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A new cellulose purification approach for higher degree of polymerization: Modeling, optimization and characterization

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ABSTRACT

Degree of polymerization (DP) is an important factor which is affected by purification process. In this study, a new purification process is proposed in which cellulose DP is preserved. Response surface methodology (RSM) was used for optimizing the purification conditions. Purification process of biomass at 100 °C in 10 g/L sodium hydroxide and 30 g/L sodium dithionite, is reported as the optimum condition of this treatment. DP, purity, weight reduction and yellowness index were 6012, 98.10%, 8.46% and 25.22 respectively. TGA, IR, XRD and SEM techniques were used to compare both this new approach and conventional purification treatments. The results showed that this proposed purification process can produce cellulose with higher degree of polymerization compare to the conventional method.

1. Introduction

Cellulose is one of the most abundant and widely used natural polymers. Since cellulose is the major consistence of plants, a large amount of this substance produces annually through photosynthesis. It can be produced from a variety of sources which differed in some features, and generally classified into two main sources of wood and cellulosic fibers (Ott, Spurlin, & Graffline, 1954). Cellulose obtained from natural sources, contains impurities and they differ with the source (Klemm, Philipp, Heinze, Heinze, & Wagenknecht, 1998). Lignin, pectin, hemicellulose, proteins and waxes are the main impurities. Lignin which contains aromatic and aliphatic groups with molecular weight of 1100 g/mole is the most important one (Kalia, Kaith, & Kaur, 2011; Klemm et al., 1998; Nevell & Zeronian, 1987; Ott et al., 1954). Therefore, biomass needs purification process in order to remove impurities, such as lignin and hemicellulose (Woodings, 2001). Generally purification is a chemical process in which impurities are removed from biomass (Iskalieva, Yimmou, Gogate, Horvath, Horvath, & Csoka, 2012). Alkaline pretreatment is the most popular method because it requires lesser temperature and milder conditions (Pappu, Patil, Jain, Mahindrakar, Haque, & Thakur, 2015; Stoklosa & Hodge, 2015). Pretreatment of lignocellulosic biomass with alkali such as sodium hydroxide (NaOH) can remove the lignin content by rupturing the ester bonds present between hemicellulose and lignin. Alkaline pretreatment is very complicated, consequently the efficiency of alkaline treatment (NaOH) depends on treatment temperature and NaOH concentration (Singh, Shukla, Tiwari, & Srivastava, 2014; Subhedar & Gogate, 2014).

Many researches have reported the application of alkaline pretreatment in purification and extraction of alpha-cellulose from agricultural biomass. Mansouri, Khiari, Bettaieb, El-Gendy, and Mhenni (2014) used 15% (w/w) sodium hydroxide at 140 °C for 2 h to extract cellulose from vine stem. In analogous study by Stoklosa et al. alkaline pretreatment was performed using 18% (w/w) sodium hydroxide aqueous solution at 135–170 °C for 1–3 h to purify hardwood species like sugar maple, silver birch and hybrid poplar. Also new methods have been proposed by several researchers for more efficient purification process. Liu et al. (2014) proposed a new two-step process for cellulose purification. Biomass was first treated with 10% ammonia at 150 °C followed by 1% sodium hydroxide at 150 °C. Ultrasound assisted alkaline pretreatment was studied by Subhedar & Gogate (2014). They found that alkaline treatment using 20 kHz ultrasound wave assists lignin removal from biomass. Microwave assisted delignification is getting very popular due to its low time span and energy consumption. Jut fiber alkali pretreatment using 350 W microwave radiation power at 90 °C for 45 min enhances cellulose purity from 64% to 84% (Chowdhury & Hamid, 2016). Ionic liquid pretreatment is another emerging method which is used to extract lignin of biomass (Ma, Zhang, Zhang, Li, Gao, & Hu, 2016). Many researchers also proposed biological and enzy-

