JPIChE 54 (1) 2026: 115-126

PAKISTAN INSTITUTE OF CHEMICAL ENGINEERS Since 1969

Journal of the Pakistan Institute of Chemical Engineers

Journal homepage: www.piche.org.pk/journals

DOI: https://doi.org/10.54693/piche.05417

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Efficient Extraction of Lignin from Walnut Shell and Peanut Shell Blend by using Ionic Liquid

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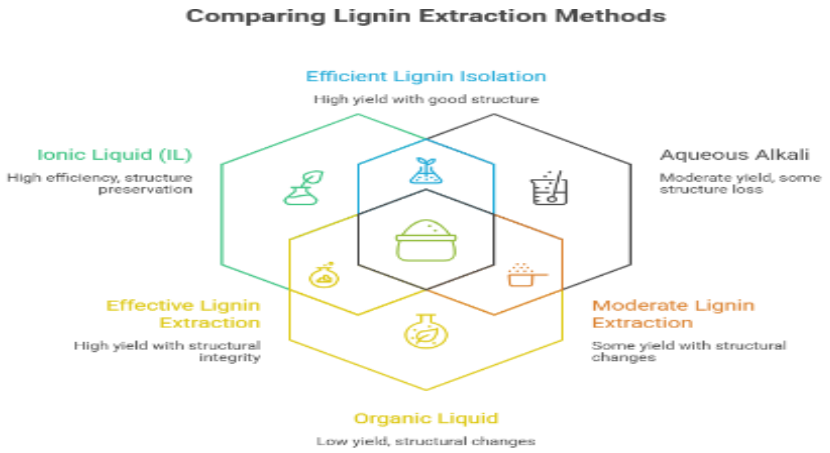
Submitted: 24/03/2026, Accepted: 25/08/2026, Published: 03/09/2026

ABSTRACT

Lignin is a valuable product with numerous applications such as Nano-lignin and an important renewable energy source, however, isolation of lignin from biomass is a challenging prospect. The present study aims to extract lignin from Walnut Shell and Peanut Shell blend using three different solvents; Ionic Liquid (IL), Organic Liquid and Aqueous Alkali. IL (Pyridnium Formate) is used to extract lignin from 1:1 blend of Walnut Shell and Peanut Shell. The performance of IL is compared with Alkali (Sodium Hydroxide) and Organic Liquid (Ethanol) where IL proved to be the most effective in lignin extraction. Consequently, the preservation of lignin structure and presence of aromatic rings as well as Syringyl (S) ring and Guaicyl (G) rings was confirmed by FTIR. It showed the existence of conjugated and non-conjugated aromatic rings which are needed for further lignin application like epoxy resins. TGA of untreated biomass and treated biomass showed easier thermal decomposition at lower temperature proving that IL pre-treatment was effective in breaking down the biomass. SEM revealed the changes in surface morphology which occurred due to pre-treatment. The treated sample had a much more amorphous and porous structure. In conclusion, at operating conditions temperature 140ºC, retention time 120 min and IL to biomass ratio of 1:20 (wt/wt), maximum lignin yield is achieved by IL which is equal to 73.6%. The yield for Alkali, at temperature 120ºC and retention time 180 min along with addition of concentrated Sulfuric acid as catalyst, is 37.6%, whereas the yield for Organic Liquid, at temperature 210ºC and retention time 90 min, is the lowest 23.4%. Moreover, the IL is regenerated and recycled to make it cost effective for lignin extraction. Hence, the present study establishes that IL is most suitable in extracting lignin efficiently.

Keywords: Lignin Extraction, Walnut Shell, Peanut Shell, Ionic Liquid (IL), Organic Solvent, Alkali



Graphical Abstract

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1. Introduction:

Lignocellulosic biomass refers to the most abundantly available feedstock in the world. Presently, biomass yield accounts for 10% of the world's essential energy[1]. Walnut Shell (WS) and Peanut Shell (PS) are part of lignocellulosic biomass. Globally, 3.5 million tons of walnuts are produced yearly, out of which 1.5 million tons are consumed without the shell. This leads to huge walnut residue in the form of WS [2]. Similarly, the annual peanut cultivation was roughly 55 million tons in 2021 and is expected to increase on a yearly basis. PS is the core remainder of the peanut crop. It accounts for 20% of the main crop which is equivalent to 9.2 million tons[3]. In Pakistan, Walnuts are grown in the Northern areas, namely Hunza, Gilgit, Shigar etc, whereas Peanuts are predominantly grown in Punjab. Annual production for Walnuts in Pakistan roughly constitutes 10400 Metric Tons, out of which 5200 Metric Tons are wasted as WS. Similarly, annual Peanut production accounts for 87900 Metric Tons, of which 26400 Metric Tons are PS waste. This waste residue of Peanuts and Walnuts provides a great opportunity to be used as a source of lignin which can be further used in industry. As a result, this will lead to reduction in agricultural waste and sustainable growth[4].

