# A comparative study of different fillers on uncoated eucalyptus digital printing paper properties: A pilot scale approach

John J. Amaya, Klaus Doelle (Assistant Professor) and Shiuli Mahmud
Department of Paper and Bioprocess Engineering
SUNY College of Environmental Science and Forestry
1 Forestry Drive, Syracuse, NY 13210

## Abstract

The use of fillers in printing and writing papers has become a prerequisite for competing in a global market to reduce the cost of materials. Use of calcium carbonate (ranging from 18% to 30% ) as filler is a common practice in the paper industry but the choice of fillers for each type of papers vary widely according to its use. The market for uncoated digital printing paper is one that continues to introduce exciting growth projections and it is important to understand the effect that different types of calcium carbonates have on the paper properties made of 100% eucalyptus pulp. The current study is focused on selecting the most suitable market available calcium carbonate for the production of uncoated Eucalyptus digital printing paper , targeting a potential filler increase of 5% above the currently used filler content. We made hand sheetsusing 13 different varieties of widely used calcium carbonates [Nine samples of PCC (two rhombic and sevenscalenohedral, covering a wide particle size range from1.2 µm to 2.9 µm), and four samples of GCC (three anionic and one cationic, with a particle size range from0.7 µm to 1.5 µm)] available in the market followed by a 12" pilot plant paper machine run. It was attempted to adjust thedesired calcium carbonate filler content in hand-sheets to 10%, 20% and 40% levels. The detailed analysis on the main structural, optical and strength properties of the hand sheets found that the most suitable calcium carbonate for uncoated Eucalyptus digital printing paper production is scalenohedral PCC, with a particle size of 1.9 µm for its positive effects on thickness, stiffness, brightness and opacity of paper.

## Introduction

The market for uncoated digital printing paper is one that continues to introduce exciting growth projections. Thus, optimizing the production cost in the manufacturing of Digital Paper is vital for any manufacturer to stay competitive in the global market. The price of uncoated digital paper is determined as a function of its market as a whole, indicating that the only way to be competitive is having a low cost product. Addition of fillers either at the wet-end or surface application in the production of traditional printing/writing paper grades is an attractive option to the paper industry for cost and energy savings and is a very common practice **1**. Calcium carbonate (CaCO3) has been intensively used for the last three decades as a substitute for part of the virgin fibers used in papermaking, and has become the dominant filler in the production of uncoated digital printing paper **2**. It improves many paper properties, like – opacity, brightness, sheet formation, dimensional stability, printability, writability, etc **3** and helps to increase furnish drainage rate, machine speed, productivity, etc **(4,5,6)**. However, increasing the level of filler beyond certain limits can reduce paper strength, increase the need for sizing agents, and produce dusting problems **(5).** The filler content limit is mainly related to the type of virgin fiber used, and ranges from 10% to 30%. It is possible to save about US$1.5 to US$4.0/ton for each 1% increase of calcium carbonate in the paper depending on the fiber cost **(7).** Thus, application of $CaCO_3$ fillers (usually 20%) to replace fibers in the uncoated digital printing papers for higher economic benefits, besides the benefits obtained in optical and printing properties, is an attractive option for the industry. Hence, identifying the best calcium carbonate for digital paper, considering all the properties needed for excellent performance, requires an extensive study of the impact of using different types of calcium carbonate on paper properties and an adequate comprehension of the most important variables involved. This forms the basis for the current study.

## Methodology

This study used a representative sample of bleached kraft eucalyptus pulp, obtained from a commercial pulp mill, refined in a Valley Beater following Tappi standard method (T 200 sp-06) to a final pulp freeness level of 320 CSF (measured using Tappi standard method, T 227 om-09) and a total of thirteen different types of commercial calcium carbonates collected from the largest worldwide suppliers were used in it (**Table 1).** In this study, it was attempted to adjust the desired calcium carbonate filler content in hand-sheets to three levels: 10%, 20% and 40%. A silica colloidal microparticle program was used to achieve the desired retention level. Cationic or anionic HMW polymeric flocculants were added, depending on the ability of these flocculants to perform good filler retention. The first pass filler retention target was 50%. Refined eucalyptus pulp was blended with cationic starch and mixed for 2 minutes. Calcium carbonate was added and mixed for 30 seconds at a 1.0% consistency. The stock was diluted in the handsheet machine to a consistency of 0.6%. Anionic or cationic PAM was added and mixed for an additional 15 seconds. Silica gel was added and mixed for 5 seconds prior to draining. Fifteen handsheets were made for every formula.**Table 2** details the chemical additives for every set of handsheets produced. Forty sets of 15 handsheets (75 g/m2) were made according to the Tappi standard method (T 205 sp-06). The Fist Pass Ash (Filler) Retention was calculated as the percentage of calcium carbonate retained in the handsheets relative to the total amount present in the stock, according to the Tappi standard method (T 211 0m-07).

