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Organosolv-Extracted Lignin from Lotus leaves and its Spectroscopic Analysis and Anticorrosive Potential

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Abstract: *Lignin was extracted from rice husk and cotton shells, two abundant agro-industrial wastes, using an organosolv process and evaluated for anticorrosive coating applications. Spectroscopic characterization confirmed successful lignin recovery. UV-Visible analysis showed a characteristic absorption band near 280 nm, indicating aromatic lignin structures, while FTIR spectra revealed dominant phenolic O-H, carbonyl (C=O), and ether (C-O) functional groups, consistent with preserved lignin chemistry.*

The anticorrosive performance of lignin is attributed to its aromatic backbone and high phenolic hydroxyl content, which enhance coating adhesion, promote metal surface passivation, and inhibit oxidative corrosion reactions through radical scavenging- These structural features contribute to the formation of an effective protective barrier against corrosive environments. The study demonstrates that lignin derived from agricultural waste can serve as a sustainable, ecofriendly alternative to petroleum-based anticorrosive materials, supporting waste valorisation and the development of green coating technologies.

Keywords: Lignin: Agro-industrial waste: Rice husk: Cotton shells; Organosolv extraction; FTIR spectroscopy; UV Visible analysis; Anticorrosive coating

I. INTRODUCTION

Lignin is the most abundant natural aromatic polymer found in nature. It naturally exists as part of different types of lignocellulosic materials (plant-based biomass). Lignin acts like a binding material that holds together two main components of biomass—cellulose and hemicellulose fibres—and provides mechanical strength to plants. The structure of lignin depends on the type of biomass, and it is quite complex because it has a high aromatic content and many branches and cross-links[1] . However, the presence of lignin can create problems when using lignocellulosic biomass to produce valuable products such as ethanol, xylitol, butanol, and paper pulp . For these processes, lignin must be removed first because it strongly interferes with biofuel production. It reduces efficiency during both enzymatic hydrolysis and fermentation, and it can also cause a darker colour in cellulose pulp. As a result, many industrial processes produce large amounts of waste streams that contain unrecovered lignin, which can negatively affect the environment[3]. In Occurrence, the amount of lignin extracted by industries each year is only about 1.5–1.8% of the total lignin available in the biosphere. It is estimated that by 2030, industrial lignin production will reach 225 million tons. However, only a very small portion of the leftover lignin extracted each year and about 0.075 million tons is recovered from biorefineries and paper manufacturing processes, even though these industries produce the largest amounts of lignin waste. Recently, lignin obtained from leftover lignocellulosic materials (agricultural and industrial plant waste) has gained a lot of attention. This is because lignin is abundant, low-cost, and biodegradable, and it also has high thermal stability and high carbon content[4]. These properties make lignin useful for many industrial applications, such as producing:

- High-value chemicals

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- Energy and fuels
- Intermediate compounds used in chemical manufacturing[5].

For this reason, many research projects are now focusing on recovering lignin from Lignocellulosic Agricultural and Industrial Waste (LAIW). This approach follows the important ideas of sustainability and the circular economy, where waste materials are fully utilized and the use of non-renewable raw materials is reduced[6]. These efforts are important for:

- Environmental protection
- Better waste management
- Promotion of the bio-economy

However, there are some challenges. On one side, lignin has a very complex structure, which makes it difficult to process. On the other side, lignocellulosic biomass contains more cellulose than lignin, so most research and industrial work has mainly focused on using cellulose. As a result, in many processes, lignin is still treated not as a valuable co-product but as a low-value by-product [1], [7].

Lignin is a type of copolymer made mainly from three basic building blocks called phenylpropane monomer units (monolignols). These three units are:

- p-Coumaryl alcohol
- Coniferyl alcohol
- Sinapyl alcohol

Lignin is a valuable bio-based raw material (feedstock). It can be used directly in products or broken down (depolymerized) to produce useful chemicals [8].

Direct Uses of Lignin

Lignin can be directly used to manufacture several materials, such as:

- Lignosulfonates
- Carbon materials
- Polymer resins
- Adhesives (glues)
- New materials and composite materials

Lignin can also be added to other polymers as an additive or copolymer. For example, when lignin is mixed with polymers like:

- Poly (lactic acid) (PLA)
- Polyethylene (PE)

It can improve their thermal stability and mechanical strength. It can also provide new properties such as:

- Antioxidant properties
- Antimicrobial properties
- Better barrier properties (protection against moisture or gases)