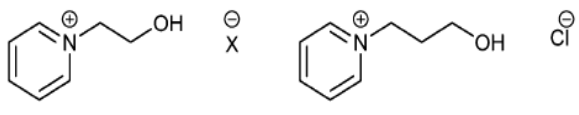
Lignocellulosic Biomass consists of three major components, namely Cellulose, Hemicellulose and Lignin. Approximately, cellulose accounts for 35-55% by weight, hemicellulose accounts for 20-40% by weight and lignin accounts for 10-25% by weight of lignocellulosic biomass[5]. Lignin is a part of a class of complex organic polymers mainly found in key structural materials of plants. Lignin offers a huge valorization capacity which has a great scope of applications, ranging from biofuel feedstock to nanoparticles. It can provide us with a vast range of value-added products such as better-quality adhesives, isocynate binders, thermosetting resins, bio plastics and lignin-based carbon fibres[6]. Additionally, lignin has a major role in the production of lignin nanoparticles, Nano-lignin. These nanoparticles can be used in a diverse range of fields from biomedical, for tissue regeneration and drug delivery system, to environmental, for underwater antifouling materials. Lignin nanoparticles also have uses in food industry in terms of food packaging films. Thus, lignin provides a major opportunity for advancement in "green" (environmentally safe) materials.

To add economic value to lignin we must use it to make high value products and for that it is crucial to obtain high purity lignin. This is a complicated phenomenon that consists of breaking bonds formed between the plant matrix and lignin molecules, and the subsequent diffusion of lignin into solvent[7]. The basic obstacle faced during lignin extraction is that the extraction techniques and severity of process (higher operating pressures and temperatures, along with extended dissolution times) result in modifications in the original lignin structure[8]. Along with this the severe operating conditions cause the entire process to be costly. Effective separation of lignocellulosic biomass would ensure that the structure of the biopolymers, lignin, cellulose and hemicellulose, is intact[7]. Most prevalent solvent fractionation technique for lignin isolation are Acid Hydrolysis [9], [10], [11], Kraft pulping [11], [12], [13] and Organosolv treatment [14], [15], [16]. Although, these methods successfully extract lignin, the reaction times and temperatures needed are long which makes the entire process time consuming. Along with that, the lignin obtained by these processes does not remain structurally intact. Moreover, acid hydrolysis requires special corrosion resistant reactors and proper acid recovery and waste neutralization while organic solvents have high cost of handling and low recyclability. A summary of various solvent techniques used to extract lignin from biomass along with their features are given in table 1.

Table 1: Summary of Different Solvent Fractionation Techniques of Lignocellulosic Biomass

Pre-treatment Method	Solvent Employed	Features of the lignin isolated	References
Acid Hydrolysis	Sulfuric Acid (70-72%)	Large-scale structural changes are required for neutralization, prior to treatment with enzyme or acid separation from sugar. Causes development of toxic materials and corrosion to equipment.	**[17]**
Alkaline Pre-treatment	Sodium hydroxide/sodium sulphide (White liquor)	Lignin structure is modified due to severe reactions. Operating temperature requirement is high.	**[18, 19]**
Deep Eutectic Solvents (DES)	Deep Eutectic Solvents	The solvent cost is less. It is less toxic and easy to synthesize, along with being thermally stable, and non-flammable. However, solubility of lignin is restricted and only lab-scale applications are observed.	**[20, 21]**
Organosolv Process	Organic Solvents	Solvent recovery in the recycling process is low due to high volatility. Operating temperature requirement is high. Cooking time is longer.	**[22]**
Ionic Liquid Treatment	Ionic Liquids	It has thermal stability and reduced viscosity. High recovery of cellulose, low molecular weight and thermally stable lignin. Improved qualities of lignin are observed; reduced polydispersity and thermally stable. The cellulose recovered has lower Mr and is stable in a range of temperatures. Overall operating costs are high such as the solvent and solvent recovery cost along with requirement of extended dissolution times and higher temperatures.	**[22-24]**

Recently, ILs have emerged as green solvent compared to conventional liquids which give great efficiency in lignin extraction [25] [26]. Among various ionic liquids, biodegradability of aromatic cations imidazolium, thiazolium and pyridinium was explored. Imidazolium cations showed a trend of poor biodegradability < 35%. Similarly, thiazolium exhibited low biodegradability. However, pyridinium presented good levels of biodegradability with some derivatives reaching up to 65%. In the same study, biodegradability of anions was also determined. Formates, acetates and other simple carboxylates were employed as IL anions and found to give very good biodegradation. Thus, PILs can be considered green solvents. Following figure, Figure 1, shows the extent of biodegradability of Pyridinium cations with various anions [27].



109, X = Br, 65%*
110, X = NTf_2, 62%*
111, X = I, 65 ± 10%**

112, 51%**

Figure 1: Biodegradability of Pyridinium Cations with Different Anions[27]

Achinivu, et al was one of the first to use Ionic Liquids for lignin extraction. Biomass used was corn straw.

Three different cations (pyrrolidinium, pyridinium and imidazolium) were used while the acetate anion was kept the same. Pyrrolidinium acetate was reported to be the best as it removed 50% w/w lignin from corn straw. Moreover, little to no dissolution of cellulose and hemicellulose was witnessed[23]. Similarly, Rashid, et al explored the use of various ILs and concluded that the pyridinium basedILs were very effective for lignin dissolution. 91.23% lignin was extracted at temperatures below 78ºC. ILs are chemically and thermally stable and have low vapour pressure which make them a good option but they are relatively expensive which makes them unsuitable for large scale use [28]. Furthermore, IL 1-ethyl-3-methyl imadizolium acetate was employed to extract lignin from sugarcane bagasse by Saha et al. and it was concluded that IL was successful in extracting 90.1% of lignin from biomass [29].

