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# Auto-catalyzed acetic acid pulping of jute

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ABSTRACT

A number of acetic acid (HAc) based pulping trials were carried out to determine the best conditions to produce a jute pulp with low residual lignin content and high physical properties. The extended delignification, with increasing temperature, strongly affected the strength properties. The highest tensile strength of 24 N m/g was found at 150 °C and 10 min, 300 ml CSF condition. However, increasing temperature to 200 °C dramatically reduces the strength in the acetic acid system especially for beyond 20 min cooks. The improvements of tensile strength (5–25%) with certain level of refining were observed. The highest tensile strength of 27 N m/g was found at 150 °C and 10 min pulping conditions which freeness of 100 ml CSF. The results found with Simons' stain procedure over acetic acid jute pulps were generally consistent with the strength properties of the pulps.



## 1. Introduction

Extensive research on new environmentally friendly pulping processes has been carried out to overcome the drawback of conventional chemical pulping processes. Delignification with organic solvents is of interest as an alternative to conventional pulping processes due to many advantages such as; low boiling points, simplicity of process, non-sulfur formulas, and easy recycling possibilities with some organic chemicals (Biermann, 1993; Sahin, 1997, 2003; Smook, 1994; Young, 1998).

A number of organic solvents such as ethanol, acetic acid, esters, soda-amine, and ethanol-alkali have been intensively studied at the laboratory scale and promising results were noted for wood and non-wood pulping processes (Hergert, 1998; Sahin, 2003; Sarkanen, 1990).

Acetic acid was one of the first organic acids used for delignification of lignocellulosic raw material in laboratory studies. It can be used as a pulping solvent uncatalyzed or catalyzed on woods (Nimz and Casten, 1986; Young and Davis, 1986). It was already reported by a number of researchers that acetic acid pulping properties of woods have comparable with conventional chemical processes and have some advantages in comparison to other organosolv processes at laboratory scales (Davis et al., 1986; Groote et al., 1993). However, no satisfactory acetic acid based pulping process has been established which allows delignification of all lignocellulosic species to low lignin content with low operational costs (Hergert, 1998).

Jute is an annual plant and mostly grown in Southeast Asian countries. The chemical component of jute varies among plants from different geographic locations, ages, climates and soil conditions (Rowell et al., 1997). However, according to experimental results, there are no considerable differences in cellulose, lignin and hemicellulose content throughout the jute plant, although there are some differences found for xylan, ash and iron content, which decrease as the plant matures (Young, 1994, 1997). The chemical composition and fiber dimension of jute is given in Table 1 (Han and Rowell, 1997; McGovern et al., 1990; Sahin, 1997).

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**Table 1 – Chemical composition (%) and fiber dimensions of jute**

| Constituent | Bast fibers | Stick fibers |
|---|---|---|
| Cellulose | 58 | 58 |
| Lignin | 21–26 | 26.8 |
| Pentosans | 18–21 | 21.5 |
| Extractives | 3.7 | – |
| Ash | 0.5–1.8 | 1.9 |
| Fiber length (mm) | 2.5 | 1.1 |
| Fiber diameter (μm) | 20 | 26 |

The objective of this study is to discuss some of the most common pulp properties for acetic acid–jute pulping, which is glacial acetic acid (90% by volume) in water, for pulping of jute were evaluated. It was aimed to accelerate delignification and retard both lignin condensation and carbohydrate hydrolysis during the pulping, hence acceptable strength of pulps for various purposes.

## 2. Experimental

Air-dried, jute bast (*Chorus capsularis*), fibers were obtained from the Jute Research Institute in Bangladesh. In each experiment 35 g of jute bast fibers and the desired volume of cooking liquor were mixed in the reactor at ambient temperature.

The 1 l stainless steel labaratory type reactor was used in all cooking trials. The time of cooking did not include preheating or heat-up time. The sealed reactor was placed in a temperature-controlled oil bath for the specified reaction times. Solutions of 90% acetic acid, $CH_3COOH$ (HAc) in water were used as cooking liquor between 150 and 200 °C temperature levels with various cooking times.

