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Novel Use of Wheat Grass Extract in Enzymatic Deinking of Printed Paper

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ABSTRACT:Wheat grass is an excellent source of enzymes such as amylase, esterases, lipase etc. Use of enzymes for deinking is emerging over the chemical deinking techniques considering the drawbacks of latter such as high environmental impact and costs. The present work examines chemical and enzymatic deinking procedures for Mixed Office Waste (MOW) and newspaper samples. The novel feature of the present study is use of wheat grass extract for acquiring the required enzyme while the chemical deinking process uses conventional method for deinking. The effectiveness of the process depends upon the retention time for enzymes during the enzymatic hydrolysis and the extent of use of bleaching chemicals for chemical deinking. The choice of the enzyme also depends upon the quality and the grade of the paper used. Extent of deinking is estimated by analysing the optical properties of hand sheet paper made. The results are encouraging and show a good potential in use of wheat grass extract in enzymatic deinking over the conventional chemical deinking method.

KEYWORDS:MOW (Mixed Office Waste), ONP (Old Newspaper), Deinking Optical Analysis, Deinking, Wheat grass extract.

I. INTRODUCTION

Paper is an important material and inseparable part of human life, used for various purposes worldwide. The global production of paper was 407 million metric tons through a survey conducted in 2014. More than half of the paper produces goes for packaging and one third is attributed to the graphic paper. The world's largest producer and consumer is United States of America. U.S Forest, paper and packaging generates a revenue of 96.1 billion dollars. The per capita consumption in India accounts to 11 kg. This ever increase in demand of paper has increased the stress of reusing the wastepaper by recycling it.

For the purpose of recycling the waste paper chemical deinking process is widely used on a large scale The chemical deinking method were very effective in the past, but this has started to change as the use of inkjet printing on industrial levels. The efficiency of separation of ink depends upon the ink properties. The dyes, letter press inks and oil-based inks are easily removed. This is due to the fact that the ink particles are larger (50-200 microns) and hence they agglomerate effectively on the bubble during the washing or the floatation step and can be removed easily [1]. Non-impact printed paper are the most difficult to remove because of the thermoplastic and the synthetic polymers present in the laser and photocopy toner. Also the size of the ink particles in the offset prints are very small (5-20 microns) which makes it difficult to collect over the air bubble and hence not removed completely [2]. Generally the deinking industry for paper recycle deals with two main goals :- (i) Detachment of the ink particle from the paper. (ii) Removal and separation of the dispersed ink from the pulp solution.

The traditional chemical deinking method involves use of large amount of chemicals which makes it expensive and also has more damaging impacts on the environment [1]. On the contrary enzymatic deinking procedure dislodges the ink from the fibre without any discharge of pollutants Use of enzymatic deinking produces minimum treatment effluent and has comparatively less COD as compared with chemical deinking process [4]. Apart from the ink removal, enzymatic deinking may improve the strength of paper by removing fines content and improving the interfibrillar

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bonding of paper[5].Washing or the floatation method is used to remove the dislodged ink particles from the pulp solution, washing method being used for smaller particles(<20µm) whereas floatation is done for larger particle size(20-300µm).

The aim of the present work is to remove ink particles from a known composition of MOW and ONP using appropriate floatation method. Hand sheet paper samples are prepared by blending deinked paper& fresh filter paper pulp. Characterisation is carried out using reflectance and whiteness test of hand sheet paper samples.

II. MATERIALS AND METHODS

MOW (Mixed Office Waste) and ONP (Old Newspaper) were shredded into 5cmX5cm pieces and mixed in 1:1 ratio. This mixture of shredded paper was washed thoroughly and soaked into 0.25M HCl solution. This is then proceeded for the enzymatic and chemical treatment procedures. Three samples ED-101 & 102 and CD-101 are prepared.

2.1 Enzymatic Deinking

The enzymatic deinking process involves a series of steps as shown in Fig.1. Commercial grade chemicals like sodium hydroxide, sodium silicate, and CMC (Carboxymethylcellulose) for the pulping stage, amylase extracted from wheatgrass during the enzymatic hydrolysis, Palmitic acid, calcium chloride and Tween 80 for floatation, hydrogen peroxide as bleaching agent and soluble starch as binder are used.

