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Soda-Isopropanol Pulping: An environmentally friendly pulping for *Nypafrutican* Petioles

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Abstract

This work evaluates the potentials of a secondary alcohol as environmentally friendly pulping liquor for Nypafrutican petioles. The pulping was done at 120°C and 150°C with a pulping liquor-to-sample ratio of 10:1. The effects of pulping temperature, pulping time and concentration of the pulping liquor on the pulp yield and residual Klasonlignin of the pulp were also evaluated. The results revealed that the higher the pulping temperature, time, and the pulping liquor concentration, the lower the pulp yield and residual lignin, implying higher rate of delignification of Nypafrutican petioles.

Keywords:

Introduction

In the conventional pulping process, sulphite, kraft (sulphate) or soda liquors are used to delignify lignocellulosic raw materials. These conventional processes impart severe environmental hazards (especially sulphites and sulphate-based processes) and produce pulps with a high Kappa number (i.e., high residual lignin). Therefore, the demand for environmentally friendly chemicals for pulping has increased interest in alternative pulping processes[1]. This concern led to the introduction of organo solvent (organosolv) pulping to serve as an alternative pulping process since it minimizes cellulose degradation during pulping and also enhanced high level of delignification of the pulping raw material, hence consuming less bleaching chemical. The increase in global warming because of the deforestation has given researchers interest in investigating the alternative source of pulping raw materials from non woody raw materials such as annual plants and forest waste materials. These raw materials can be delignify effectively using organosolv pulping[2].

Organo solvent pulping is a chemical pulping process in which delignification of the pulping raw material is done using organic solvent such as alcohols, acetone, aldehyde and carboxylic acid[3]. However, the advantages of organo solvent process are its low residual lignin of the pulp and being environmentally friendly process, and the silica generated during pulping usually retained in the pulp without affecting the system, also organosolv process does not release sulphur to the environment[4-5]. Pulping temperature, time and concentration of the cooking liquor also affect organo solvent pulping process in the same way as in conventional pulping processes[6].

Organosolvent pulping has been evaluated by a number of investigators[7-8], and many research works have been reported on the utilization of alcohol as pulping liquor. Pulping with methanol has been reported[9-12]. Sahin[13] evaluated base-catalyzed organosolv pulping of jute. Propanol and isopropanol Semi-chemical and chemical pulping have been investigated[14]. Enzymatic hydrolysis as a pre-treatment process for organosolv pulping has also been reported[15,16]. Soda, soda-ethanol, and soda-butanol pulping of *Nypafruticans* petioles have been reported in our previous works[17-18].

Therefore, this present work aims at investigating the effect of utilizing a secondary alcohol (isopropanol) as environmentally friendly pulping liquor in the delignification of *Nypafrutican petioles*. Also, to investigate the influence of operating variables, namely; pulping time, temperature, and concentration of the cooking liquor on the yield of the pulp and residual Klason lignin of the resultant pulp in order to compare the results with our previous works[17,18], and to ascertain the suitability of this solvent as pulping liquor for *Nypafrutican* petioles.

Materials and methods

Sample collection and preparation: *Nypafrutican* petioles, was collected from a *Nypafrutican* plantation in Oron L.G.A. of Akwa Ibom State, South - South Nigeria. The samples were cut into chips measuring about 1 cm by 1 cm. It was air dried for one month in order to reduce the moisture content.

Preparation of the pulping chemicals and Pulping of the raw material: Soda pulping chemical (8% and 12%) were prepared by dissolving 80g and 120g of sodium hydroxide respectively in 1000 ml of distilled water. Soda-isopropanol solution was prepared by mixing 50/50 (v/v) of 8% and 12% solution of sodium hydroxide respectively with of isopropanol/water system 60/40 (v/v). The samples were pulped in the 10-liter thermostatic laboratory digester. *Nypafruticans* petioles chips

(10 g) were charged into the digester at the pulping chemical-to-wood sample ratio of 10:1. The process variables evaluated were pulping time (10–120 minutes), pulping temperatures (120°C and 150°C), and the pulping liquor concentrations (8% and 12% NaOH solution) respectively mixed with isopropanol at the ratio of 1:1. After pulping, the digester was allowed to cool by keeping for 10 minutes. Thereafter the black liquor was filtered. Tap water was used to wash the resultant pulp to neutral pH. The pulp obtained was dried in the oven, and gravimetric analytical technique was used to determine the yield of the pulp. TAPPI standard method designated T236 Om 99 was used to determine the residual Klason lignin of the pulp as presented in equation 1.