### Table 1 Calcium carbonate data corresponding to thirteen different commercial samples

| | PCC | | | | | | | | | GCC | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rhombic | | Scalenohedral | | | | | | | Anionic | | | Cationic |
| Avg. particle size, µm | 1.2 | 2.2 | 1.4 | 1.6 | 1.8 | 1.9 | 2.3 | 2.7 | 2.9 | 0.7 | 0.8 | 1.4 | 1.5 |
| Specific BET, m²/g | 7.9 | 4.0 | 10.6 | 12.0 | 7.7 | 5.3 | 6.2 | 5.0 | 4.6 | 11.5 | 8.0 | 7.0 | 6.7 |
| Brightness Tappi, % | 96.8 | 97.1 | 98.3 | 98.1 | 98.1 | 97.8 | 98.2 | 98.0 | 98.2 | 96.5 | 96.0 | 97.2 | 96.7 |

### Table 2 Aid retention program used according to each type of calcium carbonate and filler level

| | All PCC samples + Cationic GCC sample | | | Anionic GCC Samples | | |
|---|---|---|---|---|---|---|
| | Filler Level 1 | Filler Level 2 | Filler Level 3 | Filler Level 1 | Filler Level 2 | Filler Level 3 |
| Cationic Starch | 6 | 6 | 6 | 6 | 6 | 6 |
| Anionic PAM | 0.20 | 0.25 | 0.40 | - | - | - |
| Cationic PAM | - | - | - | 0.65 | 1.00 | 1.00 |
| Silica gel | 2 | 3 | 3.8 | 4.5 | 4.5 | 5.5 |

## Result

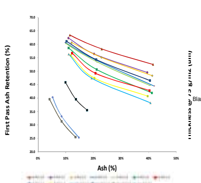

Figure 1 Effect of Calcium carbonate particle size, morphology and ionic charge demand on filler retention.

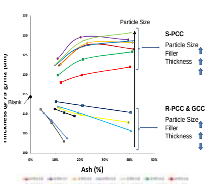

Figure 2: Impact of calcium carbonate filler loading on the structural properties -*thickness*- of handsheets from bleached eucalyptus pulp.

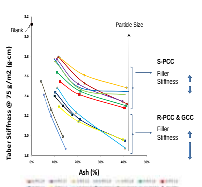

Figure 3: Impact of calcium carbonate filler loading on the structural properties -*Taber stiffness*- of handsheets from bleached eucalyptus pulp.

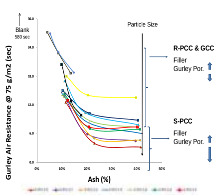

Figure 4 Impact of calcium carbonate filler loading on the structural properties -*Gurley air resistance*- of handsheets from bleached eucalyptus pulp.

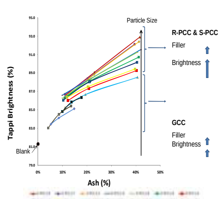

Figure 5: Impact of calcium carbonate filler loading on the optical properties -*brightness*- of hand-sheets from bleached eucalyptus pulp.

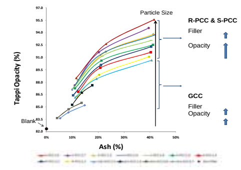

Figure 6: Impact of calcium carbonate filler loading on the optical properties -*opacity*- of hand-sheets from bleached eucalyptus pulp.

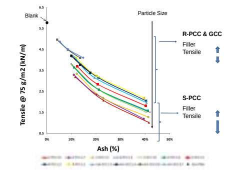

Figure 7: Impact of calcium carbonate filler loading on the strength properties -*tensile*- of hand-sheets from bleached eucalyptus pulp.

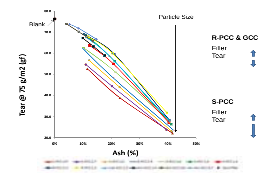

Figure 8: Impact of calcium carbonate filler loading on the strength properties -*tear*- of handsheets from bleached eucalyptus pulp.

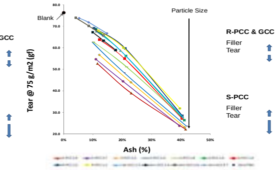

Figure 9: Relationship between thickness and tensile for handsheets made from bleached eucalyptus pulp and loaded with a wide range of calcium carbonate types.

