Effect of Bleaching with Potassium Hydroxide on the Properties of Egg Carton Pulp for Nitrocellulose Production

Amena Andok[1], *Seng Hua* Lee[2], *Melissa Sharmah* Gilbert Jesuet[1], and *Ismawati* Palle[1*]

[1]Faculty of Tropical Forestry, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah
[2]Department of Wood Industry, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM) Cawangan Pahang Kampus Jengka, Bandar Tun Razak 26400, Pahang, Malaysia.

Abstract: Nitrocellulose known as gun cotton and the main component of smokeless gun powder. The primary cellulose sources for nitrocellulose manufacturing are refined cotton linters and wood pulp. This research aims to look into the possibilities of egg carton pulp (ECP) as a resource in the manufacturing of nitrocellulose. The effect of different concentrations of KOH (0.6 M, 1.0 M, and 1.5 M) on ECP properties was evaluated. The ECP was characterized by chemical composition, Fourier transform infrared (FT-IR), and thermogravimetric analyses (TGA). This study showed that bleaching using 1.0 M KOH reduced the lignin content by up to 1.01% and enhanced cellulose content by up to 86.94%. The presence of a 1420 cm^{-1} band in FT-IR spectra after the bleaching process reveals the existence of cellulose in the ECP. Based on the onset temperature degradation, the highest temperature measured was 294 °C for 1.0 M bleached ECP, corresponding to the cellulose degradation temperature. The presence of a high proportion of cellulose in the ECP after bleaching with 1.0 M of KOH indicates that the ECP has the potential to be used as a source of raw material in nitrocellulose production.

1 Introduction

Nitrocellulose (NC), is one of the oldest types of inorganic cellulose derivatives which is a highly flammable compound used in various applications including explosives and lacquers. This polymer is created by nitrating the hydroxyl groups of cellulose, which includes replacing some of the hydroxyl groups in cellulose with nitrate groups ($-NO_2$). Guncotton, a propellant alternative for weapons to gunpowder, was one of its earliest significant uses. Gismatulina et al. [3] state that NC is the primary component of contemporary gunpowder when the nitrogen content is above 12.2% and that it can be used to manufacture lacquer and paints when the nitrogen content is below 12.2%.

Until today, wood pulp, cotton, and cotton lint have been the main traditional sources of cellulose for the manufacturing of NC [1]. Schimansky [21] has employed cotton linters as the primary cellulose source for the NC product whilst Muvhiiwa et al. [20] synthesized NC

* Corresponding author: isspalle@ums.edu.my

from tobacco stalks and utilized the soda pulping process to produce cellulose pulp. Pulp used as a raw material for NC production must have high levels of cellulose. Bleaching of pulp is indeed a crucial step in the production of NC. NC is typically a white or colorless material thus bleaching is done to eliminate residual lignin and other impurities, resulting in a pulp with a high level of whiteness and purity which is suited for nitration.

Egg carton containing almost 6-17% residual lignin [13]. It is one of the types of waste paper that contains lignin, waxes, synthetic polymers, and resins [18]. Bleaching using potassium hydroxide (KOH) is a chemical treatment process that can be employed in certain industrial applications. KOH is effective at breaking down and reducing the yellowing colour from the pulp and improving its brightness which is important for NC production. It also can help in the removal of lignin and certain impurities that may be present in pulp. Nevertheless, it is not common bleaching for wood pulp in the production of NC, which more typically involves chlorine-based or peroxide-based bleaching [3]. Therefore, the aim of this study is to evaluate the effect of different concentrations of KOH as a bleaching agent on ECP properties. The resulting ECP was characterized by TGA and FTIR analyses.

2 Materials and Method

2.1 Materials

The egg cartons were obtained from nearby eateries. It is hydro-pulped to obtain separate fiber strains before sieving and screening with a sieve shaker to a consistent size of 30-60 mesh. All of the compounds used in this study were reagent grade and utilized without further purification.

2.2 Bleaching Process

The ECP bleaching processes (Figure 1) were conducted using different concentrations of KOH (0.6 M, 1.0 M, and 1.5 M) at 60 °C for 120 min [4]. The residual ECP was then rinsed with distilled water and filtered through crucible glass (No. 1).

