EFFECT OF WASTE EGGSHELL PARTICLES ADDITION ON THE OPTICAL PROPERTIES OF PAPER

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Abstract:

*For this study, eggshells were collected during household food processing, and their protein membrane was manually separated from each eggshell. Membrane-removed eggshell waste was subjected to washing, drying, grinding, and sieving processes. The size of the prepared eggshell powder was less than 45 μm and was used, as an alternative to industrially precipitated calcium carbonate, in the production of laboratory paper. Filter paper was used as the basis for the paper pulp, while the filler content was varied from 5 to 20%. To determine the effect of adding eggshell powder on the optical properties of the paper, papers with the same $CaCO_3$ content were produced in parallel as a control. It was observed that adding both types of fillers, eggshell powder and calcium carbonate, to laboratory-produced paper increases its reflectance. However, the impact on L*a*b* values of paper is different for these fillers. Calcium carbonate increases its lightness (L* value) more than eggshell powder, and reduce the a* and b* value unlike eggshell powder that increases them.*

Keywords: *eggshell waste, filler, optical properties, paper*

1. INTRODUCTION

Dominantly used fillers in papermaking industry are mineral ones divided in two main classes, natural and synthetic. Worldwide, commonly used fillers in papermaking are ground calcium carbonate (GCC), talc and clay as natural inorganic, particulate materials and precipitated calcium carbonate (PCC) and titanium dioxide as synthetic ones [1]. They have an important role in reducing cost in papermaking industry [2,3,4] as their usage can replace up to 40% of fibrous material in a paper pulp [5]. Beside the fact that their usage is leading to direct cost savings, they also improve various properties of the manufactured paper. Fillers normally help in paper dimensional stability, appearance, opacity, brightness (if the filler is brighter than the pulp), surface smoothness and gloss, improve the reduction in printing strike through and uniformity in printing ink receptivity on paper [6,7]. However, due to excessive use of fillers, the abrasive properties of mineral fillers are manifested in increased wear of the wire on the paper machine and the printing plates in the printing press. Excessive amounts of filler reduce the bonding in the paper, thereby increasing the tendency to dust [1]. An alternative to most used calcium carbonate can be waste biomaterials such as chicken eggshells or marine shellfish (marine molluscs, mussels, clams, oysters, scallops and cockles) as they contain high calcium carbonate content [8]. FT-IR analysis of eggshell waste indicated an almost identical chemical composition to precipitated calcium carbonate or PCC, a synthetic calcium carbonate product that is used in large quantities in paper production [9]. Namely, chemical composition of eggshells is calcium carbonate in the form of calcite ranging from 94–97% and 3–4.5% organic matter. While other elements such as MgO (0.83%), SO_3 (0.66%), P_2O_5 (0.43%), Al_2O_3 (0.15%), K_2O (0.08%), SiO_2 (0.07%), Cl_2O_3 (0.06%) and SrO (0.04%) have been detected in minor traces [8]. The composition of the eggshell may vary slightly depending on the feed the chickens are fed. [10]. The colour of the shell does not dictate the amount of calcium carbonate. Although the eggshell can be brown- or white-coloured, the colour does not affect the amount of calcium carbonate [8]. Eggshell is a globally available waste material, and in year 2020 chicken egg

production was reached up to 86.7 million tonnes [11]. This abundant and discarded by-product can serve as a potential replacement for calcium carbonate derived from sedimentary rocks. Reuse of all kinds of waste is a closely connected with the awareness of environmental pollution and a lack of certain materials. Therefore, it is of great importance to examine the possibilities of alternative raw materials usage for the paper industry. So far there were some studies about eggshell usage as a paper filler [12,13,14,15,16] and paper coating [17].

2. EXPERIMENTAL

Materials in this study were household waste eggshell, calcium carbonate precipitated, p.a. (Kemika d.d., Croatia) and round filter paper, blue ribbon (Whatman, Germany). As the filter paper made from high-purity cellulose fibres, specifically cotton linters, was used as a source of cellulose fibres in Table 1 some of its basic characteristics are given.

Table 1: Characteristics of filter paper

Filter paper	Weight (g/m^2)	Thickness (mm)	Ash Content (%)
Blue ribbon	85	0.15	≤ 0.01

2.1 Waste eggshell powder (ESP) preparation

Processes of preparing waste eggshell powder (ESP) included: separating protein membrane from eggshell, washing in tap water, drying in a Memmert drying oven at a temperature of 40 °C, grinding in an IKA laboratory grinder and sieving to the desired particle size of < 45 μm by Retsch AS 200 vibratory sieve shakers. In Figure 1 the final product, waste eggshell powder, gained from waste eggshell is presented.

Figure 1: Eggshell waste and waste eggshell powder (ESP)

2.2 Laboratory paper production

For laboratory paper production as a source of fibres ashless/blue ribbon filter paper was used (Whatman, Germany). 80 g of absolutely dry filter paper was disintegrated in tap water (T = 40°C; t = 20 min) to a consistency of 5% in an Enrico Toniolo disintegrator. During the homogenization process in the homogenizer Frank, PTI (t = 5 min), tap water was added so that a total of 10 L of pulp was prepared, which was divided into batches in which fillers (calcium carbonate precipitated, p.a. (Kemika d.d., Croatia) or prepared ESP) were added in a defined proportion given in Table 2.

Table 2: Samples of laboratory paper

Paper sample	w ($CaCO_3$), %	w (ESP), %
FP (control)	-	-
FP_5%$CaCO_3$	5	-
FP_10%$CaCO_3$	10	-
FP_15%$CaCO_3$	15	-
FP_20%$CaCO_3$	20	-
FP_5%ESP	-	5
FP_10%ESP	-	10
FP_15%ESP	-	15
FP_20%ESP	-	20

Laboratory papers of 150 mm diameter and defined composition were made on a Buchner funnel with a vacuum pump and were dried by laboratory sheet dryer Rapid Kothen.

