GLUCOSE PRODUCTION FROM OIL PALM TRUNK

SYAFIQAH BINTI HUD

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ABSTRACT

Glucose is simple sugar (monosaccharide). Glucose is derived from hexanal, a chain of six carbon atoms terminating with an aldehyde group. Glucose is also called an aldohexose. Oil palm (*Elaeis guineenis*) was first introduced into Malaysia for planning through the Botanical Gardens in Singapore in 1870. Commercial cultivation however, was not initiated until 1917. Since oil palm trunks can still be rather moist at the time of felling it was deemed appropriate to initiate a project on the feasibility of using palm trunks for the production of glucose. The objective of this experiment is to produce glucose from oil palm trunk by using acid hydrolysis. The parameter that have been used in this experiment is concentration of acid hydrolysis, pH and concentration of oil palm trunk using Response Surface Methodology (RSM) based on central composite design (CCD). Method that been using for this experiment is acid hydrolysis, hydrolysis of α-cellulose by H_2SO_4 is a heterogeneous reaction is influenced by physical factors. The twenty experiments have been designed by RSM for analysis. The results show there is interaction between the parameter which is pH and acid sulfuric concentration proportional to glucose concentration, acid sulfuric concentration and oil palm trunk concentration proportional to glucose concentration and the last one between pH, oil palm trunk concentration and glucose concentration. For the optimize condition, RSM predicted the best condition of parameters were 66.46% of concentration of acid sulfuric, 5.19 of pH and 0.09 g/ml of concentration of oil palm trunk with the glucose production predicted 3.43629. Based on this condition, the actual production of glucose is 3.445 and the error is 0.25%.

ABSTRAK

Glukosa adalah gula ringkas (monosakarida). Glukosa berasal dari hexanal, rantai dari enam atom karbon diberhentikan dengan kumpulan aldehid. Glukosa juga disebut sebagai aldohexose. Kelapa sawit (Elaeis guineenis) pertama kali diperkenalkan ke Malaysia untuk perancangan melalui Kebun Raya di Singapura pada tahun 1870. Walaubagaimanapun, Komersial penanaman tidak bermula sehingga 1917. Oleh sebab batang kelapa sawit masih agak lembab pada masa penebangan, ia dianggap sesuai untuk memulakan projek menggunakan batang kelapa sawit untuk pengeluaran glukosa. Tujuan kajian ini adalah untuk menghasilkan glukosa dari batang kelapa sawit dengan menggunakan hidrolisis asid. Parameter yang digunakan dalam kajian ini adalah kepekatan hidrolisis asid, pH dan kepekatan batang kelapa sawit menggunakan Kaedah Tindakbalas Permukaan (RSM) berdasarkan Rekabentuk Komposit Pusat (CCD). Kaedah yang telah digunakan untuk percubaan ini adalah asid hidrolisis, hidrolisis α-selulosa oleh H_2SO_4 merupakan reaksi heterogen dipengaruhi oleh faktor fizikal. Dua puluh percubaan telah dirancang oleh RSM untuk dianalisa. Keputusan kajian menunjukkan adanya interaksi antara parameter di antara pH dan kepekatan asid sulfurik berkadaran dengan kadar glukosa, kepekatan asid sulfurik dan kepekatan batang kelapa sawit adalah berkadaran dengan kadar glukosa dan yang terakhir antara pH, kepekatan batang kelapa sawit dan kepekatan glukosa. Untuk mengoptimumkan keadaan, RSM menjangka keadaan parameter yang terbaik adalah 66.46% dari kepekatan asid sulfurik, pH 5.19 dan 0.09 g/ml kepekatan batang kelapa sawit dengan pengeluaran glukosa 3.43629 g/ml diramal. Berdasarkan keadaan ini, pengeluaran sebenar glukosa adalah 3.445 g/ml dan ralat antara kadar glukosa yang diramal dengan kadar glukosa sebenar dalah 0.25%.