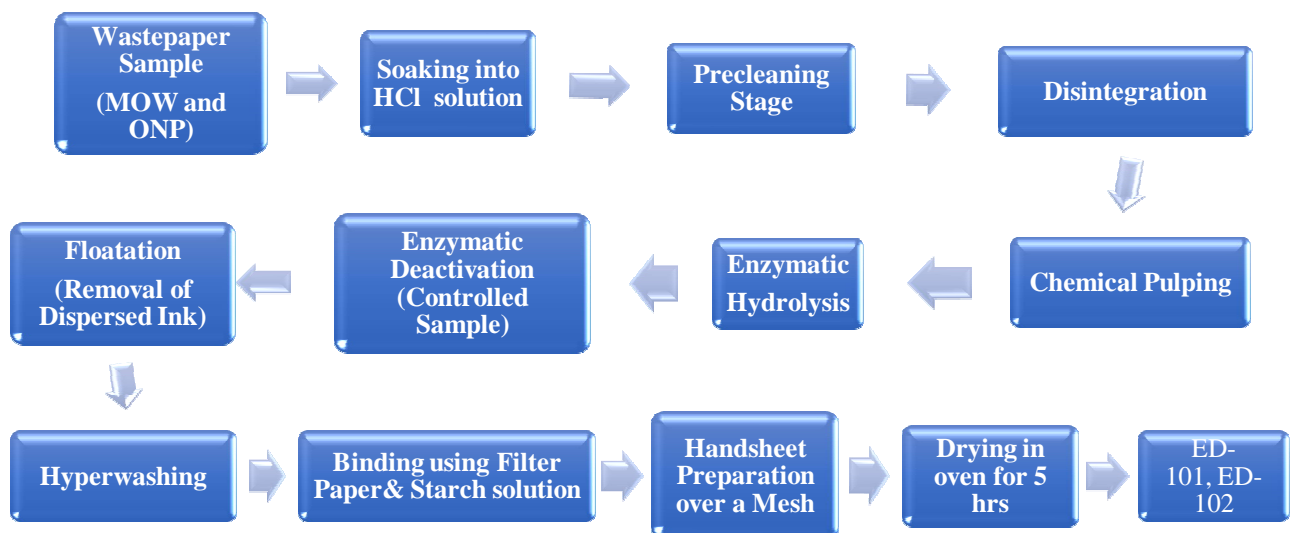


Fig. 1. Flowchart of Enzymatic Deinking Methodology

2.1.1 Experimental Procedure

Firstly wheatgrass was grown from wheat seeds which were germinated and subsequently grown in soil for 6-7 days. 35-40 grams of wheatgrass was crushed to obtain a green coloured solution containing necessary enzyme. The pulp from the laser printed office waste and newspaper is prepared after soaking & heating into HCl to obtain 8% (w/w) pulp consistency for 5 min at 50 °C. This subjected to pulping stage at 6% pulp consistency, at temperature of

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55-60°C, and pH=8-10 in a container with 3ml 1M NaOH, 3 gm Na₂SiO₃& 1.5-2 gm CMC for 25-30 min. After pulping, enzymatic hydrolysis of the pulp was carried out using enzyme solution in a 1000-ml container under control temperature of 50°C at 3.5-4 pH at 4% pulp consistency for 60-75 min. An additional controlled sample was formed by deactivating the enzymes by boiling the pulp solution at 100°C for 10 min. After the enzymatic hydrolysis, the hydrolysed pulp was subjected to the flotation process at 2% consistency. The flotation process was carried out in a 800-ml vertical container. 4 gm Palmitic acid in the form of shaving cream, 3 gm CaCl₂ and 4mL Tween 80 were added and it was subjected to floatation. The aeration was provided with the help of compressor at a pressure of constant 4 bar. Temperature during the floatation was 35-40°C and pH around 8-8.5. Following the floatation step, bleaching was carried out using 5mL hydrogen peroxide in a 500ml glass beaker. It was kept in the condition for 10 min and finally washed with running water. The treated pulp was mixed with a new pulp of filter paper of size 15x15cm, weighing 25 gm. Both pulps are binded by using starch solution (5gm soluble starch in 25 ml water) and kept for 35-40 min. The blended pulp was hyperwashed & prepared as hand sheet paper samples ED-101 & 102 over a 200 mesh screen and dried in oven at 80°C for 5 hrs, followed by analysis. For sample ED-102, additional process step of heat controlled deactivation of enzyme was carried out. Fig 2 depicts day wise growth of wheat grass starting from the germinated seeds of wheat.

