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Ecological utilization of printed waste paper

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The use of printed wastepaper as a source of secondary fiber material for the production of paper and cardboard is related to the process of de-inking through flotation.

The ink removal from waste paper through flotation treatment with enzymes while the pH is neutral leads to modification of the cellulose fibers. The process is fully environmentally friendly.

Restoring the sheet-formation properties of secondary fibers as a result of bio-modification with enzymes helps to increase the number of cycles of waste paper usage and improves some of the characteristics of recycled paper.

The present study is a research on the removal of ink from paper with offset printing through flotation by the usage of the enzymes cellulase and lipase.

Key words: *de-inking, enzymes, printed waste paper*

INTRODUCTION

The use of recycled fiber material for the production of paper and cardboard has a significant role for solving the problems of environmental protection and contributes to energy savings by decreasing the energy consumption.

One of the most important processes used in the recycling of printed waste paper is de-inking, i.e. the removal of ink from the used paper in order to get a whiter recycled fiber pulp. The process includes removing the ink particles from the surface of the fibers and separating them from the fiber suspension through washing or flotation. [1]

A useful method for removing the ink from the waste paper through flotation is the treatment with enzymes while the pH is neutral. When recycling waste paper, enzymes are used to enhance the disintegration of fibers and improve the process of draining, to remove the ink from paper used for Xerox copies and laser printing, as well as to prevent the formation of sticky substances. [2]

Enzymes are complex protein molecules which act as catalysts. The activity of enzymes is essential to the process and is closely related to the chemical and physical environment (temperature, pH), the type and concentration of the substrate. [3]

Offset printing is superficial. The printed and non-printed elements are on the same surface. The printed elements are covered with ink, while the rest are moistened.

Removing the ink with enzymes aims at reaching a balance between the strength of fibers, the strength of interfiber connections and the loss of output, which have to be reduced to a minimum. [4]

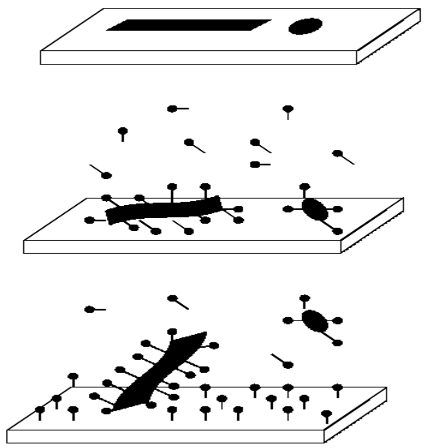

Fig. 1. De-inking in the presence of surfactants

The improved regeneration of the sheet-formation properties of secondary fibers as a result of enzyme treatment is capable of increasing the number of cycles of waste paper usage, as well as improving some characteristics of the paper made from secondary fibres. [2]

The aim of the present study is to investigate the process of removing the ink from waste paper with offset printing through flotation by the use of cellulase and lipase enzymes in combination with surfactants.

The surfactants have the following functions during the process of de-inking through flotation:

- They remove the ink particles from the surface of the fibers and prevent them from settling again on the fibers during the process of de

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- -inking; They agglomerate the small ink particles into large ones and change the surface of the particles from hydrophilic into hydrophobic;
- They act as foaming agents accumulating froth on the surface of the flotation cell and enhancing the de-inking process [5].

The purpose of this study is to review and analyze the established possibilities for obtaining and application the biocomposites based on keratin/ polyurethane in the medicine and other areas as compared to those based on collagen/ polyurethane.

EXPERIMENTAL

Materials and Reagents

The waste paper with offset printing used in the present research has a grammage of 80 g/m^2. The enzymes flotation is carried out with the following surfactants: BRIJ 35, Sigma Aldrich and the enzymes Cellulase (C) and Lipase(L).

Apparatus

Laboratory hydropulper. An amount of 500 grams of waste paper weighted prior to the experiment is torn into small pieces and is soaked into water for an hour. The soaked pulp undergoes the process of disintegration of the fibers inside the hydropulper.

