# MODIFIED DEINKING OF DIGITALLY PRINTED PAPER WITH WATER BASED INKJET INK

DOGAN TUTAK

*Marmara University, School of Applied Sciences, Printing Technologies, 34722 Istanbul, Turkey*
✉ *Corresponding author: D.Tutak, dtutak@marmara.edu.tr*

*Received*July 27, 2015

One of the most difficult recycling tasks is deinking of digitally printed paper with water based inkjet inks. The deinking of such paper is very important for the improvement of the digital printing industry. Generally, the manufacturers' preferred method is INGEDE Method 11p, which defines the universal deinking process. Based on this method, two different deinking procedures were assessed. The first was based on the standard procedure and standard chemicals of INGEDE method 11p, while the second followed the standard procedure of INGEDE method 11p, but with modified chemicals, applying soy-based oleic acid from soy oil. Using these deinking procedures, deinked papers with better optical properties were achieved. In addition to this, the second modified deinking procedure was also applied involving a different kind of bleaching agent, commercial bleach Oxi-Clean, which contains sodium percarbonate and sodium carbonate.

***Keywords***: inkjet, INGEDE, deinking, soy oleic acid

## INTRODUCTION

For solving the problems related to insufficient raw materials, sustainable recycling technologies should be developed in addition to the focus on sustainable forestry practices. In this sense, extracting useful components from waste paper by economical and environmentally friendly methods is extremely important.[1] With the development of digital printing technologies, they have gained a growing share of the market.[2] Compared with other traditional printing methods, digital printing is easy to control and convenient.[3]

Paper recycling is directly connected with the printing industry. A generally preferred method for removing detached particles from the pulp is flotation, but this technique is only effective for particles with diameter ranges from 20 to 150 microns.[4] The toner particle size of Liquid Electrophotography (LEP) digital presses that use an LEP ink is very small, of 1-2 microns, which is smaller than for dry toners.[5] Also, non-impact inks are very difficult to remove using conventional deinking methods. These inks are usually water-based with a hydrophilic character, which makes them very difficult to remove from the pulp slurry.[6,7]

The major challenge of paper recycling is to remove ink from the fiber. Water-based flexography and inkjet prints are two typical inks that are hard to remove *via* flotation deinking.[8] For an effective deinking, it is very important to prevent the redeposition of ink particles onto the fibers prior to removal.[9] This ink removal process can be summarized by two main stages. Initially, the interaction of ink particles with air bubbles occurs. This event is generally believed to be governed by the size and the hydrophobicity of both ink and bubbles.[10] Secondly, the bubble/ink heterostructures flow in the froth, where the efficient upward flow of ink particles is closely correlated to the stability of the froth phase and the adhesion energy of ink particles to air bubles.[11]

Deinking agents often include fatty acids, non-ionic surfactants, or mixtures of both species, but these materials can be modified with different chemicals to achieve better results. The purpose of the present study is to achieve deinked paper with better optical properties.

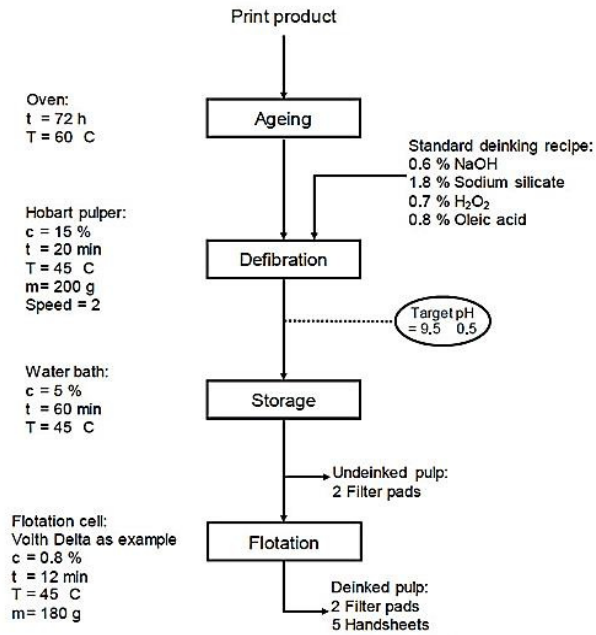


Figure 1: Flow chart of INGEDE method 11p[12]

