Processing nanoemulsions

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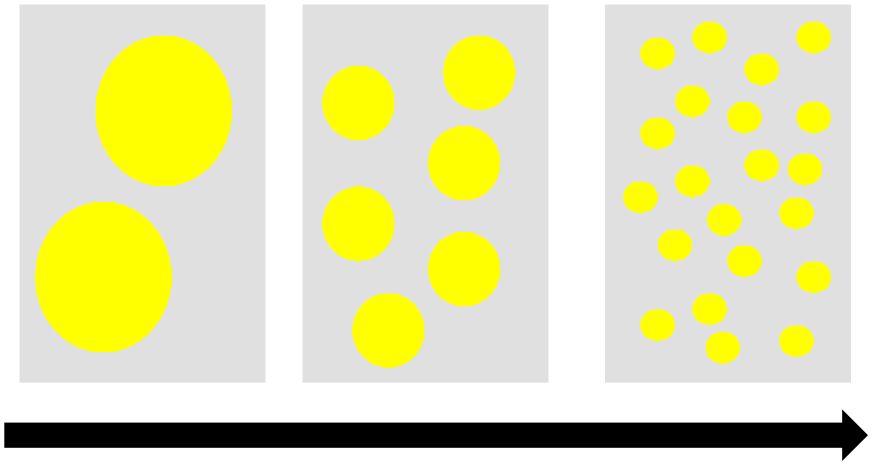
Aim of work

- Understand nano-emulsion production
  - Food grade

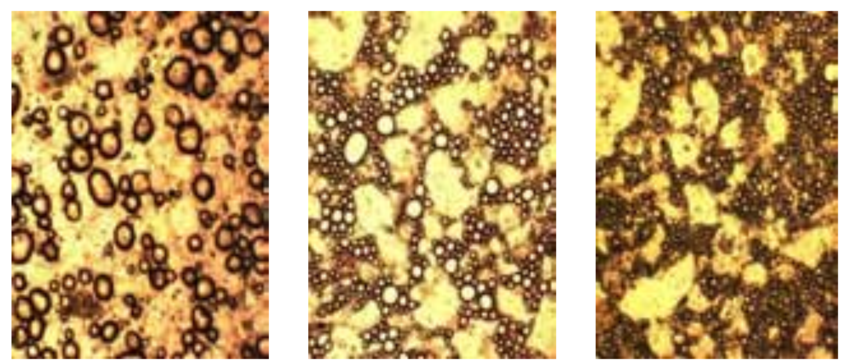
- Compare high pressure devices:
  - Microfluidizer
  - High pressure valve homogeniser

Why nanoemulsions?

- Prolong stability
- Translucent
- Enhance mouthfeel
- Faster flavour release



Increased stability & decreased light scattering



Flow regime and droplet break-up

- Reynolds number

$$\mathrm{Re} = \frac{du\rho}{\mu}$$

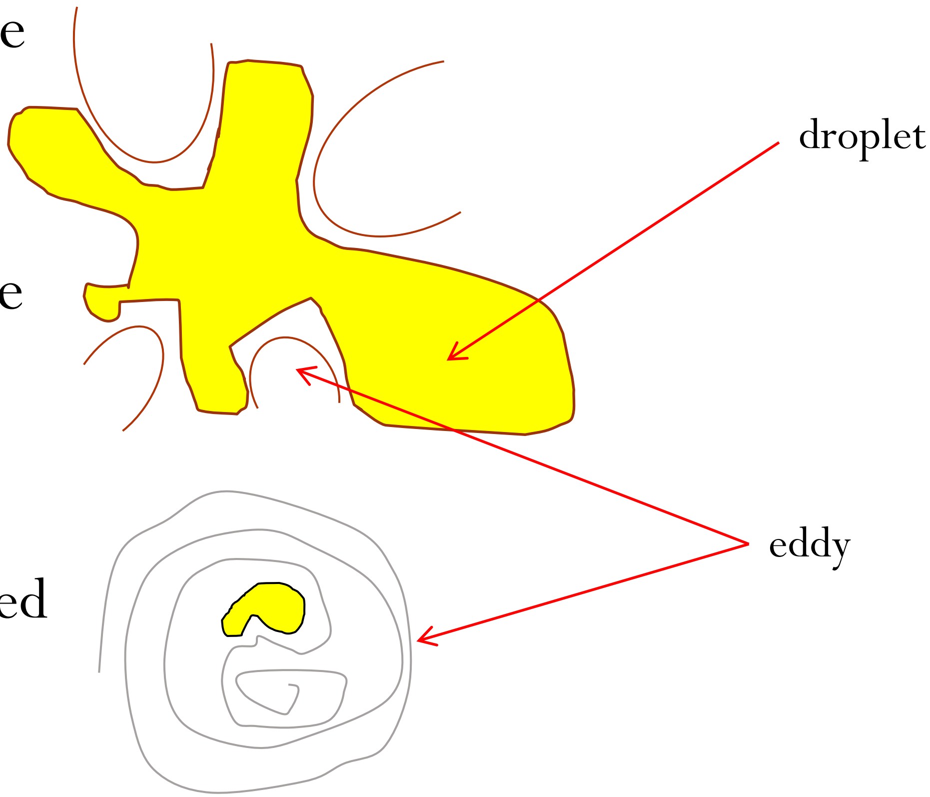
- Laminar

- Turbulent
  - Velocity fluctuations in all directions
  - Energy dissipation from eddies

