
**EXTARACTION AND CHARACTERISATION OF LIGNIN FROM SOYA BEAN
STEMS AND SORGHUM STALKS**

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**THE RESEARCH PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF
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DECLARATION

I Musasizi Ezra declares that this project is original work and has not been published or Submitted before to any university or higher institution of learning except where referenced.

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Sign..........Date.....11/10/2024.....

APPROVAL

This Research project report has been done under my supervision and guidance.

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Dr. Kamoga Omar

Sign..........Date.....07/10/2024.....

DEDICATION

This Report is dedicated to my mother Alikoba Peluusi for her financial Support. Special thanks go to my dear father Mr. Batambuze Moses Kisame for his endless Financial and mentor support all through my academic journey.

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I would like to thank the Almighty God for the gift of life He has blessed me with, had He not been there for me, I would not have succeeded in my education. Thank you Oh Lord!

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ABSTRACT

Lignocellulosic biomass has been known for potential use to produce chemicals and biomaterials. Lignin is a three-dimensional, highly cross-linked macromolecule composed of three types of substituted phenols which include: coniferyl, sinapyl, and p-coumaryl alcohols by enzymatic polymeration, yielding a vast number of functional groups and linkages. This research was intended to extract lignin from soya bean stems and sorghum stalks by soda pulping.

Samples were chopped manually in sizes of about 3-5 cm, screened to get rid of the fine, clean with distilled water to eliminate adhered soil. The materials were dried at room temperature in the laboratory. The dry materials were soaked in water at room temperature. Then the black liquor were obtained and different treatments were carried out in order to obtain the lignin.

It was found that lignin obtained from sorghum stalks provided the greatest yield of ...16.5%.....compared to lignin from soya bean stems of ...12.5%...by weight yielding low lignin. It was also found out that the lignin obtained from sorghum stalks were more hydrophilic due to its higher content of hydroxyl group, sorghum stalk lignin were more soluble in water and hexane , making it a better choice for applications where they are preferred as solvents. On the other hand, lignin obtained from soya bean stems were compatible with polar solvents due to its phenolic groups .Soya bean stem lignin were more soluble in ethanol and methanol making it a better choice for application where they are needed to be used.

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CHAPTER ONE

1.0 INTRODUCTION:

1.1 BACKGROUND

Most of the physical and chemical properties of the plants are determined by its main constituent called 'lignin'. The word lignin has been derived from the Latin word *lignum* which means wood.

Lignin is the substance that makes trees woody and is present mostly in cell walls of the vascular plants, ferns and club mosses. It is a phenyl-propanoid structural polymer which binds the fibres and cell walls together and gives plants the required rigidity. It also decreases permeation of water across the cell walls of the xylem tissue and makes the wood resistant to attack by micro-organisms. The lignin content in the plants varies from about 18% to 35% of the total wood content. About 1010 tons of terrestrial biomass is produced annually through photosynthesis, and 5-36% of this Lignocellulosic biomass of softwood (gymnosperm) and hardwood (angiosperm) is lignin. Softwood species have a higher lignin/cellulose ratio than hardwood species(Lê et al., 2016).

Lignin and cellulose (including hemicellulose) are the main structural components of almost all the plants. Natural decay or biodegradation of plant tissues is therefore the key process of the carbon cycle in nature(Ni & Hu, 1995). Interspersed with hemicellulose micro fibrils, the lignin results in a heterogeneous composite aromatic polymer having biologically stable carbon to carbon and ether (C-O-C) linkages: This makes wood a good and lasting building material as well as a fuel. Plant cells can be viewed as a chemical factory wherein a large variety of highly sophisticated chemical compounds are synthesized from simple raw materials with the help of enzymes(Mangal et al., 2015). Plants are thus the source of many important renewable chemicals, industrial compounds and energy. Lignin is a complex macromolecule mainly synthesized from three p-hydroxy cinnamyl alcohols (p-coumaryl, conifer, and sinapyl) which give rise to p-hydroxyphenyl, guaiacyl, and syringyl units with a variety of inter-unit linkages (β -O-4, α -O-4, β -1, 5-5, 4-O-5, β - β , and so on). Out of the three components, cellulose is the most abundantly available natural resource and the demand for it is steadily growing for its environment-friendly and biocompatible nature. Cellulose has been used in various ranging from wood and plant fibres to act as a source of energy for applications in building materials, paper, textiles, as well as clothing today. Another growing application of cellulose is in