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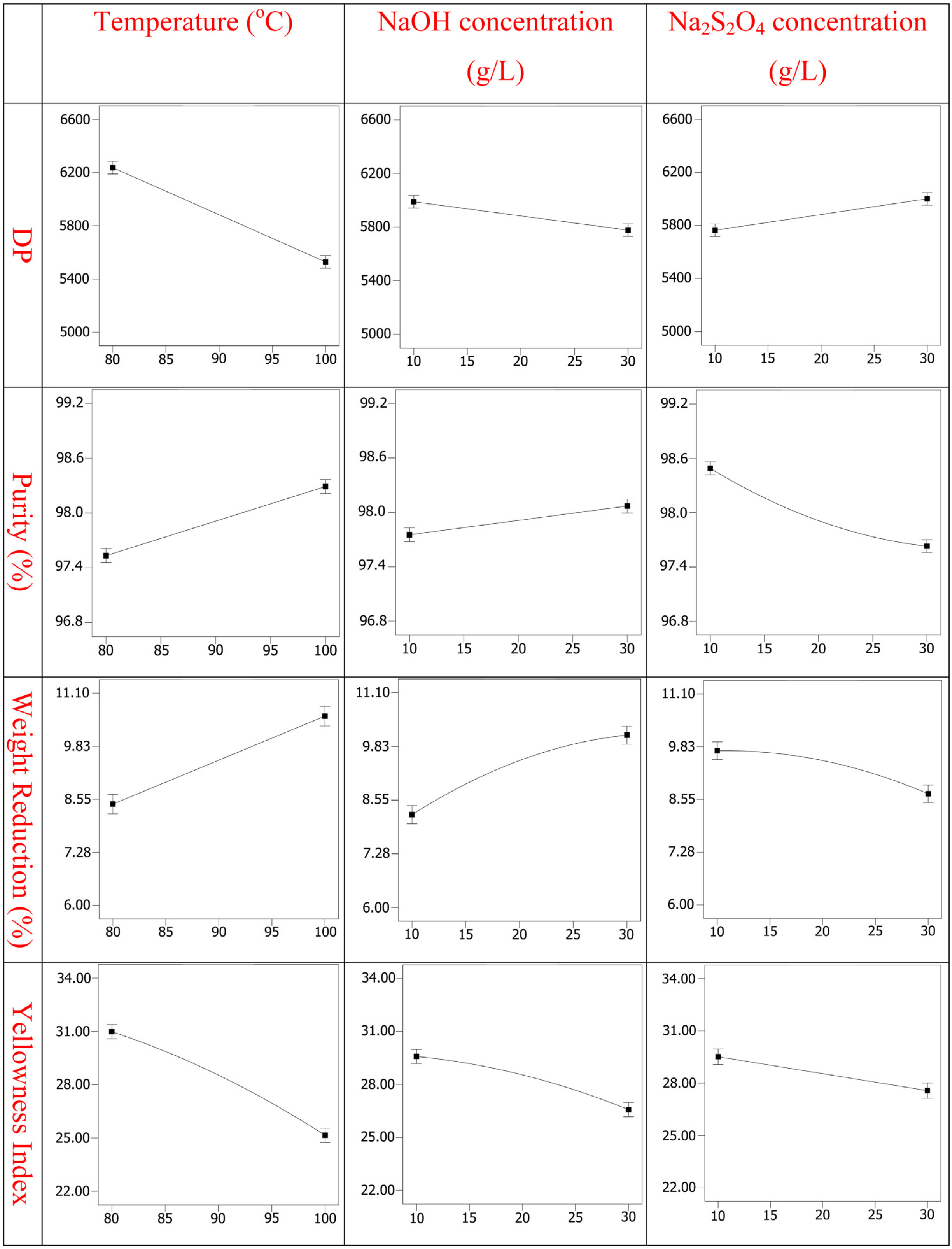

Fig. 1. One factor graphs of DP, Y.I, weight reduction and purity.

matic biomass pretreatment to introduce environmentally friendly approach with less chemical demand (Financie, Moniruzzaman, & Uemura, 2016; Mohanram, Rajan, Carrier, Nain, & Arora, 2015).

In most of the studies focus of researches was on development of new methods for higher purity and lesser price of purification. However, effect of purification conditions on degree of polymerization (DP) has not been studied. DP of purified cellulose is also as important as purity and lignin content of produced cellulose, which is important in textile industry application. For example, in production of regenerated fibers like acetate cellulose and chemi-