Droplet break-up mechanisms

Turbulent droplet break-up

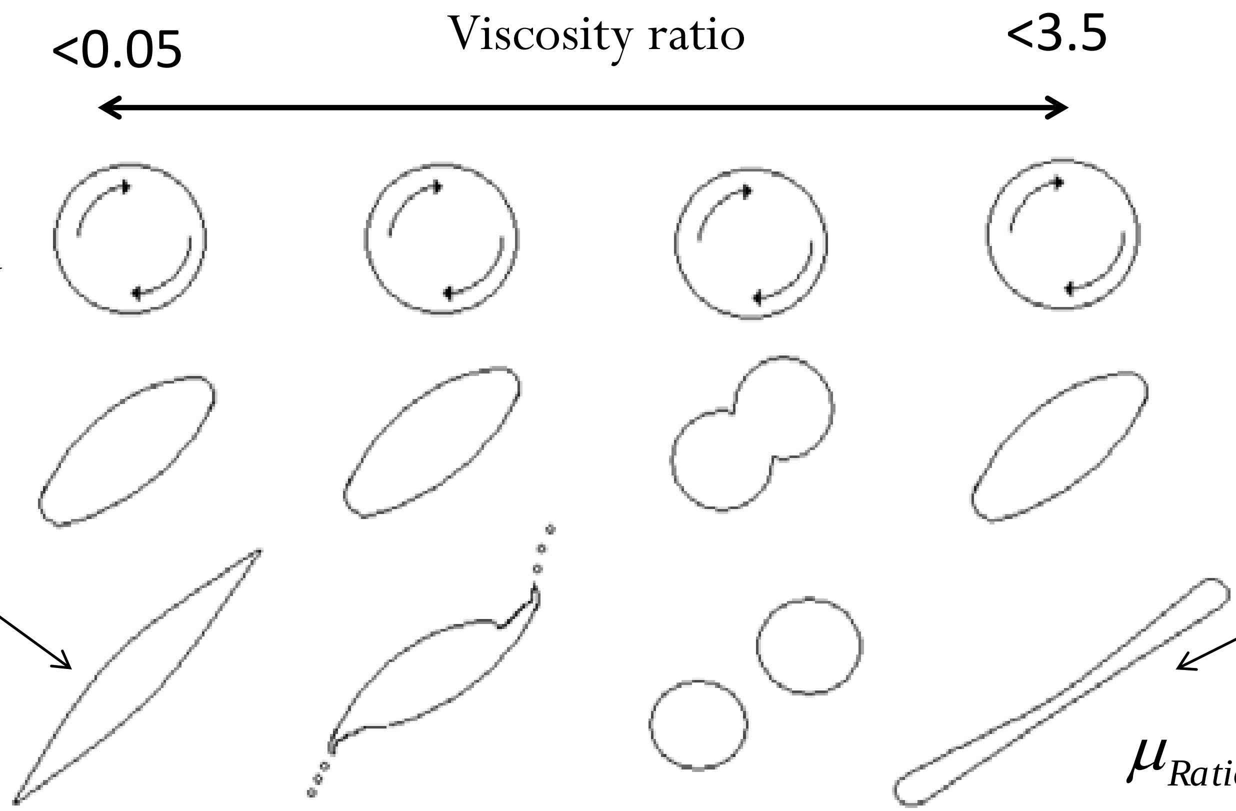
- Turbulent inertial regime
  - d>λk
- Turbulent viscous regime
  - d<λk
  - Viscosity ratio
    - 0.1 – 5
  - Droplet break-up equated to simple shear[1]



1. WALSTRA, P. & SMULDERS, P. E. A. 1998. Emulsion Formation. *In:* BINKS, B. P. (ed.) *Modern Aspects of Emulsion Science*. Cambridge: Royal Society of Chemistry.

Viscosity ratio

Droplet break-up in simple shear



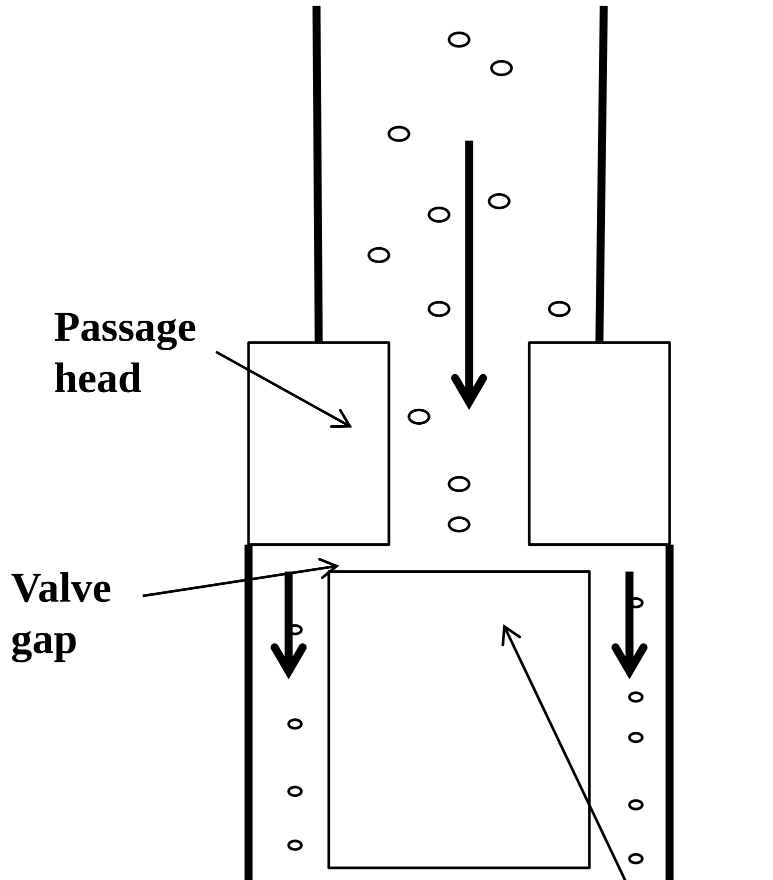
Low viscosity dispersed phase compared to continuous