composite materials as reinforcement in polymeric materials. Still, the disadvantages that come with using cellulose are the incompatible nature of the material with hydrophobic polymers, the aggregation of cellulose during processing, and the high water absorption properties. These characteristics can significantly reduce overall properties of cellulose which can also be a direct result of the extraction technique and plants used for the extractions (Clark, King, Klejwa, Swayze, & Vergo, 1990).

Lignin is insoluble in water and stable in nature and acts as the “glue” that connects cellulose and hemicellulose. Furthermore, lignin specifically creates a barrier to enzymatic attack while the highly crystalline structure of cellulose is insoluble in water, then the hemicellulose and lignin create a protective sheath around the cellulose (Clark III et al., 1977).

As a natural and renewable raw material, obtainable at an affordable cost, and great chemical and physical properties, lignin's substitution potential extends to any product currently sourced from petrochemical substances. The areas in which it is applicable include: emulsifiers, dyes, synthetic floorings, sequestering, binding, thermosets, dispersal agents, paints and fuels to treatments for roadways (Lê et al., 2016).

There is a wide range of cellulose and lignin sources available including: jute, hemp, cotton and wood pulp (Jones Jr & Case, 1990). Hence, their physical and chemical behaviour will be different with respect to original source and extraction method used. Therefore, their use in many applications may vary based on formulations. For instance, lignosulfonate, with respect to the sulphite pulping process is one of the traditional forms of lignin that has been used for the high sulfonic acid functional groups gives them great binding and emulsifying properties (Wang et al., 2021).

1.2 PROBLEM STATEMENT

Today we use and rely on many commodity consumer products like energy, materials, plastics, chemicals and transportation fuels. These consumer products largely originate from fossil resources which will be depleted sooner or later and contribute to carbon dioxide emissions that lead to global warming and climate change. The current depletion of fossil raw materials like the use of coal in road construction makes the use of alternative feedstock such as biomass necessary, for a partial or total substitution of petroleum derivatives in construction and palliative. Just like in the tree, lignin work as a dust palliative by binding the different sizes of road particles together when applied topically.

Lignin sulfonate treatments tend to be more effective at suppressing dust and holding the road together than chlorides on gravel roads containing higher levels of fines and sand, especially in dry, arid climates.

There is a need for utilization of lignocellulosic biomass from different sources. Therefore the extraction of lignin can be used in the control of dust in road construction

1.3 OBJECTIVES

1.3.1 General objective

To extract and characterize lignin from Lignocellulosic biomass, from soya bean stems and sorghum stalks.

1.3.2 Specific objectives

To extract lignin from soya bean stems and sorghum stalks

To determine the yield of lignin

To determine the solubility of lignin

1.4 SIGNIFICANCE OF STUDY

This research project is intended to look for efficiently and sustainably use plant derived sources as alternative sources of binding such as binding the soil particles together by extraction of lignin from soya bean stems and sorghum stalks and characterizing it.

1.5 SCOPE

Biomass samples of soya bean stems and sorghum stalks were collected from fields near Nagongera Town council and taken to the laboratory for analysis. Lignin were extracted and characterized.

JUSTIFICATION

The finding will inform the subsequent course of action towards improvement of service reliability of road construction across the country as it work as dust control by binding the different sizes of road particles together. If lignin is not extracted, there will be continuous road breakages and dust will continue affecting the people's health and their properties in the area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 LIGNIN

The term lignin is derived from Latin word for wood *lignum* (Henriksson, 2009). Lignin is a major constituent in structural cell walls of all higher vascular land plants. Its polyphenolic structure is well known for its role in woody biomass to give resistance to biological and chemical degradation. This is due to its hydrophobic nature and insolubility in aqueous systems preventing access of degrading chemicals and organisms. The monomeric units of phenylpropanes in lignin polymers are linked in a complex network through different types of ether and ester bonds as well as carbon-carbon bonds (Hatakeyama & Hatakeyama, 2005).

