FROM MILK TO 3D PRINTING: A SUSTAINABLE JOURNEY OF UPCYCLED PROTEINS

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Research context

The increasing consumption of single-use plastics in packaging raises environmental concerns due to fossil fuel depletion and plastic waste accumulation, prompting urgent demand for sustainable alternatives like biobased and biodegradable materials. In Italy, pasteurized milk has a short shelf life of 6 days, after which it must be discarded or repurposed for animal feed, compost, biogas, or fertilizers. Our research aims to upcycle expired milk into biodegradable packaging, reducing biowaste while adding value by upcycling.

Casein was extracted from expired milk by various methods, producing powders with varying structures and behaviours. These were used to make dispersions under a variety of conditions (solvent, pH, concentration), whose rheological properties were assessed through small amplitude oscillatory shear measurements carried out at 25 °C. The dispersions' rheological behaviour depended on powder type, solvent, and pH. Preliminary structural and thermal analyses were done by FTIR and TGA. Based on results, the best dispersions are proposed for 3D printing biobased food packaging.

This approach reduces milk waste and offers a sustainable alternative to petroleum plastics. Future work will optimize printing parameters and mechanically characterize the materials.

Experimental part

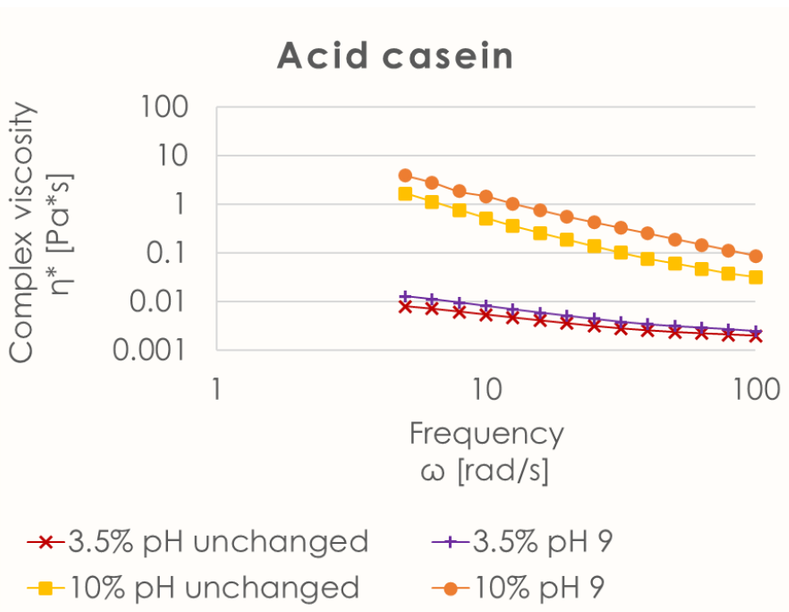
Casein was first separated from milk using different methods, which affected the structure and properties of the resulting material. Thermal and rheological analyses were performed to determine their processability and suitability for 3D printing. The most promising formulations, showing good thermal characteristics and processability, were then tested in preliminary 3D printing trials. In the results, we are highlighting the rheological differences of respective formulations.

Results and discussion

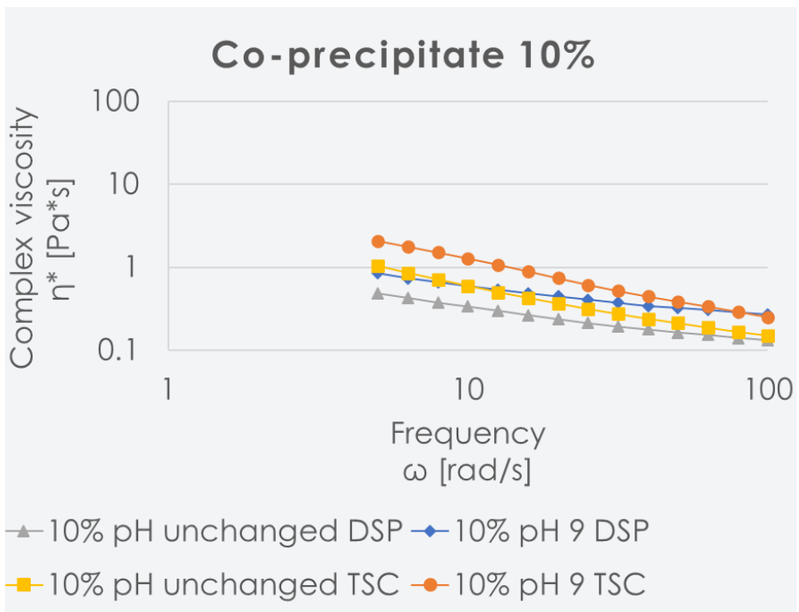
Trisodium citrate (TSC)
- organic salt
- food additive: preservative, acidity regulator (buffer), and anticoagulant

