Tailoring gastric food structure disintegration and function release kinetics by gastrointestinal structure engineering (GINSENG)

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The research field of gastrointestinal structure engineering (GINSENG) has been developed at the ETH food process engineering laboratory based on a reverse structure engineering concept applied for the industrial processing of functional food systems. Main focus for this approach is a process based understanding of the digestive disintegration of food structure in the context of the physiological operation characteristics of the human gastrointestinal tract. This denotes in further detail, the mechanical, physiological, biochemical and medical aspects of digestion from mouth to colon in order to better understand and optimize metabolic responses by tailored structure processing in the industrial manufacture of food systems.

The functional relationships between food structure, its industrial processing and its related disintegration during digestion are highly non linear and transient. Exploring related mechanistic aspects from a structure engineering perspective has to take the characteristic length and time scales of food structure into account. Accordingly the processing length scales have to be adapted and related time scales be synchronized. Otherwise function tailoring would fail.

A major section of the gastrointestinal human tract concerning absorption of micro and macronutrients is the duodenum. The chyme transport from stomach through pylorus and duodenum is quite rapid thus giving only limited time for optimal absorption of valuable food components. As a consequence the stomach has a major role in preparing food structure for efficient nutrient transfer within the duodenum. This has to be taken into account in case of "structure-designing" fortified food systems, supplements or carriers containing functional components (FC) to be delivered in the duodenum.

Depending on the nutrient and metabolic requirements for optimal or personalized nutrition different scenarios for structure transformation of and component release from food matrices within the human stomach can be derived. Two extremes are:

a) Fast stomach passage with preferred residence time less than 0.5-1 hours without significant structure breakup and FC release.

b) Long term (> 8-24 hours) residence time in stomach with controlled structure disintegration and release kinetics of specific components.

In order to manage such different scenarios the (i) fluid mechanical (ii) biochemical and (iii) structural/rheological material processing conditions within the stomach have to be quantified. In order to gain such quantitative knowledge (i) in vitro experiments, (ii) fluid dynamical structure disintegration simulation by computational fluid dynamics (CFD) as well as in vivo experimental (iii) MRI- and (iv) efficacy studies were coupled within the ETH-FPE GINSENG approach.

The respective toolbox will be demonstrated and first results given for micronutrient release from food supplements and fortified food systems.