Decolourisation of Waste Paper by Fungi

Ahmed Y. M.*, Mansour O.Y.**, Abd-El-Kader; Mona** and El-Melgi M.G.**

Microbial Biotechnology Dep*, Cellulose and Paper Dept.**, National Research Centre, Dokki, Cairo, Egypt.

Abstract

The wastepapers used in this work were printing, writing papers and newsprint. Both A. niger and P. chrysosporium were used in the fungal deinking treatments. The waste papers treated with A. niger have black spots on the surface of the hand sheets which are difficult to separate from the surface, while P. chrysosporium displayed better colour reduction abilities in sterilized sample. The maximum brightness obtained for recycled printing papers was 75% at initial pH 7.24; while for recycled writing papers the brightness was 80% at initial pH 7.5. On the other hand, the newsprint papers, show maximum brightness of 39% at initial pH 11.3 Adhesives materials such as starch-silicate complex (3-5%) is adequate to overcome the slight decreasing of the mechanical properties of the recycled waste papers.

INTRODUCTION

Waste papers such as news, writing and printing papers material cause environmental pollution due to the presence of carbon, on which harmful bacteria and fungi can grow which causes health hazards. This waste papers can be recycled in the form of board after deinking (1). Deinking can be done by chemical methods using detergent (2) or applying biological technology using fungi. One of most obvious application of white rot fungi and their oxidative enzymes is in biobleaching and biopulping and paper industry to replace environmentally unfriendly chemicals (e.g. chlorine) such as P. chrysosporium which can be degrade lignin and chlorinated organic compound (3,4). Bjerkandera adusta produces peroxidases which can be used in decoloriation as biobleaching process (5). On the other hand, Garzillo (6) extracted laccase from white-rot fungus Trametes trogii an important oxidizing enzyme for biobleaching. The enzyme also shows oxidizing activity for lignin, a number of phenolic and non-phenolic compounds.

A new lignin-degrading basidiomycete, strain I-62 (CECT 20197), isolated from decayed wood exhibited both a high dephenolization activity and decolorization capacity when tested on effluents from the sugar cane byproduct fermentation industry. These ligninolytic activities depend on phenoloxidase (laccase), in conjunction with small amounts of manganese peroxidase (7). Aspergilli are known to overproduce high levels of hemicellulolytic enzymes as endoxylanases, the main activities required for enzyme-aided bleaching. The key application areas are biopulping and biobleaching where a reduction in the use of environmentally harmful chemicals traditionally used in the pulp and paper industry is envisaged (8).

The aim of this work is trying to recycling of the waste papers using fungal treatment to get rid of pollution which results from burning of this waste papers.

EXPERIMENTAL

Microorganisms: Phanerochaete chrysosporium NRRI 6361. Aspergillus niger.

Fungi was grown and maintained on malt extract-yeast extract-agar containing the following gradient: yeast 4.0; malt extract) extract 4.0; glucose 4.0, distilled water up to 1L, in case of slant 20.0 agar were added.

The culture was grown on malt-yeast extract medium in conical flask for 4 days under sterile condition at 32±2°C. The fungal mat was recovered and suspended in sterilized effluent samples macerated aseptically using a homogeniser. The suspensions thus prepared was used as a starter.

The wastepapers used in this work were printing (copy paper), writing papers and newsprint. The wastepapers were cut into small pieces and immersed into warm water at 50±2°C for at least 3 hours. All samples were beated individually using the Valley beater at 5% consistency to obtain a slurry.

Each conical flask was contained 45 ml of the sterilized medium contained 2.0 gm glucose and 2.5 gm of ammonium dihydrogen phosphate per liter. 3 gm of treated wastepapers sample after filtration through piece of cloth were supplemented to the medium. The flasks were inoculated with 5 ml of starter culture and incubated on rotary shaker (250 r.p.m. min^{-1}) for 7 days at 32±2°C unless other wise stated. Control flask contains the same component without starter.

The contant of the waste papers before and after decolorization by white-rot fungi from α-cellulose, extractable hemicellulose, lignin (Institute methods; No. 42B), ash contents and average molecular weight ($\bar{M}n$) were determined according to the German Standards Methods (Merkblatt IV/2gA).

