Current high-pressure research at UAB Food Science

From alternative protein functionalization to UHPH safety of donor human milk

dynamic pressure | structure-function | process windows

pressure is converted into shear, impact, cavitation and an ultra-short heat pulse

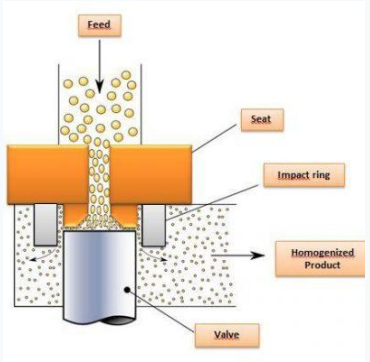
One pressure toolbox, two food-science questions

HPH / UHPH pressure event

Alternative proteins (FUNALPRO)
Improve solubility, emulsification, foaming, gelling and water/oil retention

Donor human milk
Achieve microbial safety while preserving immunoglobulins and bioactivity.

A very short, dissipative event that changes particle size, interfaces, thermal history and microbial survival.



Do not confuse dynamic homogenization with high hydrostatic pressure: this is a continuous pressure-drop process, not isostatic compression.

Common logic: define the pressure-homogenisation window where useful structural change is maximized and damage is minimized.

HPH is not HPP: it is a continuous dissipative pressure drop

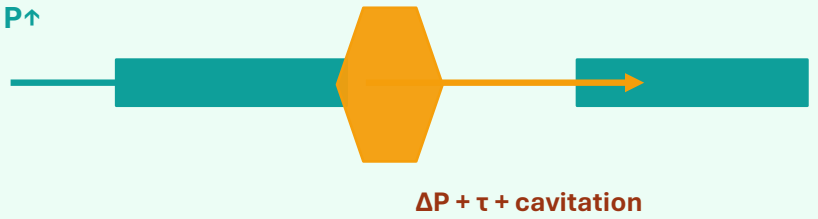
For pressure physicists, the distinction is the central idea.

High-pressure processing (HPP)

- Pressure applied nearly isostatically
- Batch or semi-continuous; solids and liquids
- Equilibrium thermodynamics are highly relevant
- Typical food use: microbial inactivation

High-pressure homogenization (HPH/MF)

- Pressure forces a fluid through a valve/gap/chamber
- Continuous; liquids and pumpable dispersions
- Shear, extensional flow, turbulence, impact and cavitation
- The pressure drop becomes mechanical work and heat



In HPH, “pressure” is the controllable knob; the agents of modification are the transient hydrodynamic and thermal fields.

Functionalizing alternative proteins project

Research objective

Use UHPH, microfluidization and ultrasound to turn underperforming protein concentrates into ingredients with controlled techno-functionality.

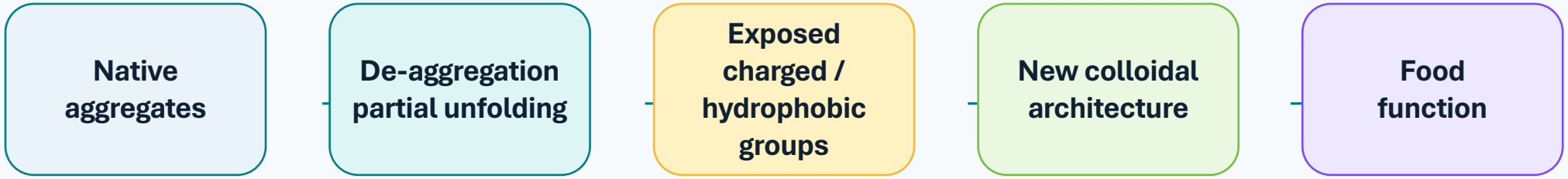
Substrates
Pea protein concentrate
Pig spleen protein concentrate
Plant-animal binary blends

Treatments
UHPH
Microfluidization
Ultrasound
Optimized sequences

Target functions
Solubility
Emulsions and foams
Gelation
Water/oil retention

Industrial demonstrators: gelled emulsions and UHT protein-rich beverages.

The mechanistic question: when does disruption become functionality?



What has to be measured

- particle size and zeta potential
- surface hydrophobicity / free SH
- solubility, WHC and OHC
- emulsion, foam and gel performance
- rheology and microstructure in model foods

For physicists and chemists: the opportunity is to link pressure event history to population balances, interfacial adsorption, denaturation kinetics and re-assembly pathways.

Food functionality is structure made measurable

The FUNALPRO project targets a small set of high-value techno-functional properties.

Solubility

dispersion in water

Emulsification

oil–water interface

Foaming

air–water interface

protein structure

Gelation

network formation

WHC / OHC

water & oil retention

Digestibility

bioaccessibility & release

A good ingredient is not “more denatured”; it is denatured in the right way for the application.

