Development of edible filament for 3D printing of fully biodegradable robotic components

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Edible, soft robots are biodegradable when discarded in the environment and digestible upon consumption by humans and animals. Robotic components such as soft actuators or flexible sensors with complex geometric designs have been fabricated using Fused Deposition Modelling. Fused deposition modelling (FDM) is an additive manufacturing technique developed for 3D of printing plastics. It is a robust technology which enables manufacturing of complex structures with embedded functionality. Certain proteins have thermoplastic behaviour and via plasticization can be processed into edible filament that is suitable for 3D printing. Therefore, the aim of this study was to develop and characterize protein-based edible filaments, and investigate their 3D-printing performance using FDM. Selected proteins i.e. zein (corn protein), gluten (wheat protein), and caseinate (milk protein) were plasticized with glycerol to create powdery mixtures. These mixtures were processed into edible filaments using a mini-extruder. The thermal and mechanical properties of the protein-glycerol mixtures were characterized by differential scanning calorimetry (DSC) and closed-cavity rheology (CCR). The obtained edible filaments were characterized in terms of mechanical properties using texture analysis (e.g. flexibility) and 3D-printing performance. Results show that it is feasible to produce edible filaments using plasticized protein materials, and the 3D-printing performance of the filament is influenced by its formulation. Finally, an edible exoskeleton for a pneumatic actuator was created using edible filaments as proof of principle. This work contributes to the development of 3D food printing and will open up new avenues for fully biodegradable and edible robots.