The lignin occurring in plant cell walls is commonly closely associated with polysaccharide structures of hemicellulose. Wood and lignocellulosic resources are used to extract the cellulose fibres for paper or composite applications or for the production cellulose. To remove and dissolve the hydrophobic lignin it is chemically degraded or modified under harsh (alkaline) conditions (Kutscha & Gray, 1970).

The residual black liquor containing the lignin fraction is used as fuel feedstock for plant operation. In this way a large part (up to 40%) of the photosynthetic carbon fixed by the plants is inefficiently utilized and released in the ecosystem as carbon dioxide. The (bio/ecological) life cycle of lignin carbon is a major element in the closing of complete carbon dioxide cycle and the mineralization process of carbon from plant biomass (Kumar, Mohanty, Erickson, & Misra, 2009).

Natural mechanisms of lignin decomposition include the bio-degradation by microbial enzymes and irradiation by sun light, but also the fragmentation at elevated temperatures or under pressure of mechanical shear. Lignin (bio) degradation is an aerobic process and anaerobic conditions, such as in peat soils and compost, it is found to be stable for long periods. In soil sciences these lignin residues are referred to as insoluble humic acids.

Next to the production of lignin residue (black liquor) in the pulp and paper industry, more recently a new type of lignin residue is emerging. With the development of biorefinery processing of lignocellulosic biomass to monomeric sugars for the production of second generation (2G) biofuels and desired bio-based products ,e.g ‘green’ chemicals and

biopolymers , a non –digested fraction in the spent fermentation broth will be generated. This fraction consists for a large part of lignin.

As it is known that phenolic lignin degradation products may inhibit the ethanol fermentation process it is suggested to remove lignin by (bio) chemical means before the saccharification processes for an efficient production of biofuels from Lignocellulosic. In the degradation processes of Lignocellulosic the recalcitrance of the lignin polymeric structure is well known.

Acid and alkaline depolymerizations of lignin will result in breaking of the ester bonds and some of the ether bonds, but the reactivity of the liberated fragments may result in a rearranged and even more condensed polymeric structure. Therefore, is the extraction conditions that are applied to lignocellulosic biomass substantially affect the structure and properties of the resulting (technical) lignin(Gellerstedt & Henriksson, 2008).

2.2 LIGNIN STRUCTURE

Lignin occurs widely in the middle lamellae and secondary cell walls of higher plants and plays a key role in constructive tissues as a building material, giving it its strength and rigidity and resistance to environmental stresses(Hemati, Nazari, Asgari Lajayer, Smith, & Astatkie, 2022). Lignin contents may vary in softwoods from 24-33%, in temperate zone hardwoods from 19-28% and in tropical hard woods from 26-35%. In non-wood fibre crops the content is generally lower and ranges from below 3%, in cotton and in extracted flax or hemp bast fibers, to around 11-15% for sisal.

In grasses such as cereal stalks, bamboo or bagasse the lignin content ranges from 15-25%. Compared to wood lignin, lignin from annual crops such as from grasses are reported to be less condensed. Some examples of these grass lignin, e.g. soya bean stems were studied in this dissertation. Besides other important properties of lignin in the cell wall, as previously described, its major functional role in woody tissues can be regarded as being a structural component(Albersheim, Darvill, Roberts, Sederoff, & Staehelin, 2010).

The bio-composite is composed of a stiff three-dimensional cross-linked matrix (very similar to thermosetting resins like phenol-formaldehyde resins) reinforced with cellulosic fibrils, connecting the individual cells. Despite its rigidity, the lignin matrix needs a large flexibility when exterior physio-mechanical forces act upon it leading to shear stresses and deformation, leads to more to more condensed polymers (like is observed in compression wood).

Self-repairing mechanisms in the cell walls by means of a radical type of reaction easily can lead to demethylation and demethoxylation, as well as the formation of novel C-C bond and ring structures(Rogers & Campbell, 2004). This phenomenon is also observed when extracted lignin fragments are being handled or analysed. The molecules tend to coagulate under certain conditions' which complicates working with lignin substantially.