High viscosity dispersed phase compared to continuous

$$\mu_{Ratio} = \frac{\mu_{Dispersed}}{\mu_{Continuous}}$$

High pressure valve homogeniser

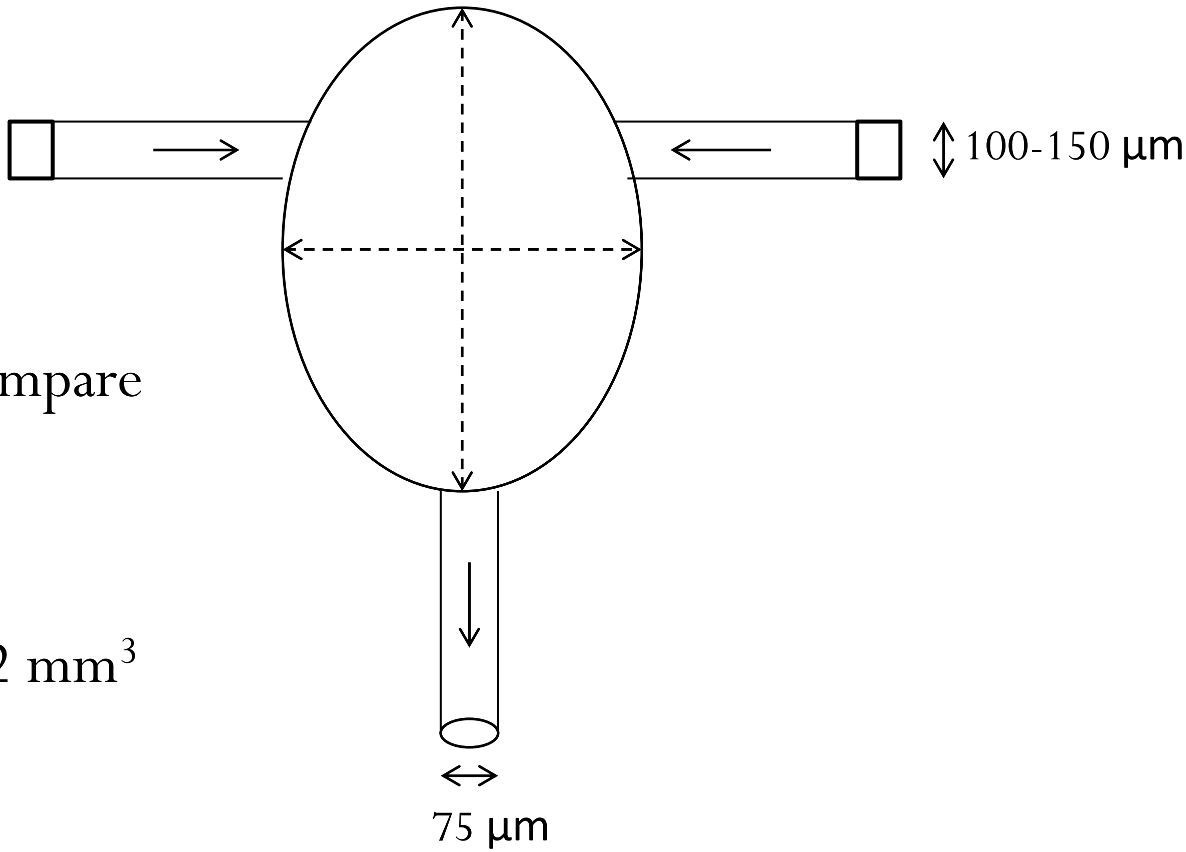
- Up to 150 MPa
- Gap height
  - ~10 µm[1]



1. INNINGS, F. & TRÄGÅRDH, C. 2007. Analysis of the flow field in a high-pressure homogenizer. *Experimental Thermal and Fluid Science,* 32**,** 345-354.

Microfluidizer

- Up to 150 MPa
- 200 – 400 m/s
- Impinging jet
  - Developed to compare
- Chamber size
  - Best estimate – 2 mm^3



