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Separation and recovery of cellulose from *Zoysia japonica* by 1-allyl-3-methylimidazolium chloride

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ABSTRACT

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1. Introduction

Cellulose, which comprises glucose monomers linked by β -1,4glycosidic bonds (Gardner & Blackwell, 1974), is the most abundant component of renewable biomass in nature. It is usually non-toxic, biodegradable and biocompatible, with distinct physicochemical properties (Penga, Rena, Zhong, & Sun, 2011). Plant biomass mainly consists of cellulose (35–50%), hemicelluloses (20–35%) and lignin (5–30%) (Huber, Iborra, & Corma, 2006). Potential sources of such biomass include crops (e.g. corn and sugarcane), agricultural wastes (e.g. straws, the residues of farmlands and orchards and wastes from agricultural processing), forest products (e.g. branches and leaves), grasses and algae (Lucas, Macdonald, Wagner, Joyce, & Rector, 2010). Grass is one of the most common and abundant lignocellulosic resources on earth.

The main components of grass are cellulose (25–40%), hemicelluloses (25–50%) and lignin (10–30%) (Sánchez, 2009). Lignocellulose is assembled in a complex three-dimensional structure that is remarkably resistant to chemicals and microbial attack. Moreover, intra- and inter-molecular hydrogen bonds make cellulose extremely difficult to dissolve in water and most common organic solvents. Cellulose incorporated with other polymers in

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We investigated the use of ionic liquid (IL) 1-allyl-3-methylimidazolium chloride (AMIMCl) for extracting cellulose from *Zoysia japonica* by using Fourier transform infrared spectroscopy, nuclear magnetic resonance, scanning electron microscopy and thermogravimetric analysis to analyze the IL and its effects on cellulose extraction. After water pretreatment at 121 °C for several minutes, cellulose extraction rate was 71% under optimized conditions, and the yield of cellulose was >99% by AMIMCl. The effectiveness of AMIMCl as an extraction agent can be attributed to the prevalence of intra- and inter-molecular hydrogen bonding in cellulose. By contrast, hemicelluloses were not recovered by AMIMCl because hemicelluloses in plant cell walls are connected to lignin by covalent bonding. Results also showed that the regenerated cellulose was exactly the same as untreated cellulose, except for the degree of crystallinity.

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plant cell walls is more difficult to hydrolyze than pure cellulose in the absence of other cell wall components. Due to the abundance and widespread use of cellulose as a raw material, its production has attracted much attention.

Numerous biomass pretreatment methods have been conceptualized and developed for the production of paper from lignocellulosic biomass. The goal of all of these methods is the disruption of lignin (Mosier et al., 2005) or the hydrolysis of cellulose and/or hemicelluloses by procedures such as AFEX (ammonia fiber expansion) pretreatment (Krawczyk, Persson, Andersson, & Jönsson, 2008; Li et al., 2011). Current processes for grass dissociation use extreme conditions (high temperature or high acidity), and several suitable solvent systems have been developed. These include N-methylmorpholine N-oxide (NMMO) (Doganand & Hilmioglu, 2009); LiCl/N,N-dimethylacetamide (DMAc) (Nattakan, Takashi, & Ton, 2009); LiCl/N-methyl-2-pyrrolidine (NMP); LiCl/1,3-dimethyl-2-imidazolidinone (DMI); dimethyl sulfoxide (DMSO)/paraformaldehyde (PF) (Zhang, Wu, Zhang, & He, 2005) and NaOH/urea (Song, Zhang, Gan, Zhou, & Zhang, 2010) - all result in the decomposition of grass into desired products that are high cost and difficult to separate (Huber et al., 2006). Ionic liquids (ILs) that have melting points at/near room temperature have been widely promoted as 'green solvents', and are attracting much attention for applications in fields interested in the commercial applications of carbohydrate polymers (Pinkert, Kenneth, Marsh, & Mark, 2009). The unique ability of ILs to completely dissolve lignocellulosic biomass, including cellulose, could potentially lead to high-efficiency separation by adding anti-solvents to selectively



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induce precipitation of cellulose, hemicelluloses and/or lignin (Fort et al., 2007; Stark, 2011; Swatloski, Spear, Holbrey, & Rogers, 2002). Recently, the use of ILs as solvents for biomass has been intensively investigated, owing to their chemical stability, thermal stability, low vapor pressure and excellent environmental profiles. Recent studies have focused on the application of ILs in the dissolution of wood and switch grass, and the extraction of cellulose using 1-allyl-3-methylimidazolium chloride (AMIMCl) (Li et al., 2010; Wang, Li, Cao, & Tang, 2011).