While ILs have been investigated in literature for lignin extraction from biomass, it is primarily focused on feedstocks such as corn stover, sugarcane bagasse or oil palm. However, this study aims to isolate lignin from WS and PS blend which is a major waste material in Pakistan, has a high content of lignin and remains understudied. Moreover, in this study performance of IL (Pyridinium Formate) is compared with Organic Liquid (Ethanol) and Alkali (Sodium Hydroxide) providing clear insights into the differing mechanisms and results for lignin extraction using different solvent systems. In addition, structural analysis and physicochemical characteristics of the extracted lignin are evaluated using FTIR, SEM and TGA.

2. Materials and Methods:

WS and PS were collected from the local market. They were washed with 2% detergent solution to remove dust, oil and grease, and then dried under direct sunlight for 48hrs. After this they were ground and sieved to achieve an average size of 5-10mm [30]. Blend of WS and PS was formed by mixing both shells in 1:1 ratio. It was treated to find out the moisture content, ash content, acid-insoluble lignin as well as extractives which is shown in Table 1. Pyridinium Formate (>97%), Ethanol and Concentrated Sulfuric Acid were purchased from Sigma Aldrich. Aqueous Sodium Hydroxide solution was made by Sodium Hydroxide pellets to a concentration of 50g/l. Optimum operating conditions were selected based upon thorough review of previous studies involving lignin extraction by employing ILs, Alkali and Organic Liquids. Accordingly, these conditions are detailed in the experimental procedure section.

Table 2: Analysis of Biomass

Proximate Analysis	
Moisture Content	6.64%
Ash Content	2.52%
Extractives	1.72%
Bio-chemical Composition	
Lignin	33.73%
Cellulose	31.47%
Hemicellulose	30.13%

2.1. Experimental Procedure:

Three sets of experiments were conducted with three different solvents. The aim was to attain maximum possible lignin yield.

I. Experiment with IL

WS and PS blend in 1:1 was added to Pyridinium Formate, and heated at 140°C for 2 hours in silicon oil bath, with continuous stirring at 600rpm using hot plate and magnetic stirrer. Once reaction process was completed the mixture was then allowed to cool to room temperature. Then, acetone/deionized water in 1:10 v/v was added to the mixture to allow separation of extracted lignin fraction. Following that, the resulting suspension was stirred at room temperature for 1 hour, and subsequently vacuum filtration was carried out using 2-micron filter paper. The solid residue obtained after filtration was Cellulose Rich Material (CRM) and filtrate was labelled Black Liquor. CRM was washed with acetone/deionized water and dried overnight at 60°C. After that it was weighed and stored. Black Liquor, containing dissolved lignin and IL, was heated on hot plate at 60ºC until precipitation was visible. Subsequently, it was cooled to room temperature, and filtered under vacuum with 2-micron filter paper. Lignin was obtained as residue while Lignin was obtained as residue, which was washed with deionized water and then dried overnight at 50°C, before being weighed and stored for sampling. Pyridinium Formate, found in filtrate, was recovered by heating at 100 °C to remove moisture and then reused for further experiments.

II. Experiment with Sodium Hydroxide

300 ml of 50g/L of NaOH solution was prepared by dissolving NaOH pellets in distilled water. Biomass was dissolved in the alkaline solution at a biomass to solvent ratio of 1:17 w/w. The mixture was heated in autoclave for 180 minutes at 120°C. After reaction completion, it was allowed to cool to room temperature. Then, vacuum filtration was carried out using muslin cloth to separate Cellulose Rich Material (CRM) from mixture. CRM was separated as Residue. Filtrate, known as Black Liquor, containing Lignin Rich Material (LRM) was stored. pH of CRM was noted. CRM was washed with Distilled Water till pH reached 7. Then CRM was air dried at room temperature. Finally, weight of CRM was recorded and it was stored. pH of Black Liquor was checked. Lignin recovery from Black Liquor was done by dropwise addition of concentrated Sulfuric Acid, till pH of Black Liquor reached 2. This caused precipitation of Lignin particles. The Black Liquor was centrifuged at 3000 rpm for 30 minutes to isolate Lignin. Filtration of Centrifuged Liquid gave Recovered Lignin as Residue. Lignin was washed with Distilled Water and dried overnight in hot air oven at 50ºC. Weight of dried Lignin was recorded and Lignin sample was stored for characterization.