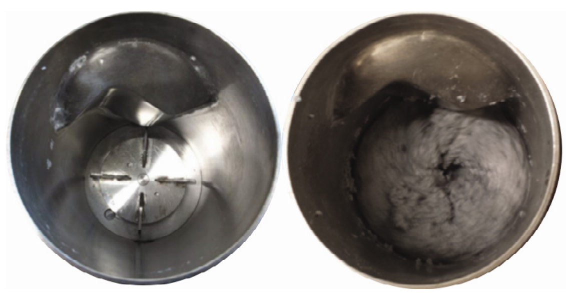

Figure 2: Micro-Maelstrom pulper

## EXPERIMENTAL

In this study, Epson semi matte photopaper was used, printed using an Epson 9800 Pro digital printing machine. Epson inkjet ink was used. This printed paper was recycled, by applying two different procedures and three different bleaching agents. The first procedure followed INGEDE method 11p (Fig. 1)and the second was a modified version of INGEDE method 11p. This method is explained below.

### Chemicals

In the first procedure, INGEDE method 11p (Fig. 1) was applied with standard chemicals. The second procedure was also based on a modified INGEDE method 11p involving oleic acid from soy oil, while the third experiment followed the modified INGEDE method, but applied a different bleaching agent, Oxi-Clean, a commercial bleaching agent.

All three experiments are described in detail below.

### Experiment 1:INGEDE method 11p with standard chemicals

All waste samples were torn into 2x2 $cm^2$ pieces, subjected to accelerated aging and then oven dried (OD) for 72 hours at 60°C according to INGEDE method 11p. After aging, the paper was weighed to 80g OD. A Micro-Maelstrom pulper (Fig. 2) was used for 20 min at 45 °C to create the pulp slurry. The pulping chemicals included: sodium hydroxide (0.6%), sodium silicate (1.8%), hydrogen peroxide (0.7%), and oleic acid (0.8%) for standard INGEDE method 11p. All the flotation processes were carried out using a 2-liter laboratory flotation cell. Each sample was floated for 12 minutes. Handsheets (1.2g OD) and filter pads (8g OD) were prepared according to TAPPI Standard 272. Five handsheets and two filter pads were prepared for each stage (deinked pulp (DP) and undeinked pulp (UP).

**Experiment 2: INGEDE method 11p with soy-based oleic acid from soy oil**

In this stage, the procedure was also based on INGEDE method 11p and carried out as described above, with the only difference that oleic acid was replaced by soy-based oleic acid from soy oil. The oleic acid was obtained from soy oil by the procedure described below.

**Preparation of sodium soaps from soy oil**

Sodium soap was prepared from pure soybean oil. For the saponification reaction, 5g ofZoye100% pure soy oil, 15 mL of 6M NaOH and15 mL of ETOH were used. The reaction was carried out under the following conditions: reaction time – approximately 20 min, saponification heating to 230°C, stirrer level 6, and solution temperature of 60°C. The clearing out of the solution signified that the saponification reaction was completed. After this, solid soap was prepared by the "salting-out" reaction and solid sodium soap was obtained from pure soybean oil. Part of the sodium soap was saved for further experiments, while the rest was further processed in order to obtain free fatty acids.[13]

**Preparation of fatty acids from sodium soy oil soaps**

The following step was to carry out fatty acid initial saponification and acid number reactions based on the procedure described in "Determination of the total crude fatty acids contents within alkalinesoaps".[12] First, sodium soap was dissolved in deionized water and was neutralized with 4N sulfuric acid until precipitated white mass stopped forming on the surface of the water. The oily phase consisted of diethyl ether and the respective fatty oil. At the end of this stage, oleic acid was obtained from pure soybean oil.