The goal of this work is to investigate the effects of AMIMCl on grass. Having first investigated the feasibility of pretreating grass with water to enhance its porosity and render the cellulose more accessible to IL, we investigated the mechanisms by which AMIMCl facilitates the dissolution of grass. We found that hemicelluloses could not be dissolved by AMIMCl without additional treatment. We then compared the regenerated cellulose from IL with microcrystalline cellulose, focusing on the structures and crystallinities of both forms. All the measured physical characteristics, including cellulose crystallinity, were compared using Fourier transform infrared spectroscopy (FT-IR), nuclear magnetic resonance (NMR), thermogravimetric analysis (TG-DTG) and scanning electron microscopy (SEM).

2. Materials and methods

2.1. Materials and preparation

Zoysia japonica, collected from Nankai University, was milled using a Masport Mill (Model BioWizz65, New Zealand), and then a mini Mill with a 100-mesh screen (Model FZ102, Tianjin, China). Ground samples were kept in sealed bags at 20 °C prior to use. Microcrystalline cellulose was purchased from Serva (Heidelberg, Germany).

2.1.1. Van Soest method

The Van Soest method (Goering & Van Soest, 1970; Van Soest, Rovertson, & Lewis, 1991), commonly used to analyze the constitution of lignocelluloses – especially for straws, feeds and grass – was used. First, 100 ml of neutral detergent, 0.5 g of Na₂SO₃ and several drops of octanol mixed with 1.0 g of sample were kept boiling for about 1 h. Then the solution was filtered and washed several times. The precipitate was dried and weighed (W₁). Second, the precipitate was refluxed with 100 ml of acidic detergent for 1 h. After filtration, the precipitate was dried and weighed (W₂). Third, the precipitate was mixed with 10 ml of 72% sulfuric acid (Tianjin Chemical Reagent Co., China) for digestion overnight. Then the precipitate was washed and filtered. After being dried, the precipitate was weighed (W₃). Finally, the precipitate was incinerated at 550 °C

Table 1

	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Others (%)
Untreated	29.71	40.86	19.87	9.56
80°C 1 atm	29.71	40.86	19.87	6.51
100 °C 1 atm	29.71	40.86	19.87	3.87
121 °C 2 atm	29.71	40.86	19.87	2.74
134 °C 3 atm	25.28	35.73	18.92	1.93
160°C 6 atm	18.16	29.97	16.52	1.05

for 4 h. After cooling, the ash was weighed (W₄). The contents of various components were calculated as follows:

 $Hemicelluloses\% = (W_1 - W_2) \times 100\%$

Cellulose% = $(W_2 - W_3) \times 100\%$

Lignin% = $(W_3 - W_4) \times 100\%$

The grass was analyzed using the Van Soest method and consisted of 29.71% cellulose, 40.86% hemicelluloses and 19.87% lignin (Table 1). The sample was then allowed to air dry in a 105 °C conventional oven until a constant weight (i.e. for at least 4 h), using a sub-sample as a reference.

2.1.2. Grass pretreatment

To loosen the structure of lignocellulose and expand the intermolecular pores, so that cellulose could be dissolved more easily by IL, the grass sample was treated by water in a 500-ml stainless steel tank (GCF-0.5, Dalian Automation Equipment Factory, China) at 100–160 °C for 5 min, which would not destroy the molecular configuration. Each batch comprised 10 g of dried grass in 200 ml of water. After the pressure was released, the material was collected in a flask and dried in a conventional oven at 105 °C.

2.1.3. AMIMCl synthesis

We synthesized AMIMCl as described previously (Ren, Wu, Zhang, He, & Guo, 2003; Zhang et al., 2005). We added 100 ml of N-methylimidazole (Tianjin XuanAng Co. Ltd., China) and 120 ml of allyl chloride (Shanghai Kefeng Chemical Reagent Co. Ltd., China) (molar ratio 1:1.2) to a 500-ml three-necked round-bottomed glass flask. The reagents were added drop-wise under nitrogen protection in ice-water bath at the initial stage, prior to violent stirring with a reflux condenser for 8 h at 40 °C. After removing the residual allyl chloride by vacuum distillation, diethyl ether (Tianjin Chemical Reagent Co.) was applied repeatedly to eliminate N-methylimidazole. The AMIMCl product obtained was slightly amber. The synthesis of AMIMCl is depicted in Fig. 1.