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LIST OF SYMBOLS/ABBREVIATION

RSM	-	Response Surface Methodology
CCD	-	Central Composite Design
DNS	-	Dinitrosalicylic
OPT	-	Oil Palm Trunk
g/ml	-	Gram per milliliter
mg/ml	-	Milligram per milliliter
°C	-	Degree celcius
%	-	Percentage

CHAPTER 1

INTRODUCTION

The palm tree belongs to a family of plants known as Palme or *Palmaceae* which include about 3000–3700 species grouped among 240–387 genera. Brazil, being a tropical country possesses an enormous diversity of palm fruits, most of which are excellent sources of oil. However, the potential of most of the palm fruits as a source of oil and protein for human consumption is not exploited. The dendezeiro (*Eliaes guineensis*) is a tropical oil palm, the fruit of which contains high concentration of oil. Distribution of lipids in the exocarp and mesocarp of the three varieties of oil palm fruit was (George and Arumughan 1991). The nutrient and fatty acid composition of the kernel oils of two Nigerian oil palm varieties were investigated (Akpanabiatu et al.2001). Beside the variation in the fatty acid composition, information on amino acids composition of the proteins of pulp and kernel portions of the oil palm fruits is minimal. (Bora et al. 2003). Figure 1.1 below, show the palms oil exports to the world consumption year 2005 presented how much oil palm being planted and oil palm waste being made.

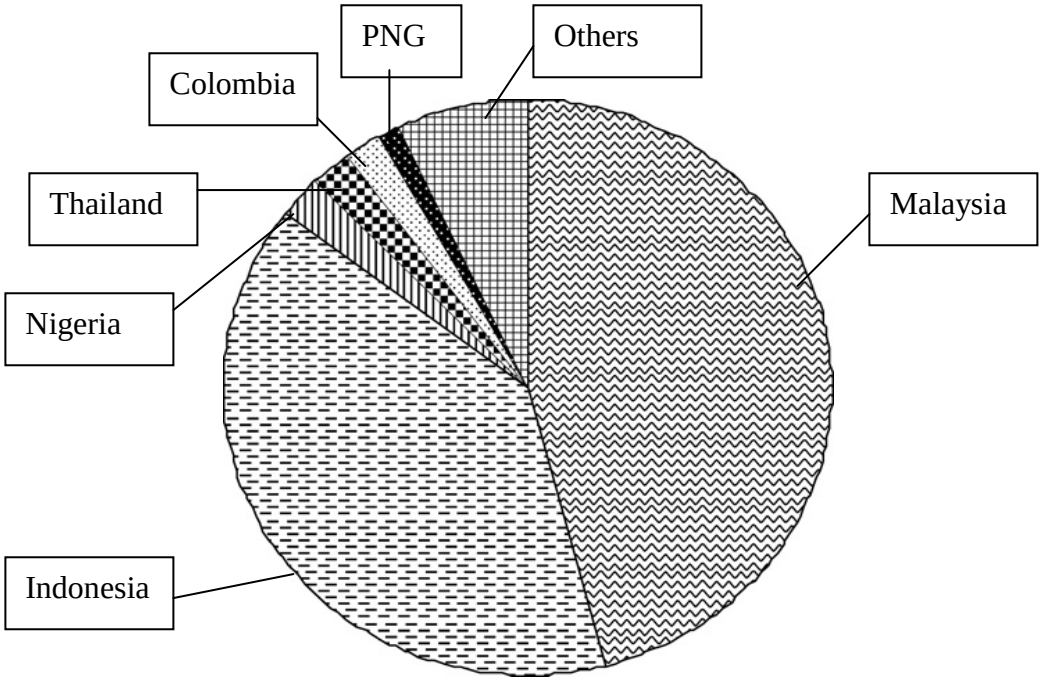

Figure 1.1: Palm oils exports to the world consumption year 2005

Table 1.1: Present and forecasted production of palm oil for the year 2000–2020 in MnT

Year	Malaysia	Indonesia	World total
Annual production			
2000	10100(49.3%)	6700(32.7%)	20495
2001	10700(48.1%)	7720(34.7%)	22253
2002	10980(48.4%)	7815(34.5%)	22682
2003	11050(47.7%)	8000(34.6%)	23149
2004	10900(45.6%)	8700(36.4%)	23901
2005	(45.611700%)	9400(36.6%)	25666
5 years averages			
1996-2000	9022(50.3%)	5445(30.4%)	17932
2001-2005	11066(47.0%)	8327(35.4%)	23530
2006-2010	12700(43.4%)	11400(39.0%)	29210
2011-2015	14100(40.2%)	14800(42.2%)	35064
2015-2020	15400(37.7%)	18000(44.1%)	40800

The total amount of carbohydrates present in the oil palm trunk of an 8 years old palm and acid hydrolysis of the polysaccharides fraction released mainly glucose together with appreciable proportions of a material with the chromatographic properties of xylose together with some fructose (Henson et al., 1999).