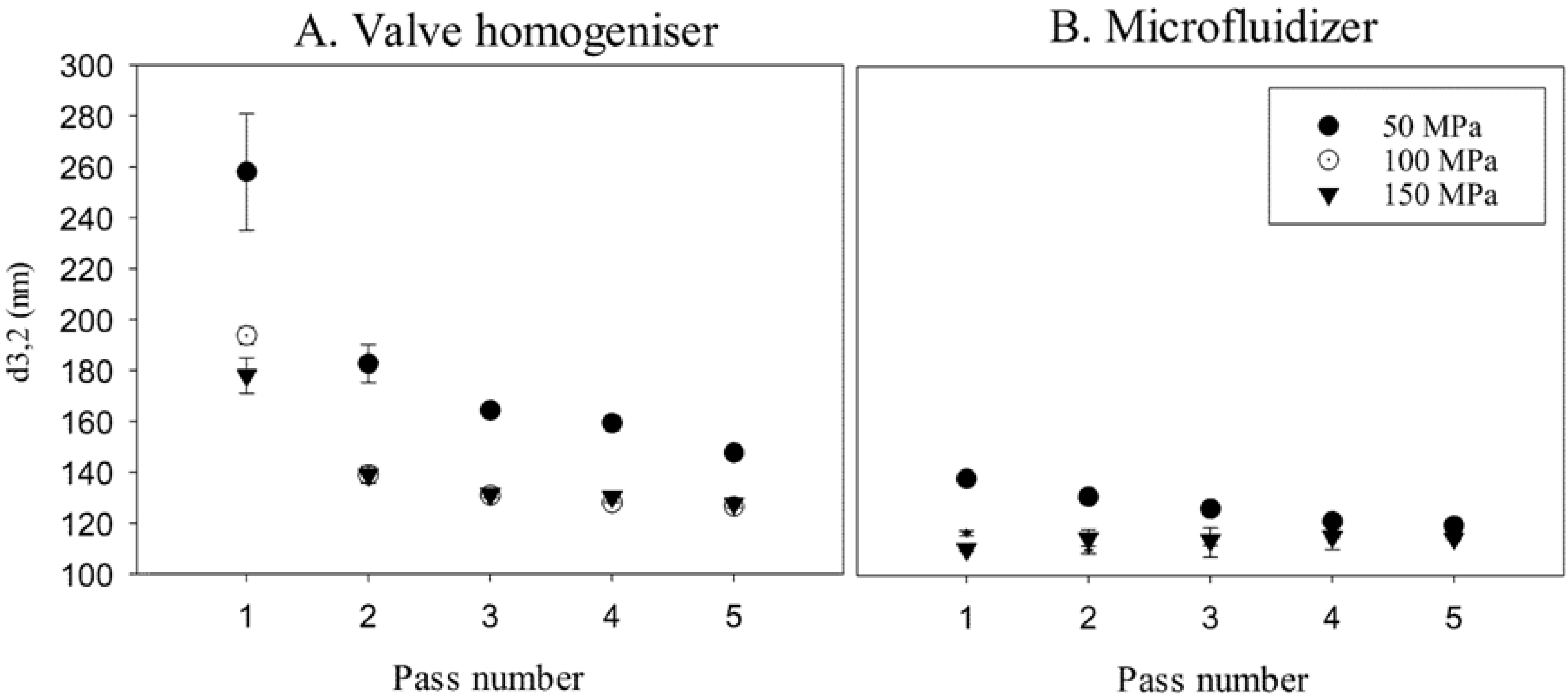
COOK, E. J. & LAGACE, A. P. 1985. *Apparatus for forming emulsions*. Aug 6, 1985.

Emulsion preparation

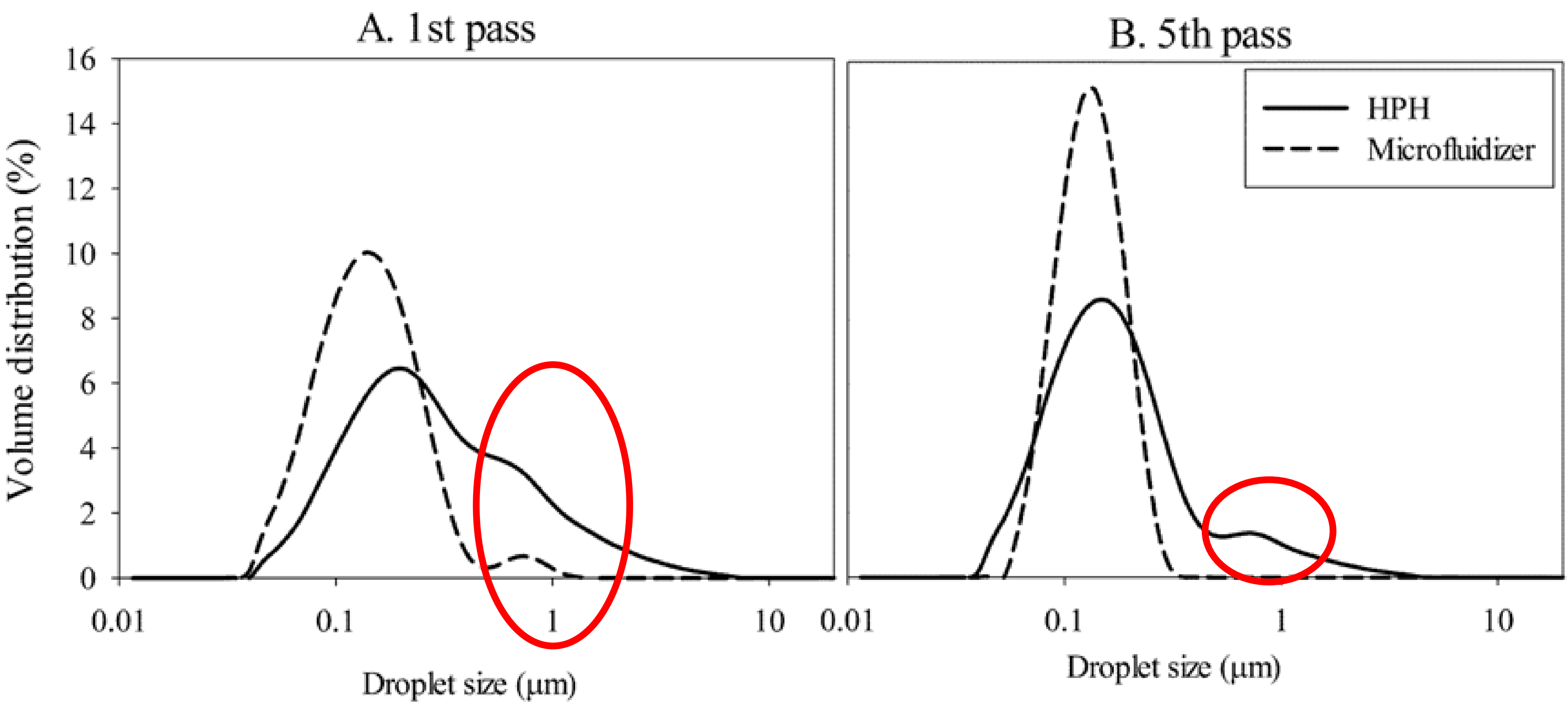
- Materials
  - Silicone oil (0.05 Pa s)
    - Similar viscosity and interfacial tension to sunflower oil and water
  - Emulsifiers
    - Tween 20, SDS and sodium caseinate
- Method
  - Coarse emulsions
    - High shear mixer at 5000 rpm for 1 minute
- Error
  - Standard deviation calculated from 3 repeats