The liquor to material ratio was 7:1 (by weight) for all runs. The washing of pulps after cooking was with aqueous acetic acid of the same concentration as the pulping agent, followed by hot water.

All chemicals were purchased from Aldrich Chemical Co. (Milwaukee, WI) with a purity of at least 99%.

The pulp was dried *in vacuo* at 60 °C overnight, and the yield was reported as grams of oven dry pulp per gram of oven dry jute.

The pulps were refined in PFI mill directly until the specified level of Canadian Standart Freeness (CSF) as described in Tappi Standard T 248. For the evaluation of pulps obtained from various acetic acid trials, papers were prepared with using laboratory type English Sheet Mold as described in Tappi Standard T 205. The bulk and residual lignin content of papers were determined with using Tappi Standard T 220 and T 236. Selected paper physical properties such as; tensile, burst, and tear strengths (reported as index) were evaluated Tappi Standard T 403, T 414, T 494, respectively.

The pulps were further evaluated by scanning electron microscopy (SEM) in order to evaluate the fibrillation. For SEM analysis, the selected samples were photographed with a Hitachi type 450 SEM.

The Simons' staining procedure was used to evaluate pore structure and degree of fibrillation for acetic acid jute pulps. The mixture of two stains Pontamine Sky blue 6 BX and Pontamine Fast orange 6 RN) with 1:1 ratio was applied and established staining situation examined under the microscope, Nikon type 144. The detailed information on application of Simons' stain technique can be found elsewhere (Sahin, 1997; Yu and Atalla, 1998).

**Table 2 – Acetic acid pulp properties of jute**

| Time (min) | Yield (%) | Kappa number | Bulk ($cm^3/g$) |
|---|---|---|---|
| 150 °C | | | |
| 10 | 90 | 56 | 3.1 |
| 15 | 84 | 53 | 3.0 |
| 20 | 83 | 52 | 2.9 |
| 30 | 77 | 50 | 2.9 |
| 175 °C | | | |
| 10 | 82 | 53 | 2.9 |
| 15 | 81 | 52 | 2.9 |
| 20 | 80 | 51 | 3.0 |
| 30 | 76 | 49 | 3.2 |
| 200 °C | | | |
| 10 | 82 | 51 | 2.9 |
| 15 | 81 | 47 | 2.9 |
| 20 | 78 | 46 | 2.9 |
| 30 | 76 | 42 | 2.7 |

## 3. Results and discussions

Table 2 shows a summary of the pulping experiments and conditions to obtain low residual lignin (kappa number) in the acetic acid pulping trials from jute. As expected, high temperatures cause yield loss and improve lignin removal. Generally, increasing temperature can favor depolymerization of lignin macromolecule, but yield (%) and lignin content is still very high and better to consider in semichemical or chemimechanical pulps rather than full chemical pulps. These are generally defined as that category of pulps with yields in the range of 75–95% with high residual lignin content (e.g., > 10%).

The yield of 76% was found at the lowest kappa number of 42 at 200 °C and 30 min reaction level, but in this level, papers had marginally no strength. This is probably related to porous structure of jute. Hence, acetic acid can quickly penetrate into fiber and may affect the carbohydrate degradation along with removal of lignin. The backbone of cellulose may

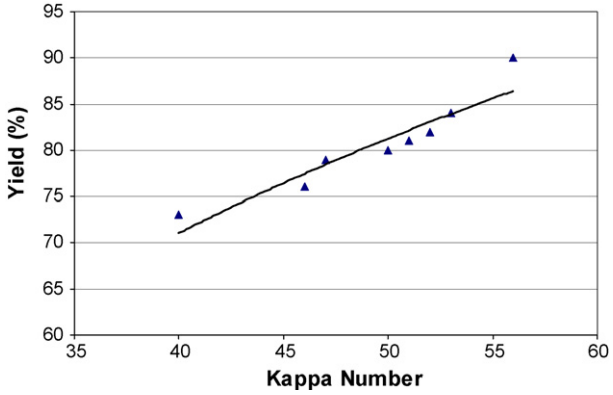


**Fig. 1 – Yield vs. kappa numbers of acetic acid pulping for jute.**