**Experiment 3: Commercial bleach Oxi-Clean**

All the waste paper samples were torn into 2x2 $cm^2$ pieces, subjected to accelerated aging and oven dried (OD) for 72 hours at 60°C, similarly to the steps followed in INGEDE method 11p. After aging, the paper was weighed to 80g OD. A Micro-Maelstrom pulper (Fig. 2) was used for 10 min at a temperature of 45 °C to create the pulp slurry (80g OD, 250 mL $H_2O$ (with $CaCl_2$)). Then, the pulp slurry was mixed for 10 min with 350 mL $H_2O$ (with $CaCl_2$) and 5g bleaching agent Oxi-Clean. For the defibration, the pulper speed was set to 500 RPM, the pH was maintained at 9.9, time of 20 min. After this time, the pulp and plastics were separated from each other with the help of a screen (Fig. 4). Then, 6000 mL $H_2O$ (with $CaCl_2$) was added and the pulp was allowed to stand for 45 min (pH = 9.2).Following this, handsheets and filter pads were made according to TAPPI Standard 272. Five handsheets and two filterpads were prepared for each stage (deinked pulp (DP) and undeinked pulp (UP).

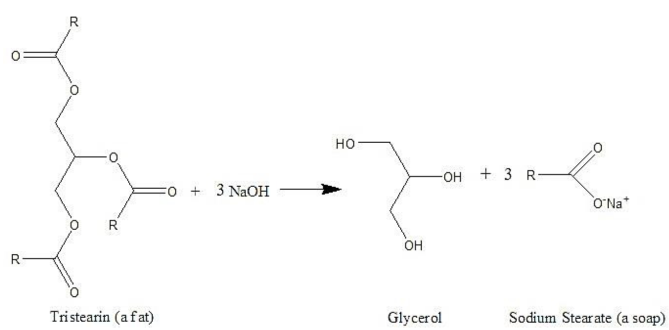


Figure 3: General saponification reaction of triglycerides resulting in sodium soap and glycerin


Figure 4: Screen for separation of pulp fibers and plastic coating

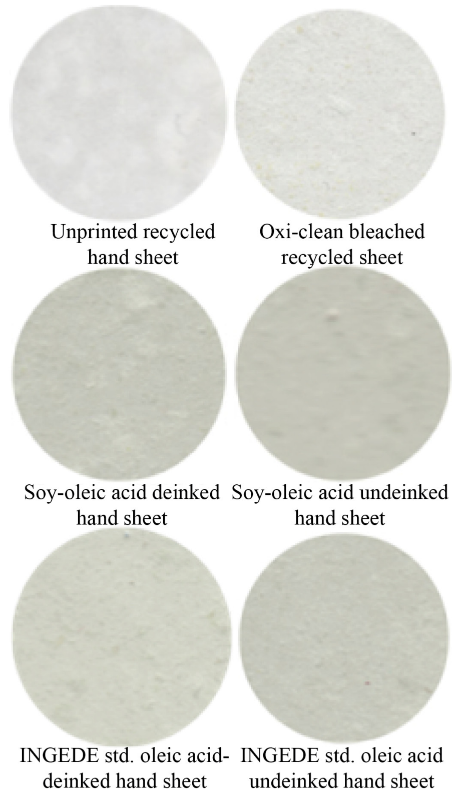


Figure 5: Surface images of undeinked and deinked handsheets

During all the laboratory experiments, only deionized water was used. Water hardness and water temperature were kept under controlled conditions during all recycling stages. The brightness of these samples was measured via a Technidyne BrightiMeter Micro S-5 (TAPPI Standard 458, C/2° light source, 457 nm). Luminosity (Y, 557 nm), CIE a* and b* were also determined with this instrument based on TAPPI standard 524 (45/0).

## RESULTS AND DISCUSSION

At the end of the experiments, the optical properties of the handsheets were measured on both sides for 10 times, then the results were averaged, and graphs were constructed. All the results obtained are described as follows.

Upon visual assessment of the handsheet surface images, it may be noted that the Oxi-Clean handsheet is the closest, with regard to its brightness, to the unprinted handsheet, compared to the rest of the handsheets (Fig. 5). Figure 6 illustrates a comparison of the brightness values of both handsheets and filter pads, undeinked and deinked by the procedure described in the experimental part, measured in accordance with TAPPI standard 458, at C/2° light source and 457nm. It should be remarked that, among all the samples, the brightness value of the Oxi-Clean sample is higher than those reached following INGEDE method 11p or modified INGEDE method 11p.