From a chemical point of view, lignin are considered as complex polyphenols and despite many research efforts, its chemistry, biosynthesis and molecular biology is up till now not fully understood . As a result, the lignin structure is not exactly defined, but several researchers published representations of the prominent substructures of lignin.

Lignin are built in plants starting from three basic monolignals via oxidative phenolic coupling reactions to generate the polymer. The heterogeneity of forces acts upon it leading to shear stresses and deformation. Rearrangements of bonds within the network under external stress conditions, leads to more condensed polymers (like is observed in compression wood)

2.2.1 The chemical structure of lignin

Lignin consists of complex and diverse structures. Lignin includes three primary precursors which have different proportion in softwood and hardwood lignin. Lignin precursors are linked together by different functional groups, the frequency of the linkage results in the variation of the structure in lignin(Nayak, Parkhey, & Sahu, 2020).

2.2.2 The distribution of lignin in the cell wall

The cell wall consists of several of several layers which are depicted in the classical representation in Figure 2.1. The layers of the cell wall from outer to inner are as follows: middle lamella (M), the primary wall, the secondary wall (divided into the S1,S3, and S3 layers), and the hollow inner region called the lumen. The layers of the secondary wall differ based on the thickness of cell wall layer and the micro fibril angle(Rößler, Trümper, Noll, Hellwig, & Niemirowska, 2021).

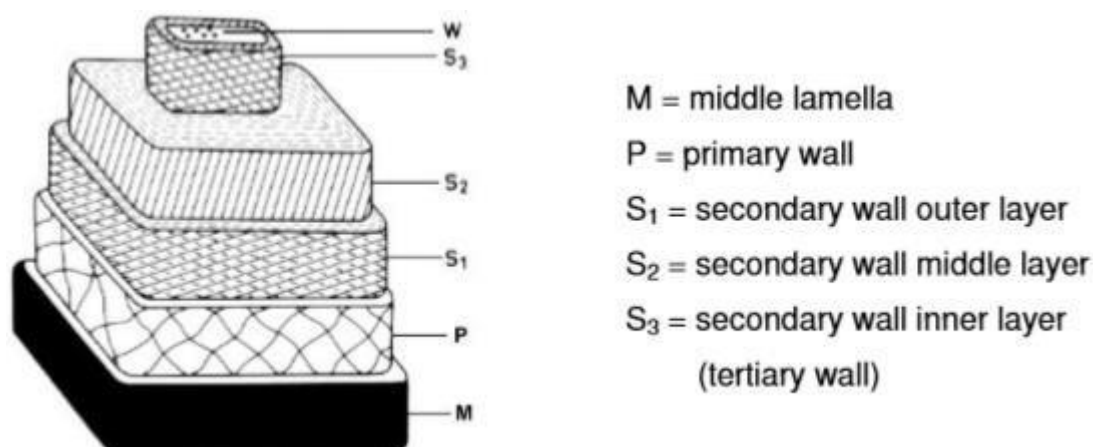


Figure 2.1 the structure of cell wall in wood.

Lignin is found mainly in middle lamella and the secondary wall. In the middle lamella the lignin content is high, but, because the layer is thin, only a minor fraction of the total lignin is located in this layer. In hardwood, the lignin concentration in the middle lamella is lower than in that of softwood. In addition, the majority of lignin is contained in the secondary wall although the relative concentration of lignin is low.

2.3 BIOSYNTHESIS OF LIGNIN

The biosynthetic process of producing lignin is called “lignification” and refers to cascade of radical polymerisations, catalysed by peroxidase and lactase enzymes employing monolignols as building blocks. The latter compounds are synthesized starting from L-phenylalanine and L-Tyrosine, two aromatic amino acids derived from carbohydrates through the shikimic acid pathway-phenylalanine and L-Tyrosine are converted to the corresponding cinnamic acid-derivatives through a series of enzyme-catalyzed steps and finally resulting in the monolignols.