Glucose is the simplest sugar that also called monosaccharide. The molecular formula of glucose is $C_6H_{12}O_6$. Sugar was made from sugarcane or sugar beet. In natural habitat, glucose is one of the product of photosynthesis in plants and the breakdown of glycogen in animal. We know that glucose is a precursor. Same in industry, glucose is used as a precursor in order to make vitamin c in the Reichstein process. Reichstein process is a process to make citric acid, gluconic acid, bio-ethanol and polylactic acid.

1.1 Problem Statement

Glucose is the simplest sugar also called as monosaccaride or disaccharide. Normally, sugar will produces from sugar cane or sugar beet and it relatively have limited sources. In Malaysia, the source to produce sugar is only come from sugar cane. Glucose are widely use in the industry. For example in food industry, glucose was used as a precursor to made food, food ingredient and even food additive.

After approximately 25 years its economical life span, oil palm trunks are cut down so as to allow replanting, the trunks simply being left on the plantation and no used productively. During replanting a very large amount of waste trunks are exhausted and cut into pieces and burned simply to prevent the breading of harmful insects and local environmental pollution. However, reckless deforestation has been proceeding rapidly in those same tropical areas. Therefore, to discover and end of use for massive quantity of waste oil palm trunks would lead to a reduction in the cutting of tropical woods and preservation of precious rain forest. (Tomimura et.al., 1992). Freshly felled sems with their high moisture content cannot be easily burn in the field. Leaving the sems in the field without further processing will physically hinder the process of

planning new crops as he stem take about five years o decompose completely. The practice of disposing oil palm stems by burning is now unacceptable as it creates air pollution and affects the environment. (Lim et al. 2005)

When left on the plantation floor, these waste materials create great environmental problems (Srekala et al.1997 and Reddy et al. 2005). Therefore, economic utilization of these fibers will be beneficial. In spite of the agro fibers application, the bibliography covering comprehensive fundamental aspects of specific agro-fibers is quite scare, disperse, and inadequate. (Khalid et al. 2006).

1.2 Objective

The research was proposed to study the possibility and optimum condition for production of glucose from oil palm trunk

1.3 Research Scope

i. To study acid hydrolysis of oil palm trunk using acid sulfuric

ii. To study the optimum condition of glucose production using Response Surface Methodology (RSM)

iii. To study the effect of acid sulfuric concentration, pH and oil palm trunk concentration in glucose production

iv. To study the effect of interaction between the parameter chosen.

1.4 Rationale and Significant

Nowadays, sugar is really in high demand because of this we need to provide the alternative to produce sugar. Oil palm trunk is not just environmental friendly but also the cost much lower than other source. This is because oil palm trunk is a waste.

Oil palm trees have high possibility to become organic polluters if it's continuous. This experiment can reduce the pollution. Beside, the usage of the palm oil tree also will be maximizing.

CHAPTER 2

LITERATURE REVIEW

2.1 Glucose Overview

Glucose ($C_6H_{12}O_6$) is monosaccharide, an aldohexose and reducing sugar. The general structure of glucose and many other aldohexoses was established by simple chemical reactions. When the alcohol component of glycoside is provided by a hydroxyl function on another monosaccharide,the compound is called dissacharide. Four examples of dissacharides composed of two glucose units. Notice that the glycoside bond maybe alpha as in maltose and trehalose or beta as in cellobiose and gentiobiose. Acid catalyzed hydrolysis of these saccharides yields glucose as the only product. Cellobiose is obtained by the hydrolysis of cellulose.