Lignin as a Source of Chemicals

The structure of lignin makes it a possible source of high-value aromatic chemicals, which are usually produced from petroleum (fossil fuels) in the petrochemical industry. Because oil reserves are gradually decreasing, researchers are increasingly studying sustainable and environmentally friendly alternatives for producing energy and chemicals[9], . In this situation, biomass is becoming an important renewable and affordable option. Therefore, lignin is considered a promising and valuable source of different aromatic compounds and hydrocarbons, which can be widely used in the chemical industry in the future [10]. Rice husk (RH) and cotton shells are two common types of lignocellulosic biomass (plant-based agricultural waste)[11]. Worldwide, about 750 million tons of rice are produced every year. From this, around 150 million tons of rice husk are generated annually as a by-product [12]. In cotton production, about one-third of the weight of a cotton bale becomes cotton shells (cotton waste). Because cotton is produced in large quantities around the world, a significant amount of cotton shells is generated every year. This cotton waste usually contains Thorns, Leaves, Dust, Seeds, Stems, Fine particles. Globally, the annual production of cotton is reported to be about 27.5 million tons. The most common methods used to dispose of rice husk and cotton shells are: Landfilling (dumping in landfill sites), Incineration (burning). However, both of these methods are harmful to the environment[12]. Cotton shells contain large amounts of hydroxyl, carboxyl, and carbonyl chemical groups. Because of these properties, cotton shells are considered suitable for wastewater treatment applications, as it can help remove pollutants from water.

In addition, rice husk and cotton shells are valuable sources of lignin. If lignin can be extracted from them, it can be used to make or improve many products such as: Asphalt binders (road construction materials), Cement, Pulp and paper, Carbon fibre, Activated carbon. However, the progress in using lignocellulosic biomass has been limited because the chemical and biological processes needed to convert plant materials into simple components (monomers) and final useful products are often expensive. To convert biomass into useful materials, the first step is to separate lignin from cellulose. There are several methods to separate lignin from cellulose in lignocellulosic biomass.[13,14]

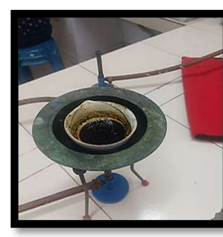
II. MATERIALS AND METHODOLOGY

Fresh lotus leaves were first thoroughly washed to remove dust and impurities, then dried and weighed. About 40 g of dried lotus leaves was chopped into small pieces to increase the surface area for efficient extraction. 300 mL of ethanol was taken in a round-bottom (RB) flask, and the chopped lotus leaves were placed in a thimble for extraction using a condenser setup (Soxhlet extraction). The extraction process was carried out by heating the system at 90°C for 8-9 hours, allowing continuous reflux of ethanol through the plant material for effective extraction of bioactive compounds. During this process, the soluble components from the lotus leaves were gradually extracted into the ethanol and collected in the round-bottom flask. After completion of extraction, the solvent was evaporated, leaving behind a sticky concentrated extract of lotus leaves. This extracted material was obtained in a viscous form and was used as a natural binder/hardener for further applications.

Lotus leaves

Solvent extraction

Extracted solution



Lotus leaves Lignin/ Binder

PREPARATION OF EPOXY RESINS

A refined soyabean oil 20ml was taken in a beaker. The reaction mixture of acetic acid and hydrogen peroxide was prepared in a test tube as the 1:3 ratio (0.5:1.5) molar basis. Then, the above reaction mixture was poured into the soyabean oil, which was heated at a temperature 50-60℃ on a hot plate for 6 hours in a closed system. After the completion of reaction, we get the epoxy resins as a final product which was cooled at room temperature [15].

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Epoxy resins

Lignin-alkyd bio-resin coating(Lotus Leaves Procedure) .

In this process polystyrene was dissolved benzene and form a uniform solution then lotus leaves lignin was taken in China dish and the above solution was added in it. The solution was stirred well to obtain a uniform coating material. Finally, the prepared mixture was applied onto the corroded metal surface to protect it from further corrosion.

Lotus Leaves Lignin

Lotus leaves lignin composition

Corroded material

Coated Sample

Water Treatment

Acid Treatment

Lotus leaf lignin coating showed effective corrosion protection. Cotton shell and rice shell lignin coatings showed poor anticorrosive performance. Lotus leaf lignin formed a more compact and hydrophobic barrier layer. Poor adhesion and higher porosity may be responsible for the lower performance of cotton shell and rice shell coatings. Lotus leaf lignin is a suitable eco-friendly material for anticorrosive coating applications.