The laboratory hydropulper has a cylindrical shape and a vertically installed propeller. The apparatus has a volume of 100, l and functions when the concentration of the mass is 2%. The apparatus is working for 2 hours. The produced suspension is drained with a sieve, additionally squeezed to a state of dryness of 20-30% and the secondary fiber pulp is stored in a refrigerator.

Laboratory disintegrator. 20grams of oven dry fiber pulp are taken from the hydropulper and put inside a disintegrator for 10 minutes. Depending on the type of examined pulp samples after the initial time, the necessary reagents are added in a sequence. The fiber suspension is further disintegrated - the process is prolonged by 10 minutes with each one of the reagents. The disintegrator has a working volume of 4 l and a maximum concentration of 2%.

Laboratory froth flotation cell. The suspension of fiber pulp taken out of the disintegrator is then placed into a froth flotation cell (Photo.1). The air is switched on, as well as the stirring paddle. Some flotation froth is formed on the surface which is removed. The process of flotation continues for a certain period of time and the ink-free fiber pulp is stored in a container.

The froth flotation cell consists of a flotation chamber connected to a pipe for air supply and a stirring paddle. The stirring paddle is responsible for turning the fiber pulp into a homogeneous mixture. The even-dispersion of air in the fiber pulp is a condition of utmost importance because it makes it possible for all the ink particles to reach the air bubbles.

Photo 1.

The turbulence inside the froth flotation cell has to be controlled in a way that not a single zone remains stagnant, which would lead to a flotation of fibers and leaving of dirt on the walls of the cell. On the other hand, the turbulence should not be too strong because the fiber pulp can be mixed with the froth on the surface.

Laboratory sheet-moulding apparatus (apparatus Rapid- Keten). The ink-free fiber suspension is divided into a number of moulds which are made up with the help of a laboratory sheet-moulding apparatus Rapid-Keten.

The sheet-moulding apparatus consists of a moulding and a drying sector. The moulding part includes a cylindrical chamber, a sieve and a suction device. The wet pulp settles on the sieve, and then it is drained with the suction device which removes and collects the water. The drying sector consists of two nests for drying.

Laboratory apparatus for establishing the degree of brightness Frank Spectrophotometer Brightness Colour. Brightness is the property of paper to reflect light in a dispersed and homogenous way along the whole range of the visible spectrum.

Brightness is measured as a % of reflected light with a defined wavelength in the blue segment

Table 1. Content of pulp suspension samples.

Name of samples	*Waste paper g/m²*	*Surfactants, %*	*Cellulase, %*	*Lipase, %*
Zero sample	80	-----	-----	-----
Waste paper + Surfatants	80	0,3	-----	-----
Waste paper +Surfatants +0,1 Cellulase	80	0,3	0,1	-----
Waste paper +Surfatants +0,3 Cellulase	80	0,3	0,3	-----
Waste paper +Surfatants +0,1 Lipase	80	0,3	-----	0,1
Waste paper +Surfatants +0,3 Lipase	80	0,3	-----	0,3
Waste paper +Surfatants+0,1Cellulase +0,1Lipase	80	0,3	0,1	0,1

