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# Optimization of pulping conditions of abaca. An alternative raw material for producing cellulose pulp

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**Abstract**

The influence of temperature (150–170 °C), pulping time (15–45 min) and soda concentration (5–10%) in the pulping of abaca on the yield, kappa, viscosity, breaking length, stretch and tear index of pulp and paper sheets, was studied.

Using a factorial design to identify the optimum operating conditions, equations relating the dependent variables to the operational variables of the pulping process were derived that reproduced the former with errors lower than 25%.

Using a high temperature, and a medium time and soda concentration, led to pulp that was difficult to bleach (kappa 28.34) but provided acceptable strength-related properties (breaking length 4728 m; stretch 4.76%; tear index 18.25 mN m$^2$/g), with good yield (77.33%) and potential savings on capital equipment costs. Obtaining pulp amenable to bleaching would entail using more drastic conditions than those employed in this work.


*Keywords:* Non-wood; Abaca; Pulping optimization; Pulp; Paper; Soda; Cellulose

## 1. Introduction

Around 95–97% of all raw materials used by the paper industry to obtain cellulose pulp consist of hardwood or softwood. The other raw materials used for this purpose are known collectively as "non-wood" materials. The principal interest of the latter is that they provide fibres of excellent quality for making special paper or constitute the sole affordable source of fibrous raw materials in some geographical areas. In addition, non-wood plants are an alternative to the increasingly scant forest wood as a source of pulp fibre. Non-wood plant materials include agricultural residues and non-agrofood crops such as kenaf, paper sorghum or abaca (Patel et al., 1985; Atchinson, 1996; Morimoto, 2001).

Pulping raw materials produces polluting effluents, particularly when they contain sulphur compounds (e.g. air emissions from the recovery boiler from sulphite- and sulphate-based pulping processes).

Although the possibility of using sulphur-free organic solvents has been known for long time, the process has so far been implemented on a pilot plant scale only (Jiménez et al., 1997; Hergert, 1998; Muurinen, 2000). This, together with the scarcity of alternative processes, has refocussed attention on the oldest known chemical pulping process, which uses soda to cook raw materials (Gullichsen and Paulapuro, 2000).

The present cellulose pulp output falls short of consumer demand, which is growing very rapidly in developing countries. This entails the establishment of new industrial plants involving small investments and low production costs to obtain products of a high quality while preserving the environment and making efficient use of raw materials (by ensuring high yields) (Jiménez

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et al., 1997; Hergert, 1998; Muurinen, 2000; Gullichsen and Paulapuro, 2000) other than the typical wood resources (Patel et al., 1985; Atchinson, 1996; Morimoto, 2001). This can be accomplished by using non-wood raw materials such as abaca in soda pulping processes.

Abaca (*Musa textilis nee*), also called "Manila hemp", is a plant of the *Musaceae* family similar to the banana tree but having an inedible fruit and a stalk that provides high-quality fibres. Abaca originated in the Philippines and started to be grown in Ecuador during World War II. An overall 83,000 tons of abaca fibre was obtained worldwide in 1999; the Philippines was the first producer, with 79%, followed by Ecuador, with 19% (Leatham et al., Ecuador SICA web site).

For years, abaca has been used to make fishing nets—its fibres are especially resistant to salty water—and wrappings for electrical conductors, as well as to manufacture speciality paper for banknotes, cigarettes, baby napkins, toilet paper, machine filters, hospital textiles (aprons, hats, gloves), tea bags, etc. (Silvario, 1976; Leatham et al., Ecuador SICA web site; Anon, 2001a,b).

The earliest applications of soda and alkaline processes to abaca pulping date from the 1970s and provided yields of 50–72% (Heyse, 1973; Misra, 1990). In the 1980s, abaca pulp was cooked and bleached with sulphur-free (alkali) and chlorine-free (hydrogen peroxide) reagents, respectively (Mita et al., 1988). In the 1990s, the properties of paper sheets manufactured from mixed pulp made from abaca, cotton residues, acacia, rice straw and salago were comparatively examined (McLaughlin, 2000). More recently, abaca has been used to obtain thermomechanical (TMP), chemothermomechanical (CTMP), cold soda cooked (CSP) and neutral sulphite cooked (NSSC) pulp (Estudillo et al., 1998; Mabilangan et al., 1998; Yu et al., 2000; Morimoto, 2001). Finally, abaca has been subjected to biotechnological processes intended to remove parenchymal fibres by use of pectinases (Itoh et al., 1998).

Despite the abundant literature on abaca pulping, no mathematical model appears to have been used to derive equations for predicting the quality of abaca pulp as a function of process variables with a view to identifying the most suitable operating conditions.

Most mathematical models applied to the pulping of raw materials rely on the delignification kinetics to predict the extent of delignification. Such models are complex and impractical when more than two independent variables must be considered. This is avoided by empirical models constructed using an experimental factorial design to estimate different dependent variables for the pulp (e.g. yield, kappa index) and strength-related properties of paper sheets obtained from it, as a function of different independent operational variables.

In this work, a central composite factorial design was used to study the influence of independent variables in the pulping of abaca (viz. temperature, time and soda concentration) on the yield, kappa index and viscosity of the pulp, and the breaking length, stretch and tear of the resulting paper sheets, with the aim of identifying the optimum operating conditions.

## 2. Experimental

### 2.1. Material

Prior to harvesting, the abaca plant is defoliated by stripping leaves from the stalk. The stalk consists of a central core wrapped by a succession of layers (similar to those in bamboo or *Arundo donax*) that are usually called "sheaths".

Preparing abaca stalks for conversion into cellulose pulp entails removing sheaths by mechanical stripping; this provides higher fibre yields than the use of whole stalks. Stalks are stripped by combing; this separates fibres from all other organic matter and allows various fractions of different purity or quality to be obtained as a function of closeness to the core (Leatham et al., Ecuador SICA web site).

A stalk fraction provided by the firm Celulosas de Levante, S.A. (CELESA) was used in the present study. Fibres were 6 mm long and found to contain 2.45% ethanol–benzene extractables, 1.35% ash, 87.91% holocellulose, 67.85% α-cellulose and 10.37% lignin. This abaca fraction was pretreated in order to ensure a high holocellulose content and hence a high pulping yield.

### 2.2. Characterization of the raw material, cellulose pulp and paper sheets

The abaca used as raw material was characterized in terms of its contents of ethanol–benzene extractables, ash, holocellulose, α-cellulose and lignin, which were determined using TAPPI 204, TAPPI 211, the method of Wise et al. (1946), TAPPI 203 os-61 and TAPPI 222 om-98, respectively.

The abaca pulp was characterized in terms of yield, kappa index (UNE 57-034) and viscosity (UNE 57-039).

Finally, the paper sheets were analysed for breaking length (UNE 57-054), stretch (UNE 57-028) and tear index (UNE 57-033).

### 2.3. Pulping

The raw material was pulped in a 15 l cylindrical batch reactor wrapped in a heating wire jacket. The reactor was connected, via a rotary axis, to the control unit, which included a motor actuating the reactor stirring (by turnover), and temperature and pressure measurement and control instruments.

The raw material was placed in the reactor and supplied with the amounts of soda and water required to