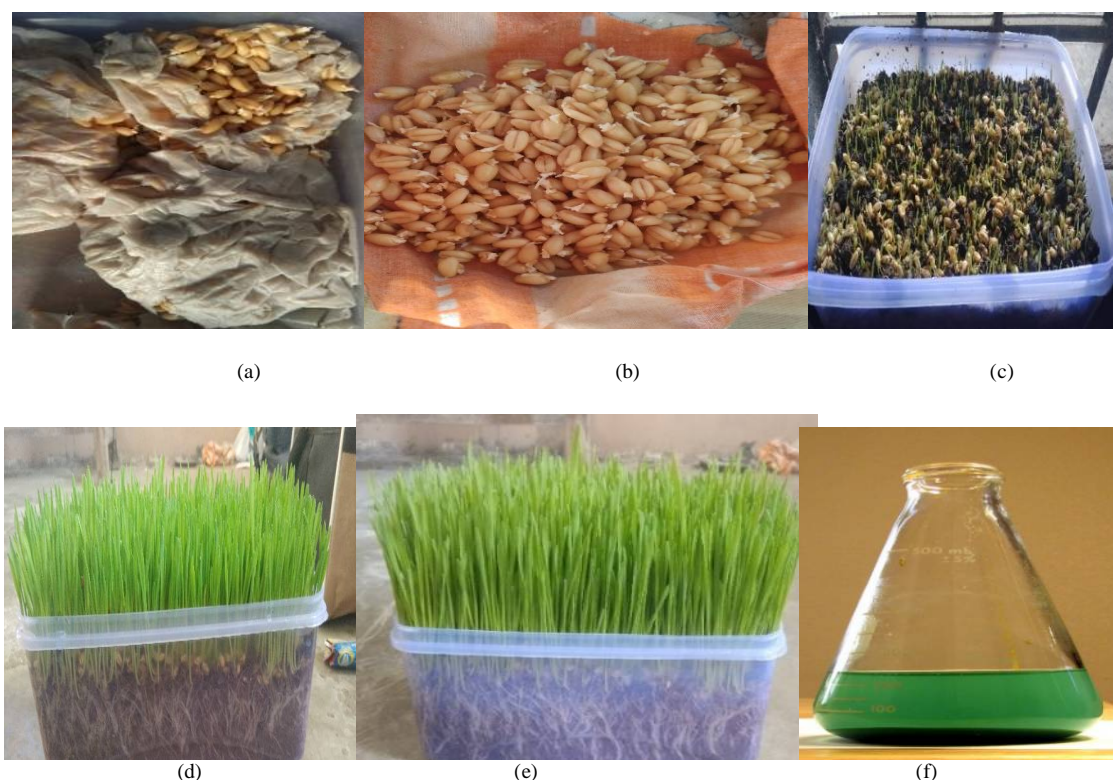


Fig. 2. Day wise wheat grass growth and Enzymesolution (f). (a , b- Day 1, c- Day 3, d- Day 5, e- Day 7)

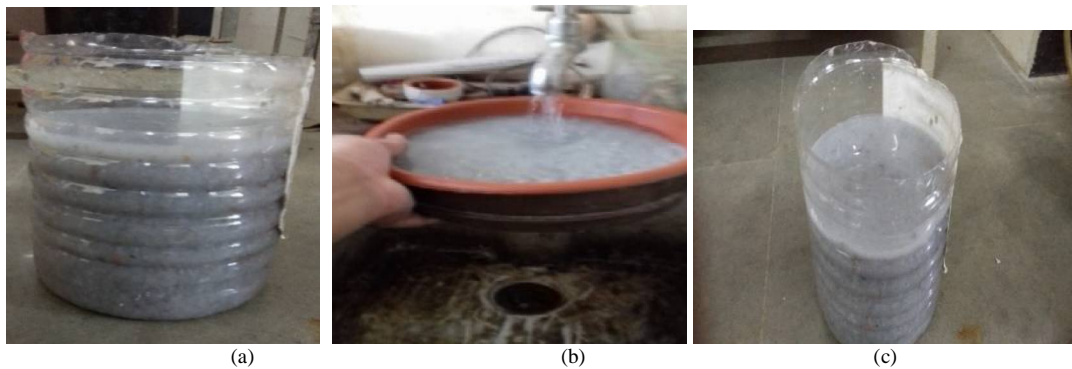
The enzymatic deinking process carried out on lab scale is depicted in a schematic manner with the help of the actual images

