The third generation: Aerogels from biopolymers – State of research with special emphasis on highly porous scaffolds from plant and bacterial cellulose

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Cellulosic aerogels are sometimes referred to the 'young' third generation of aerogels. They are intriguing materials as they feature properties similar to their inorganic, mostly silica-based and synthetic organic counterparts in terms of density and porosity, along with specific properties of the natural polymer cellulose.
Shaped cellulose aerogels can be obtained by supercritical drying ($scCO_2$) or freeze-drying of lyogels from both cellulose I (Iα: bacterial cellulose, Iβ: plant cellulose) and cellulose II (regenerated plant cellulose). Direct dissolution of cellulose in appropriate solvents such as $NMMO{\cdot}H_2O$, aq. NaOH/urea, or DMSO/TBAF etc., subsequent shaping and regeneration with cellulose anti-solvents leads to lyogels which consist of a cellulose II network. Their cellulose I pendants can be obtained either from bacterial cellulose aquogels after replacing water by a CO_2-miscible solvent or from lyogels of microfibrillated cellulose, the latter being prepared by mechanical disintegration and enzymatic treatment.
Cellulose aerogels are a promising class of novel materials which is supposed to enter many applications in near future. However, application of these highly porous materials for several purposes is often limited by their low mechanical stability. Increasing the stability by simply increasing the solid content of the aerogels cancels the outstanding properties of aerogels, such as heat, impact and sound insulation, to a certain extent. For biomedical applications, in particular as cell scaffolding materials, the considerable inflammatory response of cellulosic materials, activated via the alternative pathway, has to be considered. On the other hand, bacterial cellulose aerogels have turned out to be almost ideal materials for cosmetic or sanitary purposes.
The current paper intends to give an overview on recent research activities and to convey the valor of “re-growing” biopolymers in aerogel applications. The communication will particularly address recent approaches for modifying and reinforcing cellulosic aerogels aiming at a far-reaching preservation of the highly porous aerogel structure, yet introducing increased mechanical stability and special properties. Furthermore, we report on the preparation and properties of cellulose phosphate aerogels with a special emphasis on improved hemocompatibility and their use as scaffolds for growth and osteogenic differentiation of skeletal stem cells. In the last part, the loading / release behavior of bioactive compounds such as D-panthenol or L-ascorbic acid onto / from bacterial cellulose aerogels is presented.