Tappi standard method was used to prepare handsheets from recycled wastepaper by white-rot fungus. During sheet formation, some adhesives and fillers were added. The adhesive used was starch-silicate complex (3% to 5% based on dry pulp). The filler used was kaolin (10%) based on dry pulp (kaolin was delivered from Rakta Co., Alex.). To improve the sizing property of writing paper; rosin size was used (2-3%) based on dry pulp together with 10% alum to reach pH-4-5 (rosin size delivered from Rakta Co. Alex). The grammage of the hand sheets were 48 gm/m^2 for newsprint and 60 or 80 gm/m^2 for writing and printing papers respectively.

The produced papers were conditioned for 24 hours at 25°C and 50% R.H. then the tensile, bursting strengths and tearing resistance were measured. Physical properties such as basis weight and density were calculated. Optical properties such as brightness and opacity were measured.

RESULTS AND DISCUSSION

Two fungi were used in this work namely Aspergillus niger and Phanerochate chrysosporium Their potential to remove the ink colour of waste papers effluent under sterilized conditions were compared. The test was done in conical flasks of 45 ml medium 3 gm sample sterile of each waste papers and 5ml of the inoculme were inoculated to the flasks. The flasks were incubated in rotary shaker 150 r.p.m. for 7days at 32°C. The results indicated that A. niger can't grow well even in the presence of 10 gm glucose. The hand sheets prepared from the pulp treated by A. niger have black spots, while, P. chrysosporium displayed better colour reduction abilities in sterilized sample which could be attributed to decomposition of colour.

The results in Table 1 indicated that the maximum brightness percent obtained for printing papers is 75% in case of, inoculated with P. chrysosporium, while it is 69% only in case of un-inoculated printing paper. The brightness of fungal treated writing papers were 77% while it was 70% for the brightness of uninoculated writing papers. On the other hand, the brightness was 33.2% for inoculated news paper and 30% for uninoculated paper.

White-rot fungi P. chrysosporium were tested in different waste papers (printing paper, writing paper, news print). Different PHs were tested (5-11.4), the PH were adjusted with HCI and NaOH to the required initial PH. The culture were incubated for 7 days at 32°C. The results in Table 2, 3 and 4 shown that the tested white-rot fungus P. chrysosporium proved to be effective in diluting colour of sterilized waste papers webs. The maximum brightness obtained for recycled printing papers was 75% at initial pH 7.24, but for recycled writing papers the brightness was 80% at initial pH 7.5. It is noticeable to see that tap water and ink as shown in Table 5 contain elements which are essential for the production of enzymes and is very effective for colour reduction. The role of organism in decolourization of the colour from the waste papers depend on the formation of peroxides which are found in most white-rot fungi (8,9). Glucose oxidase which is known in P. chrysosporium fungi has been shown to be the predominant source of hydrogen peroxide in lignin degrading cultures. (10,11). The presence of some elements in the writing and printing inks stimulated hydrogen

Table 1. Effect of the treatment of waste papers with P. chrysosporium

Waste paper	Inoculated with P. chrysosporium %	Uninoculated %
Newspaper	33.2	30
Writing paper	77	70
Printing paper	75	69

peroxide formation by P. chrysosporium. The increasing of hydrogen peroxide formation combined with the oxidation of both organic and inorganic compound found in the ink, then the detaching of the oxidizing particles by swelling of the fibre.

In case of newsprint papers, the maximum brightness obtained was 39% at initial pH 11.3, the NaOH used have another role as swelling agent making it easier for the dye particles to be detched from the fibres and may also cause saponification of the oil particles (12). This medium is suitable for growth of this organism since the constituent of newsprint papers decreased the alkalinity of the medium which is evident from the measuring of the final pH which equal to 9.0. Also, alkaline chemicals react with hydrogen peroxide to form perhydroxyl ion, OOH^-, which is instrument in bleaching action of the hydrogen peroxide (13,14).

Generally, inks of the newsprint which may constitute from organic compound can be affected by H_2O_2 to form decolourized compound and these can be detached from the fibre due to the swelling of the fibre in water.

Analysis of the recycled papers

Recycled paper which has maximum brightness can be chemically analyzed for α-cellulose, hemicellulose, lignin, ash and the average molecular

Table 2. Effect of different pH on decolourization of printing papers both alone and by action of P. chrysosporium with basis weight 60 gm/m².