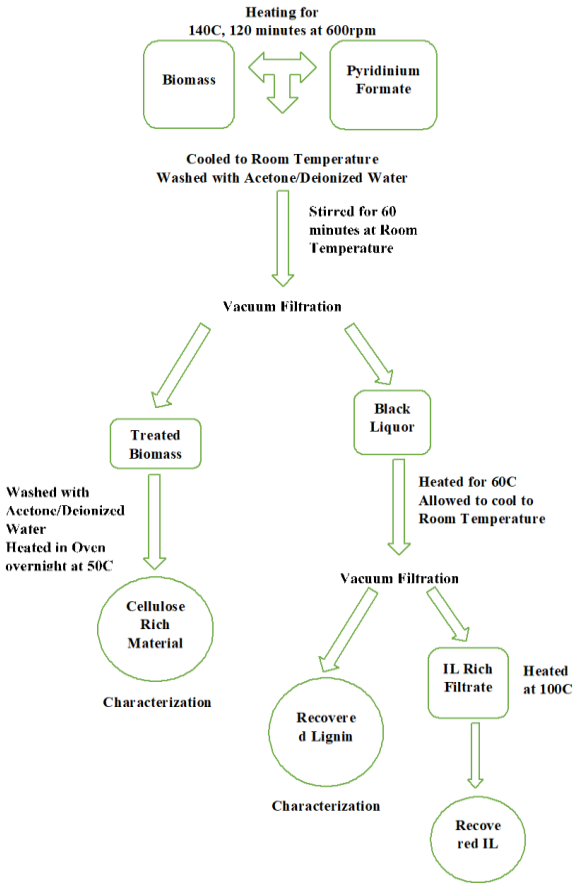


Figure 2: Process Diagram for IL

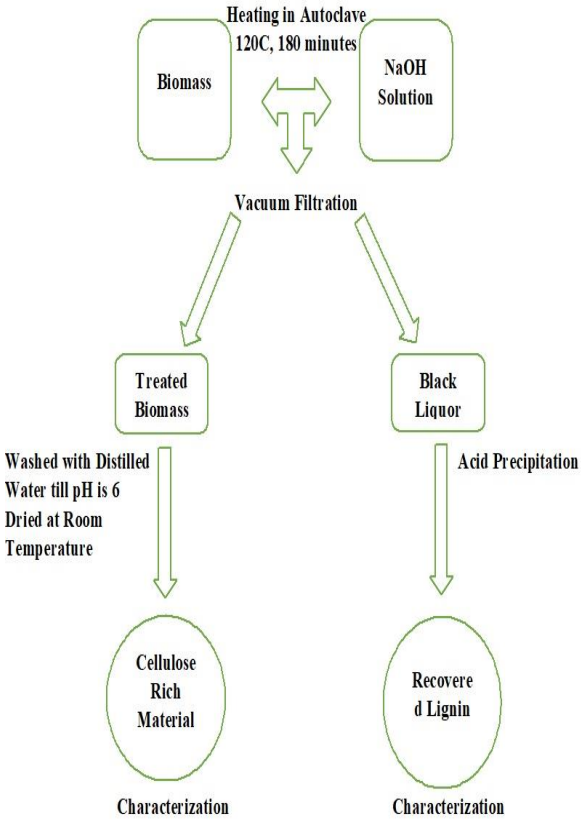


Figure 3: Process Diagram for Alkali

III. Experiment with Ethanol

A 60% (v/v) ethanol solution was prepared by combining 60ml of ethanol with 40ml of distilled water. Biomass was added to Ethanol solution (10ml solution per 1g biomass) in Autoclave at 210ºC for 90 minutes. The mixture was cooled to room temperature. After completion of treatment, it was filtered to obtain CRM as residue while LRM was obtained in filtrate. LRM was sealed and refrigerated before further use. CRM was washed with fresh Ethanol/Water solution in same amount and concentration as used before. This Ethanol/Water solution was also stored and refrigerated. CRM was dried overnight in oven at 50ºC and then weighed and sampled for characterization. LRM and Washing Liquid were combined; this was named Combined Liquor. Combined Liquor was sprayed into cold refrigerated water in 1:3 w/w to allow lignin particles to become buoyant. The solution was left for 30 minutes at room temperature. Subsequently, it was centrifuged at 4200rpm for 1 hour. Lignin was obtained after decanting the centrifuged liquid. The recovered lignin was then dried and weighed before being sampled for characterization.