Fig. 1. Synthesis route of AMIMCI. Substrates were mixed and stirred vigorously in an ice-water bath under nitrogen protection for 2 h, prior to an 8-h reaction at 40 °C.

Table 2

Optimal dissolution rate analysis. With increasing dissolution rate, the dissolution time was extended. When dissolution rate was >4%, the transparency sharply declined and the dissolution time doubled. Meanwhile, there was somewhat of a positive correlation between transparency and solubility. A 4% dissolution rate proved best.

	Dissolution rate (w/w%)	Transparency	Dissolution time (min)
1	2	+++	20
2	3	+++	26
3	4	+++	30
4	5	++	60
5	6	+	150

For transparency, +++ indicates transparent; ++ semitransparent; and + opaque.

2.2. Grass dissolution

Due to the viscosity of ILs, a series concentration of grass dissolution was performed. With increased concentration and dissolution time, increasing amounts of cellulose was dissolved. When the cellulose concentration in IL solution was over a certain value, the viscosity increased rapidly, thus rendering the solution unusable, although mixing with DMSO reduced the viscosity. The dissolution capacity also needed to be considered. Through the experiments, an optimal concentration (4% w/w) was achieved (Table 2). In the present study, 1.20 g of dried grass with 30 g of AMIMCl was mixed in a 100-ml beaker. Mixing with DMSO (Tianjin XuanAng Co. Ltd.), the suspension was agitated using a magnetic stirrer (200 rpm) at 80 °C for 30 min. After centrifugation of the suspension at 10,000 × g for 10 min, the precipitate was washed several times with water to ensure that all residual IL was removed. After vacuum filtration, the precipitate was analyzed using the Van Soest method.

2.3. Cellulose extraction and AMIMCl regeneration

The supernatant was mixed with deionized water to regenerate cellulose extracted from the grass, and the cellulose was separated by reduced filtration before being air dried at 105 °C in a conventional oven.

IL in the filtrate was recovered by evaporation water at reduced pressure using RE-2000B Rotary Evaporators. Impurities and pigments, if any, were removed by washing three times with diethyl ether at room temperature.

2.4. Characterization of fresh and regenerated cellulose/AMIMCl

2.4.1. FT-IR

The sample powder was dried for 24 h and mixed with spectroscopic-grade KBr. Test specimens were then prepared using the KBr-disk method (Li et al., 2009). The sample IL was filled in sample cell. Spectra ($4000-400 \text{ cm}^{-1}$) were recorded using a Bruker-Tensor 27 FT-IR spectrometer. Both cellulose and ILs were measured under TR unit. Scans were taken for each sample recorded from 4000 to 400 cm^{-1} at a resolution of 2 cm^{-1} in the transmission mode.

2.4.2. NMR spectroscopy

The solution-state ¹³C NMR spectra were recorded on a Bruker AVANCE 400 spectrometer at 25 °C after 30,000 scans. A 60° pulse flipping angle, a 3.9 μ s pulse width and a 0.85 s delay time between scans were used. The sample (fresh/recycled AMIMCI) was added with 0.5 ml of D₂O in the sample tube.

The solid-state ¹³C superconducting NMR spectra were recorded on a Varian Infinity-plus 400 spectrometer at 25 °C at 100 MHz with a 4 mm MAS probe at a ¹H frequency of 100.61 MHz for cellulose.



Fig. 2. Extraction rate (Wang et al., 2011) at different times and temperatures. Cellulose was extracted at a series of temperatures and times by AMIMCI.

2.4.3. Thermogravimetric analysis

To illustrate the relationship between samples and temperature in a program-controlled system, we used a TG209 TGA instrument (NETZSCH, Germany) to study the thermal stability of AMIMCI. Weight loss in the range from room temperature to $500 \,^{\circ}$ C was recorded using a heating rate of $10 \,^{\circ}$ C/min.

2.4.4. SEM analysis

We prepared SEM images of both untreated and treated grass solid samples that were air dried and ground under 100-mesh, using an S-3500N microscope (Hitachi Ltd., Japan). Samples were fixed to a metal-base specimen holder using double-sided adhesive tape, coated with Au/Pd and observed using a 10 kV accelerating voltage.