UHPH for donated human milk project

Why this matters
Holder pasteurization is the standard in milk banks, but it can reduce heat-sensitive bioactive components. The goal is safety with better immunological quality.

UHPH design
- Ypsicon A60, 60 L/h
- Valve temperatures about 61-85 °C
- 150-300 MPa screening

Formula model
Find pressure window

→

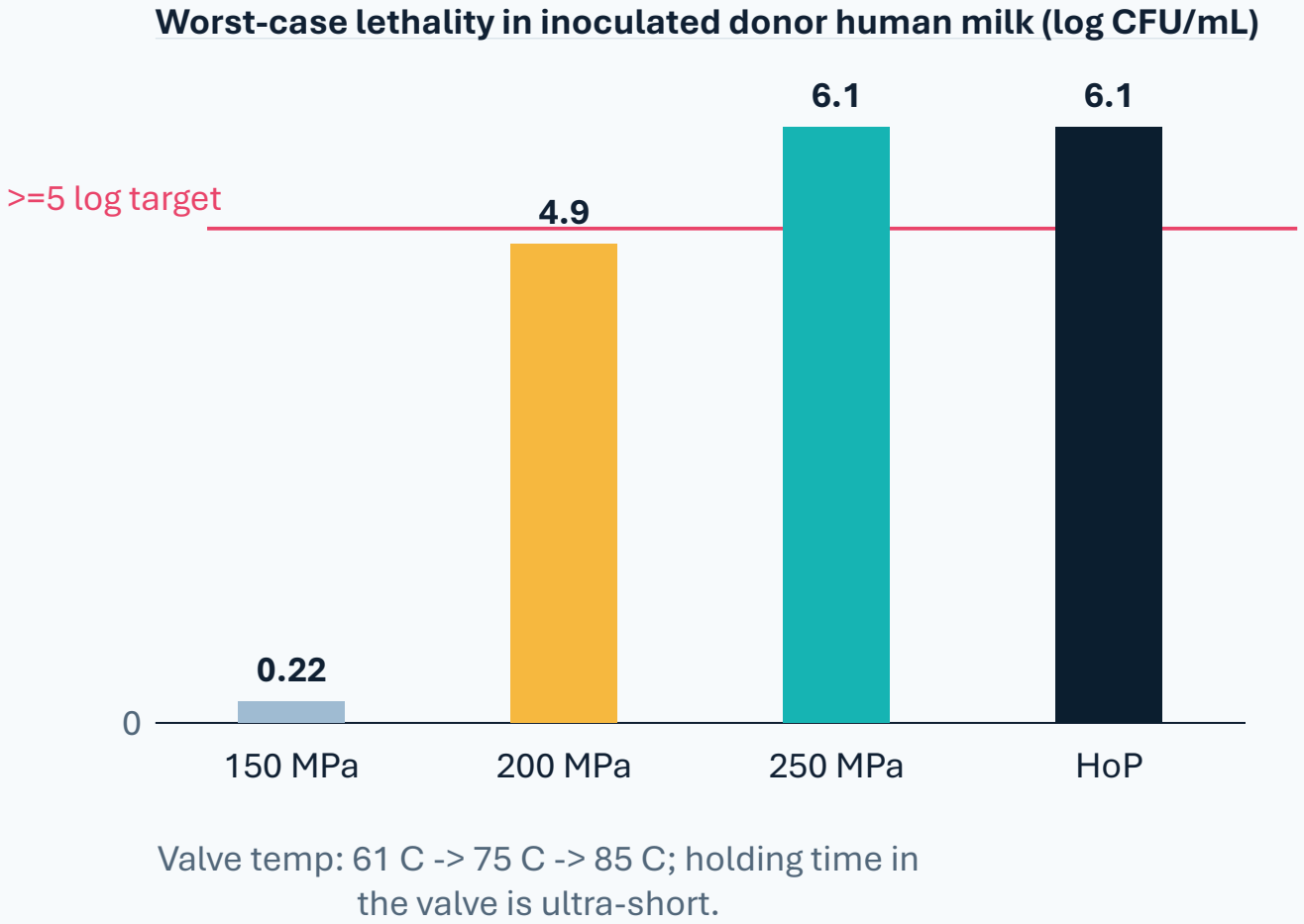
Donor human milk
Validate safety and Ig retention

→

Compare with HoP
62.5 °C for 30 min

Surrogates: *L. innocua*, *S. carnosus*, *C. helveticus* and *E. coli*

Result 1: UHPH defines a microbial safety window



Valve temp: 61 C -> 75 C -> 85 C; holding time in the valve is ultra-short.

Interpretation
150 MPa is clearly insufficient.

