Biopulping and Biobleaching by White Rot Fungi

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Received: 21 August 2001; accepted: 19 February 2002

The potentials of white-rot fungi namely Coriolus versicolor NRRL 6102, Phanerochaete chrysosporium NRRL 6359, P. chrysosporium NRRL 6361 and P. chrysosporium NRRL 6370 are evaluated for brightness of banana waste. The banana fruit stalk is used as a sole carbon source under sterilized solid state fermentation (SSF) at 35 °C for one month. Of these, P. chrysosporium NRRL 6370 cultured supported maximum brightness (30.5 per cent than under control 17.8 per cent). This fungus degrades lignin and hemicellulose with does not effect on cellulose fibres (55.4 per cent than under control 40.01 per cent). The three useful types of paper are prepared from biopulping banana fruit stalk. The two types of them are bleached by hydrogen peroxide (writing and printing 40 %R) and greasy paper (80-82 %R). While the board is prepared from unleached biopulping at 25 %R. The strength properties of biopulping increases from 15-20 per cent for the hand-made sheet. Also the brightness is higher, i.e., > 20 per cent than under control. Results show that biopulping controls yield and avoids losses in viscosity and strength properties.

Introduction

Using agricultural residues is replacement source for wood raw materials for manufacturing paper pulp, thereby avoiding serious risks of deforestation and decreasing environmental problems arising from fires and pest.

Saikia et al.¹ have used the three wild banana species in the formation of paper sheet from pulp (pulp freeness 45 °R) has high strength properties for writing and printing paper, while paper sheets prepared to a pulp freeness of 90 °R showed good greasy properties. Yamazaki et al.² have shown that the addition of banana stem wastes to the straw improves the strength properties of the resulting pulp.

The biological pulping has the potential to improve the quality of pulp and the properties of paper and to reduce the energy costs and environmental impact relative to traditional pulping operation³⁴. The technology focuses on the white rot fungi, which have complex extra-cellular ligninolytic enzyme systems that can selectively remove or alter lignin and produces cellulose fibres. These enzyme systems are lignin peroxidase, manganese peroxidase, and laccase⁵. Arbeloa et al.⁶ have evaluated the potencies of lignin peroxidase from Phanerochaete chrysosporium improve bleachability of kraft pulps.

In the present study the biodegradation of banana waste was used to produce different types of useful papers such as board, writing, printing, and greasy paper. Whereas the biopulping maintained pulp yield and avoided losses in viscosity and strength properties.

Materials and Methods

(i) Raw Material

Banana fruit stalks were collected from market and kaolin, and rosin size were derived form Rakta company in Alex.

(ii) Organisms and Cultures

Four white-rot basidiomycetes, namely Coriolus versicolor NRRL 6102, Phanerochaete chrysosporium NRRL 6359, P. chrysosporium NRRL 6361 and P. chrysosporium NRRL 6370 were obtained from Department of Agriculture, Research Service. Peoria, Illinois, USA. The organisms were maintained on yeast extract-malt extract agar. The medium contain (g/L) malt agar 4.0, glucose 4.0, yeast extract 40, distilled water up to 1L, and agar 20.0 the pH (6.4).

The four white-rot fungi were compared for their potential as delignification agricultural waste to obtain maximum brightness. They grew on banana fruit stalk under SSF and sterilized conditions. On milliliter of each heavy spore’s fungus was used to inoculate sterile test tube (30 mm x 190) containing...
2.0 mL distilled water and 15.5g of banana fruit stalk as substrate. The inoculated tubes were incubated at 35°C for one month and the brightness degree was examined every week to find out the optimum duration of efficient fungal incubation.

(iii) Chemical Analysis of Banana Waste

The banana waste was chemically analyzed before and after biopulping and bleaching for hemicellulose and average molecular weight, α-cellulose and extractible hemicellulose, Klasson lignin, and ash content were tested, according to method suggested by Casey.

(iv) Bleaching

Biopulping and control of banana fruit stalk were bleached by hydrogen peroxide in two stages. The bleaching mixture in each stage is contained 4 per cent hydrogen peroxide, 0.5 sodium silicate, and 0.1Mg SO₄, the pH (10-11) was adjusted addition by NaOH. It was further kept at 75°C for 1.5 h. The pulp was washed thoroughly with water after each stage.

(v) Details of Paper Manufacture

(a) Preparation of Board (150 g/m²) — Unbleached pulp was beaten in Jordan beater at 3.6 consistency till it attained 25 S'°R.

(b) Preparation of Writing and Printing Paper (60g/m²) — Bleached pulp was beaten till it reached 40 S°R and during sheet formation some additives were added such as, 10 per cent kaolin and 2 per cent rosin size 10 per cent aluminum sulphate was added till pH 4.5 was obtained.