A comparison of the samples' luminosity (Y) values by C/2°and D65/2° light sources is shown in Figure 7. Measured under the specified conditions of C/2° and D65/2°, the luminosity Y value of the handsheets treated with the bleaching agent Oxi-Clean is higher than the luminosity of the handsheets treated using the standard or modified INGEDE protocol.

CIE a* values and CIE b* values for the undeinked and variously deinked handsheets and filter pads, measured according to TAPPI standard 524 (45/0), are shown in Figure 8 and Figure 9, respectively. As regards the CIE a* value of the samples, it may be concluded from the results obtained the value of the handsheet treated with Oxi-Clean bleaching agent is the lowest among all the sample groups. Similarly, the same handsheet exhibited the lowest CIE b* value, very close to that of unprinted recycled handsheets.

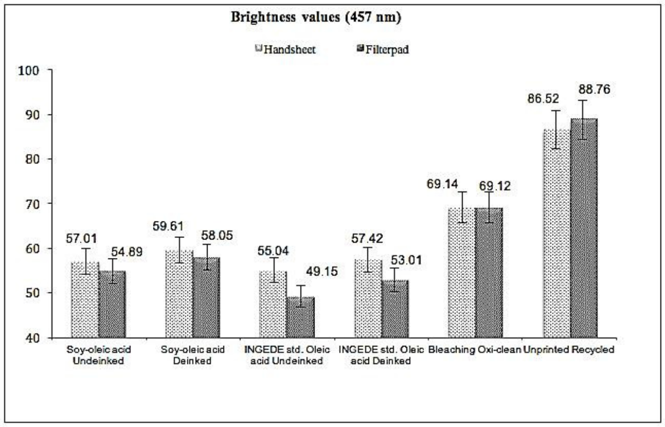


Figure 6: Brightness of undeinked and variously deinked handsheets and filter pads measured according to TAPPI Standard 458

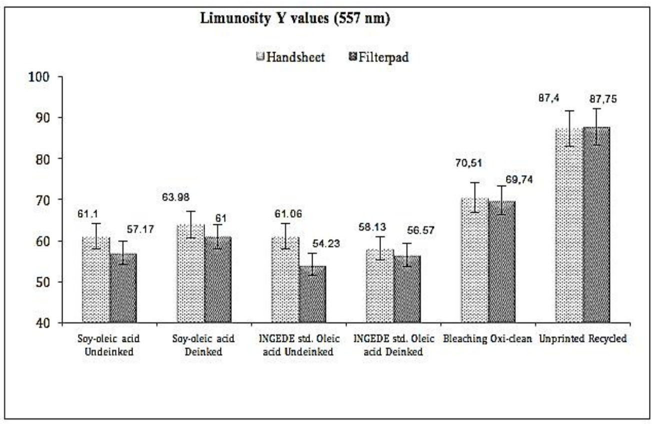


Figure 7: Luminosity Y values of undeinked and variously deinked handsheets and filter pads

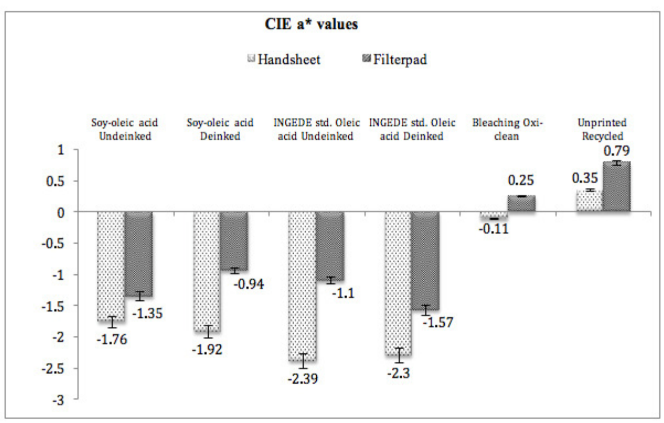


Figure 8: CIE a* values of undeinked and variously deinked handsheets and filter pads