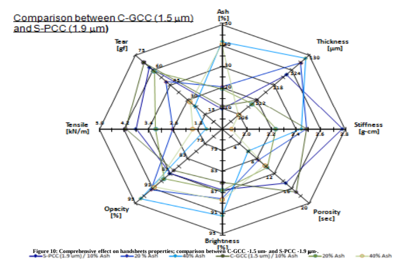

Figure 10: Comprehensive effect on handsheets properties; comparison between C-GCC -1.5 µm- and S-PCC -1.9 µm-

**Table 4-1: Comparison of the effect of calcium carbonate filler loading on paper properties (handsheets study).**

| (+ = Improved) | PCC | | | | | | | | | GCC | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rhombic | | Scalenohedral | | | | | | | Anionic | | | Cationic |
| Avg. Particle Size, µm | 1.2 | 2.2 | 1.4 | 1.6 | 1.8 | 1.9 | 2.3 | 2.7 | 2.9 | 0.7 | 0.8 | 1.4 | 1.5 |
| Thickness | -1 | -1 | +1 | +1 | +3 | +3 | +2 | +2 | +2 | -3 | -3 | -1 | -1 |
| Taber Stiffness | -3 | -3 | -2 | -2 | -1 | -1 | -1 | -1 | -1 | -4 | -4 | -3 | -3 |
| Air Resistance | -1 | -2 | -3 | -3 | -3 | -3 | -4 | -4 | -4 | -1 | -1 | -2 | -2 |
| Brightness | +2 | +2 | +2 | +2 | +3 | +3 | +3 | +3 | +3 | +1 | +1 | +2 | +2 |
| Opacity | +2 | +2 | +3 | +3 | +3 | +3 | +4 | +4 | +4 | +1 | +1 | +2 | +2 |
| Tensile | -2 | -2 | -2 | -3 | -3 | -3 | -4 | -4 | -4 | -1 | -1 | -2 | -2 |
| Tear | -1 | -1 | -1 | -1 | -2 | -2 | -2 | -2 | -2 | -1 | -1 | -1 | -1 |

## Conclusion

In this study three anionic GCC, one cationic GCC, two rhombohedral PCC and seven scalenohedral PCC types of calcium carbonate were analyzed. The characteristics of the calcium carbonate types, and their different influences on the uncoated digital printing paper properties were determined.

First pass filler retention was higher for all types of PCC and cationic GCC. To attach anionic GCC to fibers demands many more chemical additives than cationic GCC types demands. The higher the calcium carbonate particle size, the higher the filler retention. Scalenohedral shapes present higher retention levels, as compared with rhombohedral.

Thickness of the handsheets is affected differently when filler is added. When filler loading of rhombohedral shapes is increased, the thickness is decreased; however, for scalenohedral forms, thickness is increased at higher filler levels. In addition, the higher the particle size, the higher the thickness. For S-PCC with particle size higher than 2.3 µm, thickness is increased when filler loading is between 0% and ~ 30 %, and then begins to drop. S-PCC makes it possible to produce a bulky paper.

All calcium carbonate types have a negative effect on Taber stiffness. S-PCC with high particle size has the least negative impact, while rhombohedral shapes with low particle size have the highest negative effect.

Both PCC and GCC have a detrimental impact on air resistance. However, when comparing S-PCC and GCC with the same particle size of ~1.5 µm, the Gurley air resistance is about 3 sec higher for GCC. In general, the lower the particle size, the higher the air resistance.
It is possible to achieve a great improvement in brightness and opacity when the loading filler levels of calcium carbonate are increased. S-PCC allows for higher levels of brightness and opacity than GCC and R-PCC. The lower the particle size, the lower the improvement on optical properties.

Tensile strength and tear strength are always decreased when calcium carbonate filler loading is increased, for both PCC and GCC. The lower the particle size, the lower the negative impact on tensile and tear strengths. PCC and GCC with a similar particle size have a similar effect on tensile strength and tear strength.

After reviewing the changes on handsheet properties due to the increase of a calcium carbonate filler, the findings of this study indicate that when eucalyptus pulp is used, the optimum calcium carbonate for uncoated digital printing paper is S-PCC with a particle size of 1.9 mm.

## Reference

1.Shen, J., Song, Z., Qian, X. and Ni, Y."A Review on Use of Fillers in Cellulosic Paper for Functional Applications". *Industrial and Engineering Chemistry Research*, Vol. 50, No. 2, 2011.
2. Fairchild, G.H. "Increasing the Filler Content of PCC-filled Alkaline Papers." Tappi, 75(8), pp. 85-90. (1992).
3. Deng, Y., Zhao, Y., & Ono, H. " Improvement of Paper Properties Using Starch-Modified Precipitated Calcium Carbonate Filler". *TAPPI Journal & Solutions. Vol. 4(2)* , (2005).
4. Dong, C.; Song, D.; Patterson, T.; Ragauskas, A.; Deng, Y. "Energy Saving in Papermaking Through Filler Addition". *Industrial and Engineering Chemistry Research*, *47* (21). pp. 8430–8435, (2008).
5. Shen, J., Song, Z., Qian, X., Liu, W. and Yang, F. "Fillers and the carbon footprint of papermaking". BioResources 5 (4), pp. 2026-2028, (2010).
6. Hubbe, M. A.; Pawlak, J. J.; Koukoulas, A. A. "Paper's appearance: A review". *BioRes. 3*, pp. 627–665, (2008).
7. Zhao, Y., Hu, Z., Ragauskas, A., & Deng, Y." Improvement of paper properties using starch-modified precipitated calcium carbonate filler". *TAPPI Journal. Vol. 4(2)*, (2005). .