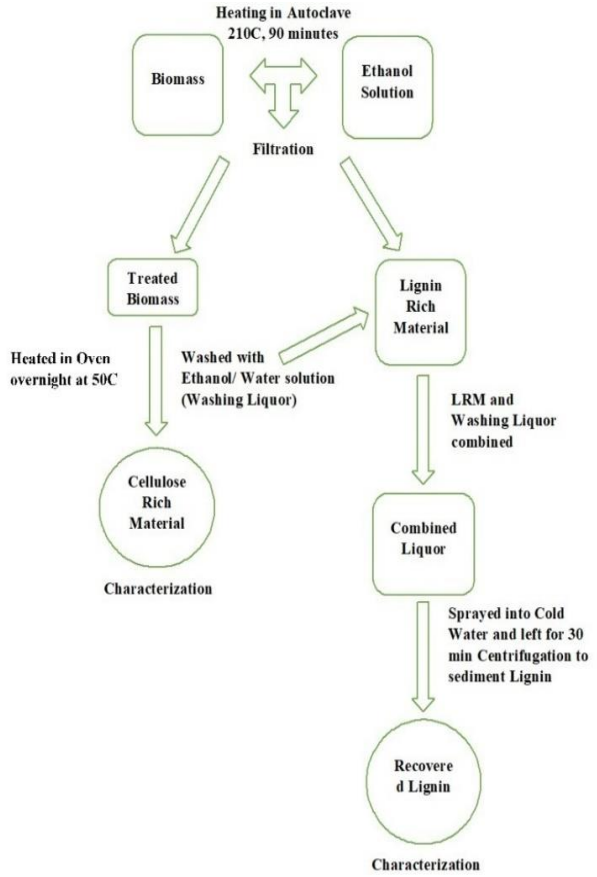


Figure 4: Process Diagram for Organic Liquid

2.2. Extraction of Lignin from Biomass:

Lignin Yield was calculated by determining the weight of the dry, recovered lignin fraction and the weight of the lignin fraction in the dry biomass.

$$Lignin\ Yield\ (\%) = \frac{Weight\ of\ Dry, Recovered\ Lignin\ (g)}{Weight\ of\ Lignin\ in\ Dry\ Biomass\ (g)} \times 100\%$$

The recovered lignin samples were dried to constant weight prior to measurement to eliminate the influence of residual moisture on yield calculations.

2.3. Characterization of Lignin:

Lignin characterization was done using three techniques; SEM, FTIR and TGA. SEM gave an overview of the changes in the surface morphology of biomass that occurred as a result of IL pre-treatment. FTIR provided information about the characteristic lignin functional groups as well as the preservation of aromatic units in lignin, whereas TGA was performed to compare the thermal stability and degradation properties of untreated biomass and extracted lignin. Overall, the employed techniques allowed thorough insights into the extraction efficiency of the three solvent systems and structural integrity of the extracted lignin samples.

3. Results and Discussion:

3.1. Lignin Yield:

Lignin Yield from all three solvents was calculated as an average with a mean standard deviation of ±95% and is shown in the table (Table 2) below

Table 3: Lignin Yield from Different Solvents

Extraction Technique	Extracted Lignin Yield (%)
Ionic Liquid	73.6
Alkali	37.6
Organic Liquid	23.4

IL achieved the highest lignin yield, followed by Alkali and then Organic Liquid. IL's enhanced performance is based upon its capability to disrupt the hydrogen bonding network in the lignocellulosic biomass. The formate anion achieves selective lignin dissolution by interacting with hydroxyl groups in the biomass, whereas the pyridinium cation stabilizes the lignin by interacting with its aromatic rings. Thus, IL is most effective in lignin isolation.

On the other hand, alkaline extraction yields moderate results because alkali causes degradation of aromatic functional groups in lignin and leads to structural modifications. Similarly, organic liquid resulted in lowest lignin recovery due to its inability to break the lignin-carbohydrate complexes.

Thus, IL proved to be the most effective in lignin recovery from WS-PS blend while preserving lignin's important characteristics.

3.2. Scanning Electron Microscopy (SEM):

Scanning Electron Microscopy (SEM) is a characterization technique used to investigate and analyze the surface morphology of the sample. It gives high resolution images of the sample and provides pictorial view of the structure of the sample. The technique uses a beam of electrons to scan the surface. The atoms in the surface interact with the electron in the beam and produce various signals which are reflected back at different angles and directions. These reflected signals are detected by special detectors and generates

images accordingly. The images are detailed and give deep insight of the topography of the sample.

The surface morphology of the Untreated Biomass (left side) and IL Treated Biomass (right side) was investigated using SEM. The images were obtained at three resolutions; 5.0µm, 3.0µm and 1.0µm. The figure (Figure 5) below shows the structure of UT Biomass as well as IL Treated Biomass.

