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SHAPE MEMORY AND THERMOMECHANICAL PROPERTIES OF STARCH-BASED FOAMS

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Shape-memory polymers are an emerging class of smart materials [Liu, 2007]. Recent studies evidenced the possible storage of residual stresses in vitreous starch, leading to shape memory capabilities [Chaunier, 2009; Véchambre, 2010]. In the present work, the shape recovery of starch-based extruded foams was investigated when triggered by heating in oil, or water bath. Its efficiency was linked to their thermo-mechanical properties.

Maize flour was formulated with sugars and extruded as dense and expanded materials ($Ø_{die}$=2mm, T_{die}= 170°C, SME=190J/g). When cooled below their glass transition temperature (Tg) at the outlet of the die, a first "permanent" shape S1 was obtained : straight cylinders (L=50mm). The moisture content was equilibrated at 9% (wb) under a stable relative humidity (RH=59% at 20°C). The density was 0.6g/cm^3 for the expanded products and 1.5g/cm^3 for the dense materials. Tg was measured by Differential Scanning Calorimetry (DSC) at 52°C. A second shape, S2, was given above Tg by bending each straight specimen to θ_{max}=180°. This "temporary" shape was fixed when cooling below Tg and the bent samples were stored at a low humidity level. Then, each specimen spontaneously recovered its "permanent" straight shape when heated or submitted to moisture uptake.

The shape recovery was assessed in thermostated bath by images acquisition and analysis (Fig.1-a), to determine the recovered angle (θ) and to obtain the recovery ratio (Rr), as presented on Eq.1 : $Rr=(\theta_{max}-\theta)/\theta_{max}*100$ (1).

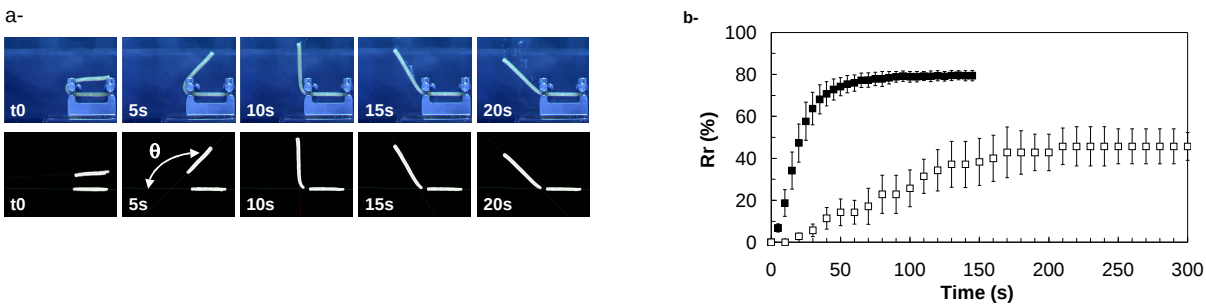

Figure 1: Assessment of the recovered angle (θ) by images acquisition and analysis on immersed specimen in thermostated bath (a). Evolution of the recovery ratio, Rr, in oil bath at Tg+50°C (■) and in water at 85°C (□) (b).

An important recovery was obtained with starch-based foams when triggered by heating in oil bath (Rr=80% after 2min at Tg+50°C, Fig.1-b). Values were less important in the case of their recovery in water (Rr=46% after 4min). This was mainly due to their loss of stiffness, because of the water sorption. It led to a decrease of the modulus, measured by DMA from E'=2 GPa to 0.3 MPa, for the dense material constitutive of their gaseous cells walls.

In the light of these results, starch-based foams can be designed with an interesting shape recovery, especially when triggered by heating. This opens the field of new self-deploying smart biodegradable foams, even being edible.

References

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