Novel Synchronous Multi-Scale 3D-printing of foods for tailored sugar-reduced sweetness perception

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Introducing additive manufacturing (AM) techniques into the food value chain is challenging due to low margins typically associated with food products compared to medical or mechanical engineering products. Furthermore, the complex rheology of food requires careful design of extruding and/or dispensing units posing additional hurdles for AM applications. Here, we present a novel AM approach capable of producing complex 3D food structures at elevated production rates and with added functionality perspective. As a food category of elevated interest for significant calorie density reduction by novel AM means, we chose multiphase chocolate confectionery products. The complex 3D structure was broken down into three main length scales denoted as macro-, meso- and micro scale. The macro scale product elements acting as scaffold for the meso-scale elements are manufactured by twin-screw cold extrusion applying a macro-scale printing die (cm-range). Two six-axis robots equipped with a single screw meso-scale (mm-range) extruder system and an electromagnetically triggered single/multi jetting micro-scale (100 micrometer scale) nozzle dose and shape the meso- and micro- scale product elements and connect them synchronously to the macro scale printed scaffold element.
With the introduced SYnchronous MUltiScale (SYMUS) 3D-printing technology we demonstrate how to rapidly manufacture a multiphase chocolate confectionery product composed of different phases from print materials with non-Newtonian and highly temperature dependent flow behavior. Moreover, we show how to apply this novel AM-based production technology for the processing of high-quality chocolate confectionery products with significantly lowered calorie density by sugar reduction while still providing a well perceived sweetness sensation. For the latter aspect approval, we applied not only conventional sensory evaluation but in addition neuroscience-based methodologies (EEG, fMRI) enabling complementary brain response information access on the sweetness perception kinetics dependency from the spatial arrangement of printed “sweet product domains”.
Such spatially resolved texture and aroma/flavor functionality of the presented chocolate products indicate the powerful toolbox for the generation of new organoleptic properties while fulfilling requirements for nutritional and sustainability benefits thus generating added value across the entire food value chain using the introduced Synchronous Multiscale 3D-Printing based Additive Manufacturing technique.