Development of bio-based cellular materials

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Within the context of sustainable development, one solution to overcome the issues related to the management of plastic waste, oil price fluctuations, and the gradual depletion of fossil resources, is to substitute bio-based polymers for traditional ones. However, the number of commercial bio-based polymers available at the industrial scale is quite limited, and among these products polylactic acid (PLA) is gaining great academic and industrial attention [1-2] as its mechanical properties are equivalent or superior to those of some petroleum-based polymers [3]. In this context, the present study is focused on the chemical foaming by extrusion of two commercial PLAs.

Two commercial grades linear PLA, different mainly by their melting temperature (151 °C and 170 °C respectively) were used. PLAs are mixed with two different chemical foaming and nucleating agents (CFA) (different by their initial decomposition temperature and by their gas yield) with variable content. Initially, for each PLA, the processing conditions (temperature profile, screw speed, die temperature, cooling system) will be optimized to achieve maximal void content. Then, the void content, the cellular structure (cell size and density, cell-wall thickness) as well as the foams mechanical properties under tension will be assessed. The effect of the material parameters on the cellular structure and the resulting properties will be analyzed.

The results obtained show that the die temperature of the extruder affects significantly the void content. Indeed, the void fraction of the extruded foamed reached a maximum (except to 20 rpm) value for an intermediate die temperature of 195 °C. The temperature profile (profile A and B: the temperature profile A is less high compared to the profile B) also has a notable effect on the apparent density of extruded alveolar materials. It increases with the temperature in the barrel of the extruder. Moreover, the void fraction increases gradually (the foam density decreases) with the CFA content, regardless the PLA type or temperature profile.

Most PLA-based foams obtained by using optimized processing conditions present a relatively homogeneous cellular structure (PDI close to 1), with low open-cell ratio, and that regardless the type of PLA. For one of PLAs, an increase in CFA content leads to a decrease in cell density and an increase in average cell diameter. While for the other one, an increase in cell density is noticed. A degradation of the specific stress at yield and break values is also noticed until certain CFA content, without significant variation in elongation at yield and break. The void fraction obtained with both CFA is almost similar. However, a reduction of the cooling temperature for extruded materials with the Hydrocerol CT makes possible to increase it.

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