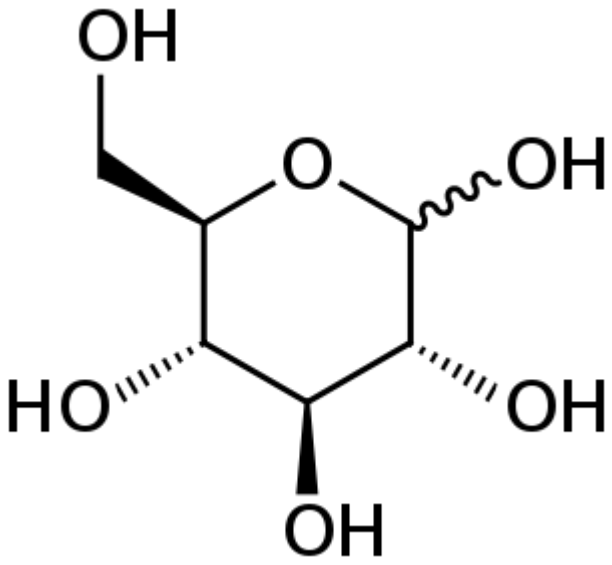

Figure 2.1 Glucose structure

Glucose is stored in the body as glycogen. The liver is an important storage site for glycogen. Glycogen is mobilized and converted to glucose by gluconeogenesis when the blood glucose concentration is low. Glucose may also be produced from non-carbohydrate precursors, such as pyruvate, amino acids and glycerol, by gluconeogenesis. It is gluconeogenesis that maintains blood glucose concentrations, for example during starvation and intense exercise. Gluconeogenesis is the biosynthesis of new glucose, (i.e. not glucose from glycogen). The production of glucose from other metabolites is necessary for use as a fuel source by the brain, testes, erythrocytes and kidney medulla since glucose is the sole energy source for these organs. During starvation, however, the brain can derive energy from ketone bodies which are converted to acetyl-CoA. The primary carbon skeletons used for gluconeogenesis are derived from pyruvate, lactate, glycerol, and the amino acids alanine and glutamine. The liver is the major site of gluconeogenesis, however, as discussed below, the kidney also has an important part to play in this pathway. Synthesis of glucose from three and four carbon precursors is essentially a reversal of glycolysis.

2.2 Raw Materials

2.2.1 Oil palm trunk

Enzymatic saccharification of oil palm trunk have been studied They divide the trunks into billets of 1.5 meter each, starting from 1.5m above the ground and labeled A, B, C and D

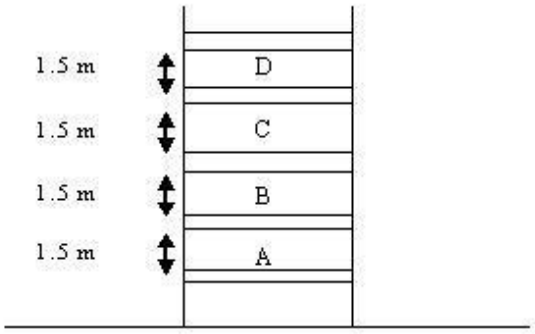

Figure 2.2: Sampling of oil palm trunk

Unlike other common timbers, the oil palm trunk is a heterogenous material. Previous studies have shown that its physical and chemical composition varies with height and width (Lim & Khoo 1986). The alpha cellulose content, for example, increases from the pith towards the outer region. A greater quantity of short-chain carbohydrates is found in the inner portion of the trunk which is richer in parenchymatous tissue. Hence, in any attempt to use the oil palm trunk (OPT) as a substrate, different portions of the trunk would show different susceptibility (Akmar, P.F et al. 1990).

Total biomass produced by palm oil industries, about 10 % was counted as the crude palm oil. While others remaining as the lignocellulosic wastes are present as trunks, fronds, palm pressed fiber and empty fruit bunches. It was reported that about 27 % of total weight of the fresh fruit bunch would be the crude oil whereas the other portion left was the solid wastes; 23 % EFB, 14-15 % fibre, 6-7 % kernel and 6-7 % shell. It has been believed that palm oil trunks yielded about 24-32 % of hydrolysable sugars (Ghasem et al. 2007).

2.2.2 Olive Tree

Olive tree biomass, obtained from pruning, is a renewable and cheap lignocelluloses residue, lacking of alternative uses, whose disposal is necessary to prevent propagation of vegetal diseases. Olive tree pruning biomass is composed of leaves, thin branches and wood (branches more than 5cm diameter). The stem pretreatment of olive tree wood in an ethanol production scheme has been previously reported. (Cara et al. 2006; Ruiz et al. 2006).

