Improving the Mouthfeel of Plant-Based “Meat”

Neutrons and X-rays provide information on structure formation that can help us improve meat alternatives

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Improving the Mouthfeel of Plant-Based "Meat"

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Credit: Ekaterina D. Garina.

Sustainability, health and animal welfare concerns drive consumers to plant-based meat alternatives, but their mouthfeel is still lacking. Mimicking the complex fibrous meat structure is key for alternative whole-cut products to be accepted by meat lovers. A recent study, published in *Food Hydrocolloids,* shows what neutrons and X-rays tell us about hierarchical structure formation of soy-based meat alternatives. This is a multi-institutional study by scientists from the Delft University of Technology, Wageningen University & Research, ISIS Neutron and Muon Source and the European Synchrotron Radiation Facility.

How is a multiscale structure formed during meat alternative production?

The food industry seeks routes to provide the consumer with whole-cut plant-based products that do not compromise sensory appeal. A promising technological route most amenable for industrial implementation is shear processing through high-moisture extrusion (HME). In HME, plant proteins and polysaccharides are mixed to create meat alternatives with improved mouthfeel.

One of the critical challenges of the currently commercially used HME process is its lack of robustness against variations in ingredient and processing conditions.

This is primarily due to a lack of insights into the evolution of protein structures on multiple scales during shear processing. It is an open question of how two biopolymers, one a plant protein and the other a polysaccharide, contribute to the anisotropic structure formation during HME – a material directional nonuniformity important for developing meat-like texture. The current study addresses these challenges.

Proteins and polysaccharides are different in the development of structural anisotropy

In our study, we abruptly stopped the operating extruder during plant-based meat alternative production to collect samples representing different extrusion steps (Figure 1), such as mixing and hydration, thermo-mechanical treatment and cooling, to reveal the ”black box” mechanism of HME. By using a combination of small-angle neutron scattering (SANS) and small-angle X-ray scattering (SAXS), we measured the role of both proteins and polysaccharides in the anisotropic structure formation from the nano-to-submicron scale. Better sensitivity of neutrons to the proteins and X-rays to the polysaccharides provided a comprehensive understanding of the structure formation process.

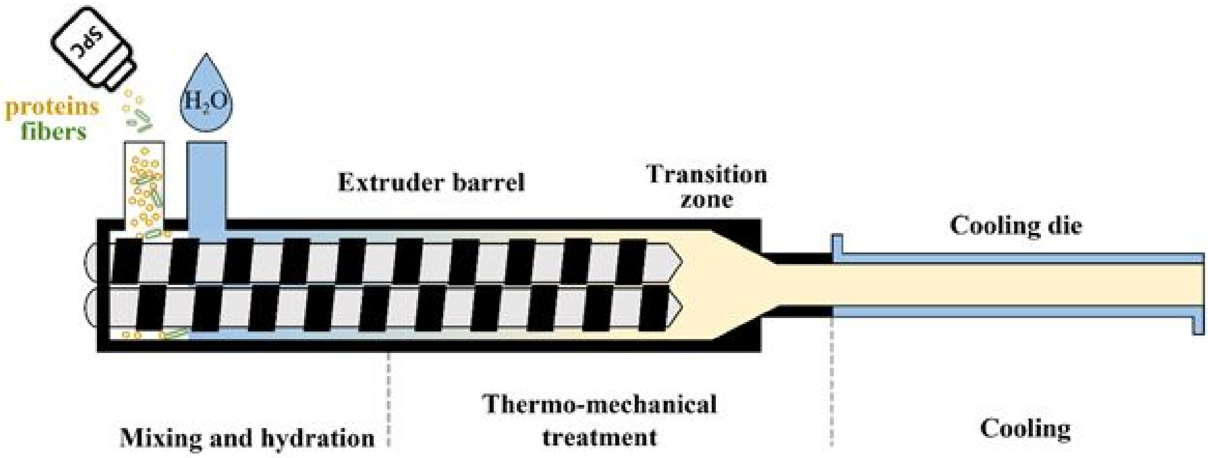

Figure 1: Diagram illustrating the steps of high-moisture extrusion involved in the production of plant-based meat alternatives. *Credit: Ekaterina D. Garina, adapted from Garina et. al 2024 under creative commons 4.0 license.*

The key findings of the paper were:

- SANS and SAXS provide complementary information on structural evolution during HME
- Protein fibril alignment starts in the extruder section with further development along the cooling die, while polysaccharide fibers have the strongest local alignment before the cooling die
- Anisotropy is visible when structures larger than 10 nanometers are probed

Developing a model for multiscale structure formation in relation to texture

This work shows that SANS and SAXS are powerful tools for studying the structure of materials at the nanoscale, providing unique insights into the arrangement of proteins and polysaccharides in the meat alternatives created through HME.

Particularly, we demonstrate that protein aggregates constituting the building blocks of protein fibrils are already formed during the mixing and hydration step and reach a stable size during the thermo-mechanical treatment step. These protein fibrils align before the hot melt reaches the cooling die. The anisotropic structure develops quickly as soon as the material progresses through the cooling die.

On the other hand, the alignment extent of polysaccharide fibers is strongest in the transition zone between the extruder barrel and cooling die, while the structure in the cooling die seems to be relaxed.

The structures of proteins and polysaccharides at this small scale impact how they bundle to form larger structures, which are the ones your mouth will feel when eating. By understanding what is happening at both scales and how two biopolymers impact the physics of the system, and therefore the mouthfeel, we hope to create a model that can be used to predict which protein powders and processing parameters will make better products. This will reduce waste, as it will reduce the number of samples a company needs to produce and test, making meat alternative products more affordable.

However, it is worth mentioning that the complex hierarchical architecture of extrudates necessitates the use of multiple characterization techniques in order to cover the size ranges of interest. In this context, combining small-angle scattering (SAS) methods with microscopy and magnetic resonance imaging seems to be an effective strategy for studying size ranges from the nano- to the macro-structural level.

From *ex-situ* to *in-situ*

In addition to working on the complementary use of multiple characterization techniques, we plan to measure structure formation under real processing conditions. This means we will need to build an extruder that transmits both neutrons and X-rays to study the material while it is undergoing extrusion.

Reference: Garina ED, den Adel R, van Duynhoven JPM, et al. SANS and SAXS: A love story to unravel structural evolution of soy proteins and polysaccharide fibres during high moisture extrusion for meat alternatives. *Food Hydrocoll*. 2024;155:110121. doi:10.1016/j.foodhyd.2024.110121