2.4.5. Crystallinity measurement

The crystallinity index, defined by the infrared ratio $A_{1428 \text{ cm}^{-1}}/A_{898 \text{ cm}^{-1}}$ (Fu & Mazza, 2011), was measured using a Nicolet-380 FT-IR spectrometer.

3. Results and discussion

3.1. Compositional analysis

The various water pretreatment conditions and the amounts of lignocellulose components in *Z. japonica* before and after pretreatment are shown in Table 1. Compared with untreated materials, there were no compositional differences only at temperatures <134 °C. Nonetheless, SEM revealed that the structure became loose and porous. As the temperature approached 121 °C, the structural changes became more obvious. Partial hydrolysis of cellulose and hemicellulose became evident at temperatures >134 °C. Such hydrolysis was anticipated, given that the water would be ionized and rendered acidic under the high-temperature and high-pressure conditions.

For IL treatment, studies have found that (1) AMIMCl is an effective solvent to solubilize cell walls of plant tissue at mild temperature (Mora-Pale, Meli, Doherty, Linhardt, & Dordick, 2011; Wang et al., 2011), (2) cellulose precipitation and regeneration via addition of water as anti-solvent could significantly exclude hemicelluloses–lignin in the solution, and (3) the optimal reaction temperature and time for *Z. japonica* are 80 °C and 30 min, respectively (Fig. 2).

A suspension of *Z. japonica* in IL was prepared by combining 1.20 g of dried grass with 30 g of IL and 5 ml of DMSO in a 100-ml beaker. After heating at 80 °C for 30 min, with vigorous stirring at 200 rpm using a magnetic stirrer, the color of the solution became darker. The solution was then centrifuged at 10,000 × g for

Table 3
Composition of precipitates

	Cellulose (%)	Hemicelluloses (%)	Lignin (%)	Others (%)
Untreated grass	29.71	40.86	19.87	9.56
Regenerated cellulose	99.57	0	0	0.43
IL treated grass	10.92	51.78	25.18	12.12

10 min. A clear, dark amber solution was obtained and the precipitate was washed several times with deionized water to ensure the residue was removed. The clear, dark amber solution obtained was recycled by the addition of deionized water. The appearance of the white precipitate that accompanied this step indicated that its main components were carbohydrates. All precipitates were analyzed (Table 3) using the Van Soest method.

The recovered *Z. japonica* samples had significantly reduced lignocellulose contents compared to untreated *Z. japonica*.

3.2. Characterization of fresh and recycled AMIMCl

The FT-IR spectra (Fig. 3A) of both fresh and recycled AMIMCl were compared with the spectra of allyl chloride (CAS: 107-05-1), propene (CAS: 107-05-1) and 1-methylimidazole (CAS: 616-47-7) from National Institute of Advanced Industrial Science and Technology, Japan (AIST). Absorbance bands at 3500–3100 (=NH antisymmetric stretching vibration), 3100–3000 (sp² C=C–H antisymmetric stretching vibration), 2950–2850 (sp³ C–H stretching



Fig. 3. FT-IR and 13 C NMR spectra of fresh and recycled AMIMCI. The spectra (A) show the functional groups and the spectra (B) show the structures.



Fig. 4. Analysis of AMIMCl by TG-DTG. The TG-DTG profiles show that the two ionic liquids have the same thermal stability.

vibration), 2408–2404 (Cl stretching vibration), 1908 (allyl group vibration), 1675–1640 (trans- and tert-carbon substituted doublebond stretching vibration and sp² C=C stretching vibration), 1578 (N–H scissor bending vibration), 1456 (CH₃ antisymmetric bending vibration), 1433 (CH₂ bending vibration), 1384 (CH₃ symmetric bending vibration), 1350–1000 (C–N stretching vibration), 1291 (Cl bending vibration), 997 (=CH₂ surface distortion vibration, allyl group) and 765–763 cm⁻¹ (Cl vibration); in the AMIM⁺ ring, the ring C–H vibration bands at 3154–3135 and 2517 cm⁻¹ are characteristic bands of AMIMCl. The recycled AMIMCl had the same structure as the fresh AMIMCl that we synthesized.