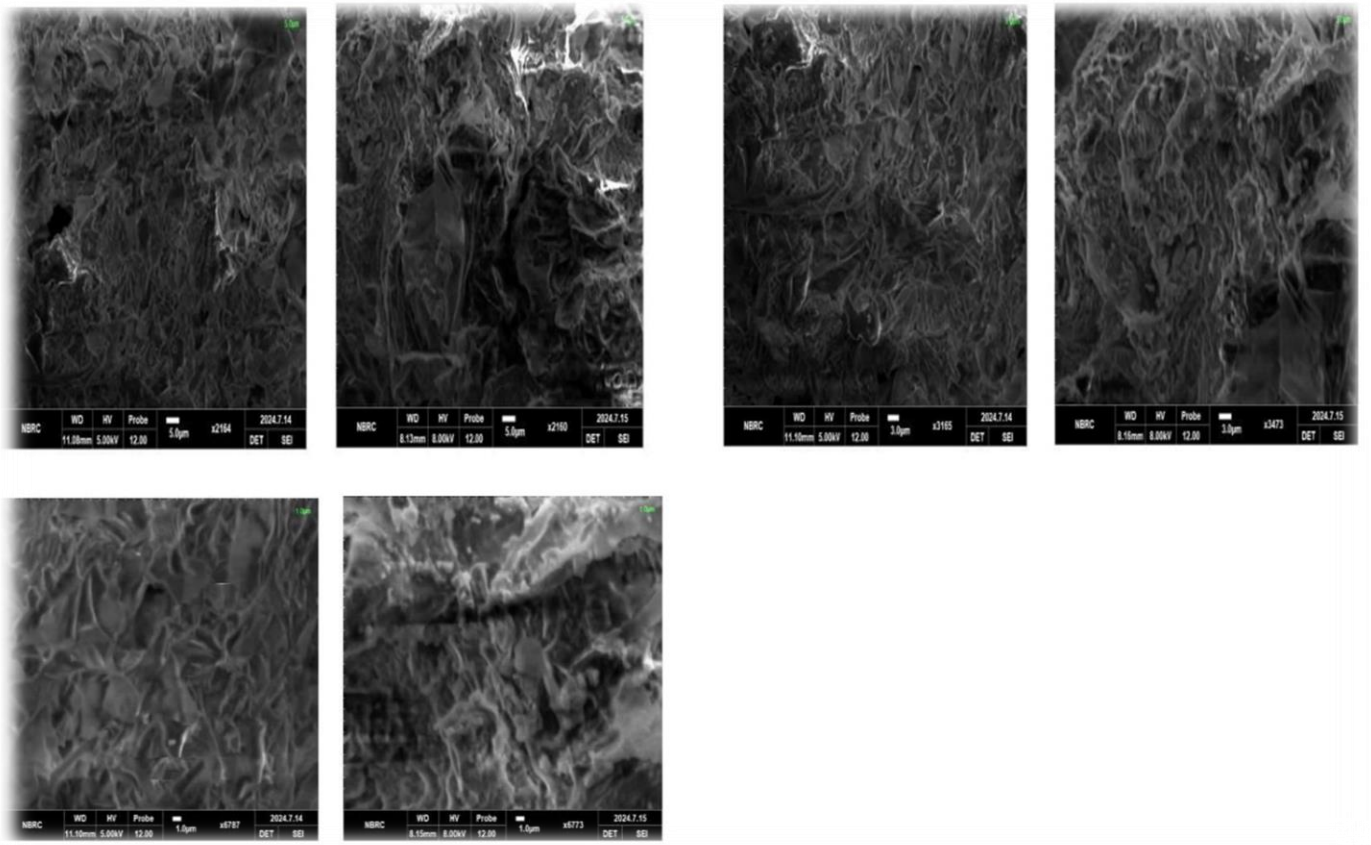


Figure 5: SEM of Untreated Biomass (LEFT) and IL Extracted Lignin (RIGHT)

The SEM graphs indicate the clear structural differences in the Untreated sample and IL Treated sample. The Untreated sample is smoother and more compact, which is typical for intact lignocellulosic biomass, compared to the IL sample which depicts severe structural destruction. The IL sample shows that surface has burst open to a greater degree and is displaying the underneath contents, leading to enhanced lignin accessibility. Similarly, IL sample has visible pores, fissures and more ridges compared to UT sample and this increased porosity supports the high lignin recovery achieved by IL. These morphological changes correlated with the main aim of IL pretreatment, which was to breakdown the biomass in order to release lignin. Thus, proving that IL pretreatment was most successful in breaking open the structure of the lignocellulosic biomass.

3.3. Fourier Transform Infrared Spectroscopy (FTIR):

Fourier Transform Infrared Spectroscopy is an analytical technique which identifies the functional groups in a sample. In FTIR infrared radiations are focused on a sample from 10000 $cm^{-1}$to 100 cm^{-1}. Some radiation is absorbed and some is transmitted by the sample. The radiations are detected and used to plot a spectrum ranging from 4000 cm^{-1} to 400 cm^{-1}. Each functional group and molecule have a unique radiation which allows it to be identified easily. FTIR spectrum was employed to understand the distribution of the various functional groups present in the lignin fractions, such as carboxyl, hydroxyl, methoxyl and carbonyl groups. FTIR was performed in the range of 4000 cm^{-1} to 600 cm^{-1}.