(c) Preparation of Greasy Paper (45g/m²) — Bleached pulp was beaten till it reached 80-82 S°R.

The paper sheets were prepared according to TAPPI standard methods using the sheet former of A B Lorentzen und Wettre (Stockholm, Sweden). The produced papers were conditioned for 24 h at 20°C and 50 per cent RH.

(vi) Examination of Physical Properties

The optical properties such as, brightness and opacity were examined by Hunterlab colour/difference Meter D25-2. Also the strength properties such as tensile strength were measured by Ametek Lloyd instruments 1996, bursting strength by Mullen tester B F P Perkins and tearing resistance by Elmendorf Tearing Tester. The tensile strength can be converted to the breaking length by considering the basis weight and strip length. Whereas the strength properties optical properties, and sizeability were measured according to method of Casey.

Results and Discussion

(i) Screening of White-rot Fungi for Ability to Remove Lignin

A comparative study was undertaken using four strains of white-rot fungi to obtain the highest percentage of brightness. These strains were screened on banana fruit stalk as a sole carbon source under SSF, incubated at 35°C for one month. We examined their susceptibility for biopulping periodically during 1 to 4 weeks. It showed that the brightness increased corresponding to increase time of incubation except in the case of C. versicolor NRRL 6361, as shown in Figure 1. The time work agreed with experimental work by Gary et al. Phanerochaete chrysosporium NRRL 6370 was observed to be the most efficient in per cent of brightness 30.5 per cent than control 17.5 per cent. Figure 1. Table 1 shows that P. chrysosporium NRRL 6370 degraded lignin (10 per cent) as compared with control (17.6 per cent). This result was confirmed by Arbeloa et al., who evaluated the potencies of lignin peroxidase from P. chrysosporium in reduced lignin content. The most microorganisms for lignin degradation are those that can produce xylanases and phenoloxidases. The former degrade xylene to xylose (a sugar required to satisfy microbial energy requirements) and the latter take part in lignin degradation. The xylose is one of the structure of hemicellulose, this is sugar requirement to microbial
energy attributed to degrade lignin. This results in decrease in the hemicellulose ratio compared with control (19.2 per cent to 28 per cent). The fungus degraded lignin and hemicelluloses did not have any effect on cellulose fibres bound by them (55.4 per cent inoculated, 40.1 per cent control). Also ash content of inoculated was less than control (6.2 per cent, 11.8 per cent respectively) which gave a brittle pulp.

(ii) Mechanical Properties of Board from Banana Pulp and Other Wastes (150g/m²)

Figures 2-4 show that the strength properties of biopulping were higher than untreated pulp, similar trends are reported by Oriaran et al. This result was attributed to decrease in ash and lignin content (Table 2). The board from blended banana waste with pulp of magazine waste had good strength properties (Tensile strength 7.3, burst strength 3, and tear resistance 125) compared with other different board patterns. Since the pulp of magazine waste is a chemical pulp and this contains some percentage of

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Untreated</th>
<th>Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollowcellulose per cent</td>
<td>68.1</td>
<td>74.6</td>
</tr>
<tr>
<td>α- Cellulose per cent</td>
<td>40.1</td>
<td>55.4</td>
</tr>
<tr>
<td>Extractible hemicellulose per cent</td>
<td>28</td>
<td>19.2</td>
</tr>
<tr>
<td>Klason lignin per cent</td>
<td>17.6</td>
<td>10</td>
</tr>
<tr>
<td>Ash content per cent</td>
<td>11.8</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Note: The brightness of untreated banana waste was 17.8 per cent but the brightness of treated banana waste was 30.5 per cent.
lignin and higher percentage of cellulose if compared with a pulp of cotton stalk and Rosella. Also the pulp of newsprint contains higher percentage of lignin compared with pulp of magazine. The blended board from banana waste with newsprint waste is higher than board from banana waste with Rosella or cotton stalk, as shown in Table 2.

From these results, we observed that the addition of banana waste to different wastes improved the strength properties of these residues.

(iii) Hand-made Sheets for Writing and Printing Paper (60g/m²)

Banana waste, either inoculated or uninoculated, was bleached in order to obtain a suitable paper for writing and printing. We used hydrogen peroxide for bleaching after biopulping in order to bright character of paper. Table 3 illustrates that decrease in lignin, hemicellulose and ash content of biopulping banana waste after bleaching (2.8 per cent, 13.9 per cent, and 18 per cent, respectively). The hydrogen peroxide under certain conditions formed perhydroxyl ion (–OOH–) which was capable of further degrading quinoid lignin structures and changing lignin into small fragments dissolved in it bleaching mixture. Also, hydrogen peroxide had severely degraded to the hemicellulose (low-molecular weight) to a certain extent.