Percentage Residual Klason Lignin (RKL) = Kappa number x 0.13 (1)

Results and discussions

The results of this experiment are presented in Table-1 to 4 and illustrated in Figure-1 and 2.

Table-1: 8% Soda-isopropanol Pulping of *Nypafrutican* Petioles at 120°C.

Time to pulping Temp. (min.)	Time at pulping Temp. (min.)	Yield of the Pulp (%)	Kappa number	Residual Klason lignin (%)
18	10	51.90	26.8	3.5
18	20	50.89	25.3	3.3
22	30	50.33	24.8	3.2
19	60	49.66	25.4	3.3
20	90	48.87	24.2	3.1
27	120	47.97	22.8	3.0

Table-2: 8% Soda-isopropanol Pulping of *Nypafrutican* Petioles at 150°C.

Time to pulping Temp. (min.)	Time at pulping Temp. (min.)	Yield of the Pulp (%)	Kappa number	Residual Klason lignin (%)
34	10	40.11	25.2	3.3
40	20	38.65	23.4	3.0
31	30	37.53	18.4	2.4
29	60	36.02	16.3	2.1
37	90	34.89	16.6	2.2
31	120	33.71	15.3	2.0

Table-3: 12% Soda-isopropanol Pulping of *Nypafrutican* Petioles at 120°C.

Time to pulping Temp. (min.)	Time at pulping Temp. (min.)	Yield of the Pulp (%)	Kappa number	Residual Klason lignin (%)
18	10	46.63	25.9	3.4
18	20	42.80	26.9	3.5
22	30	43.20	26.5	3.5
19	60	41.79	26.4	3.4
20	90	40.45	21.3	2.8
27	120	39.77	19.5	2.5

Table-4: 12% Soda-isopropanol Pulping of *Nypafrutican* Petioles at 150°C.

Time to pulping Temp. (min.)	Time at pulping Temp. (min.)	Yield of the Pulp (%)	Kappa number	Residual Klason lignin (%)
34	10	35.50	25.4	3.3
40	20	34.38	22.1	2.9
31	30	33.98	18.4	2.4
29	60	33.70	14.2	1.8
37	90	33.48	14.1	1.8
31	120	31.91	13.1	1.7

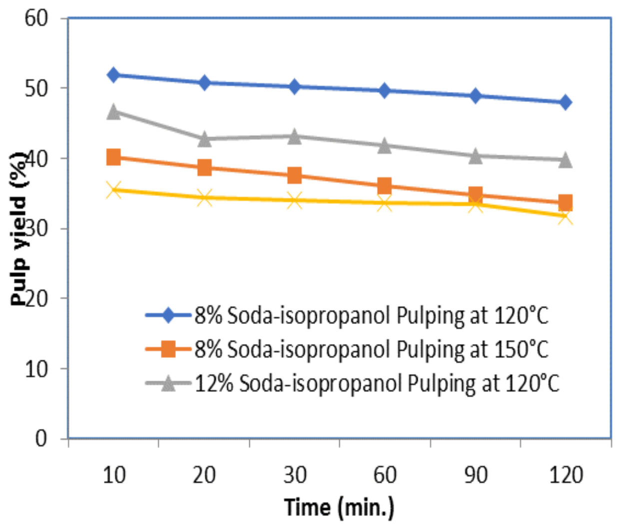

Figure-1: Effect of pulping time on the pulp yield of *Nypafrutican* petioles.