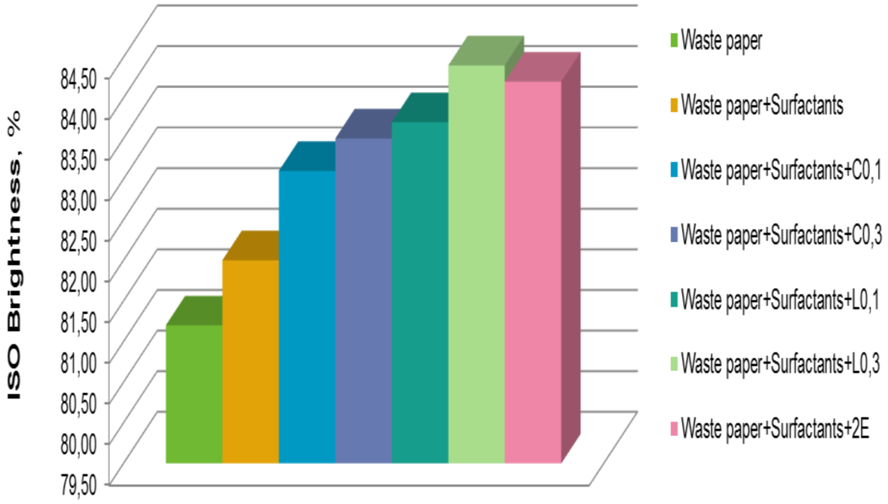

Fig. 2. Brightness of the samples defined according to ISO Brightness.

(457nm) and is termed as Brightness R_{457} (ISO 2470:2002). [6]

RESULTS AND DISCUSSIONS

The waste paper with offset printing undergoes the process of disintegration of fibers, followed by further disintegration with the help of enzymes in combination with surfactants and finally, flotation to separate the cellulose pulp. The following paper samples have been tested, cf. Table 1.

Testing the degree of Brightness of the paper samples. The degree of brightness of the samples is presented in Figure 2.

The results show that the degree of brightness is increased in all samples of de-inked paper. However, it is highest in the samples obtained after flotation with surfactants in combination with lipase enzyme.

De-inking capacity. It is estimated on the basis of a comparison of results after measuring the degree of brightness of the waste paper before de-inking (Zero sample) and the de-inked samples. The following formula is used:

De-inking capacity = {(de-inked sample –zero sample)/zero sample}x 100, [%]

Figure 3 shows the de-inking capacity of enzymes and their possible combinations in percentages. [7]

The greatest de-inking capacity is measured in samples produced after flotation with surfactants in

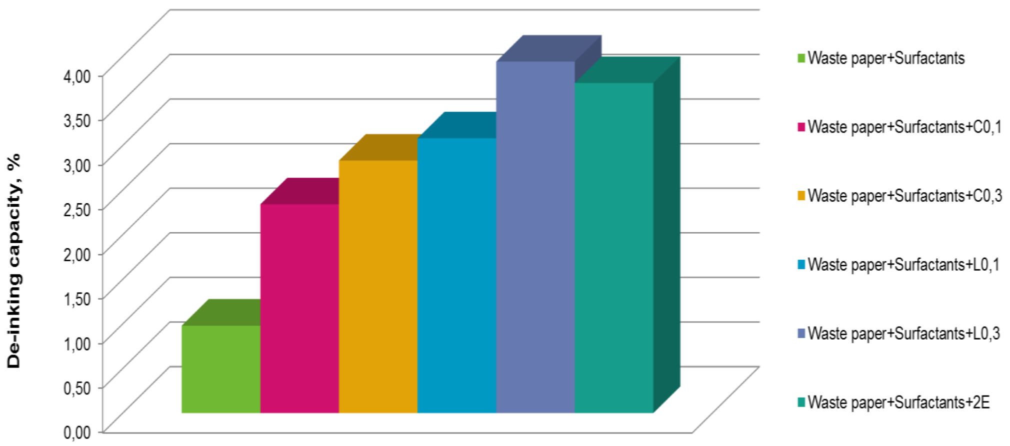

Fig. 3. De-inking capacity

combination with lipase enzyme. The other samples also show an increased de-inking capacity, which leads to the conclusion that both enzymes have a positive effect in the process of de-inking.

Breaking length (L),[m]. This is the length at which a strip of the tested paper with a width of 15mm, suspended at one end, would be torn by the force of its own weight. It is calculated by the formula of Hartig:

$$L=(F.l.100)/d,$$

where:

F – force of tearing in [N], measured by the dynamometer;

l – length of the strip in [m], defined by the distance between the two ends of the dynamometer;

d – weight of the strip in [g], measured after it has been torn from the hooks. [7]

Figure 4 shows the breaking length in [m] of the samples.

