Platform for Continuous Microcapsules Manufacturing
Case study: solvent free complex coacervation (cc)

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Video

Aim

Going away from batch encapsulation and developing a platform for continuous microencapsulation. Easy manipulation of particle size, shell thickness and shape. Potato protein, Gelatine and Gum Arabic were used to create the shells via complex coacervation.

Background

- **MEMBRANE EMULSIFICATION (ME)** low energy method was used to generate uniform emulsion [1].
- High throughput generation of emulsions continuously has recently been demonstrated[2] .
- Industrial capsule production by CC normally completed by a batch process in stirred tanks (CSTR) and it is difficult to create uniform capsules with low surface oil after spray drying with Span<1 ($Span=(D_{90}-D_{50})/D_{10}$ measure of uniformity).
- In this work we used cross flow membrane system to create drops and then the oscillatory pulsed flow reactor (OPFR) to induce the crosslinking (to prevent drop breakage) and get the core-shell capsules followed by spray drying. Aim was to obtain free flowing powder with the least amount of free surface oil.

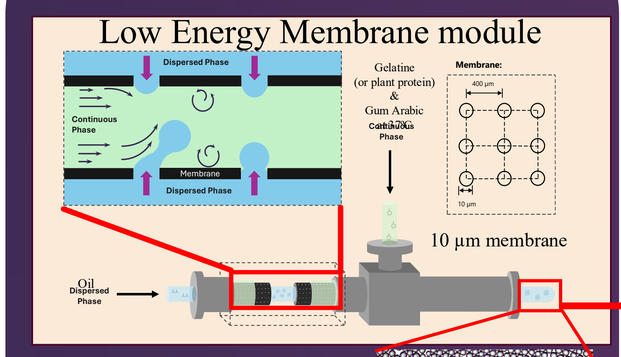
Novelty

- Scalable
- Low energy emulsification.
- Continuous production.
- Simple modular control.
- High encapsulation.

Methodology

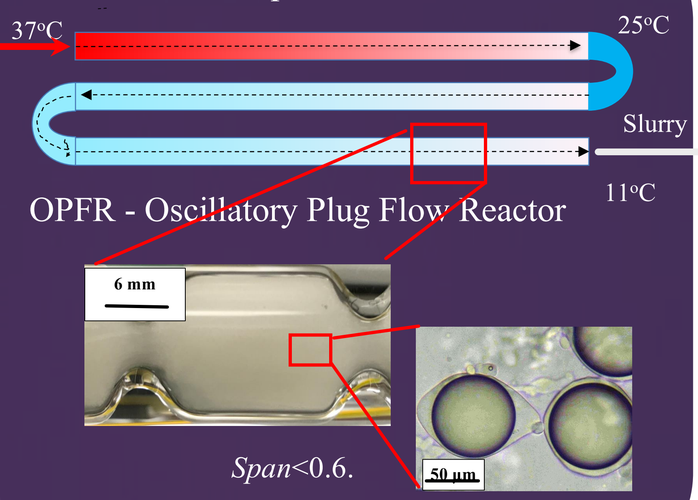
Continuous manufacturing drop to powder

Drop formation Emulsification



- Drop size controlled by the continuous phase flow.
- Drops (D_{50}) 50-350 µm.
- *Span*<0.6 changing shear on the membrane surface [2].

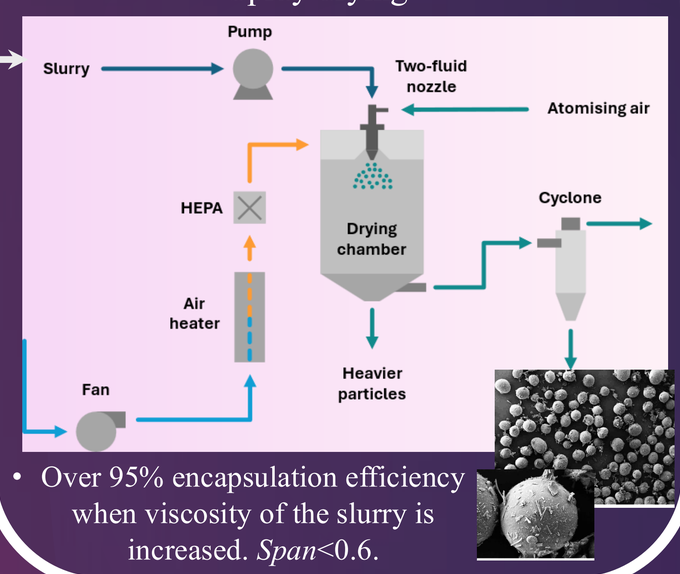
Shell formation Complex Coacervation



Span<0.6.

