Abstract

Bio-CaCO₃ from Eggshell Waste as Raw Material for Eco-Ceramic Products †

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Nowadays, the scarcity of natural resources and the quantity of generated waste are problems that need to be tackled urgently. The interest in waste valorization has been increasing in the last years, not only due to the environmental impact, but also to economic benefits. The eggshell waste generated in Europe is around 150 kton/y and is usually landfilled. An eggshell’s structure comprises an organic membrane and 95 wt.% calcium carbonate (shell weight). Consequently, once separated from the membrane, the shell can be an alternative source of calcium carbonate (CaCO₃). Limestone (CaCO₃), a natural raw material, is used in the formulation of several materials, such as cement, ceramic wall tiles, stoneware, bricks, etc. In the ceramic materials, the formulations have between 10 and 15 wt.% of limestone. The global limestone market size was valued at approximately EUR 64 billion in 2019 and is expected to grow at a compound annual growth rate of 4.4% from 2020 to 2027. Therefore, eggshell waste can be valorized in ceramic products.

This work aims to study eggshell waste as a possible source of calcium carbonate and evaluate its economic impact. The eggshells and limestone were ball milled with a weight proportion of 1:4:4 (raw materials:balls:water), and different milling times were tested. X-ray fluorescence analyses showed that limestone and eggshell are mainly composed of calcium, 96.5 and 98.4 wt.%, respectively. X-ray diffractograms of eggshell and limestone are very similar, presenting only calcite as a crystalline phase. DTA/TG analyses showed that eggshell waste still presents organic matter due to the presence of an exothermic peak between 400 and 500 °C, accompanied by a small weight loss (≈5 wt.%). In DTA, there was an observed endothermic peak, between 700 and 850 °C, very similar to that of limestone, which corresponds to the calcium carbonate decomposition. In both cases, the weight loss stabilizes around 800 °C, with values of 48 wt.% and 44 wt.% for the eggshell and limestone, respectively. It was observed that a longer milling time is required for the eggshell waste to achieve a D50 of 4 µm (the reference value), 60 min vs. 10 min for limestone. So, a simplified economic analysis was done, and two scenarios were considered for ceramic wall tile compositions with 12 wt.% of calcium carbonate: (A) limestone as a CaCO₃ source and landfilling of the eggshell waste; (B) eggshell waste as CaCO₃ source and landfilling of the membrane (5 wt.% of the shell). The results showed that the ceramic paste with eggshell waste will only have an estimated additional electricity cost of ≈3 EUR/ton. Savings up to 28.8 EUR/ton of generated eggshell waste can be expected for the egg processing companies. To conclude, the eggshell is very similar to limestone and the economic analysis favours the use of this waste as a secondary raw material in ceramic products. Further, the consumption of raw materials and landfilled waste decrease contributes to a more sustainable production.
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