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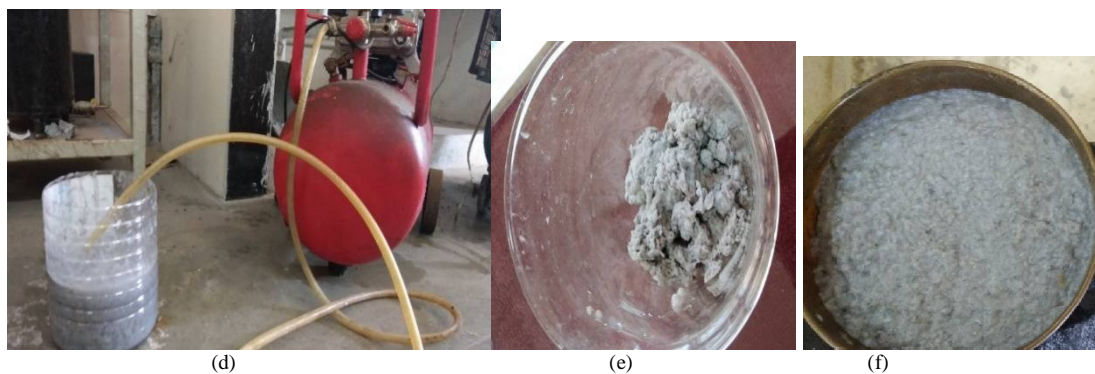
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The hyperwashing step as shown in Fig.3 (b) is an essential step for the removal of the dispersed ink particles after the pulping stage.



After carrying out the enzymatic deinking methodology sequentially as shown in Fig. 1 , two hand sheet of paper was prepared namely ED-101 & ED-102, where ED-102 is the heat controlled deactivated sample as shown in Fig.3 (h).

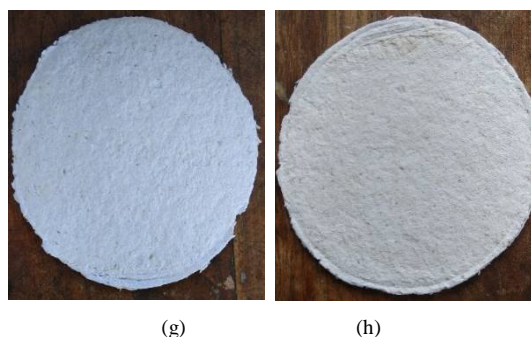


Fig. 3. Images of Enzymatic Deinking Methodology. (a)- Pulping Stage (b)- Hyperwashing (c)- Enzymatic Hydrolysis (d)- Flotation (e)- Binding using starch solution (f)- Hand sheet preparation (g)- ED-101 (h)- ED-102.

2.2 Chemical Deinking Process

In the chemical deinking process the pulp (50 gm oven dry basis) of MOW and ONP is taken. It is precleaned thoroughly over a 200 mesh screen with running water. Followed by disintegration step at a temperature of 50°C for 5

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min with gentle agitation to obtain 8% pulp consistency. It was subjected to pulping stage with 6% pulp consistency, temperature 55-70°C, and pH=8-10 in a container with 3ml 1M NaOH, 3 gm Na₂SiO₃, 2-3mL H₂O₂, 2 gm CMC for 25-30 min. It is hyperwashed and put into the fatty acid floatation unit where the dispersed ink particles after pulping are removed using palmitic acid(4 gm) and CaCl₂(3 gm) at 35-40°C for 20 min. The froth collected at the top is removed manually. It is introduced into floatation unit-2 where an non-ionic surfactant Tween-80 is used to perform the similar floatation process at same temperature conditions and pH=8-8.5 for 15 min. The aeration was provided with the help of compressor at a constant pressure of 4 bar. After this, bleaching of the pulp was carried out using 5 mL hydrogen peroxide followed by blending with filter paper(15X15cm, 25 gm), 5gm soluble starch solution in 25 mL water, finally hand sheet paper sample CD-101 was prepared over a 200 mesh screen. These hand sheets were dried in oven at 80°C for 5 hours and proceeded for optical property analysis. The flowchart of procedure & the photographic details are given in Fig 4 and Fig 5.