- OPFR cooling from 37 to 11°C (≤1°C min^{-1} [5]).

Powder formulation Spray drying

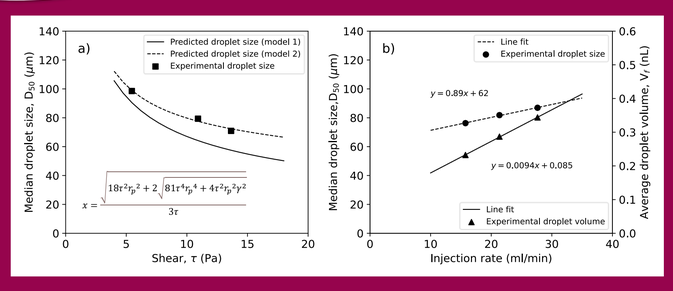


- Over 95% encapsulation efficiency when viscosity of the slurry is increased. *Span*<0.6.

Results

Drop formation[6]

Emulsification

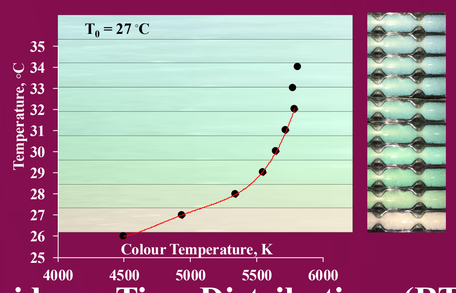


(a) Median droplet diameter D_{50} as a function of the shear τ at a dispersed phase flowrate of 16 ml/min and the predicted droplet diameter from the force balance model.

(b) Influence of the dispersed phase injection rate on the median droplet size D_{50} and the median droplet volume V_f at a constant shear of 10.9 Pa.

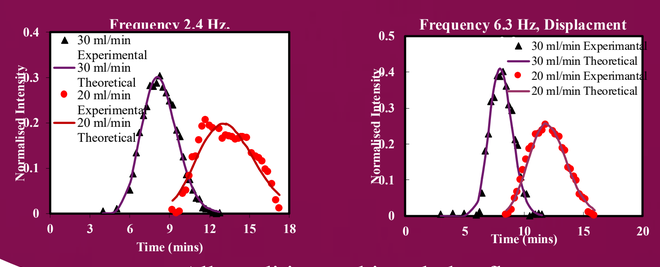
Shell formation

Temperature Calibration using home made capsules with thermotropic core



Residence Time Distributions (RTD)

- RTD inside the OFR was investigated at different: Flowrates, Oscillation frequencies (f), Displacements (d)

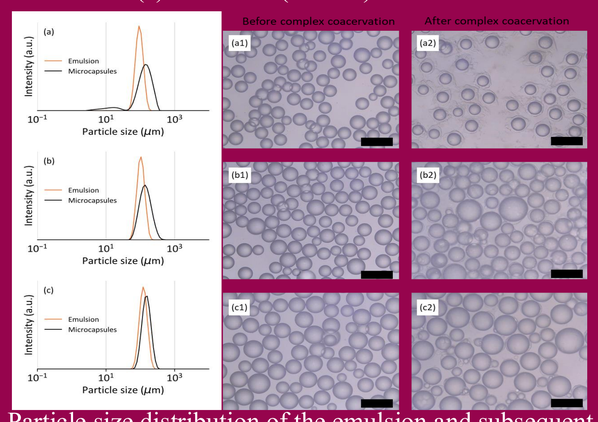


- All conditions achieved plug flow

Capsule

protein & polysaccharide (PP) : oil (O) ratio

(a) 0.570 and (b and c) 0.126.

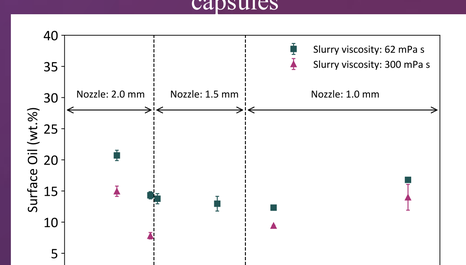


Particle size distribution of the emulsion and subsequent coacervate microcapsules produced via membrane emulsification.
Microscope images corresponding to the particle size distribution found on the left, where the scale bar corresponds to 200 µm.