Enzymatic pretreatment with xylanase from P. chrysosporium NRRL 6370 improves bleachability of banana waste. The results have shown strong dependence of prebleaching effect on end products. The enzyme maintains pulp yield and avoid loss in viscosity and strength properties which was also confirmed by Gliese et al.

(iv) Physical Properties of Hand-made Sheet from Bleached Banana Waste (60g/m²)

Table 4 shows that the strength properties of inoculated pulp are higher than uninoculated pulp.

<table>
<thead>
<tr>
<th>Waste</th>
<th>Analysis</th>
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<tbody>
<tr>
<td></td>
<td>α-cellulose per cent</td>
</tr>
<tr>
<td>Magazine waste</td>
<td>75</td>
</tr>
<tr>
<td>Newsprint waste</td>
<td>59</td>
</tr>
<tr>
<td>Cotton stalk</td>
<td>56.6</td>
</tr>
<tr>
<td>Roselle stalk</td>
<td>50.4</td>
</tr>
</tbody>
</table>

Table 3 — Analysis of bleaching biopulping banana waste by hydrogen peroxide

<table>
<thead>
<tr>
<th></th>
<th>Uninoculated</th>
<th>Inoculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollowcellulose per cent</td>
<td>84.2</td>
<td>90</td>
</tr>
<tr>
<td>α- Cellulose per cent</td>
<td>63.2</td>
<td>76.1</td>
</tr>
<tr>
<td>Extractible hemicellulose per cent</td>
<td>21</td>
<td>13.9</td>
</tr>
<tr>
<td>Klason lignin per cent</td>
<td>5.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Ash content per cent</td>
<td>3.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Average molecular weight</td>
<td>795.6</td>
<td>818</td>
</tr>
</tbody>
</table>

Table 4 — Physical properties of hand-made sheets (60g/m²) of bleaching biopulping with or without additives

<table>
<thead>
<tr>
<th>Test</th>
<th>Blank</th>
<th>With additives</th>
<th>Blank</th>
<th>With additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brightness per cent</td>
<td>70.5</td>
<td>70.5</td>
<td>48.6</td>
<td>48.6</td>
</tr>
<tr>
<td>Opacity per cent</td>
<td>85.7</td>
<td>87.1</td>
<td>90.3</td>
<td>92.1</td>
</tr>
<tr>
<td>Tensile strength (kg)</td>
<td>6</td>
<td>4.5</td>
<td>5.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Breaking length (m)</td>
<td>2358.5</td>
<td>1767.8</td>
<td>2002.2</td>
<td>1366.9</td>
</tr>
<tr>
<td>Tearing resistance (g)</td>
<td>92</td>
<td>80</td>
<td>76</td>
<td>70</td>
</tr>
<tr>
<td>Burst strength (kg/cm²)</td>
<td>2.4</td>
<td>1.9</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Sizeability (sec)</td>
<td>1</td>
<td>12.13</td>
<td>1</td>
<td>12.13</td>
</tr>
</tbody>
</table>

Note: The additives were 10 per cent kaolin and 2 per cent rosin size.
(tensile strength 6, 5.1; bursting strength 2.4, 2.0; tearing resistance 92 and 76, respectively). These results are in agreement with those obtained by Myers et al. The inoculated sample gave more brightness than un inoculated ones (70.5 per cent and 48.6 per cent, respectively) which is confirmed by Lu et al. The strength properties decrease after addition of additives (Table 4). Since the addition of filler (Kaolin) cannot form hydrogen bonds, hence it reduces the strength by blocking fibre to fibre bonds and rosin size which gives brittle pulp. Similarly, the opacity increases after addition of additives, since the filler (Kaolin) fills the space between fibre forming fibre-filler bonding and the sizeability increases due to addition of rosin size which gets precipitated as aluminum resinate at pH 4.5 which makes the paper partially hydrophobic, and thus prevents the spreading of ink.

Generally, banana waste has higher strength properties due to its higher fibre length. The fibre length of banana pulp range between 4.5 to 5 cm, while the long fibre of bleaching wood pulp range between 1.2 to 1.5 cm.

(v) Production of Greasy Paper from Bleached Banana Waste (45 g/m²)

The production of greasy paper from biopulping banana waste reduced costs and environmental impact, compared to traditional pulping operations.

The production of greasy paper from biopulping banana waste reduced costs and environmental impact, compared to traditional pulping operations.

References