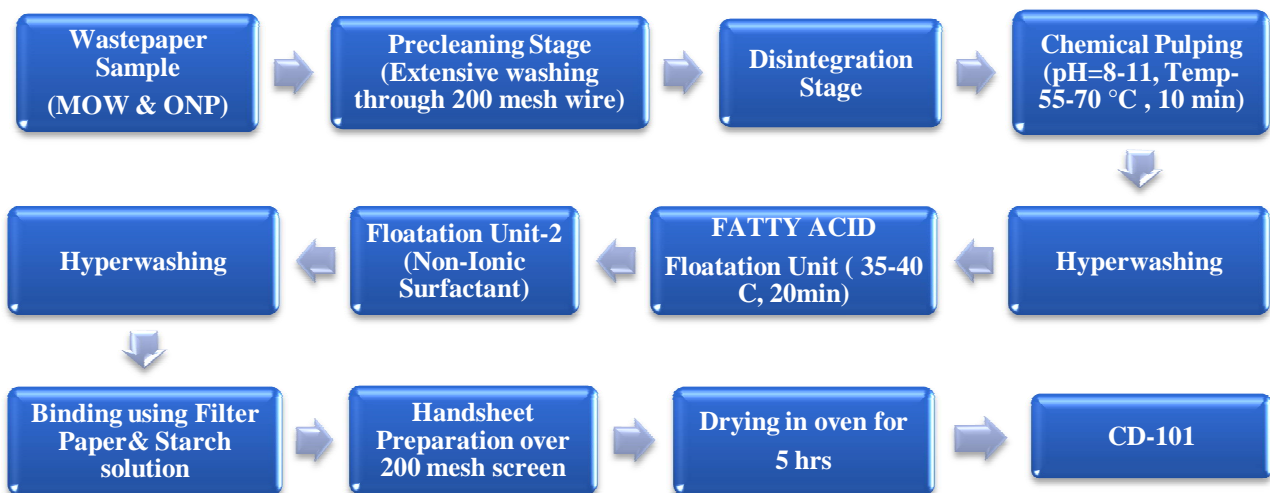
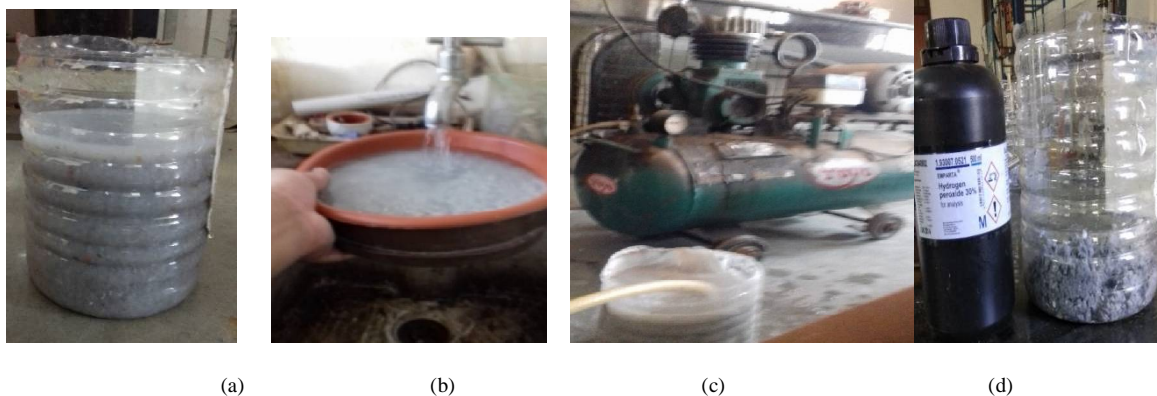


Fig. 4. Flowchart of Chemical Deinking Methodology



After the completion of the binding step the treated pulp was spread over a 200 mesh size screen as shown in Fig.5 (e). In order to facilitate easy removal of the product hand sheet, little amount of oil was applied over the mesh prior to drying.

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Fig. 5. Images of Chemical Deinking Methodology. (a)- Pulping Stage (b)- Hyperwashing (c)- Flootation (d)- Bleaching (e)- Hand Sheet Preparation (f)- Oven Drying (g)- CD-101

III. RESULTS AND DISCUSSION

After the enzymatic and chemical treatment of the MOW and ONP, the hand sheets prepared were analysed for brightness and reflectance. Tests were conducted on X-Rite Ci4200 spectrophotometer with D65 illumination. Using the percentage reflectance data and the tristimulus values the brightness and the whiteness of the product was evaluated. The object appears white if it totally reflects the light, and scatters diffusively at all wavelengths of the visible spectrum. The object appears coloured if some wavelengths of the light are reflected while the others are absorbed. It is black if the object absorbs all the wavelengths of the light in the visible spectrum [6].