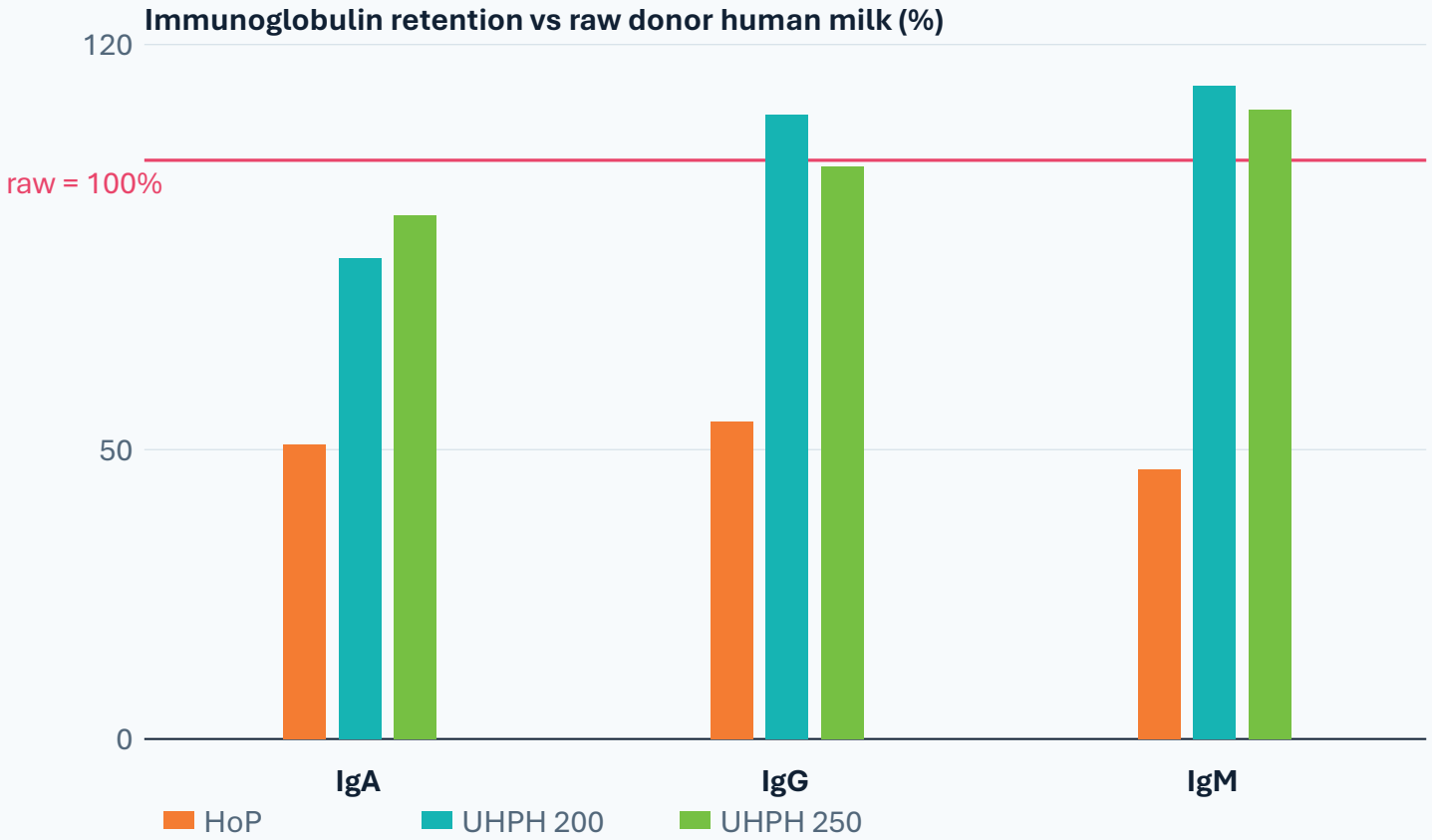
200 MPa approaches the target but ***Staphylococcus*** is the limiting surrogate.

250 MPa reaches >6 log worst-case lethality in donor human milk, comparable to HoP.

Key lesson for high-pressure science: the pressure number and the thermal history cannot be separated.

QUALITY DIMENSION

Result 2: immunoglobulin preservation changes the trade-off



Holder pasteurization reduced sIgA, IgG and IgM to roughly half of raw donor human milk.

UHPH at 200 and 250 MPa retained immunoglobulins close to raw milk levels while meeting the safety objective at 250 MPa.

Decision view: choose the window where lethality, bioactivity and process scalability are simultaneously acceptable.