Un-bleached pulp Bleached pulp

Fig. 1. Before and after bleaching of ECP

2.3 Analytical Methods

Chemical analyses of treated and untreated ECP (30-60 mesh) were performed: ethanol-toluene extraction (TAPPI Standard T207 cm-97), lignin following TAPPI standard [10] by hydrolysis using 72% of sulfuric acid, holocellulose content determined according to Le. [11], and α-cellulose extracted with 17.5% sodium hydroxide solution [12].

The Mettler Toledo TGA SDTA 851e was used to analyze about 6 to 10 mg of ECP with a continuous flow of N_2 atmosphere (20 ml min^{-1}), with 10 ºC min^{-1} heating rate in the 30 to 600 ºC range.

The Spectrum 400 FT-IR/NIR with Imaging System from Perkin Elmer was used. A total of 24 scans were accumulated at a resolution of 4 cm^{-1} within the frequency range of 4000-1000 cm^{-1}.

2.4 Data Analysis

The data was processed using the Statistical Analysis System. Analysis of variance (ANOVA) was carried out to scrutinize the effect of bleaching on chemical constituents of ECP.

3 Results and Discussion

3.1 Chemical constituent’s determination

Figure 2 shows the chemical constituents of ECP. The 1.0 M showed the highest cellulose (86.94%) and holocellulose (87.79%) with the lowest lignin content (1.01%). Clearly, increasing the concentration of the bleaching agent up to 1.0 M enhanced the amount of cellulose and reduced the lignin content. These findings aligned with the study by Ching et al. [15] that reported similar observations. During the bleaching process, cellulose, hemicelluloses, and lignin compete with one another for the bleaching agent's consumption. When the rate of the lignin reaction is fairly high compared to the rate of cellulose breakdown, those conditions are most favorable for a successful operation. Obviously, 1.0 M KOH is an excellent delignifying agent for ECP in producing high cellulose content and is preferred for preparing nitrocellulose and making as an accelerant for briquette. A high concentration of KOH (>1.0 M) shows the decrement of cellulose and holocellulose content whilst lignin content increases. A possible explanation for why the 1.5 M may have high lignin is because the bleaching process might reached its final delignification stage. According to Gellerstedt [16], prolonged heating considerably reduces the rate of lignin breakdown. This might be the case because lignin removal becomes more challenging as concentration increases since it alters the pulp reaction to bleaching [17].

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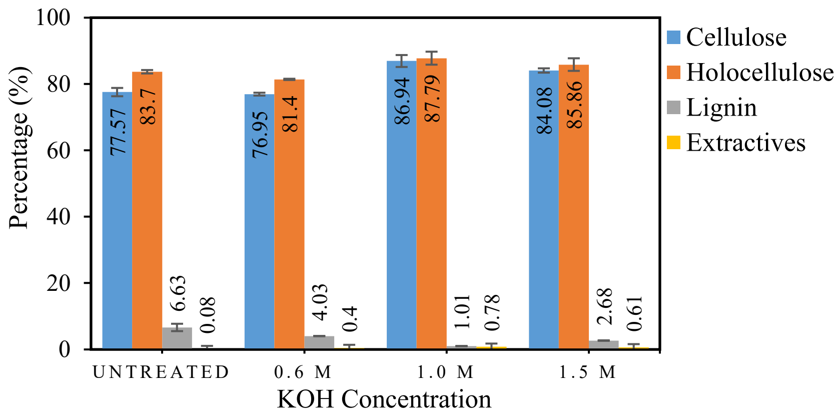

Fig.2. Chemical constituents of ECP before and after the bleaching process

3.2 FT-IR analysis

The FT-IR spectra of treated and untreated ECP are shown in Figure 3. The existence of the absorbance band located at 3300 cm^{-1} is due to the stretching of hydroxyl groups whilst the peak at 2920 cm^{-1} is due to the C-H stretching vibration [6]. The absorption band at 1610 cm^{-1} corresponds to lignin content [5] where the intensity is clearly reduced with increasing bleaching concentrations, which provides evidence of the influence of KOH concentration on the bleaching reaction. The spectra of the $-CH_2$ bond related to crystalline in cellulose [7] appear at 1420 cm^{-1}. The absorbance bands 1330 cm^{-1} show the C-H deformation in cellulose and hemicellulose vibration in pulp [8].

