From structure to nutrition: linking the multi-scale architecture of alternative food systems to their digestion mechanisms

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The transition towards more sustainable, diversified and health-oriented diets requires a mechanistic understanding of how the structure of alternative food sources governs their nutritional performance. In complex food colloids, proteins and polysaccharides are hierarchically arranged across multiple length scales, from molecular interactions to supramolecular assemblies and macroscopic networks. However, how this multi-scale architecture influences gastrointestinal digestion and subsequent nutrient transport remains poorly understood.

Addressing this gap requires a structural framework that connects the initial structural characteristics of alternative food systems with their digestion mechanisms and the nanoassembly of the resulting digestion products. By combining advanced structural techniques, including small-angle X-ray and neutron scattering (SAXS/SANS), with microscopy, rheology and compositional analysis, together with standardized *in vitro* digestion models, we are investigating how protein-polysaccharide interactions, cell wall architecture and matrix structure modulate enzymatic accessibility, proteolysis kinetics and nutrient release across different food systems. Our results show that digestion is not simply a process of molecular breakdown, but a dynamic structural reorganization. The progressive disassembly of food structures upon digestion leads to the formation of new nanoassemblies. Interactions between released peptides, soluble polysaccharides and bile salts promote the formation of distinct colloidal structures, including mixed micelles and lamellar phases. The nature and stability of these assemblies are strongly influenced by the initial matrix architecture and physicochemical properties of the digesta.

Altogether, this work demonstrates that digestion should be understood as a multi-scale structural transition. Understanding these transformations is essential to rationally design next-generation alternative food systems with tailored digestibility, nutrient bioaccessibility and metabolic functionality.