Results and Discussion

Passes and pressures



Droplet size distributions

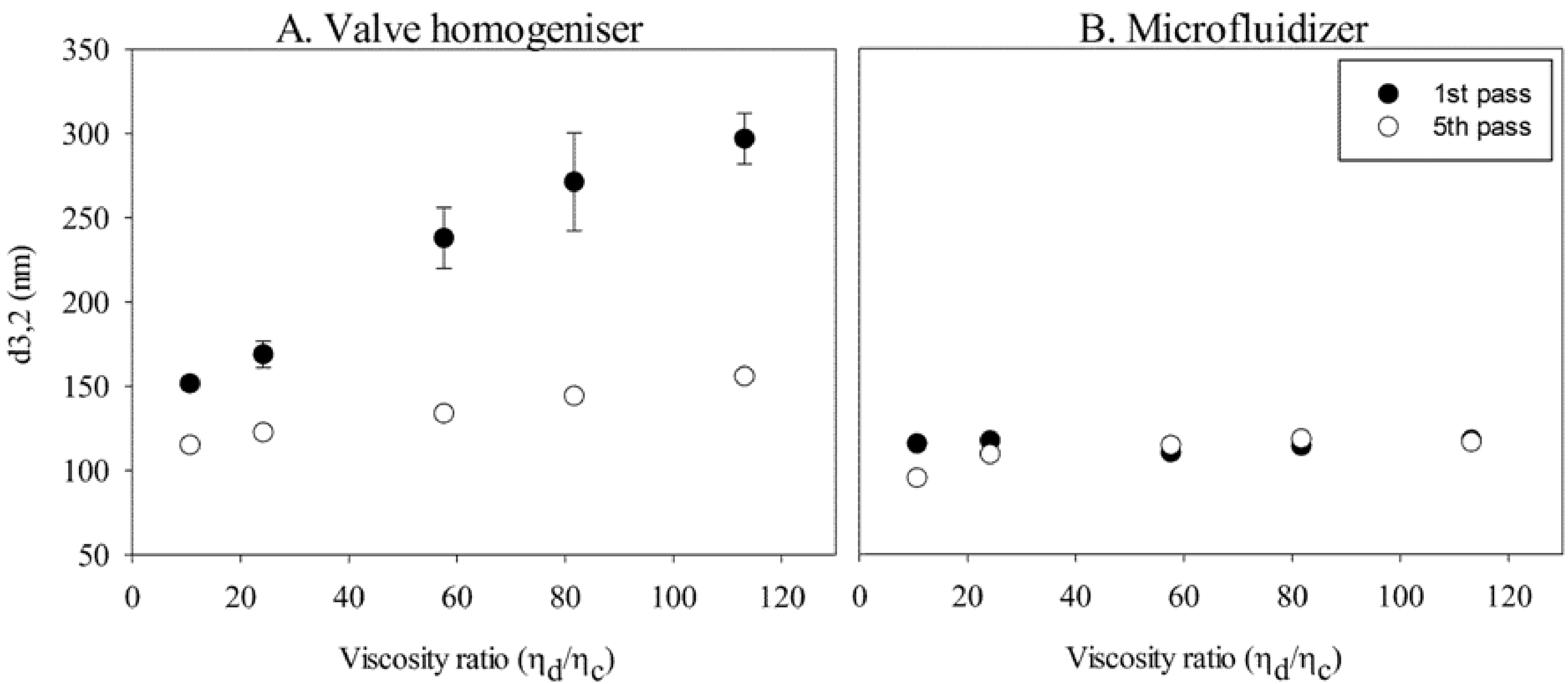


HENRY, J. V. L., FRYER, P. J., FRITH, W. J. & NORTON, I. T. 2009. Emulsification mechanism and storage instabilities of hydrocarbon-in-water sub-micron emulsions stabilised with Tweens (20 and 80), Brij 96v and sucrose monoesters. *Journal of Colloid and Interface Science,* 338**,** 201-206.