A slight increase in the breaking length of the samples is observed, with the exception of those samples obtained after flotation with surfactants in combination with lipase enzyme. The samples obtained after treatment with surfactants in combination with cellulase enzyme have the highest breaking length.

CONCLUSION

Waste paper is a competitive material for the paper industry. During the process of recycling, removing the printed ink from the paper suspension can be a problem. De-inking is a hard task because the different kinds of ink have different ingredients. Therefore, it is necessary to find the most effective and ecological method of removing the ink from the paper.

Restoring the sheet-formation properties of secondary fibers as a result of bio-modification with enzymes helps to increase the number of cycles of waste paper usage and improves some of the properties of recycled paper.

The parameters of enzyme de-inking of printed waste paper have been defined. In the process of flotation the enzymes cellulase and lipase increase the degree of brightness, the de-inking capacity and the physico-mechanical property - breaking length. Adding these enzymes, the de-inking of waste paper is improved.

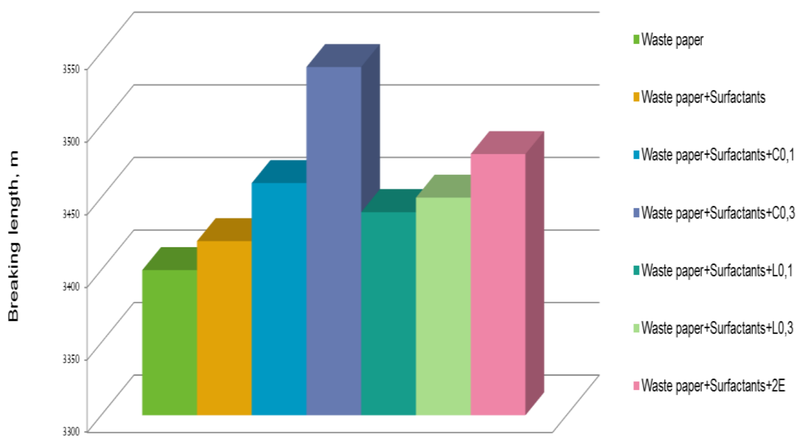

Fig.4. Breaking length of the samples.

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ЕКОЛОГИЧНО ОПОЛЗОТВОРЯВАНЕ НА ОТПАДЪЧНА ХАРТИЯ С ПЕЧАТ

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(Резюме)

Използването на отпадъчната хартия с печат като източник на вторичен влакнест материал за производство на хартии и картони е свързано с нейното обезмастиляване чрез флотация. Перспективно и екологично е обезмастиляването на отпадъчната хартия по метода на флотация с ензимно третиране при неутрално pH, което води до модификация на целулозните влакна.

В настоящата разработка се изследва влиянието на 2 ензима – целулаза и липаза, както и комбинация от тях, в процеса на флотация.

Регенерацията на гъвкавостта на влакната започва в първия етап на развлакняване на отпадъчната хартия при концентрация 4%. За поведението и характеристиката на получения влакнест материал се съди по кинетиката на отводняване, определенна на апарата Шопер-Риглер.

Ензимната флотация се провежда във флотационна клетка, осигуряваща определени хидродинамични условия на смесване на хартиената суспензия с ензимите и с ПАВ и отделяне на мастилените частици.

За охарактеризиране на физико-механичничните показателите са получени хартиени образци на апарат Rapid-Keten. Определено е съпротивлението на скъсване при опън, съпротивлението на раздиране, съпротивлението на огъване, съпротивлението на спукване. Определена е степента на белота на биомодифицирания обезмастилен рециклиран влакнест материал .

Възстановяването на листообразуващите свойства на вторичните влакна в резултат на биомодификацията с ензими способства за увеличаване броя на циклите за използване на отпадъчната хартия и за подобряване на някои показатели на хартията, получена от рециклирани влакна.