As an alternative use, olive tree pruning is being considered as a raw material for ethanol or xylitol production by means of a bioconversion process. The basic stages of such a process include pretreatment of the lignocellulosic residue, hydrolysis of the sugar polymers and yeast fermentation. Residue size reductionby grinding is a common step for all the pretreatments of lignocellulose residue as it reduces the cellulose crystallinity Hydrolysis of lignocellulose materials can be obtained by acids or enzymes. Acid hydrolysis may be conducted under either concentrated or diluted conditions. As a general rule, concentrated acid hydrolysis (50–70% acid) is conducted at low temperatures, while dilute acid hydrolysis (below 2%) requires higher process temperatures. Other acids like phosphoric acid have also been assayed for olive tree pruning hydrolysis. The fermentation of olive tree pruning hydrolysates obtained at atmospheric pressure using phosphoric acid. (Romero et al. 2007).

2.2.3 Selection of Raw Material

The raw material that has been chosen was oil palm trunk. Even though both oil palm trunk and olive tree have high potential to become a raw material, but oil palm is more suitable because it easy to find it in Malaysia. Meanwhile olive tree mostly found in Mediterranean country. Malaysia is well known as the largest producer of oil palm (*Elaeis guineensis*) in the world. Total planted area of oil palm increased from 73000, reaching 3.87 million hectares in 2004. (Khalil et al. 2006).

2.3 Structure of Oil Palm Trunk

Oil palm (Elaeis guineensis) were first introduced into Malaysia planting through Botanical Gardens in Singapore in 1870. Commercial cultivation, however was not initiate until 1917.(Government of Malaysia, 1966). Today, the total area under oil palm cultivation in Malaysia is well over 3 millions hectar and about 80% of which are in Peninsular Malaysia. Unlike the wood of most other tree species, which is mostly secondary xylem, the wood of oil palm consists of primary vascular bundles embedded in parenchymatous tissue. There is usually a very hard peripheral rind surrounding the soft central region. The wood of palm is not homogeneous (Lim et al 2005).

Generally, the density at the peripheral region is over twice the values of the central region. At any height level, the density decreased towards the centre of the trunk. The mean density ranges from 485 – 575 kg/m^3 (average 530 kg/m^3) and 190 – 280 kg/m^3 (average 235 kg/m^3) at the peripheral and central region respectively. The density of oil stem is generally low (Lim et al. 2005). The stem of oil palm contains a large amount of water. The moisture content of the stem could range from 120% to more than 500%. The peripheral region contains the lowest moisture content and increases progressively from the peripheral region to the pith or central region.

Cellulose is the most abundant organic compound in nature, comprising over 50 % of all the carbon in vegetation. Cellulose is believed to be identical in chemical composition regardless of the source and it is insoluble in water and aqueous solutions in alkalis (Choct, 1997). Cellulose makes up 40 – 45 % of wood depending on species and growing conditions and is the most important component of wood in papermaking. The term cellulose is also used more loosely in a technological context to mean the residues obtained when materials of plant origin are subjected to certain pulping processes (Myasoedova, 2000). Cellulose is a linear homopolysaccharide that consists of glucose (D-glucopyranose) units linked together by β-(1-4)glycosidic bonds (β-D glucan).

Normally, the size of the cellulose molecule is given in terms of its degree of polymerization which is the number of anhydroglucose units present in a single chain. Typical degree of polymerization of cellulose in wood is 8 000 – 10 000. The DP depends on the source and history of the 22 sample (Myasoedova, 2000). Long molecules of cellulose form microfibrils, which in their turn form the structure of a cell wall (fibre wall). The chains are stiffened by Van der Waals forces and by inter- and intra molecular hydrogen bonding. Single chains never exist under natural conditions but occur in the form of microfibrils which consists of many ordered parallel chains (Myasoedova, 2000). These structures give cellulose a rigid, strong, dense, partially crystalline, chemically and enzymatically resistant nature. Cellulose can exist in more than one crystalline form with different orientation of parallel chains relative to each other. The most common crystalline form in nature, cellulose I is metastable. Dissolution and reprecipitation lead to the stable form, cellulose II (Myasoedova, 2000). This form is manufactured commercially and sold as rayon. However, some cellulose (roughly 10 %) can also exist in an amorphous state. The cellulose fibrillous structure is shown in Figure 2.3.