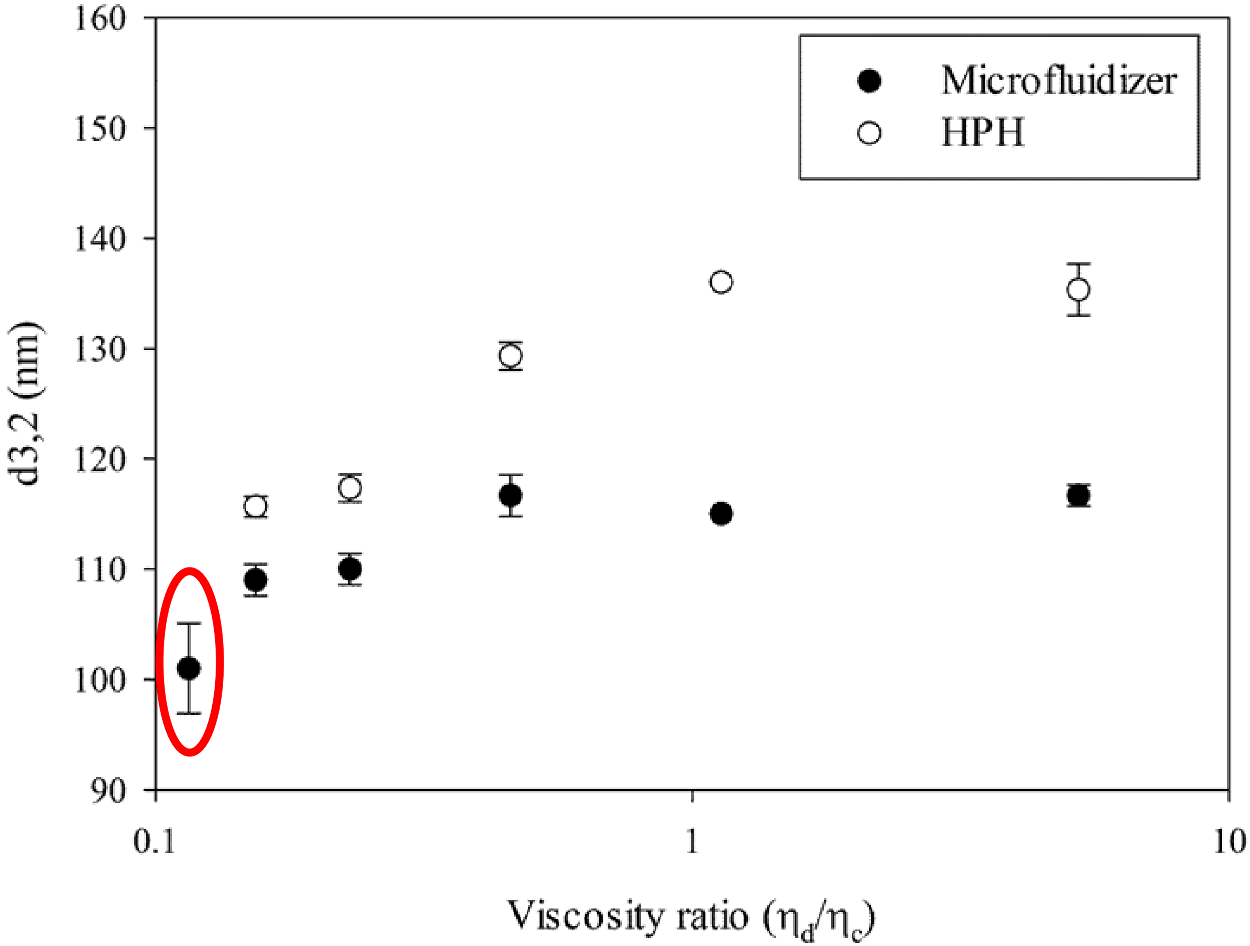
Viscosity ratio

Affect on droplet break-up mechanisms

Viscosity ratio



Viscosity ratio

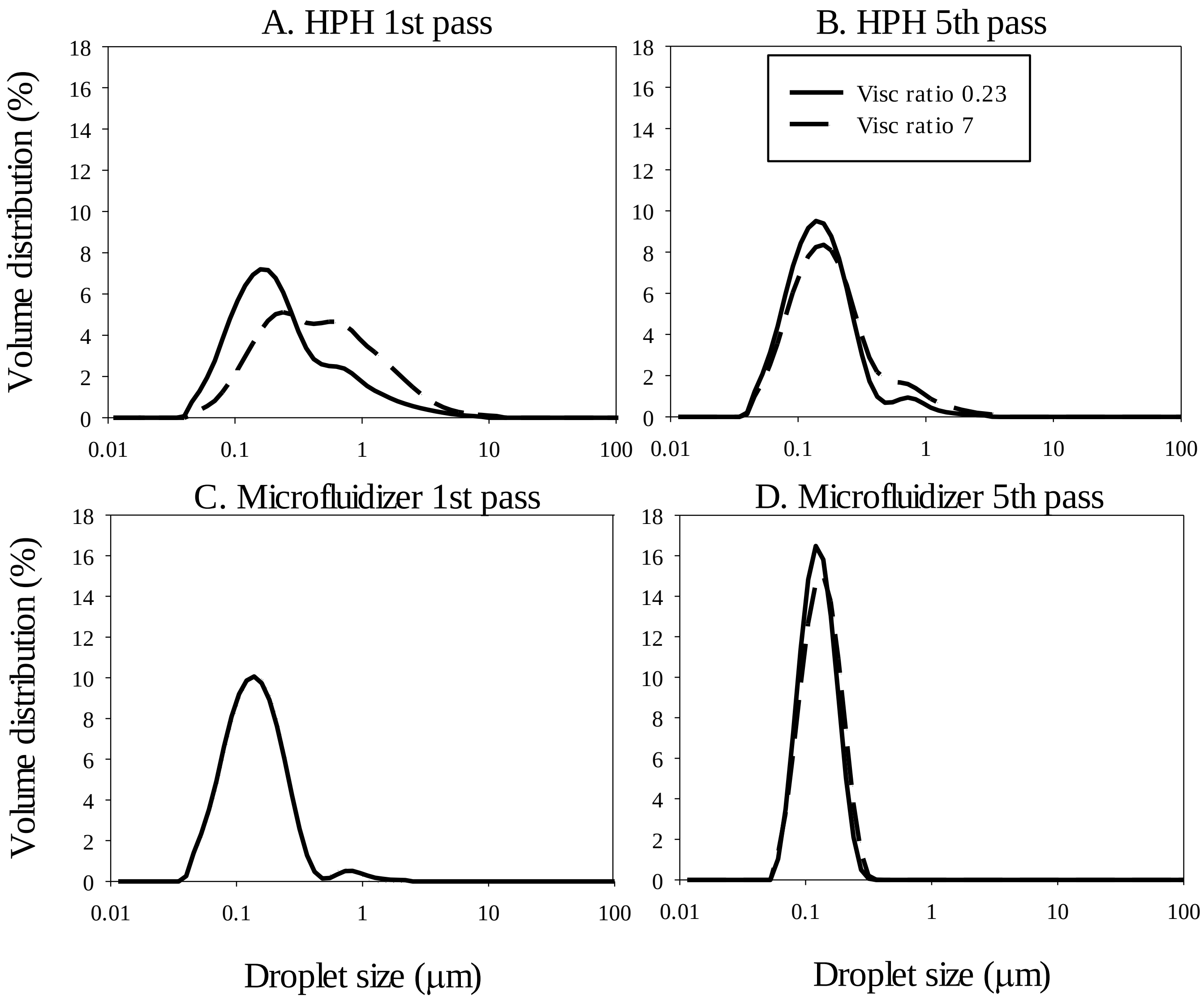


- Viscosity ratio
  - Variable Glycerol

Graph:

- 150 MPa after 5th pass with Tween 20 (3 wt.%)