3.1 Whiteness Test

Whiteness of a particular sample can be evaluated both visually and instrumentally. However, we cannot measure colour or whiteness directly. Only, the physical property, the spectral reflectance of a sample can be measured. Instrumental characterization of whiteness is made in two steps. First, reflectance spectra are measured. Then, whiteness assessments are calculated by using the tristimulus values namely X,Y,Z. These represent the red, blue and green colours respectively & are measured with the help of spectrophotometer. The values obtained from the spectrophotometer for ED-101 & 102 and CD-101 are shown on Fig.6. In the present work two types of whiteness (CIE and Ganz Whiteness) are evaluated for product samples.

$$\text{CIE Whiteness}[7] :- W = Y + 800(xn - x) + 1700(yn - y),$$

$$\text{Ganz Whiteness}[8] :- W = Y + 1869.3(xn - x) + 3695.2(yn - y)$$

The comparison of the CIE whiteness and the Ganz whiteness obtained for the 3 samples is shown in Fig 7.

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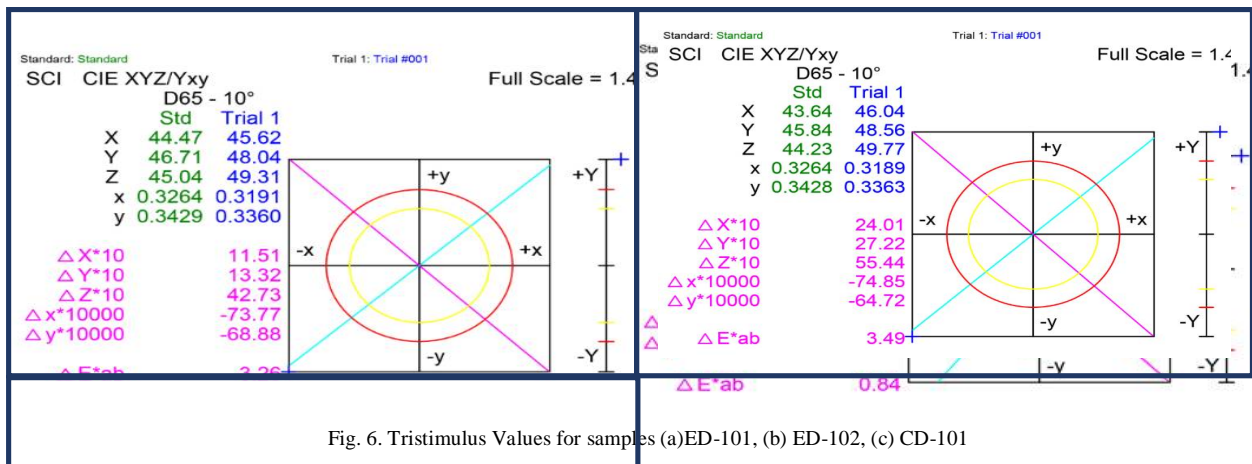


