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Short Communication

Enzymatic deinking of laser printed office waste papers: Some governing parameters on deinking efficiency

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Abstract

The protocol for the enzymatic deinking of laser printed waste papers on a laboratory scale using cellulase (C) and hemicellulase (H) of *Aspergillus niger* (Amano) was developed as an effective method for paper recycling. A maximum deinking efficiency of almost 73% by the enzyme combination of C:H was obtained using the deinking conditions of pulping consistency of 1.0% (w/v) with the pulping time of 1.0 min, temperature of 50 °C, pH = 3.5, agitation rate of 60 rpm, pulp concentration of 4% (w/v), concentration of each enzyme of 2.5 U/g air dried pulp and the enzyme ratio of 1:1. The deinking efficiency was further enhanced to 95% using the optimized flotation system consisting of pH = 6.0, Tween 80 of concentration 0.5% (w/w), working air flow rate of 10.0 L/min and temperature of 45 °C. The deinked papers were found to exhibit properties comparable to the commercial papers suggesting the effectiveness of the enzymatic process developed.

Keywords: Enzymatic deinking; Cellulase; Hemicellulase; Deinking efficiency; Deinking conditions

1. Introduction

The demand for papers continues to be strong despite the general believe that advancement in information technology and computerization would result in a paperless global society. Malaysia needs to double its capacity in paper production if the country is to achieve the state of self-sufficiency by the year 2010. However, one of the major obstacles faced by the paper making industries in Malaysia is the lack of raw materials and therefore, most of the papers products consumed in the country are imported, worth about of US$0.70 billion in the year 2000 with an annual increment of 10% (Malaysian Pulp and Paper Manufacturer Association, MPPMA). Thus, the search for new sources of fibers for paper making becomes important in ensuring the survival of the country's paper industries in the near future. Although, new fibers have been considered particularly from non-wood lignocellulolytic materials such as oil palm trunks fibers and kenaf fibers (a species of *Hibiscus* plant), the quality of the papers produced remains uncompetitive with regards to the production cost and the quality of the papers produced. Thus, recycling of the waste papers must be considered, as an economic necessity. Recycled waste papers have become an important source of new fibers in paper making throughout the world. Office waste papers which consist mainly of laser printed and xerographic papers, form a fast growing source for paper recycling due to the increase in the utilization of office photocopiers and computer printouts. The reuse of these waste papers is limited because the ink formulation used in these papers are difficult to be removed by conventional techniques such as dewashing, dispersion, washing and flotation. Moreover, most of the conventional chemical deinking techniques require the use of large amount of chemicals such as sodium carbonate, sodium hydroxide, sodium silicate, hydrogen peroxide, hypochlorites, chelating agents and surfactants (Marques et al., 2003; Prasad et al., 1993; Woodward et al., 1994), which resulted in a costly waste

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water treatment systems (Jeffries et al., 1994). Several enzyme systems consisting of lipase, cellulase and hemicellulase or its combinations have been examined by numerous research groups for their potential in the deinking of various types of waste papers. However, the results obtained suggested that enzymatic deinking is governed not only the enzyme types but also by a large number of variables affecting the enzyme performance such as paper types and quality, toner qualities and types, sizing types and the content and amount of other components in paper finishing (Welt and Dinus, 1995). The enzymatic approach is expected to be one of the important methods to be adopted in the recycling of waste papers in order to reduce the dependence of imported papers. This communication describes the work carried out in developing the protocol for effective enzymatic deinking of laser printed office waste papers which will be translated for pilot plant study. Our long term objectives were to establish a deinking process which is robust enough to handle all types of waste papers and to replace the conventional chemical deinking process as an environmental friendly solution for paper recycling in Malaysia.

2. Methods

2.1. Source of enzymes and waste papers

Three commercially available enzyme powders used in the work were gifts from Amano Pharmaceuticals Co. Ltd. (Nagoya, Japan) comprising of lipase F-AP 15 (L) [23750 U/g powder] from *Rhizopus oryzae,* cellulase Amano 3 (C) [1017 U/g powder] and hemicellulase Amano 90 (H) [9434 U/g powder] from *Aspergillus niger*. The enzyme powders were stored at 4 °C prior to use. Waste papers (A4 size 70 g/cm^2) used in the work was produced locally and printed with laser printed toners of an average area of 80% on one side of each sheet.

2.2. Determination of enzyme activities

Cellulase activity was determined by the method described by Gessesse and Geshaw (1999) using carboxy methylcellulose (CMC, BDH, UK) as the substrate. The sugar released was measured spectrophotometrically at 575 nm using glucose as the standard. One unit of cellulase was defined as the amount of enzyme required to release 1 μmol of reducing sugar per min under the assay conditions. Hemicellulase or xylanase activity was determined using 1% (w/v) oat spelt xylan as the substrate as described by Gessesse and Gashe (1997). One unit of xylanase was defined as the amount of enzyme that liberated 1 μmol of reducing sugar per min under the assay conditions. Olive oil emulsion method was used to determine the lipase activity based on the method described by Mustranta et al. (1993). One unit of lipase was defined as the amount of enzyme which liberated 1 μmol of free fatty acids per min under the assay conditions. The concentration of free fatty acid was determined titrimetrically against 0.05 M NaOH using a pH stat autotitrator (Metrohm) at pH = 10.

2.3. Deinking process and stepwise optimization of the process conditions

Batch deinking process involved the preparation of pulp, enzymatic hydrolysis stage and flotation system. The pulp from the laser printed office waste papers used in the deinking process was prepared by disintegration to obtain 2% (w/w) pulp consistency for 4 min at 30 °C using the high speed mixer (National Model: MX-T100GN) based on the method of Moon and Nagarajan (1998). Prior to the disintegration step, the waste papers were shredded to small pieces, followed by treatment with 0.25 M of HCl. The enzymatic hydrolysis of the pulp was carried out in a 500-ml enzyme hydrolytic vessel under control temperature. The optimization of the enzymatic hydrolysis involves the modifications of the pulping preparations, temperature, pH, agitation rate, pulp (substrate) concentration, enzyme concentration, and enzyme ratio.

After the enzymatic hydrolysis, the hydrolysed paper was subjected to the flotation process. The flotation process was carried in a 600-ml vertically tubular flotation cell of diameter 3.2 cm and height 44.5 cm with water jacketed for temperature control. The top section of the tubular was constructed to collect the toner, which was lifted by the air bubbles. The aeration was carried out by air sparging *via* a pump (GAST, USA) which was connected to a microporous fibre glass sparger to disperse the air bubbles. The optimization of the flotation process was carried out by determining the effect of the types of surfactant and concentration, working airflow rate and flotation temperature. The deinked pulp was prepared as handsheet for the determination of the brightness based by the method described by TAPPI Test Methods (see below).

2.4. Determination of deinking efficiency

Deinking efficiency was expressed based on the brightness of the paper. The handsheets were prepared based on the method by the Technical Association of the Pulp and Paper Industry (TAPPI), TAPPI Test Method T218 om91 for reflectance testing of pulp (Buchner Funnel Procedure). Handsheets were conditioned under controlled conditions as described in TAPPI Test Methods (TAPPI T402) before the deinked papers were evaluated for its brightness. The paper brightness (%) was determined by the method of TAPPI T452 (Brightness of pulp, paper and paper Board) (directional Reflectance at 457 nm) using brightness and opacity tester (Mode Micro S-5, Technidyne Corporation, USA).

The control experiment was also performed using enzymes, which were heat inactivated at 100 °C for 20 min. All the experiments were carried out in triplicates and the data were presented as the mean of readings with indication of the standard deviations. Statistical analysis of variables