This process takes place in the cytosol of the cell and is followed by the transportation of the monomers to the cell wall by passive diffusion, active transport or exocytosis from the Golgi apparatus. In the cell wall matrix, the cinnamyl alcohols are dehydrogenated by a few enzymes, such as lactases and peroxidases, which possess high affinity for cinnamyl alcohol substrates. The peroxidase-catalyzed abstraction of a proton from the phenolic hydroxyl of a monolignol generates a radical structure stabilized by resonance(Jakob et al., 2022).

The monolignol undergoes a random radical coupling initiating the polymerization . A radical monomer reacts with a second phenylpropanoid unit, by radical coupling of carbon-carbon or carbon-oxygen atoms located in different positions of the unit backbone(Jakob et al., 2022).

The reaction product is a dimer called dilignol. It has been calculated that the reaction between two coniferyl alcohol radicals can lead to different dimers, but only five of them are stable enough. The elongation of the chain is caused by a further oxidation of the dimer. Therefore, Lignin biosynthesis begins in the cytosol with the synthesis of glycosylated monolignols from the amino acid phenylalanine(Hatakeyama & Hatakeyama, 2005).

These first reactions are shared with the phenylpropanoid pathway. The attached glucose renders them water-soluble and less toxic. Once transported through the cell membrane to the apoplast, the glucose is removed, and the polymerization commences

2.4 PRECURSORS OF LIGNIN

Lignin is an amorphous polymer with a chemical structure that distinctly differs from the other macromolecular constituents of wood. The Lignin polymer molecule is made up of a number of structural units. These units are similar in configuration and can be regarded as a common skeleton which is a phenylpropane or C6-C3 or C9 type.

Lignin can be defined as a polyphenolic material arising primarily from enzymic dehydrogenative polymerisation of three phenylpropanoid units, which are coniferyl alcohol, sinapyl alcohol and p-coumaryl alcohol, respectively.

Lignin classification is traditionally done according to the precursors of the polymer.

Guaiacyl lignin (G) is typical of softwood species and it is formed mostly of trans-coniferyl alcohol precursors, with the remainder consisting mainly of trans-p-coumaryl alcohol which contains p-hydroxyphenyl (H) units. In contrast, generally guaiacyl-syringyl (GS) lignin found in hardwood species, are mainly composed of trans-coniferyl alcohol and trans-sinapyl alcohol type units in varying ratios(Rogers & Campbell, 2004). Grass lignins are also classified as guaiacyl-syringyl lignin, although they contain some structural units derived from trans-p-coumaryl alcohol and some aromatic acid residues(Edvardsson, 2009).

2.4.1 POLYMERIZATION OF LIGNIN PRECURSORS (MONOMERS)

In the polymerisation process of lignin, precursors are turned into resonance stabilized phenoxy radicals by enzymatic oxidation(Patil & Argyropoulos, 2017).

Figure 2.2 shows an example of a phenoxy radical formed from coniferyl alcohol by a one – electron transfer and its resonance forms(Sangha et al., 2014). Delocalization of the singlet

electron allows covalent bonds to be formed on three different sites of the molecule. Similar radicalization occurs to lignin polymer when new precursors are added.

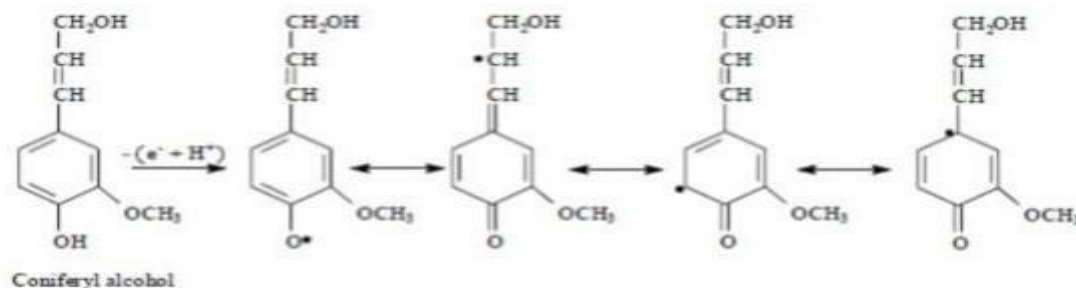


Figure 2.2 .Resonance forms of the coniferyl alcohol radical

Lignin precursors are linked together with ether linkages (C-O-C) and with carbon-carbon (C-C) linkages. Carbon-carbon linkages are considered as condensed linkages, whereas ether linkages are non-condensed. Ether-type of linkages is most common and approximately two thirds of bonds between precursors are of ether-type, the rest are of the carbon-to-carbon type.

