the ethanol production process depends on the design of the production plant. Modern technology and design can substantially reduce the amount of fresh water needed by a standard alone ethanol plant. There is zero discharge plants in operation that recycle virtually all of the water used in production, limiting the need for large supplies [1].

Apart from the water consumption during the ethanol production process, water contamination impacts of released ethanol are an important environmental issue as well. Since ethanol is a naturally occurring substance produced during the fermentation of organic matter it is expected to rapidly biodegrade in essentially all environments [26]. Thus pure ethanol poses no threat to surface water and ground water and is much less harmful in case of spilling and leakage compared to fossil fuel which is highly toxic. When gasoline, which is blended with ethanol, contaminates soil or water, ethanol is the first component to quickly, safely and naturally biodegrade. At the same time, studies have shown that the rapid breakdown of ethanol depletes the oxygen available in water and soil, actually slowing the breakdown of gasoline. This may increase the impact of petrol spillage on the environment in two ways. First, the harmful chemicals in gasoline persist longer in the environment than without ethanol. Second, as gasoline breaks down more slowly, it can travel farther (up to 2.5 times) in the marine environment, affecting a greater area [28]. Although these effects of ethanol gasoline mixtures are negative to the environment, it also to be considered that the total percentage of petrol released to the environment is reduced by the percentage of harmless ethanol. Depending on the blended percentage, this is a great advantage of gasoline which is highly blended with bio-ethanol.

9.2. Air Quality

Ethanol represents closed carbon dioxide cycle. Fermentation for ethanol production result in the release of carbon dioxide. The cellulose of which paper is made is the result of the fixation and removal of carbon dioxide from the atmosphere by photosynthesis. These 2 reactions, the removal of carbon dioxide from the atmosphere by photosynthesis and its return to the atmosphere as a result of fermentation and combustion exactly balance each other: the amount of carbon dioxide made by the production and combustion of ethanol is exactly the same as the amount of carbon dioxide removed from the atmosphere in the manufacture by the tree of the cellulose of which the paper is made. Hence there is no net increase in atmospheric carbon dioxide as a result of bioconversion of wastepaper to ethanol. In addition, the toxicity of the exhaust emissions from ethanol is lower than that of petroleum sources [27]. Ethanol derived from biomass is the only liquid transportation fuel that does not contribute to the greenhouse gas effect.

Experience over many years in Sao Paulo has proven that the use of gasohol, in that case 20 % ethanol in gasoline, has a remarkable effect in reducing smog and air pollution generally. This heavily industrialized city was a sink of bad air, and it now celebrates clear, blue skies. Such experiences have led some states such as Colorado to mandate the use of ethanol in gasoline during periods of smog.

9.3. Waste Management

Using wastepaper as a resource for bioethanol production will reduce the biodegradable fraction from MSW going to landfill. According to the mass balance from the laboratory plant, the amount of waste will be massively reduced by 80% and the main composition of solid residues from the hydrolysis process are acid insoluble lignin, ash content, protein absorbed and dead cells, which can be used as compost. This technology can be used as an alternative solution for sustainable waste management and material/energy recovery

CHAPTER TEN

10. CONCLUSION AND RECOMMENDIATION

10.1. CONCLUSION

The bioethanol production from waste paper was successful. The best conditions for acid hydrolysis of 10 g of raw material were 200 mL of 5% sulfuric acid and 120 min of reaction time at 121 ºC. After fermentation with Saccharomyces cerevisiae, 0.4 mL of bioethanol/g was obtained. Finally, some properties were measured according the standards and the obtained bioethanol conforms to the set limit. Based on the obtained results, it can be concluded that waste paper is a suitable raw material for bioethanol production.

It was found that a paper to ethanol plant was feasible from the economic point of view. It makes a significant annual multi-million birr profit, with payback time being less than three years. Therefore, Ethanol production from wastepaper is doubtlessly an attractive business from economic and environmental point of view. This technology can be used as an alternative solution for sustainable waste management and material / energy recovery.

10.2. Recommendation

Two-parameters were applied to hydrolysis step of the experimentation. Other parameters such as concentration, temperature and size were not applied to the experiment. Other additional researchers have to be carried out by using these parameters to the steps of the experiment so that the maximum obtainable quantity of ethanol may be obtained.

The fermentation process was carried out by using dry instant yeast (saccharomyces cervecie). In addition to saccharomyces cervecie it is recommended that to prepare media which is favorable to the yeast in order to get best fermented product.

Additional information needs to be obtained about the technical and resource availability aspects of the conversion of wastepaper to ethanol. More laboratory data must be generated and scaled up to test the technical assumptions of the wastepaper-to-ethanol process model. Specific locations that can support a wastepaper-to-ethanol facility need to be found. The main criterion for the site is that it must have a sufficient quantity of economically collectible wastepaper that is not yet dedicated to alternative uses.

Most of the solid wastes including wastepaper in our country have very low conversion to different usable products and as such among the major problems of health especially for cities. Hence, it is recommended that government or other investors to recover this very valuable product and to contribute to the country in reducing the highly rising quantity of wastes.

10.3. Limitation

Due to shortage of electricity and water we lost much time and we can’t conduct continuous experimental process. This also affects the obtained final product.

In the laboratory there is Shortage of equipment’s to conduct continuous experimental process and some equipment’s are out of service due to different reasons.

The main problems encountered in the chemical engineering department laboratory are: There is no oven, autoclave, centrifuge, fermenter, rotary evaporator, and alcoholmeter.

Characterizing equipment’s like alcoholmeter were not available so the product was not characterized. Due to such problems the experiment on this project was limited on determining concentration, and density.

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