Initial pH	Uninoculated recycled printing paper				Inoculated recycled printing paper		
	Brightness Bursting % strength Kg/cm²	Opacity %	Tensile Strength Kg	Bursting Strength Kg/cm²	Brightness %	Opacity %	Tensile Strength Kg
5.00	62.0	91	2.3	1	63.2	91.0	2.3 1
5.50	62.0	91	2.3	1	63.2	91.0	2.3 1
6.00	62.0	91	2.3	1	63.5	91.0	2.3 1
6.50	62.0	91	2.3	1	63.7	91.0	2.3 1
6.72	70.2	91	2.3	1	72.5	91.0	2.3 1
7.00	69.0	91	2.3	1	70.6	91.0	2.3 1
7.24	72.0	91	2.3	1	75.0	91.0	2.3 1
11.4	70.6	90.2	2.3	1	72.5	91.2	2.3 1

Table 2. Effect of different pH on decolourization of printing papers both alone and by action of P. chrysosporium with basis weight 60 gm/m².

Initial pH	Uninoculated recycled printing paper				Inoculated recycled printing paper		
	Brightness Bursting % Strength Kg/cm²	Opacity %	Tensile Strength Kg	Bursting Strength Kg/cm²	Brightness %	Opacity %	Tensile Strength Kg
5.00	68.2	90	2.5	1.1	70	90	2.5 1.1
5.50	68.2	90	2.5	1.1	70	90	2.5 1.1
6.00	68.5	90	2.5	1.1	70	90	2.5 1.1
6.50	68.6	90	2.5	1.1	70	90	2.5 1.1
6.80	72.0	90	2.5	1.1	75	90	2.5 1.1
7.00	73.0	90	2.5	1.1	77	90	2.5 1.1
7.56	75.0	90	2.5	1.1	80	90	2.5 1.1
11.24	70.0	90	2.5	1.1	71.8	90	2.5 1.1

Table 4. Effect of different pH on decolourization of news papers both alone and by action of P. chrysosporium with basis weight 48 gm/m².

Initial pH	Uninoculated recycled printing paper				Inoculated recycled printing paper		
	Brightness Bursting % Strength Kg/cm²	Opacity %	Tensile Strength Kg	Bursting Strength Kg/cm²	Brightness %	Opacity %	Tensile Strength Kg
5.00	27	95	1.35	25	28.3	95	1.35 25
5.50	27	95	1.35	25	28.3	95	1.35 25
6.00	28.2	95	1.35	25	29.2	95	1.35 25
6.50	28.9	95	1.35	25	30.0	95	1.35 25
6.81	28.9	95	1.35	25	30.5	95	1.35 25
7.00	30.8	95	1.35	25	33.1	95	1.35 25
7.56	32	95	1.35	25	35.0	95	1.35 25
11.4	34	95	1.35	23	39.0	94.4	1.35 23

Table 5. Some elements present in waste papers

Metal	P.P.M. in wastepaper
Ni	03.10
Cu	20.20
Fe	267.40
Cr^{++}	06.00
Zn	15.80
Co	00.90
Mn	54.10

weight before and after treatment P. chrysosporium. The results obtained in Table 6 showed that the α-cellulose, content was high for pulps obtained from writing and printing paper which were mainly chemical pulps while for the newsprint the α-cellulose was low because the pulp used for the manufacture of newsprint is mainly ground wood. This is ensured by the significant increased lignin (%) for newsprint rather than both the printing and writing papers (Table 6). Decolourisation of these wastepapers by white-rot fungus P. chrysosporium increased the α-cellulose content within the same ratio but decreased the lignin and extractable hemicellulose content. The average molecular weight ¯Mn for the newsprint can not be investigated because of the increased lignin content.

The Handsheets had basis weight 80 or 60 gm/m² prepared from recycled printing and writing papers respectively but for the newsprint it was 48 gm/m² under adjusted optimum conditions (incubated shaking for 7days on rotary shaker, at temperature 32°C±2 and initial pH = 7.2 for printing paper, 7.56 for writing paper and 11.2 for newsprint. The physical, optical and mechanical properties of these papers were investigated before and after the

Table 6. Analysis of waste pulps before and after decolourized by P. chrysosporium

Printing Writing Newsprint	Waste pulp paper			Decolourized waste pulp paper		
	Printing	Writing	Newsprint	Printing	Writing	Newsprint
α-cellulose %	68.2	71.6	58.6	73.5	75.6	60.0
Extractable Hemicellulose %	19.4	18.8	11.2	17.3	16.1	10.2
Lignin %	4.6	3.34	28.8	2.4	1.2	27.5
Ash	8.0	6.0	1.4	5.2	4.7	1.2
Average M.W*	290	422	-	350	450	-