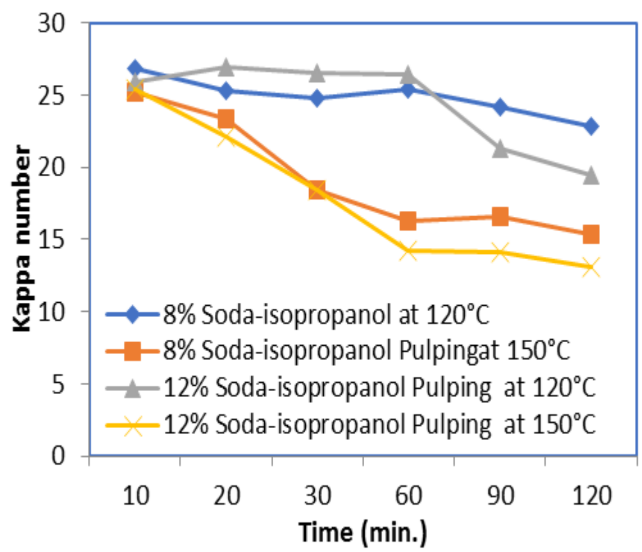

Figure-2: Effect of pulping time on the Kappa number of *Nypafrutican* petiole pulps.

As shown in Figure-1, increase in pulping liquor concentrations resulted in a low yield of the pulp. This may be due to the fact that at high concentration of the pulping liquor, led to the higher rate of delignification of the pulping raw material and cellulose degradation. This is because the cooking liquor attacks the ether bonds in cellulose resulting in the cleavage and loss of some glucose units from the cellulose molecule and hence resulting in low pulp yield[2,6]. The chips pulped with aqueous mixture of alcohol and sodium hydroxide are easier to delignified than those pulped with soda alone. On the other hand, organ solvent process has a lower effect on ether bond cleavage in carbohydrate and also possess good selectivity in the delignification of the pulping raw material[6]. At the temperature of 120°C, pulping time of 30 min and cooking liquor of 8% soda-isopropanol, a pulp yield of 50.33% was obtained; this is higher than the value reported in our previous work for soda pulping (46.85%) and soda-ethanol pulping (49.02%) of the same sample[17]. But less than that of soda-butanol pulping (52.58%)[18]. The lower pulp yield of soda pulping is mainly due to the high rate of cellulose degradation during pulping which resulted in the loss of some glucose units.

At the same conditions as above (Table-3), soda-isopropanol a pulp with kappa number of (24.8), which is less than the value reported in our previous work for soda pulping (35.7), soda-ethanol (35.4)[17] and soda-butanol (26.2)[18]. This is because alcohol remove lignin from the biomass and prevents it from condensing on the pulp, this led to the low residual lignin recorded for soda-isopropanol pulping.

High yield of the pulp and high residual lignin were obtained at the lower temperature of 120°C, while higher temperature (150°C) produced pulp with lower pulp yield and Kappa number (lower residual Klason lignin). This implies that high rate of lignin removal and cellulose degradation occurred at higher temperature. During wood pulping, both lignin and cellulose are degraded at different rates. The rate of cellulose degradation is accelerated by increasing the pulping temperature[17,20]. Also. decrease in the yield of the pulp and residual Klason lignin as the pulping time increased at a constant temperature was also noticed.

Conclusion

In recent times, organ solvent pulping processes have been utilized as an alternative to conventional pulping processes because of their environmental friendliness. Adding alcohol to soda pulping liquor resulted in an increase in pulp yield and a decreased in residual Klason lignin. Soda-isopropanol pulping resulted in the production of pulp with a high yield with low residual Klason lignin. Pulping temperatures, pulping liquor concentrations, and pulping time also exert positive effects on the pulp yield and residual Klason lignin. Hence, to obtain a pulp with a minimal rate of cellulose degradation (higher pulp yield) and a high rate of delignification (low kappa number and residual lignin), soda-isopropanol should be employed since it is more environmentally friendly than butanol.

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