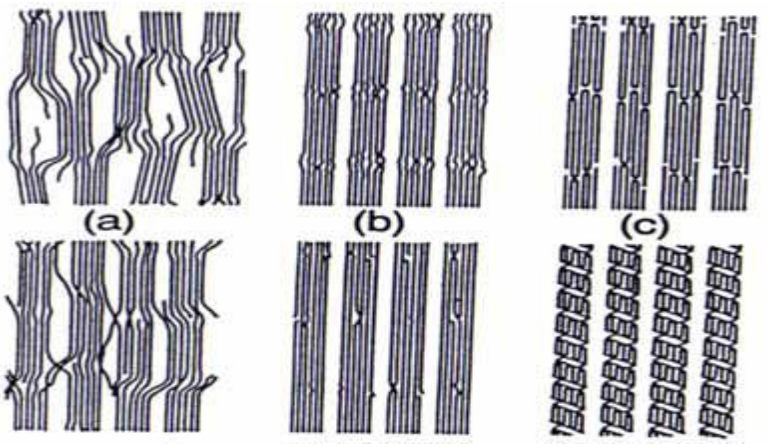

Figure 2.3: Cellulose fibrillous structures : (a) low crystallinity; (b) high crystallinity; (c) folded models

To degrade cellulose, water temperatures of ~ 250oC or strong acid are needed. The enzymatic attack requires specific pretreatment methods, otherwise the saccharification yields are dramatically low (Bobleter, 1998).

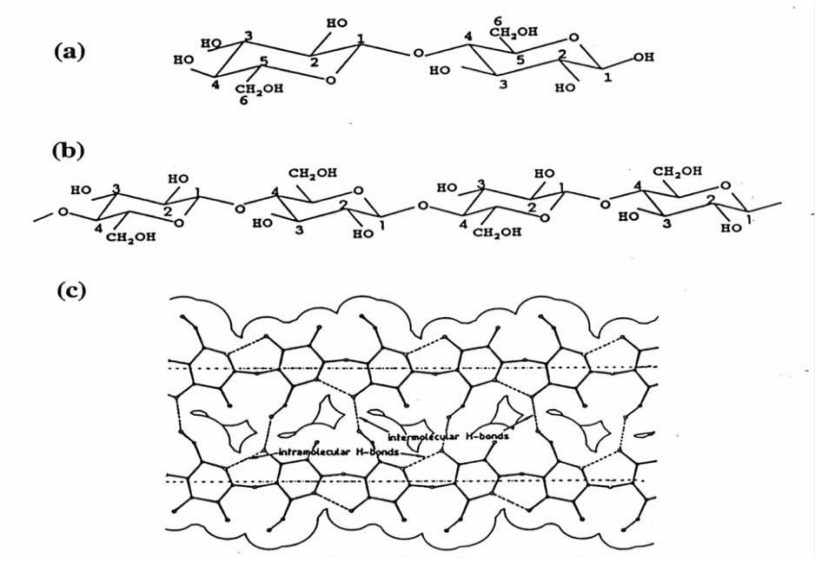

Figure 2.4: Stereo chemical formula of cellobiose and cellulose. (a) Cellobiose; (b) Segment of cellulose; (c) Two sections of cellulose chains and their intermolecular and intramolecular bonds

2.4 Chemical Method

2.4.1 Acid Hydrolysis

Hydrolysis of α-cellulose by H_2SO_4 is a heterogeneous reaction. As such the reaction is influenced by physical factors. The hydrolysis reaction is therefore controlled not only by the reaction conditions (acid concentration and temperature) but also by the physical state of the cellulose. Acid hydrolysis has been investigated as a possible process for treating lignocellulosic materials such as wood chips (Silva, 1996). Processes such as two stage acid hydrolysis can be employed to produce xylose and glucose. Treatment with dilute sulfuric acid at moderate temperature (the first stage of acid hydrolysis) has been proven to be an efficient means of producing xylose from hemicelluloses (Roberto et al. 1994). In the second stage more drastic reaction conditions are employed and glucose can be produced from cellulose hydrolysis. In general, acid treatment is effective in solubilizing the hemicellulosic component of biomass of pH, temperature, and reaction time can result in high yields of sugars (Pessoa et al. 1997).