III. RESULTS AND DISCUSSION

- UV-Visible Spectroscopy was used to study the optical properties and aromatic structure of lignin. The principle of UV spectroscopy is based on the absorption of ultraviolet light by molecules.
- FTIR Spectroscopy was performed to identify the functional groups present in the extracted lignin

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ISOLATION PROCESS OF LIGNIN FROM LOTUS LEAVES

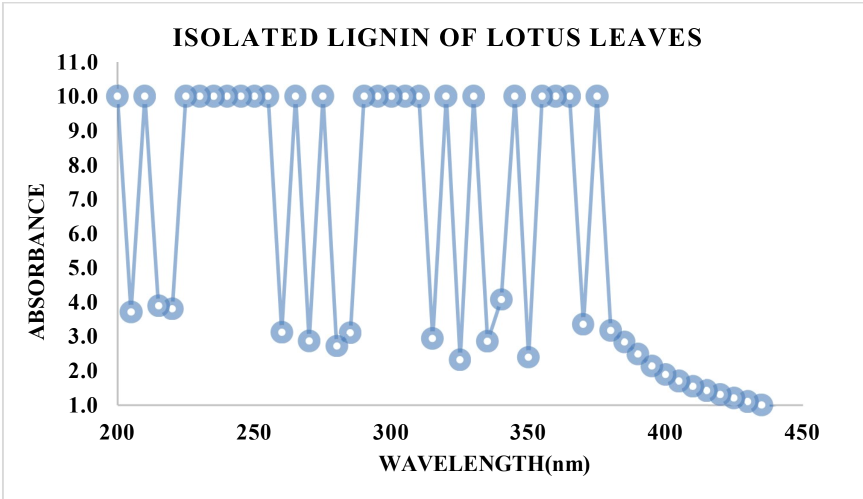

Fig: -Lignin Concentration of Isolated lignin from Lotus leaves analysis by UV- Visible Spectrophotometer

- The lignin concentration of liquor analyses by instruments UV-visible spectrophotometer Model (Agilent Cary 60 UV-Vis). The range of UV region is (200-400) nm and visible region is (400-750) nm. The baseline was set from 200nm to 800nm.
- The literature value of lignin as a main peak is 280 nm and for extracted lignin was found to be 235, 250.01, 305, 365.01nm which validate the presence of lignin.

EXTRACTION OF HYDROPHOBIC MATERIAL FROM LOTUS LEAVES (BY USING SOXHLET APPARATUS)

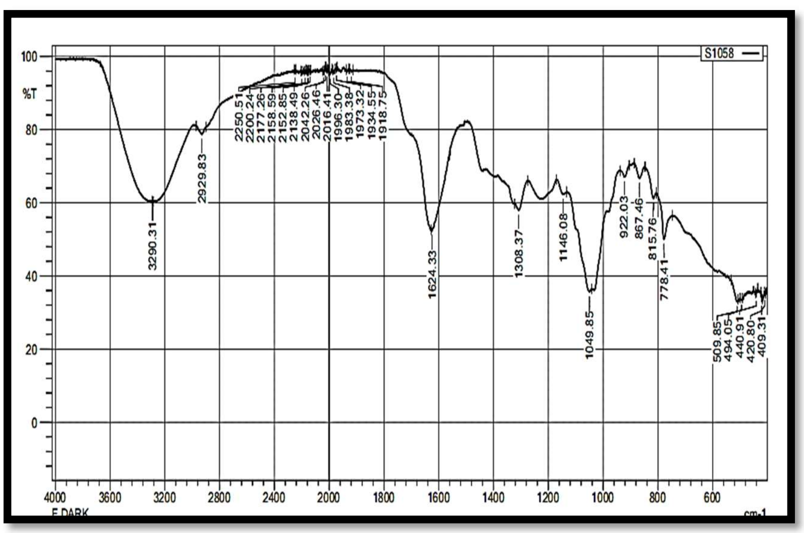

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Fig:- 3.5. FTIR spectroscopy of lotus leaves

Sr. No.	Literature value	Observed value	Interpretation
1	3200-3300	3290.31	=C-H Strech
2	2000-2500	2929.83	C=C conjugated and C≡C
3	1900-1990	1983, 1996	Aromatic ring overtone and combination bands)
4	1620	1624.33	Aromatic C=C
5	1300	1308.37	C–O stretching vibration
6	900-1200	922.03, 1049.85, 1146.08	C–O stretching and C–O–C asymmetric stretching
7	850-650	778.41 815.76, 867.46	C–H out-of-plane bending
8	600-400	409.31, 420.80, 440.91, 494.05, 509.85	Metal–Oxygen (M–O) stretching vibration

To check the anticorrosive property of modified lignin-based epoxy resin

Modified lignin-based epoxy resin was applied in tripod stand, then the applied stand was allowed to dry for 1-2 days. Once the stand was completely dried, it was dipped I water and acid to check the anticorrosive property of the modified epoxy resin.

By the study, it was observed that the tand is stable after one week which may confirm the modified lignin-based epoxy resin show anti-corrosiveness.

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