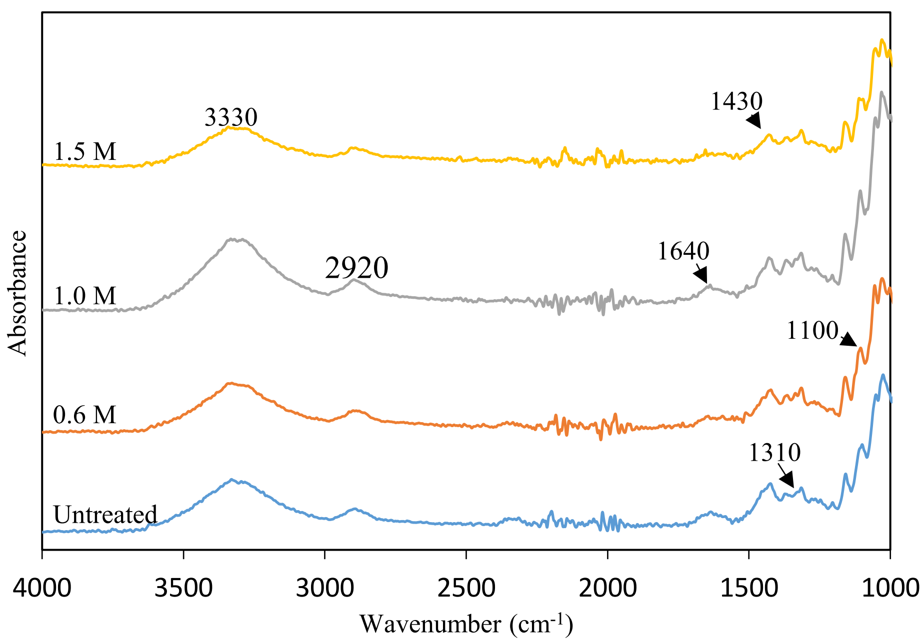

Fig. 3. FT-IR spectra of untreated and treated ECP

3.3 TGA analysis

Figure 4 shows the temperature dependence of the TG of treated and untreated ECP. The initial mass loss of around 80-180 ºC is related to the dehydration of moisture due to water loss. The main degradation stages of treated and untreated ECP are visible on DTG curves. Obviously, one main degradation stage for all treated and untreated ECP was pinpointed at 275 ºC, 328 ºC, 334ºC, and 357ºC. Hemicellulose decomposed easily, with the majority of weight loss occurring between 220 - 315 ºC [9], whereas the degradation of cellulose typically occurred at a higher temperature ranging between 315 - 400 ºC. The high degradation temperature of treated pulp using 1.0 M might be due to the high percentage of cellulose in ECP after the bleaching process. Lignin was the most difficult of the three components to degrade. It decomposed slowly over the entire temperature as shown in Figure 4 where the lignin content takes a high temperature around 410 ºC, which is also illustrated in the inset.