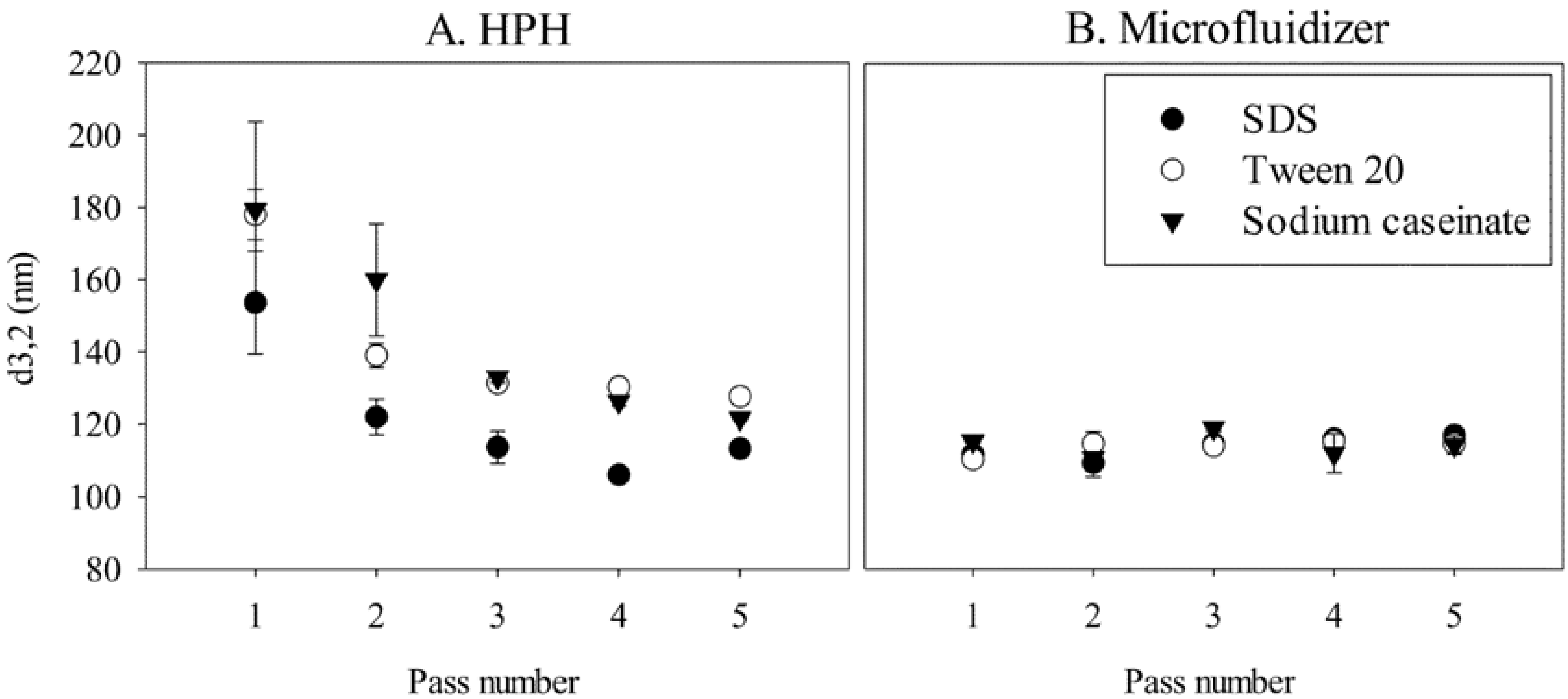
Breakup mechanisms



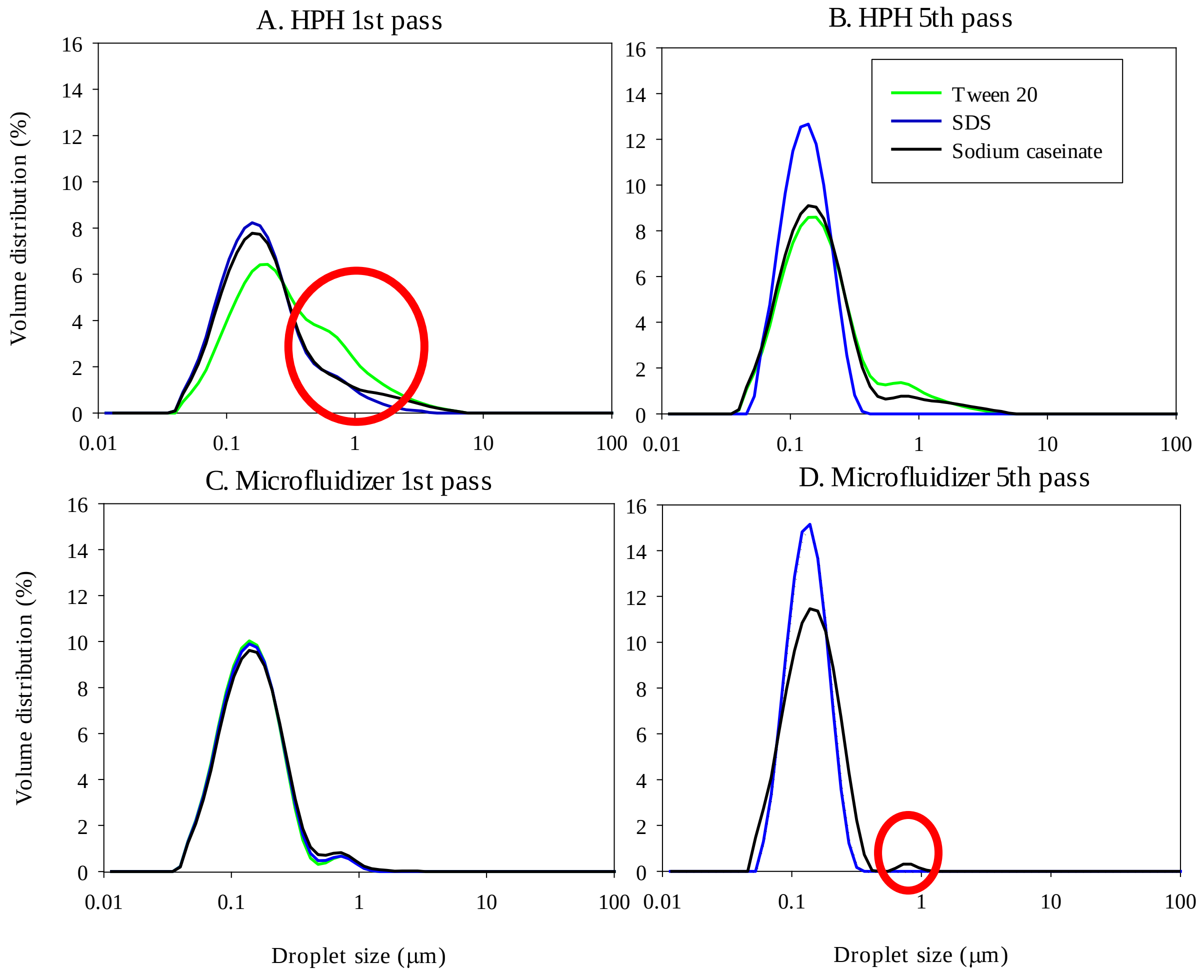
Emulsifier type

What type of emulsifier should be used?

Emulsifier type



Adsorption time OR adsorption energy?



FLOURY, J., DESRUMAUX, A. & LARDIÈRES, J. 2000. Effect of high-pressure homogenization on droplet size distributions and rheological properties of model oil-in-water emulsions. *Innovative Food Science & Emerging Technologies,* 1, 127-134.

Conclusions

	High Pressure Homogeniser	Microfluidizer
Final droplet size	~ 100 nm	~ 100 nm
Several passes required?	Yes (3-5 passes)	Yes (2 passes to remove bi-pass of flow)
Coalescence?	Yes	No
Dependent on viscosity ratio?	Yes – lower ratio leads to less coalescence	Unsure – further work required
Emulsifier choice	Tween 20 – high coalescence SDS – matches Microfluidizer performance	Independent. Beware of protein aggregation

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  - The University of Birmingham: Chemical engineering department
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