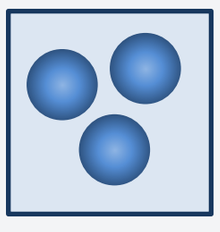
Viscosity change
- Casein structure
- Concentration
- pH
- Solvent (TSC or DSP solution)

Disodium phosphate (DSP)
- inorganic salt
- food additive: emulsifier, buffer, preventing clumping, and improving texture

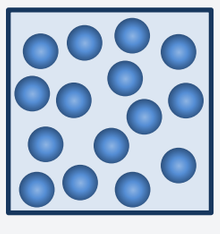


Summary of observations:
- The viscosity of 3.5% solutions was too low for our goal (regardless the structure)
- The viscosity increased with higher concentration
- The solution used (TSC or DSP) influenced the most the viscosity of rennet casein

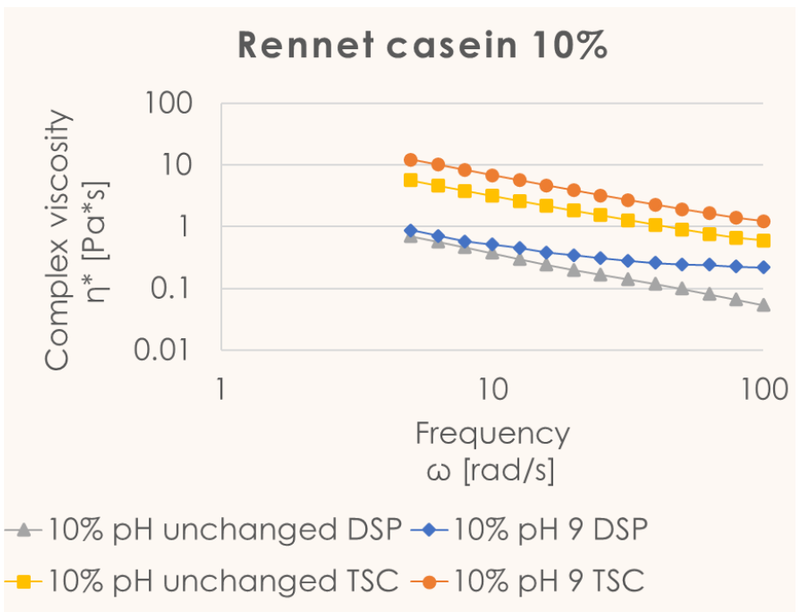


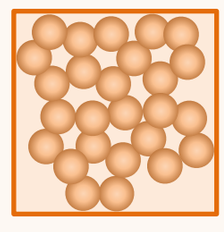


Unchanged pH:
- bigger aggregates
- smaller surface area
- Fewer inter-aggregates contacts
- Lower viscosity

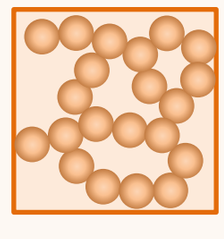


pH 9:
- smaller aggregates
- higher surface area
- more inter-aggregates contacts
- higher viscosity





In TSC:
- dense and compact protein aggregates
- fractal networks
- more friction
- higher viscosity



In DSP:
- sponge-like structures
- less interparticle friction
- lower viscosity

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