Fig. 6. Tristimulus Values for samples (a) ED-101, (b) ED-102, (c) CD-101

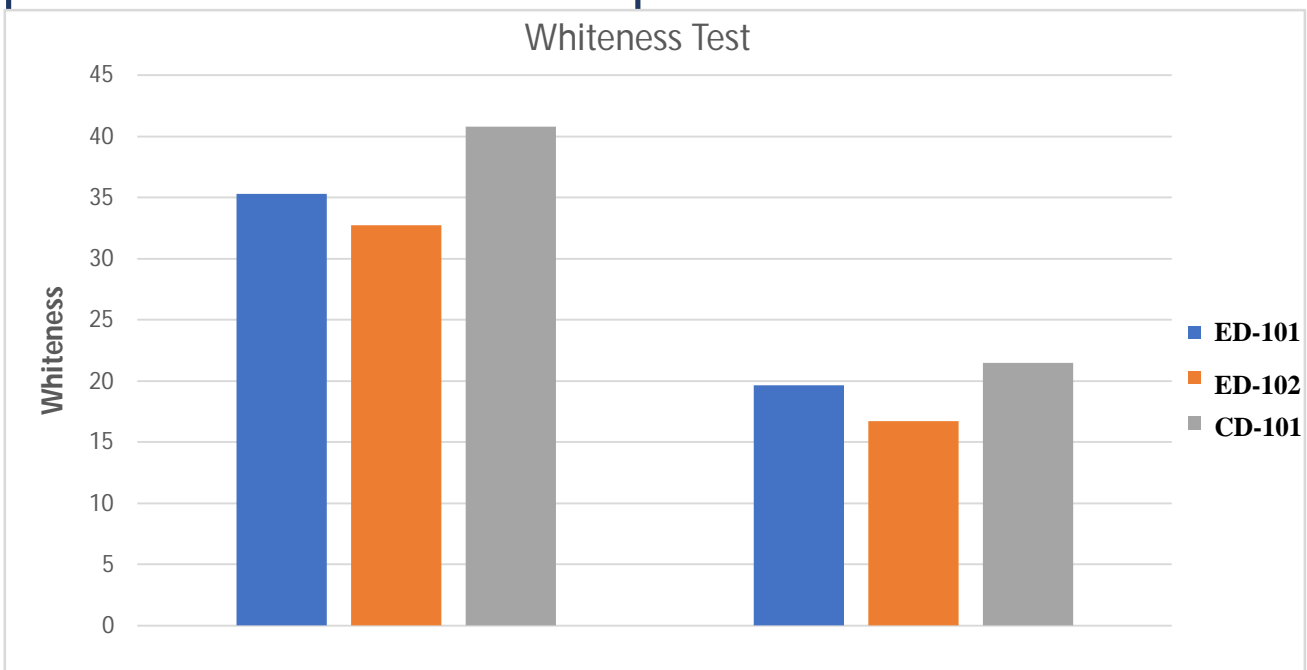


Fig. 7. Comparison of CIE Whiteness & Ganz Whiteness for Different Product Samples

3.2 Percentage Reflectance Test

The percentage reflectance of the illuminated visible light is studied at different wavelengths of visible light range (400nm-700nm). The main principle of the test is that when light is incident on the sample some of it gets reflected, some gets absorbed and some transmitted. The spectrophotometer studies the variation of light reflected in percentage with wavelength. The spectrophotometric curves were obtained on a X-Rite Ci4200 spectrophotometer which was illuminated with D65 illumination. Fig.6 shows the spectrophotometric curves for three samples ED-101, ED-102, CD-101.

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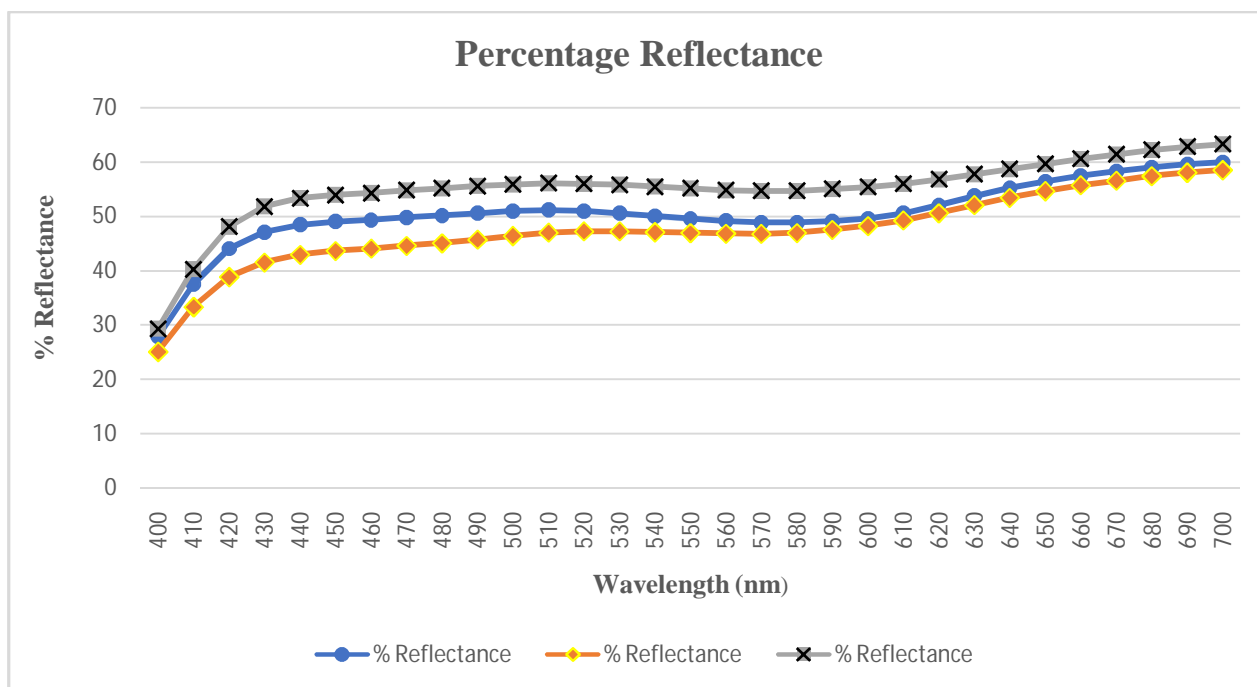