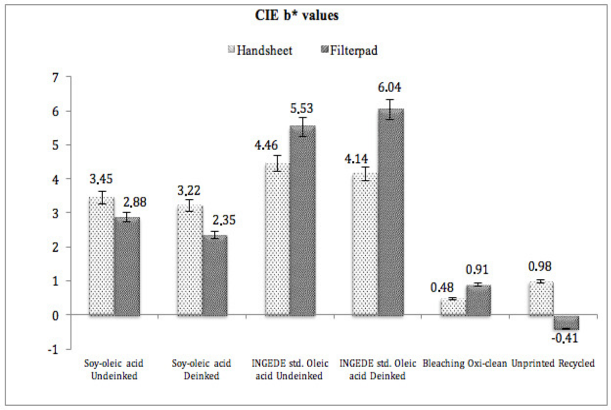


Figure 9: CIE b* values of undeinked and variously deinked handsheets and filter pads

## CONCLUSION

The present study compared different deinking procedures for deinking digitally printed paper with water based inkjet inks. From the results obtained, the following conclusions can be drawn:

- Visual assessment of the handsheet surface images revealed that the soy-oleic acid deinked handsheets looked better than the handsheets treated by INGEDE method with standard oleic acid. However, the Oxi-Clean bleached handsheets looked brighter than the rest of the samples subjected to the deinking methods under investigation, and comparable to the unprinted paper handsheet surface on a visual basis.
- Measuring brightness values confirmed that he Oxi-Clean bleached sample presented higher values than the samples deinked by the other procedures, and its brightness value was much closer to that of the unprinted recycled paper.
- The comparison of the luminosity Y values showed that the luminosity of the Oxi-Clean bleached recycled handsheet values was the closest to that of the unprinted recycled paperhandsheets among all the sample groups.
- The same trend was observed forthe CIE a* and CIE b* values, the Oxi-Clean bleached sample yielding the closest values of all deinked, recycled papers to that of the unprinted recycled paper.

In general, the handsheets deinked using the modified INGEDE method involving soy oleic acid exhibited better results than those obtained or the samples deinked by the conventional procedure with standard oleic acid. However, the Oxi-Clean bleached pulp without flotation yielded better optical properties than handsheets deinked by the other two procedures.

***ACKNOWLEDGEMENTS***: This work was carried out under the BIDEB grant offered by The Scientific and Technological Research Council of Turkey (TUBITAK). The author sincerely thanks TUBITAK, Marmara University and Western Michigan University for their support.

## REFERENCES

[1] A. Karademir, S. Karahan, S. Imamoglu, M. Ertas, A. Aygan *et al*., *J. His. Cult. Art Res*., **1**, 4(2012).
[2] INGEDE Press Release, Dig. Prin. Tech., A Nightmare for Paper Recycling, 2001.
[3] Z. Wei, Master's Thesis, Western Michigan University, USA, 2013.
[4] A. Fricker, A. Manning and R. Thompson, *Surface Coating. Int. B: Coat. Trans*., **89**, 146(2006).
[5] V. Husovska, P. D. Fleming, J. Pekarovic and J. Cameron, *Procs. Paper Con 2013*, Atlanta, USA, April 28-May 1,2013.
[6] N. Yilgor, J. Cameron, A. Velpumadugu and K. Kumar, *Procs. TAPPI Eng. Pulp Environ. Con*., Memphis, USA, October 11-14, 2009.
[7] D. Tutak, V. Husovska, A. Pekarovivova and P. D. Fleming, *Cellulose Chem. Technol*., **51**, 333 (2017).
[8] R. Gong, V. Husovska, P.D. Fleming, J. Pekarovic, J. Cameron*et al*., *Procs. TAGA-64 Conference*, Jacksonville, USA, March 18-21, 2012.
[9] A. Fricker, R. Thompson and A. Manning, *Pigment Resin Technol*., **36**, 141 (2007).
[10] D. Beneventi, B. Carre, T. Hannuksela and S. Rosencrance,http://www.tappi.org/content/events/07recycle/papers/beneventi.pdf, accessed on 10/11/2015.
[11] S. Schwarz and S. Grano, *Colloid. Surfaces A*, **256**, 157(2005).
[12] INGEDE Method 11P, Assessment of print product recyclability-deinkability test,http://www.ingede. com/ingindxe/methods/meth-e.htmL,accessed on 9/11/2013.
[13] V. Husovska, PhD. Thesis, Western Michigan University, 2013, p. 4.