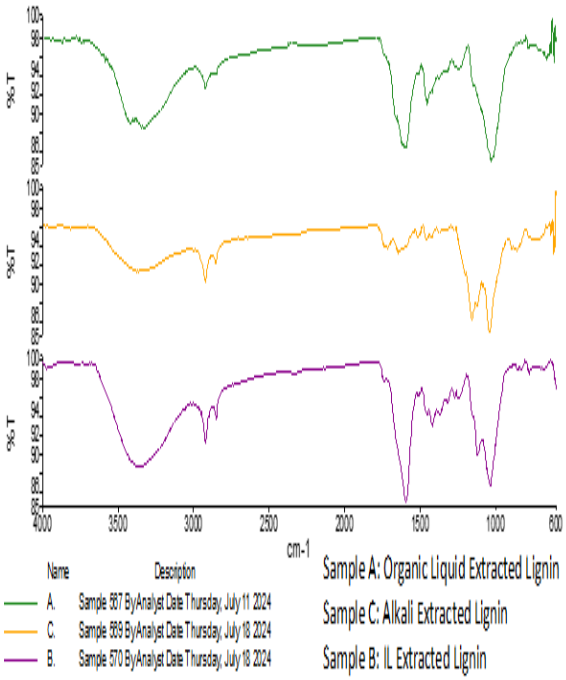


Figure 6: FTIR of Extracted Lignin

The general FTIR spectra for all lignin fractions had similar vibrations with some differences in the intensity of the bands. The difference in intensity can be attributed to the difference in separation techniques used. An extensive band appeared between 3100 cm^{-1} to 3500 cm^{-1} which shows presence of aliphatic and aromatic groups O-H groups. This band has greatest intensity in the IL treated sample where as in the Alkali treated sample the band has lowest intensity. It signifies that Alkali disrupted the chemical structure of the lignin. The peaks at 2908 cm^{-1}, 2780 cm^{-1} and 1387 cm^{-1} represent C-H vibrations of the methoxyl group. All lignin fractions show peaks at these points. However, the peaks of IL are more intense than the rest. Similarly, the peak at 1387 cm^{-1} of the Alkali treated sample is negligible compared to the rest, meaning the aromaticity of lignin is disturbed in the Alkali extracted Lignin.

The non-conjugated and conjugated carbonyl region is present between 1700 cm^{-1} and 1600 cm^{-1}. Peaks in this region show the presence of aromatic rings which are needed for future applications of lignin such as in binders and resins. The most intense peaks are seen for IL treated lignin which ensures that IL treated lignin are most appropriate for further applications. From 1600 cm^{-1} to 1000 cm^{-1}, the spectra show the aromaticity of the lignin structure. This aromaticity of the lignin structure is based on the guaiacyl (G) and syringyl (S) monomeric units of lignin, which have an aromatic skeleton. The (S) and (G) units appear between 1300 cm^{-1} and 1200 cm^{-1}. The Alkali sample does not show these peaks which means that the pretreatment destroyed the aromatic structure of the (S) and (G) units of lignin. Furthermore, the peak at 1153 cm^{-1} shows deformation of C-H bond of (S) unit aromatics. Along with that a peak at 1377 cm^{-1} is witnessed. During lignin isolation b-O-4 linkages and a-O-4 linkages are broken which is what is proved by the peak at 1377 cm^{-1}.

A summary of the various bands is given in Table 3 below.

Table 4: FTIR Band Description

Wavenumber (cm^{-1})	Description
3500-3100	Aliphatic and Aromatic O-H stretching
2908, 2780, 1387	C-H stretching of Methoxyl Group
1717	C-H vibration of Unconjugated Aromatic Ring
1676	C-H stretching of Conjugated Aromatic Ring
1377	b-O-4, a-O-4 Cleavage
1329	(S) Ring Vibrations
1211	(G) Ring Vibrations
1153	C-O stretching of (S) unit

Overall, the FTIR spectra highlights that IL was not only most efficient in lignin recovery but also in preserving key lignin functional groups, (S) and (G) units, which are essential for further lignin applications such as lignin nanoparticles, resins and binders. This is evidenced by the stronger peaks in IL spectrum compared to the rest as well as the disappearance of various peaks in Organic liquid and Alkali spectra.

3.4. Thermogravimetric Analysis (TGA):

Thermogravimetric Analysis (TGA) is a thermal analysis which is used for material characterization. In TGA the mass of a sample is observed with respect to temperature. Through this, TGA provides the information about a sample's thermal degradation.

The sample is placed in TGA pan which is situated in a furnace. A purge gas is used to control the sample environment. As the temperature changes, the change in mass is also noted. Thermogravimetric analysis was used to examine the thermal stability of UT Biomass and

IL Lignin. Temperature range of 30°C to 900°C was used. The atmosphere was inert Nitrogen gas and the temperature rate was 15°C /min.

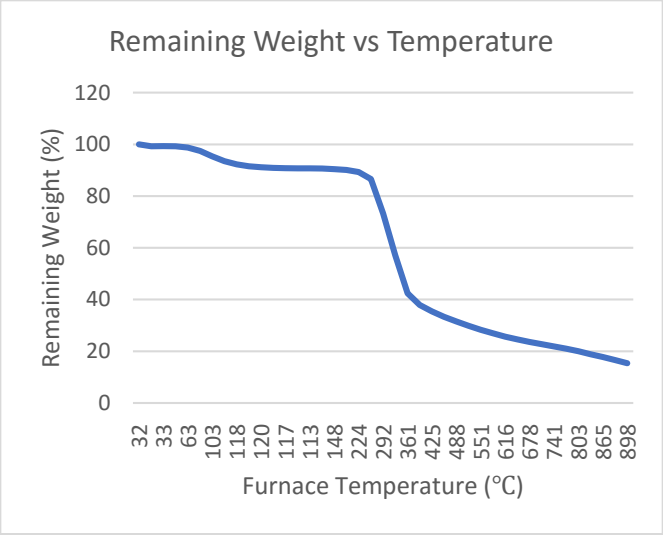


Figure 7: TGA Curve of Untreated Biomass

The TGA curve of the Untreated (UT) sample shows that there was some initial dehydration weight loss between 86°C and 120°C of 5.96%. However, beyond that major weight loss of 51.4% occurred at a much higher temperature between 224°C (T_{onset}) and 394°C, compared to the IL extracted biomass. This region denotes degradation of cellulose, hemicellulose and a portion of lignin. It illustrates that without IL disruption untreated biomass was thermally stable due to its intact structure. After 394°C, 15.4% weight loss is seen till 800°C which is the residual mass corresponding to thermally stable char and inorganic materials.

