Description for the general public

Hydrogels are three-dimensional network of crosslinked hydrophilic polymers which have the ability to absorb large volumes of water. They are well known for their beneficial properties such as great swelling, large water content, highly porous three-dimensional network structure, biocompatibility and the ability to create a friendly environment for cells. Polysaccharides (such as chitosan) are one of the most widespread biopolymers in nature. Their biocompatibility, biodegradation, hydrophilic nature and low price due to high availability make them excellent materials for the production of hydrogels. Because of their tunable properties chitosan hydrogels have been extensively researched for many medical applications such as biomaterials for regeneration of bone, cartilage and skin tissues. Due to the ease of modifying hydrogels, numerous biologically active components (e.g. bioactive glasses or plant extracts) are often added to their composition. Bioactive glasses (BGs) have bone-binding ability, controlled degradation and ease of modification with therapeutic ions. They are also biocompatible and can show osteoconductive and osteoinductive properties (which can stimulate bone regeneration and growth) what enables their use in tissue engineering. On the other hand, plants offer many biologically active compounds that have positive impact on human body. Phytochemicals, easily extracted from various plants (such as pomegranate), gain increasing attention due to several health benefits such as antioxidant, antimicrobial and anti-inflammatory properties. Pomegranate extract fruit has been proven to act against various diseases like cancer, cardiovascular disorders, diabetes, AIDS and Alzheimer's disease.

Obtaining the appropriate properties of chitosan hydrogels largely depends on the method and degree of crosslinking of the material matrix. The most common crosslinking agents for biopolymers are dialdehydes, which may cause harmful irritation to human cells. That is why scientists are looking for new solutions. An interesting and innovative approach is the functionalization of polysaccharides – glycosaminoglycans (GAGs) with aldehyde groups, which will let to use them as biocompatible crosslinking agents for chitosan-based hydrogels. Reactive aldehyde groups are able to create a strong and permanent chemical bonds with amino groups (present in chitosan) and crosslink this biopolymer with Schiff-base mechanism. Moreover the presence of BGs can also improve the crosslinking process of hydrogels. In aqueous environment inorganic ions (e.g. Ca^{2+} or B^{3+}) are released from structure of BGs and can interact with specific functional groups of chitosan hydrogels, increasing the number of chemical bonds, physical interactions and the degree of crosslinking. **Accurate determination and characterization of various crosslinking mechanism of chitosan hydrogels is therefore an extremely important issue that is still not fully understood and investigated.**

The primary goal of this project is to investigate the role of bioactive glasses with a highly diverse chemical composition on the crosslinking process of chitosan-based hydrogels as well as to explain and describe the mechanisms of the occurring processes. Moreover, functionalized polysaccharides will be used to crosslink the hydrogels and to guarantee the formation of a three-dimensional, crosslinked structure of the material. Due to the potential use of hydrogels (regeneration of osteochondral defects), the selected polysaccharides will be glycosaminoglycans, which play an important role in the regeneration of joint cartilage. **The second equally important goal of this project** is to develop materials in various forms – highly porous scaffolds, injectable hydrogels with high surgical handiness and 3D-printed personalized structures. Each form of the obtained materials can act as carriers of biologically active substances and have the potential to be used in the treatment of osteochondral defects. This solution will allow the use of materials with the same chemical composition in different clinical cases**. In this project, we propose a new look at bioactive glasses, not only as a functional additive, but also as a component of hydrogel materials that play an important role in the process of their crosslinking**

Thus, the broad spectrum of this project's objectives is expected to provide answers about the impact of BGs (with the use of functionalized polysaccharides) on the crosslinking process of chitosan hydrogels. The planned studies are going to evaluate the possibility of designing chitosan hydrogels in different forms (from highly-porous freeze-dried scaffolds, through injectable materials to advanced personalized spatial forms produced by 3D printing and bioprinting) by the appropriate selection of BGs of various compositions. **We believe that the incorporation of bioactive glasses particles and pomegranate extract will improve the crosslinking degree of chitosan Schiff-base hydrogels and act as biologically active compounds**.