One idea: pressure as controlled perturbation

1. In alternative proteins, the FUNALPRO project uses HPH/MF/US to transform structure-function relationships.
2. In donor human milk, UHPH at 250 MPa delivers a strong safety signal while preserving immunoglobulins better than HoP.
3. The shared challenge is process-window design: enough disruption for function or lethality, minimal damage to value.

Where pressure physicists and chemists can contribute

The hard questions are mechanistic, multiscale and predictive.

Hydrodynamics

Can CFD predict the stress and thermal history seen by protein aggregates inside a valve or interaction chamber?

Cavitation chemistry

When does cavitation help disaggregate proteins, and when does it promote oxidation or uncontrolled damage?

Protein energy landscape

Can MD or coarse-grained models explain unfolding, exposure and re-aggregation pathways?

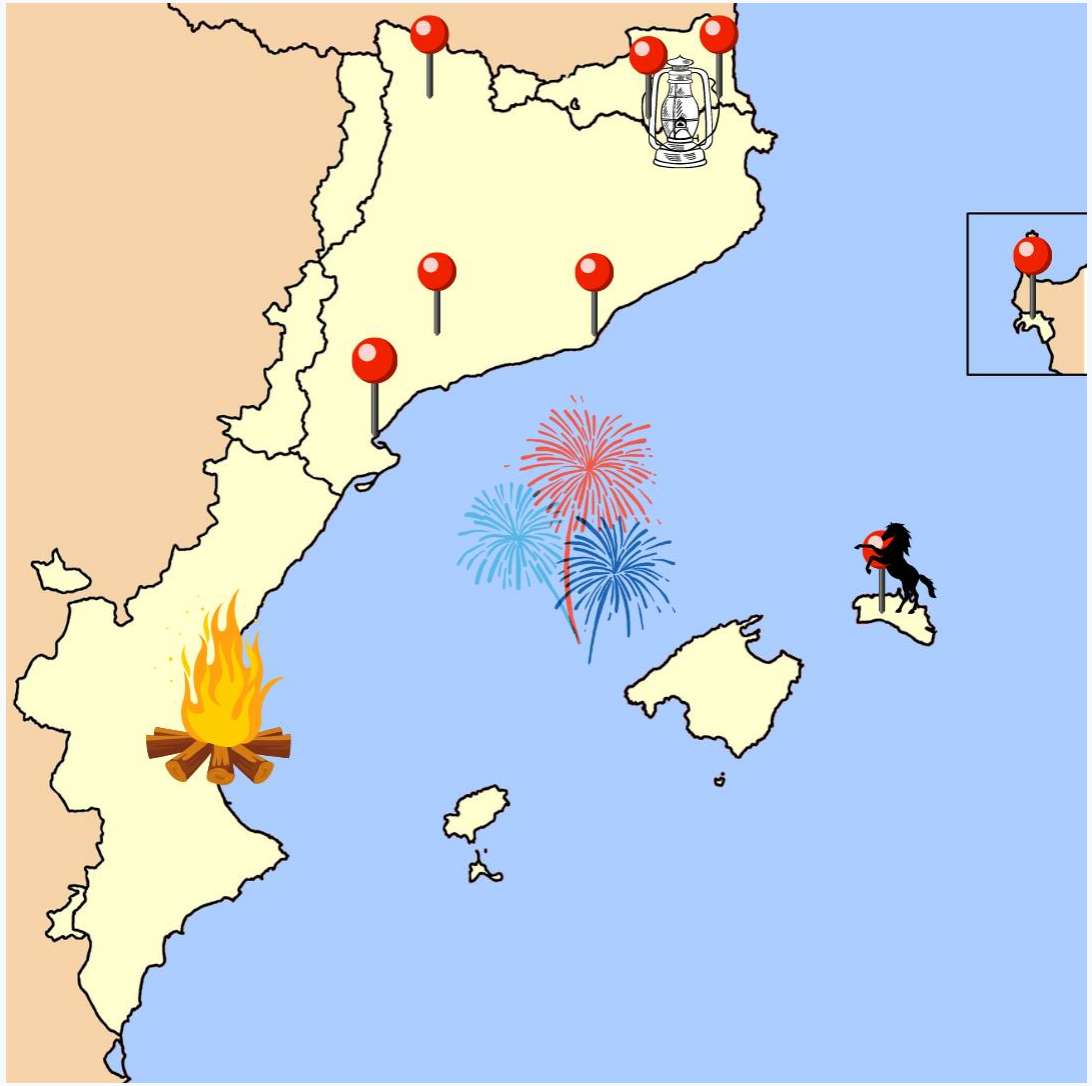
Population balances

Can aggregate-size distributions after processing be predicted from breakage and re-assembly kernels?

Inverse design

Can multi-response data identify process windows for a target food function?

Food matrices are excellent test beds for non-equilibrium soft matter.



Sant Joan

Festa nacional dels Països Catalans