In the main hydrolysis, concentrated sulfuric acid dissolves cellulose and hydrolyzes it to the short-chain glucose-polymers which are soluble in dilute sulfuric acid, and equilibrium between soluble and insoluble polymers may be established. Concentrated sulfuric acid acts as a solvent, but the solubility of cellulose in sulfuric acid of a certain concentration has not been measured and the relation of sulfuric acid concentration to the solubility has not been estimated. Concentrated sulfuric acid acts as a catalyst but the hydrolysis rate of cellulose has merely been measured in the presence of a large excess of acid. When this problem is solved, an optimum condition of the main hydrolysis may be determined reasonably and, in addition, the interpretation of mechanism of action of concentrated sulfuric acid on cellulose will approach completion (Kobayashi et al. 1960).

Acid hydrolysis of cellulose at low temperature is limited by the penetration rate of proton into the cellulose lattice. Therefore, pretreatment process loosens up the cellulose crystalline structure is the key to enhancing the yield of glucose in the low temperature process. For ideal hydrolysis, the individual fibrils of cellulose are completely separated via the destruction of their internal hydrogen bonding, and the individual glycoside bonds are exposed to the catalyst. This condition can only be met in a cellulose solution. In the solution, a relationship exists between the dissolved cellulose molecules and the solvent in forming water soluble, stable, and chelated complexes that separate cellulose fibril to its individual cellulose molecules (Cao et al. 1995).

The acids release protons that break the heterocyclic ether bonds between the sugar monomers in the polymeric chains formed by the hemicelluloses and the cellulose. The breaking of these bonds releases several compound, mainly sugars such as xylose, glucose, and arabinose. A quantitative hydrolysis of the hemicelluloses can be performed almost without damage to the cellulose because the bonds in hemicelluloses are weaker than in cellulose. Therefore, a solid waste formed by cellulose and lignin is obtained in the pre-hydrolysis. The mechanism of the hydrolysis reaction includes: (Aguilar et al. 2002)

i. Diffusion of protons through the wet lignocellulosic matrix
ii. Protonation of the oxygen of the heterocyclic ether bond between the sugar monomer
iii. Breaking of the ether bond
iv. Generation of carbonation as intermediate
v. Salvation of the carbocation with water
vi. Regeneration of the proton with cogeneration of the sugar monomer, oligomer ar polymer depending on the position of the ether bond
vii. Diffusion of reaction products in the liquid phase if it is permit for their form and size
viii. Restarting of the second step.

2.4.2 Alkaline Hydrolysis

The degradation of cellulose (a substantial component of low- and intermediate-level radioactive waste) under alkaline conditions occurs via two main processes: a peeling-off reaction and a basecatalyzed cleavage of glycosidic bonds (hydrolysis). Both processes show pseudo-first-order kinetics. At ambient temperature, the peeling-off process is the dominant degradation mechanism, resulting in the formation of mainly isosaccharinic acid. The degradation depends strongly on the degree of polymerization (DP) and on the number of reducing end groups present in cellulose. Beyond pH 12.5, the OH^- concentration has only a minor effect on the degradation rate. It was estimated that under repository conditions (alkaline environment, pH 13.3-12.5) about 10% of the cellulosic materials (average DP = 1000-2000) will degrade in the first stage (up to 10^5 years) by the peeling-off reaction and will cause an ingrowth of isosaccharinic acid in the interstitial cement pore water. In the second stage (10^5-10^6 years), alkaline hydrolysis will control the further degradation of the cellulose. Proper assessment of the effect of cellulose degradation on the mobilization of radionuclides basically requires knowing the concentration of isosaccharinic acid in the pore water. This concentration, however, depends on several factors such as the stability of ISA under alkaline conditions, sorption of ISA on cement, formation of sparingly soluble ISA-salts, etc. (Loon and Glaus, 1997)