2.3 Optical properties analysis

The colorimetric values (CIE L*a*b* system) and reflectance in a visible spectrum for all laboratory paper samples were measured by spectrophotometer X-Rite SpectroEye under a D50 illuminant and 2° standard observer. All presented results are mean value of 20 measurements.

3. RESULTS AND DISCUSSION

From Figure 2 it is evident it is visible how the addition of any type and amount of filler increases reflectance value of the laboratory paper throughout the visible part of the spectrum.

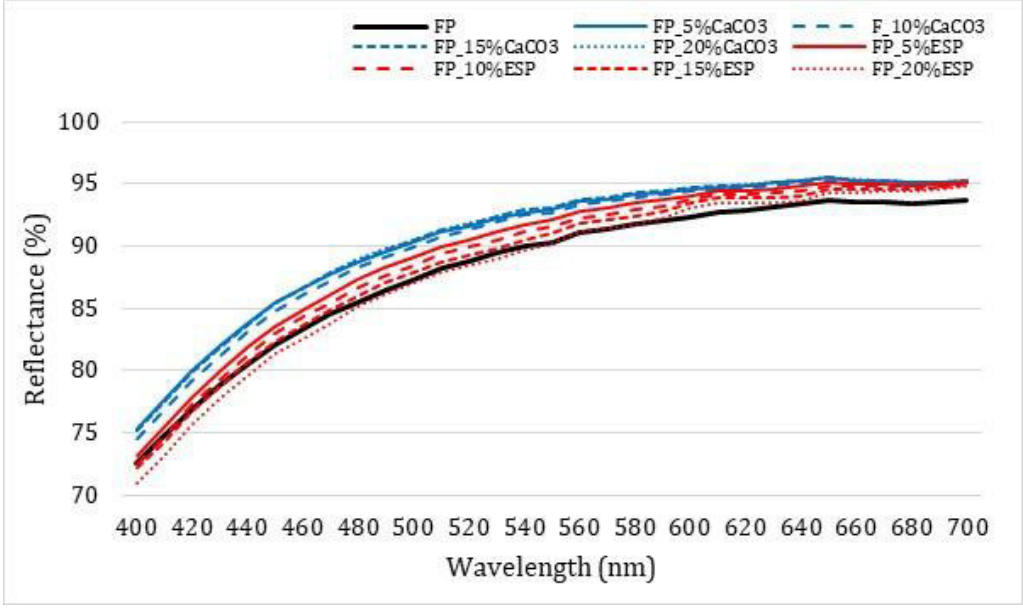

Figure 2: Reflectance of laboratory papers with addition of fillers

The optical properties of each paper are determined by the types of cellulose fibres and any added materials. Filter papers due to their application, are made from high-purity cellulose fibres (often bleached to achieve a white, pure colour and remove impurities) and is ashless (do not have fillers). By adding any type of filler ($CaCO_3$ or ESP) in paper pulp, the reflectance of the paper will be increased by increasing the scattering and reflection of light (Fig. 2). Namely, these fillers break the bonds between the fibres, creating more surfaces from which light is reflected [1].

Table 3: Colorimetric values of laboratory papers with addition of fillers

Paper sample	L^*	a^*	b^*
FP (control)	96.02 ± 0.14	0.19 ± 0.07	6.57 ± 0.26
FP_5%$CaCO_3$	97.08 ± 0.12	-0.10 ± 0.05	5.96 ± 0.21
FP_10%$CaCO_3$	97.02 ± 0.11	-0.13 ± 0.06	6.28 ± 0.30
FP_15%$CaCO_3$	97.14 ± 0.12	-0.20 ± 0.07	6.09 ± 0.29
FP_20%$CaCO_3$	97.17 ± 0.13	-0.21 ± 0.05	6.11 ± 0.24
FP_5%ESP	96.73 ± 0.12	0.02 ± 0.09	6.73 ± 0.29
FP_10%ESP	96.52 ± 0.15	0.15 ± 0.08	6.83 ± 0.20
FP_15%ESP	96.29 ± 0.18	0.30 ± 0.10	6.89 ± 0.22
FP_20%ESP	96.03 ± 0.18	0.45 ± 0.07	7.17 ± 0.10

Fillers such as calcium carbonate ($CaCO_3$) have high refractive indices and small particle sizes, which causes light to be reflected more within the paper structure, which also leads to greater perceived whiteness and brightness of paper. Since in this study, filter paper with R457 blue light whiteness of 80.01 was used as the basis for making laboratory paper, the addition of calcium carbonate and ESP did not significantly increase the CIE L* value of the laboratory papers (Tab. 3). Elementary colour component a* of laboratory paper is changed by filler addition. Namely, the presence of $CaCO_3$ reduces this value by shifting it to green area, while presence of ESP increases this value in red area. Adding filler to the paper does not have a significant effect on the b* colour component value, as it is approximately the same for all laboratory papers and is in the yellow range.

It should be emphasized that the effects of filler on the optical properties of paper in this study are not drastic, given that filter paper was used as the basis. But if recycled fibres had been used as the basis in the paper pulp, the addition of selected fillers would have had a much greater impact on the optical values. Since the basis of ESP is calcium carbonate, it is evident from this study that ESP can be a potential alternative to industrially precipitated calcium carbonate.

4. CONCLUSION

Reusing all types of waste is becoming an environmental imperative today. This research shows that eggshell powder, which is almost identical to the chemical composition of precipitated calcium carbonate, can improve the optical properties of papers when used as a filler. Of course, improvements of optical properties would be more significant if this filler would be added to a pulp of recycled fibres or unbleached fibres.

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