2.4.2 BINDING EFFECT

Just like in the tree' lignin works as a dust control by binding the different sizes of road particles together when applied topically or mixed in(Jones, 2017). The water used to liquefy lignin for application evaporates as it dries, and that's how it binds the dust to larger aggregate with its high-viscosity, naturally sticky material. Lignin is concentrated in the cell walls of wood and second most abundant organic material on Earth. As an industrial use, it is ideal for binding products together, thanks to its naturally adhesives properties. For this reason, it makes a great dust suppressant on the unpaved logging roads(Birst & Hough, 1999).

In a dust control capacity, the lignin (at this point it's technically "lignosulfonate", the lignin by product created after it is separated from the wood during the pulping process) works by binding the road surface particles together. The water evaporates from the lignin as it dries and the dust particles are trapped by the naturally viscous material. Lignin sulfonate treatments tend to be more effective at suppressing dust and holding the road together than chlorides on gravel roads containing higher levels of fines and sand, especially in dry season(Edvardsson, 2009).



Fig 2.3. Lignosulfonate for dust control

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

Natural biomass resources (soya bean stems and sorghum stalks) were collected from the local fields of Busia. Other materials which were used include.

Water, acids like sulphuric acid, alkaline reagents such as sodium hydroxide, apparatus, and autoclave, round bottomed flask, vacuum oven and hot plate

3.2 EXPERIMENTAL PROCEDURES

3.2.1 Extraction

Samples were chopped manually in sizes of about 3-5 cm, screened to get rid of the fines, clean with distilled water to eliminate adhered soils. The materials were dried at room temperature in the laboratory

The dry materials were soaked in water at room temperature for 24 hours in a solid to liquor ration of 1:8 in order to reduce the cold-water extractives. After then the materials were soaked in ten litres of water mixed with sodium hydroxide for seven days (Lê et al., 2016). The black liquor obtained.



Figures 3.1 Shows the black liquor obtained from sorghum stalks



Figure 3.2 Shows the black liquor obtained from soya bean stems

The black liquor were then placed in round bottomed flask, and also 31ml of cold (10 to 15°C) 72% sulphuric acids were added. Sulphuric acid were added gradually in small increments while the material were stirred with a glass rod. The materials were stirred frequently during this time to ensure complete dissolution. After wards, water were added to the mixture to a concentration of 3% sulphuric acid (Sameni, Krigstin, Jaffer, & Sain, 2018). Then the mixture were refluxed for 3 hours. After that, the lignin were filtered and washed with hot water. Finally, lignin were dried in the vacuum oven, at 38°C for 72 hours.

3.2.2 Determination of lignin yield

Materials

Soya bean stems and sorghum stalks samples, lignin samples, apparatus and analytical balance.

General procedure to determination of lignin yield

The lignin yield were obtained from weight of recovered lignin and weight of total dry stalks. Dry sample of material were measured and its mass were recorded and the mass of the recovered lignin were also recorded, then

$$\text{Lignin yield} = \frac{\text{Weight of recovered lignin}}{\text{Weight of total dry straws}} \times 100\%$$

3.3 CHARACTERIZATION

3.3.1 Determination of solubility of lignin

Materials

Acids, deionised water, apparatus, breakers, stirring rod, hot plate, analytical balance

General procedure to solubility of lignin

Solubility of lignin were determined from mass of lignin after evaporation and mass of the solution before evaporation(Asikkala, Tamminen, & Argyropoulos, 2012).