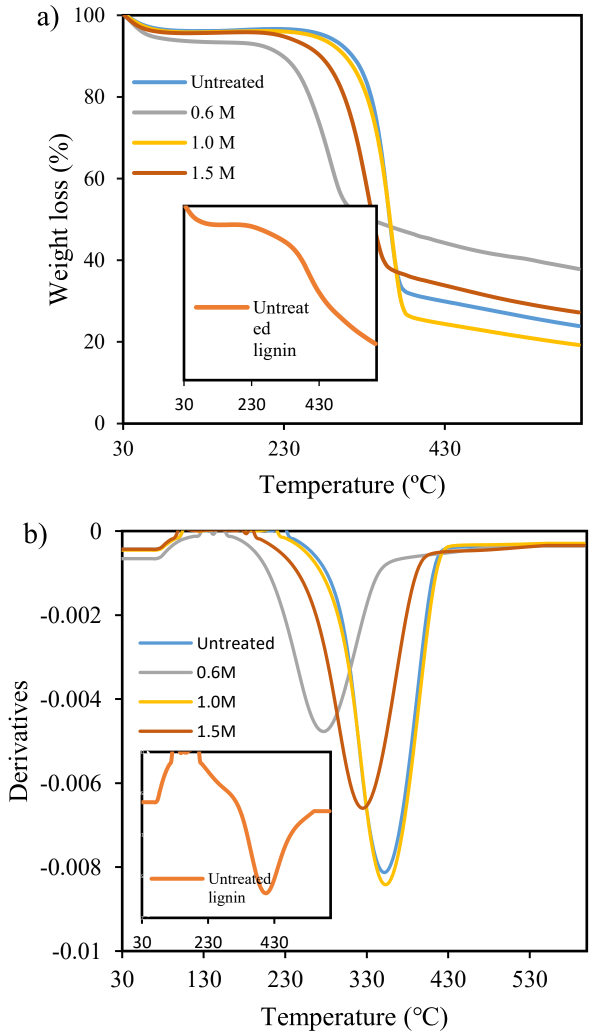

Fig. 4. TG (a) and DTG (b) curves of untreated and treated ECP

4 Conclusion

From the findings of this study, it was concluded that an excellent ECP bleaching agent was obtained using 1.0 M KOH at a temperature of 60 ºC for 120 minutes. It was found that the amount of bleached ECP cellulose increased up to 86.94% and lignin decreased to 1.01% after bleaching using 1.0 M KOH. The highest onset temperature, 294 ºC recorded for 1.0 M ECP bleach, corresponds to the cellulose degradation temperature. The increase in the absorption band at 1420 cm^{-1} after bleaching using 1.0 M KOH may be due to the effectiveness of KOH in the decomposition of ECP lignin. Therefore, the bleaching of ECP using KOH at 1.0 M is the optimum concentration to obtain the highest percentage of cellulose which is important for the production of NC as an explosive material.

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References

1. S. M. Jani, I. Rushdan. J. Trop. Agri. and Food Sci. **42**(1):51-61 (2014)
2. A. Kudzal, Z. Zhang, J. Lagassey. *Axiomatic design of an improved egg carton manufacturing process.* In Proceedings of the 8th international conference on axiomatic design. Campus de Caparica, Portugal (pp. 187-194) (2014).
3. Y.A Gismatulina, V.V Budaeva, G.V Sakovich. Propellants, Explosives, Pyrotechnics. Jan; **43**(1):96-100 (2018).
4. M.H Jazini, E. Fereydouni, K. Karimi. RSC advances. **7**(6):3507-14 (2017).
5. D. Trache, K. Khimeche, A. Mezroua, M. Benziane. J. Therm. Analy. and Cal. **124**(3):1485-96 (2016).
6. D. Ciolacu, F. Ciolacu, V. I Popa. Cellulose chemistry and technology. **45**(1):13 (2011).
7. V. Hospodarova, E. Singovszka, N. Stevulova. Am. J. Analy. Chem. **9**(6):303-10 (2018).
8. Y. Wu, J. Wu, F. Yang, C. Tang, Q. Huang. Poly. **11**(5):776 (2019).
9. H. Yang, R. Yan, H. Chen, D.H. Lee, C. Zheng. Fuel. **86**(12-13):1781-8 (2007).
10. TAPPI 222 om-02; *Acid-Insoluble Lignin in Wood and Pulp.* Tech. Assoc. Pulp and Pap. Ind. (TAPPI): Atlanta, GA, USA, (2006)
11. W. Le. Tech Assoc Pap. **29**:210-8 (1946).
12. TAPPI T203 os-74; *Alpha-, Beta-, Gamma-Cellulose in Pulp.* Tech. Assoc. Pulp and Pap. Ind. (TAPPI): Atlanta, GA, USA, (1994).
13. C. Liu, P. Luan, Q. Li, Z. Cheng, X. Sun, D. Cao, H. Zhu. Mtr. **3**(6):2066-79 (2020).
14. H. Yang, R. Yan, H. Chen, D.H. Lee, C. Zheng. Fuel. **86**(12-13):1781-8 (2007).
15. Y.C. Ching, T.S. Ng. BioResour. **9**(4):6373-85 (2014).
16. G. Gellerstedt. *The chemistry of bleaching and post-color formation in kraft pulps.* 3rd Inter. Colloq. Eucalyptus Pulp (ICEP). Belo Horizonte, Brazil. **10** (2007).
17. C.N. Pascoal, D.V. Evtuguin, F.P Furtado, A.P.S. Mendes. Ind. Eng. Chem. Res. **41**(24):6200-6 (2002).
18. M. Ioelovich. J. Sci. Res. and Rep. **3(**7), 905–916. (2014).
19. S. Noor, T. Yao, K. Muhammad, N. Yahya. J. Adv. Res. in Eng. Know. **9**(1):26-31 (2019).
20. R. Muvhiiwa, E. Mawere, L.B. Moyo, L. Tshuma. Heliyon. **7**(7) (2021).
21. W. Schimansky. *The Origin and Type of Cellulose Utilized in the Manufacture of Nitrocellulose Over the Last Thirty Years* (2005).