 13 C NMR spectra (Fig. 3B) on fresh/recycled AMIMCl prepared in D₂O, and the changes in the peak positions of carbons as well as the terminal methyl unit were monitored. The main purpose was to assess the change in the chemical shifts as a function of concentration. The chemical shifts corresponding to carbons of AMIMCl at concentrations were ascribed to different carbons from the structure. Results showed AMIMCl had characteristic peaks at 136.04 (C1), 122.30 (C2), 123.68 (C3), 121.23 (C4), 130.49 (C5), 51.46 (C6) and 35.92 ppm (C7). The recycled IL had the same spectrum as the fresh.

Thermal characteristics of fresh and recycled AMIMCl were next studied using thermogravimetric analysis. During the thermogravimetric process (Fig. 4), decomposition of IL started at a temperature of approximately 200 °C. A loss of sample weight (approximately 19–22%) below 200 °C in a nitrogen atmosphere could be attributed to evaporation of residual moisture and elimination of residual substrates that had not been removed. The decomposition temperatures corresponding to the maximum rate of weight loss (T_d) were 285.1 and 285.8 °C for the fresh and recycled AMIMCI samples, respectively–the corresponding weight losses between 200 °C and T_d were 77.45 and 78.22%. During the rapid decomposition process, the chloride anion decomposed through dealkylation, whereas the cation simultaneously underwent alkyl migration and elimination reactions (Liu et al., 2012). It appeared that the characteristics of recycled IL were identical to those of the fresh sample.

These results indicated that AMIMCl exhibited high thermal stability and could be reused. The AMIMCl retained its properties after being recycled using deionized water and evaporation under conditions of reduced pressure.

3.3. Characterization of regenerated cellulose

The cellulose was easily regenerated by adding deionized water to the AMIMCI/DMSO-cellulose solution. After removing aqueous IL, the precipitated cellulose was dried completely. To demonstrate that no other components were mixed with the regenerated cellulose, we used ¹³C super critical NMR (solid-state) and FT-IR (Fig. 5) to compare microcrystalline cellulose with regenerated cellulose from *Z. japonica*.



Fig. 5. Analysis of cellulose by ¹³C NMR (solid-state) and FT-IR. The spectra (A) show the characteristic peaks of cellulose and the spectra (B) show the functional groups.

Microcrystalline cellulose and the cellulose regenerated from Z. japonica were selected for comparison. Results showed ¹³C super critical NMR (solid-state) spectrum (Fig. 5A) of microcrystalline cellulose had characteristic peaks at 105 (C1), 90 (C4, crystalline), 85 (C4, amorphous), 78 (C2), 74 and 75 (C3 and C5), 66 (C6, crystalline) and 60 ppm (C6, amorphous) (Wang et al., 2011). The spectrum of microcrystalline cellulose contains all the characteristic peaks above, although the chemical shifts (δ) had ± 1 ppm deviation. The peak of regenerated cellulose (Fig. 5A) from IL solution disappeared at 66 ppm and was weakened at 90 ppm, which can be regarded as evidence that crystallinity decreased. Furthermore, the characteristic peaks of lignin are at 148, 133, 122, 113 and 56 ppm; and the characteristic peaks of hemicelluloses are at 76 (C2), 75 (C3), 72 (C4) and 63 ppm (C5). The ¹³C super critical NMR (solidstate) spectra of regenerated samples from Z. japonica by AMIMCI only showed the peaks of cellulose (Boonstra, Pizzi, Tekely, & Pendlebury, 1996; Gilardi, Abis, & Cass, 1995; Jebrane & Sebe, 2008). Results also showed no peaks characteristic of lignin and hemicelluloses. The spectra for both microcrystalline and regenerated cellulose were similar to each other, except for the characteristic peaks of crystallinity. Further proofs could be obtained that both inter- and intra-molecular hydrogen bonding were disrupted by AMIMCl, making them more sensitive to analysis. In this way the IL system is capable of efficient cellulose extraction from Z. japonica and was easily regenerated by deionized water.

Comparing with the FT-IR spectra (Fig. 5B) of microcrystalline and regenerated cellulose, the absorbance bands at 3500–3200 (poly-OH inter-molecular hydrogen bond stretching vibration, a broad and strong peak which will shelter the absorption of O–H stretching vibration), 1053 (primary alcohol C–O stretching vibration), 1118 (secondary alcohol C–O stretching vibration), 769–659 (O–H plane bending vibration), 2950–2850 (sp³ C–H stretching vibration), 1380 (CH₃ bending vibration), 1456 (CH₂ bending vibration) and 1166 cm⁻¹ (C–O–C antisymmetric bending vibration) are characteristic absorption peaks. We confirmed that the bands corresponding to all functional groups in regenerated cellulose from *Z. japonica* were identical to that of microcrystalline cellulose. Comparison with the FT-IR spectra of hemicelluloses (Peng & Wu, 2009) demonstrated the purity of the samples.

