3D printing of biomaterials inspired by plant cell wall

Today, one of the main global challenges is to stop environment degradation and to replace common fossil-based products by sustainable materials with green footprints. In this regard, biomass has emerged as a suitable solution due to its ubiquitous abundance, renewability, and high mechanical performance. Among food crops, **fruits and vegetables** play a special role, as they lie at the base of the human food pyramid and are of high economic importance in Poland, Europe and the world. The fruit and vegetable production and processing sector is a source of a significant amount of raw material, including waste, that can be processed and used to produce new sustainable materials with tailored functionality to various applications.

3D printing is the state-of-the-art manufacturing technique underpinning a remarkably infinite prospect of customizability, flexibility, and sustainability in the production of tailored geometries additively by depositing materials layer-by-layer. Different feedstocks for 3D printing have been already used, but successful substitution of plastics with a more sustainable and environmentally friendly components, including plant cell wall polysaccharides, have been recently demonstrated. However, current studies on 3D printing are limited to simpler systems (one or two natural components) and do not fully benefit from the natural assembly of plant cell walls. Moreover, the natural diversity and tunability of cell wall polysaccharides have not been sufficiently explored in the utilization for 3D printing.

Cell walls in plants (CW), as well in fruit and vegetables, provide a structural framework to support plant growth, maintains structural integrity by resisting internal hydrostatic pressures, retain some flexibility to support cell division, a biomechanical scaffold that enables differentiation, and a pathological and environmental barrier that defends and can be rapidly remodeled against biotic, or abiotic stress. The CW properties emerge from the physical and chemical properties mostly of the three polymers (cellulose, hemicellulose and pectin), but most notably from the interaction and specific configuration of these components organized into a coherent yet dynamic matrix. **Cellulose** and **hemicellulose** are considered to be the key polymers forming the mechanical skeleton of the plant cell wall. **Pectin** are the most complex family of polysaccharides forming an amorphous matrix in the cell wall that play a role of plasticizer (visco-plastic component) in between the cellulose-hemicellulose load bearing network. Pectin rheological properties depends on multiple factors, i.e.: molecular composition of the backbone and side chains, surface charge (degree of methylation, Ph), presence of metal ions and concentration. These variables modulate the cell wall function and mechanical properties in plant and may be used to control the rheological properties of pectin in solution. Therefore, by tuning pectin rheology and surface properties of the load bearing polysaccharides it may be possible to obtain different mechanical properties of biomaterials manufactured by 3D printing. As the three polysaccharides (pectin, hemicellulose and cellulose) in natural cell wall interact and create together mechanically tunable structure, reusing them together in the ink formulations for 3D printing and mimicking different mechanical properties of printed material is the main scientific challenge of this project.

The goal of this project is to develop a strategy of tuning properties of pectin, hemicellulose and cellulose extracted from fruit and/or vegetable to make ink formulations for 3D printing of biomaterials with different mechanical properties. In order to develop a new venue for valorization of agricultural waste to new bioproducts, the ink formulations will be made of pomace from fruit (apple) and vegetable (carrot) rich of cell wall polysaccharides, however biologically variable. To tackle the challenge, the project proposes comprehensive basic research with consideration of the key elements of the value chain: the development stage of the source material, extraction process of polysaccharides, functionalization of the polysaccharides, adjusting 3D printing technology and evaluation of the properties of printed structures.