Fig. 8. Percentage reflectance curve for samples ED-101, ED-102, CD-101

3.3 Brightness Test

ISO brightness (R_{457}) is measured with a reflectometer having the characteristics described in ISO 2469 is equipped with a filter or corresponding function having an effective wavelength of 457 nm and a width at half height of 44 nm, and adjusted so that the UV-content of the illumination incident upon the test piece corresponds to that of the CIE illuminant C [9]. The diffuse blue reflectance factor (ISO brightness) is calculated from reflectance factor data according to a special set of weighting factors, $F(\lambda_i)$ [10]. The calculated brightness is usually designated as R_{457} .

$$R_{457} = \frac{\sum_i R(\lambda_i)F(\lambda_i)}{\sum_i F(\lambda_i)}$$

Wavelength		ED-101		ED-102		CD-101	
λ (nm)	$F(\lambda_i)$ $\Delta\lambda=10\text{nm}$	$R(\lambda_i)$	$R(\lambda_i)\times F(\lambda_i)$	$R(\lambda_i)$	$R(\lambda_i)\times F(\lambda_i)$	$R(\lambda_i)$	$R(\lambda_i)\times F(\lambda_i)$
380	0	0	0	0	0	0	0
390	0	0	0	0	0	0	0
400	1	0.2778	0.2778	0.2501	0.2501	0.2926	0.2926
410	6.7	0.3744	2.50848	0.3328	2.22976	0.402	2.6934
420	18.2	0.4403	8.01346	0.3881	7.06342	0.4809	8.75238
430	34.5	0.4707	16.23915	0.415	14.3175	0.5177	17.86065
440	57.6	0.4845	27.9072	0.429	24.7104	0.5331	30.70656
450	82.5	0.4902	40.4415	0.4361	35.97825	0.5392	44.484
460	100	0.4934	49.34	0.4403	44.03	0.5426	54.26

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470	88.7	0.4977	44.14599	0.4456	39.52472	0.5478	48.58986
480	53.1	0.5014	26.62434	0.4506	23.92686	0.5516	29.28996
490	20.3	0.5056	10.26368	0.457	9.2771	0.5556	11.27868
500	5.6	0.5094	2.85264	0.4638	2.59728	0.5581	3.12536
510	0.3	0.5117	0.15351	0.4698	0.14094	0.5608	0.16824
520	0	0.5099	0	0.4724	0	0.5598	0
	$\sum F(\lambda_i)=468.5$		$\sum R_x F(\lambda_i)=228.76$		$\sum R_x F(\lambda_i)=204.04$		$\sum R_x F(\lambda_i)=251.50$

Table. 1. Reflectance factor data for samples ED-101, ED-102, CD-101

Sample no.	R_{457}	% ISO Brightness
ED-101	0.488298	48.298%
ED-102	0.435531	43.5531%
CD-101	0.536823	53.6823%

Table. 2. % ISO Brightness for the product samples

IV. CONCLUSION

The present work addresses to the deinking of printed office paper waste & newspaper waste. Two different techniques, chemical treatment & enzymatic processes have been employed. The novel feature of present work is use of wheat grass extract that contains various enzymes such as amylase, esterase and lipase etc in place of cellulase and hemi-cellulase used in conventional methods. Three hand sheet samples ED-101 & 102 & CD-101 are prepared by blending deinked pulp with fresh filter paper pulp. The reflectance, brightness and whiteness are determined and comparison is carried out. The brightness test result indicated that the brightness of the treated sample CD-101 is 58.68% ISO where for ED-101 & 102 these values are 48.298% and 43.55% respectively. Similarly the whiteness value for sample CD-101 and ED-101 & 102 are compared by graphs. Both these values are acceptable and the treatment method proved successful in removal of ink from paper.

Present work has demonstrated successful use of wheat grass extract in enzymatic deinking for the removal of ink. More experimental run need to be conducted followed by suitable characterisation methods to substantiate this claim further.

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