Regenerated cellulose could be recognized by the absence of structural and compositional transformation during AMIMClmediated dissolution and regeneration. In contrast with the cellulose sample, there was a slight difference in the spectrum of regenerated cellulose: weakening and shifting of a band at 1431–1428 cm⁻¹ indicates the destruction of intra-molecular hydrogen bonds involving O at C₆ (Zhang et al., 2005).

The results revealed that only cellulose was recovered. The cellulose extraction rate was 71% under optimized conditions, and the cellulose content was >99%. It seemed that AMIMCl was capable of dissolving complex macromolecules and polymeric materials, such as polysaccharides, with high efficiency by breaking the extensive hydrogen bonding network and promoting their dissolution (Swatloski et al., 2002). The mechanism illustrated in Fig. 6 outlines the processes of cellulose dissolution and hydrogen-bond destruction (Liu et al., 2012). The special structural features of AMIMCl, namely the small chloride anion and large cation, are believed



Fig. 6. Mechanism of cellulose dissolution – showing how AMIMCI attracts cellulose by generating new hydrogen bonds and destroying inter-/intra-molecular hydrogen bonds. When separated, deionized water destroys the bonds between cellulose and the ionic liquid, and forms new hydrogen bonds.

to account for its effectiveness in the cellulose dissolution process (Lee, Doherty, Linhardt, & Dordick, 2009; Pinkert et al., 2009; Swatloski et al., 2002). The oxygen and hydrogen atoms from the hydroxyl group of cellulose act as electron donors and acceptors, respectively. Inter- and intra-molecular hydrogen bonds can be easily formed between the 1-allyl-3-alkylimidazolium cation and oxygen, whereas the chloride anions interact with hydrogen atoms. In this case, the original hydrogen bonds were broken, and the new hydrogen bonds made cellulose dissolve in AMIMCI (Liu et al., 2012; Pinkert et al., 2009; Zhang et al., 2005). Although the structures of hemicelluloses also contained inter- and intra-molecular hydrogen bonds, ILs could not extract them. This is because hemicelluloses are connected to lignin by covalent bonds, such as the α -aryl ether bond, which are stronger than hydrogen bonds (Kim et al., 2011; Sun, Sun, Fowler, & Baird, 2004). Additionally, we used SEM to verify that AMIMCl penetrated lignocelluloses to react with cellulose (Fig. 7B). Comparison with a section of grass prior to treatment (Fig. 7A) indicated that the three-dimensional structure of the treated grass was clearly damaged. Water pretreatment caused the structure of lignocellulose to swell; and the three-dimensional structure of dried grass became loose after water pretreatment. These were the key factors that facilitated extraction using AMIMCl.



Fig. 7. Analysis of grass using SEM. Untreated *Z. japonica* (A); and treated with AMIMCI (B) – note the extent of pore opening and breakage in treated *Z. japonica* (B). By contrast, the surface of the untreated was relatively smooth (A), despite the presence of particles generated by grinding the grass during its preparation for microscopy.

The average crystallinity values of the cellulose sample and the regenerated cellulose, determined to be 1.469 and 1.113 (repeated five times), respectively, were lower than the values reported elsewhere (Fu & Mazza, 2011). This could be explained by the fact that AMIMCl broke inter- and intra-molecular hydrogen bonds during the dissolution process, causing destruction of the original crystalline form. When regenerated, the cellulose was precipitated so rapidly that there was insufficient time for cellulose to recover its original crystalline form, causing incomplete self-assembly of hydrogen bonds.

4. Conclusion

We synthesized AMIMCl and investigated its value for the extraction of cellulose from *Z. japonica* as a new approach for using waste materials. Not only did the AMIMCl/DMSO solution easily dissolve cellulose in grass, but it could be readily recovered through coagulation after it was mixed with deionized water. Regeneration of AMIMCl did not compromise its functionality. Regeneration of cellulose was associated only with a loss of its crystallinity. Our results suggest that AMIMCl is a novel, thermostable solvent with potential applications in cellulose extraction from complex biomaterials.

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