* Average molecular weight

Table 7. Physical, optical and mechanical properties for inoculated recycled printing, writing paper and newsprint in presence and absence of additives

Property	Inoculated Recycled Printing Paper				Inoculated Recycled Writing Paper				Inoculated Recycled Newsprinting	
	60gm/m²		80gm/m²		60gm/m²		80gm/m²		48gm/m²	
	Blank	Additives	Blank	Additives	Blank	Additives	Blank	Additives	Blank	Additives
Moisture %	7.2	7.2	7.2	7.2	6	6	6	6	8.5	8.5
Density gm/cm³	0.25	0.26	0.35	0.37	0.22	0.24	0.3	0.33	0.16	0.17
Brightness %	75	75	75	75	80	80	80	80	39.3	39.1
Opacity %	91	92.2	92.3	93.4	90	90.8	91	92	95.6	97
Tensile Strength (kg/cm²)	2.3	2.7	2.55	3.3	2.5	3.2	3	3.6	1.35	2.33
Bursting (kg/cm²)	0.9	1.1	1.1	1.23	1	1.23	1.25	1.36	-	-
Resistance (gm)	-	-	-	-	-	-	-	-	24	35
Sizeability (sec.)	4	13	5	20	4	20	5	30	2	11

addition of 3% adhesives, 10% kaolin, 2.5% rosin size then 10% alum till pH 4-5 for writing and printing paper but for the newsprint, the addition was 5% adhesives, 3% rosin size and 10% alum till pH 4-5. The results are shown in Table 7. It is clear from that the physical and optical properties showed little change whereas the optical property slightly increased due to the addition of filler i.e Kaolin which formed fibre to filler bonding. The mechanical properties increased as a result of adding adhesives, which lead to stonger fibre to fibre bonding. The sizeability increased as results of rosin size addition. The increased sizeability makes the paper more hydrophobic and prevents the spreading of ink or colour. Our results are in agreement with the results of newsprint paper sheets from nonwood fibrous materials (15).

REFERENCES

1. Datta A, Bettermann A, Kirk TK, Appl Environ Microbiol, 57 (5), 1453-60, (1991).
2. Dorris, G.M. and Nguyen, N., J. Pulp Pap. Sci., 21 (2) 55-62, (1995).
3. Heinfling A, Martinez MJ, Martinez AT, Bergbauer M, Szewzyk U., FEMS Microbiol Lett 1; 165 (1), 43-50, (1998).5. Duarte JC, Costa-Ferreira M., Appl. FEMS Microbiol Rev., 13 (2-3), 377-86, (1994).
4. Eriksson K.E., J. Biotech. 30, 149-58, (1993).
5. Garzillo AM, Colao MC, Caruso C, Caporale C, Celletti D, Buonocore V., Appl. Microbiol Biotech. 49 (5) 545-51, (1998).
6. Habu, N.; Igarashi, K; Samejima, M; Pettersson, B; Eriksson, KE., Biotechnol. Appl. Biochem. 26 (2) 97-102 (1997).
7. Crawford, R.L. and Crawford, D.L., Enzyme Microb. Technol. 6, 434-442 (1984).
8. Kelly, R.L. and Reddy, A., Arch. Microbiol, 144-248, (1986).
9. Wisconsin, Jon, Institute Method No-42 B, Institute of paper chemistry, Appl., (1951).
10. Kersten, P.J. and Kirk, T.K., Bacterio, 169, 2195-2202, (1987).
11. Ullmann's, Encyclopedia of Industrial Chemistry, Paper and pulp, USA, New York, PP. 545, 548, 603, 604, 610 and 616, (1991).
12. Kuney, G.W., Pulp paper Can. T 402 (1985).
13. Colodette, J.L.; Rothenberg, S. and Dense, C.W., J. Pulp and Paper of Sci., 15 (1) J 3, (1989).
14. Mansure M., Suarez T, Fernandez-Larrea JB, Brizuela MA, Gonzalez AE, Appl. Environ Microbiol 63 (7) 2637-46, (1997).
15. Naim A. Fadl, Altaf H. Basta, Samira F. El-Kalubi and Mohammed L Hassan, J. of Sci. and Ind. Res. 56, 357-365, (1997).
16. Olfat, Y. Mansour, Mona Abd-El-Kader, and Magda Goda, Polym. Plast. Technol. Eng., 36 (3), 391-397, (1997).