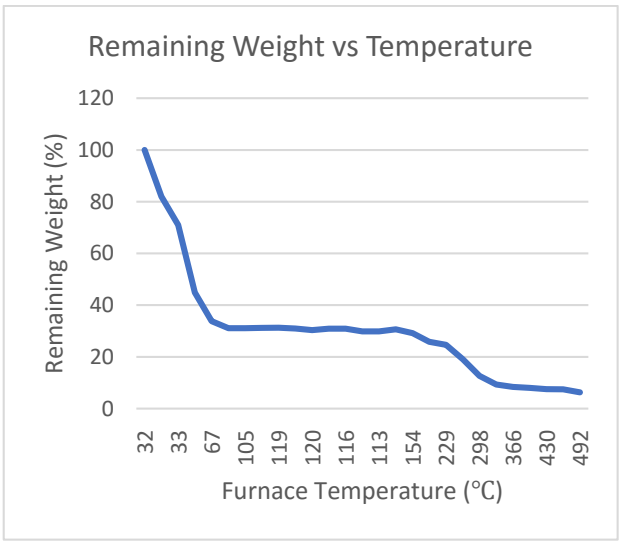


Figure 8: TGA Curve of IL Lignin

Thermal decomposition of the IL Lignin is witnessed in three stages. In the first stage, weight loss of 69.3% was seen around the temperatures between 30°C and 113°C. It is called Weight Loss Zone. This is attributed to moisture loss of lignin and evaporation of low molecular weight volatile compounds. The second stage, depicts the breakage of inter-unit linkages of lignin, depolymerization of side chains as well as cleavage of ether bonds. It is referred to as Active Thermal Degradation. Phenolic and organic products are formed as a result and Pyrolysis and Oxidation start to occur. This happens between 113°C to 330°C where weight loss is 21.3%.

Beyond 330°C the third stage, called Active Pyrolysis Range, slow decomposition accompanies degradation of aromatic rings into coke and char and weight loss is less, around 2.99%. Residual char and thermally stable inorganic compounds amounted to 6.3% which is significantly less than Untreated Biomass (27.2%) supporting the result that IL treatment effectively extracted lignin from Untreated Biomass.

3.5. Phenomenon of Efficient Lignin Extraction By Pyridinium Formate:

The phenomenon of lignin dissolution in [Py]For solution is understood by the following mechanism using two basic assumptions; a) Only lignin extraction took place and any cellulose and hemicellulose impurities were in trace amounts so they were ignored, b) Lignin extraction from cell walls to [Py] for solution occurred by diffusion. Lignin extraction occurs in a two-step process. First, [Py]For is diffused into the biomass matrix, followed by the second step which is lignin convection over the porous cellulose and hemicellulose residue into the [Py]For solution. Lignocellulosic biomass components (cellulose, hemicellulose and lignin) are interlinked by covalent and hydrogen bonding. This H-bonding plays an essential part in lignin dissolution, as the anion of [Py] For (Formate ion) dislocates the H-bonding network of cellulose and lignin. Thus, using [Py]For facilitates breakage of lignin's H-bonding, which results in efficient lignin extraction. Similarly, the [Py]For cation (Pridinium ion) stabilizes dissolved lignin aromatic fragments essentially preserving lignin structure. Moreover, a high concentration gradient exists between fresh [Py]For solution and lignin in biomass which allows the Formate ion to attack the lignin H-bonding and result in enhanced

and efficient extraction of lignin from lignocellulosic biomass [31].

4. Conclusion:

The key target of this study is to find out the most appropriate solvent for efficient lignin extraction from blend of WS and PS, in order to use recovered lignin to produce value added products. It is concluded that IL proved to be the most efficientsolvent compared to Organic Liquid and Alkali. Maximum lignin extraction was achieved by IL (73.6%), followed by Alkali (37.6%) and lowest was of Organic Liquid (23.4%). The analysis by SEM demonstrated that IL was able to break down the structure of lignocellulosic biomass, and gave access to lignin present inside so it was isolated easily. Furthermore, the characterization results by employing FTIR highlighted that the lignin structure and its aromatic backbone was preserved in the case of IL but it did not remain intact with Organic Liquid and Alkali. Similarly, TGA showed that IL extracted lignin had a lower temperature of thermal degradation than UT biomass, which strengthened the proposition that IL was able to destruct the lignocellulosic biomass and able to dissolve lignin. In the present research the novelty of the work is to use IL (Pyridinium Formate) to extract lignin efficiently from WS and PS blend. Moreover,IL can be regenerated and reused to extract lignin again. Hence, it is concluded that [Py]For is a non-toxic, less viscous and efficient solvent to be used for lignin extraction from WS and PS blend, which will allow for diversification of biomass feedstock as well as lead the way to produce Nano-Lignin.

Data Availability

The data supporting this article have been included as a part of ESI.

Conflict of Interest

There are no conflicts to declare.

Acknowledgments

The author thanks the management of NFC Institute of Engineering & Fertilizer Research Faisalabad for providing the resources.

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