Given mass of lignin were dissolved in 100g of a solvent by stirring until the solution were saturated. 10ml of the saturated solution were drawn and evaporated to dryness(Ni & Hu, 1995). The mass of sample remained after evaporation were also measured. Then the solubility of lignin in a solvent were obtained as follows: as

$$\text{Solubility} = \frac{\text{mass of lignin after evaporation}}{\text{mass of the solution before evaporation}} \times 100\text{g of a solvent.}$$

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 LIGNIN YIELD

The total extraction yields of alkali lignin obtained from sorghum stalks and soya bean stems were 16.5% and 12.5% by weight respectively as shown in the table below.

Table 1 shows the lignin yield obtained by sorghum stalks and soya bean stems

Samples	Mass of dry Sample (g)	Mass of lignin Obtained (g)	Percentage (%)
Sorghum stalks	1000	165	16.5
Soya bean stems	1000	125	12.5

For the lignin content, the temperature, time increase and ratio of acid to sample led to its remarkable reduction. The low content yield of lignin could be due to, temperature used during extraction may have contributed to low yield because higher temperatures tend to further degrade constituents, chemical interaction which may have led to the formation of lignin-carbohydrate complexes because lignin can bind to carbohydrates in the material making it harder to extract, the ratio of acid to samples, sulphuric acid was added to black liquor to make 3% percent sulphuric acid. This ratio of acid to sample is sufficient, but it requires considerable time for the acid to mix with black liquor. If the ratio of the acid to the sample is increased, less time is required for the two to mix.

Furthermore, addition of sulphuric acid prevents undesirable effects resulting from too high level of acidity. The treatment duration i.e treated for time 24hours at room temperature also followed the same trend that with the increase in time there was a reduction in the yield, and the reason was presumed to be time



Figure 4.1 Shows the lignin obtained from sorghum stalks

The lignin obtained from the sorghum stalk was reddish brown in colour as shown the figure 4.1



Figure4.2, Shows the lignin obtained from soya bean stems

The colour of lignin obtained from the soya bean stems was light brown as shown in the figure 4.2

4.2 SOLUBILITY OF LIGNIN

Table 4.1 shows the solubility of lignin from sorghum stalks in different solvents like water, ethanol, methanol and hexane

Solvent	Solubility (g)/100g
Water	0.45
Ethanol	2.85
Methanol	3.95

Hexane	2.12
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Table 4.2, shows the solubility of lignin from soya bean stems in different solvents like water, ethanol, methanol and hexane

Solvent	Solubility (g)/100g
Water	0.32
Ethanol	3.12
Methanol	4.21
Hexane	1.95

Methanol is a better solvent for lignin. This is due to the smaller molar volume of methanol than water, ethanol and hexane. The dissolution rates are strongly dependent on the molar volume of methanol and ethanol because the penetration rate increases with decreasing solvent size.

Due to the capability of hydrogen bonding, the hydrogen bonding parameter of organic solvents such as methanol is much higher than other organic solvents. The hydrogen bonding parameter is used to evaluate the hydrogen bonding capacities of organic solvents for the solubility of lignin because hydrogen bonding is a major molecular interaction between hydroxyl groups of lignin and the organic solvents with the ability to form hydrogen bonding.

CHAPTER FIVE

5.0 CONCLUSION AN RECOMMENDATION

5.1 CONCLUSION

The lignin was obtained from black liquor from Lignocellulosic mass (sorghum stalks and soya bean stems). The precipitation of black liquor with sulphuric acid was successful to obtain the lignin as solid particles.

It was found that the lignin obtained from sorghum stalks provided the greatest yield compared to lignin from soya bean stems by weight.

The low yield was due to the increased temperature, the time and ratio of the sample.

Following the solubility, the results showed that Methanol is a better solvent for lignin than as compared to water, ethanol and hexane.

It was found that the lignin obtained from sorghum stalks was more soluble in water and hexane due to its higher hydroxyl and non-polar group content than lignin obtained from soya bean stems. On the other hand, the lignin obtained from soya bean stems was more soluble in ethanol and methanol due its higher phenolic group content than the lignin from sorghum stalks.

5.2 RECOMMENDATIONS

In future, therefore we should consider the possible effects of reducing the lignin content like exposing plants to pathogens due to its application in road construction.

Since ,there is another alternative of extracting lignin from plant biomass like the use of 15-1 laboratory digester PL001, therefore further research should be carried extract to lignin using different methods.

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