Conclusion

- With higher shear smaller droplets produced using the same membrane system.
- Continuous capsule production was achieved, and it was possible to obtain the powder.
- Using the OPR uniformity was achieved maintained from Drops to Capsules.
- All tested oscillatory conditions gave **plug flow.**
- Increasing viscosity of the slurry by adding maltodextrin protected the capsules and less surface oil in the powder was observed (fig. on the right).

Surface oil of spray-dried coacervate capsules

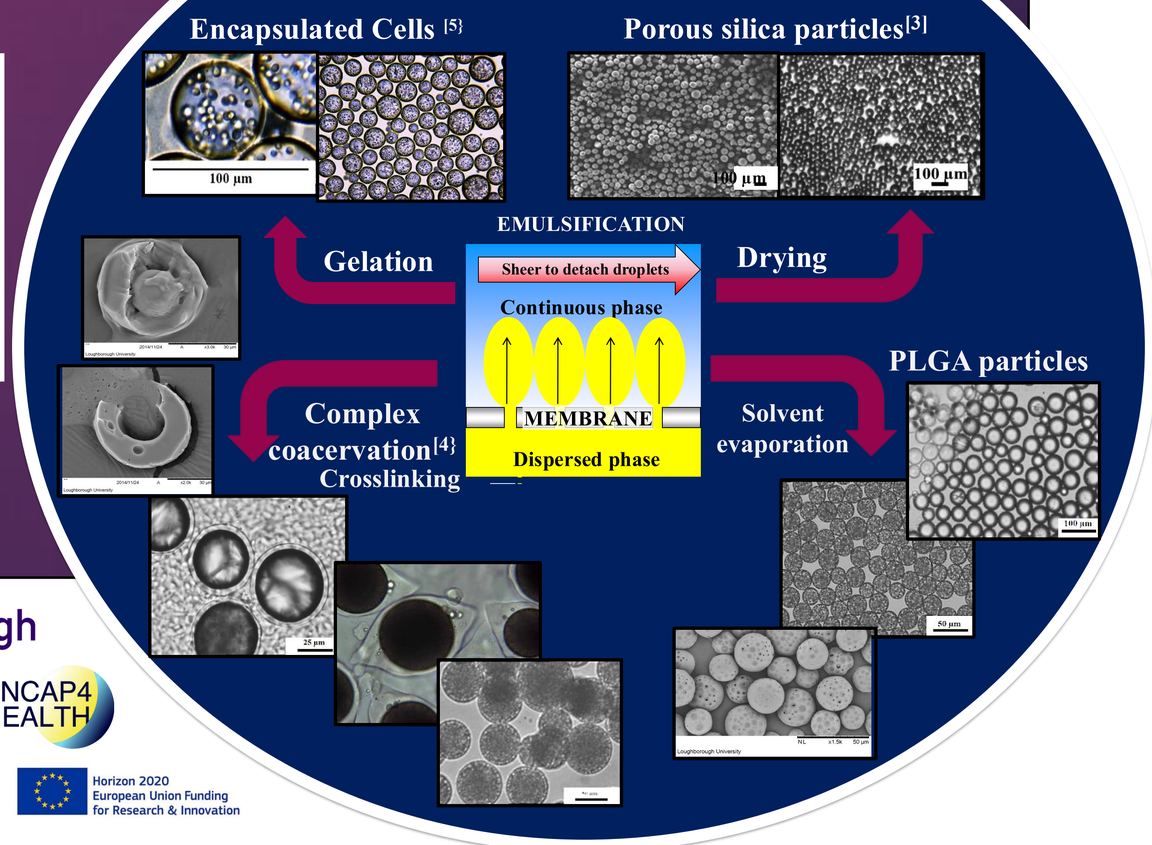


Surface oil of spray-dried coacervate capsules through a 1.0 mm, 1.5 mm and 2.0 mm nozzle and with a coacervate slurry viscosity of 62 mPa s and 300 mPa s.

Looking for Collaboration

On new formulations in Pharma, Food and Agri sector.
Scalable low sheer method presented can preserves shear sensitive compounds.

Some particles produced up to date



References

[1] Kosvintsev et al., (2005). [2] Holdich , **Dragosavac**, Williams & Trotter. (2020).
[3] **Dragosavac et al**. (2011). [4] Pu, Wolf, & **Dragosavac**. (2019).
[5] Morelli, Holdich, & **Dragosavac**, (2017). [6] Miramontes Subillaga, Heinert, Weissbrodt & **Dragosavac** (2024).

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