Oil-in-water Pickering emulsions by microfluidization using nanocellulose: Impact on *in vitro* lipid digestion

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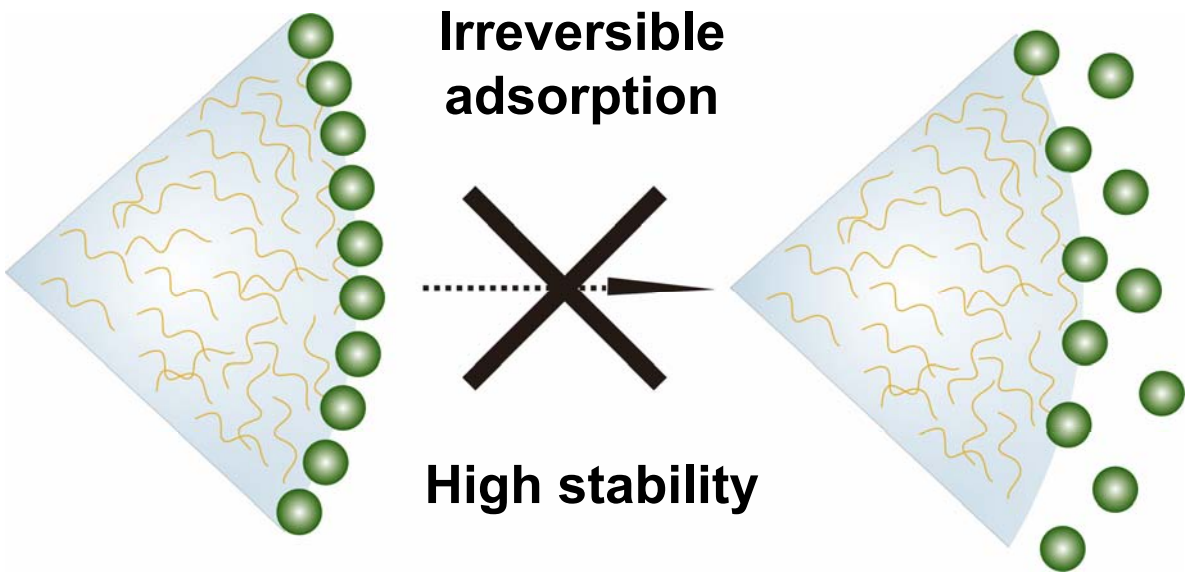
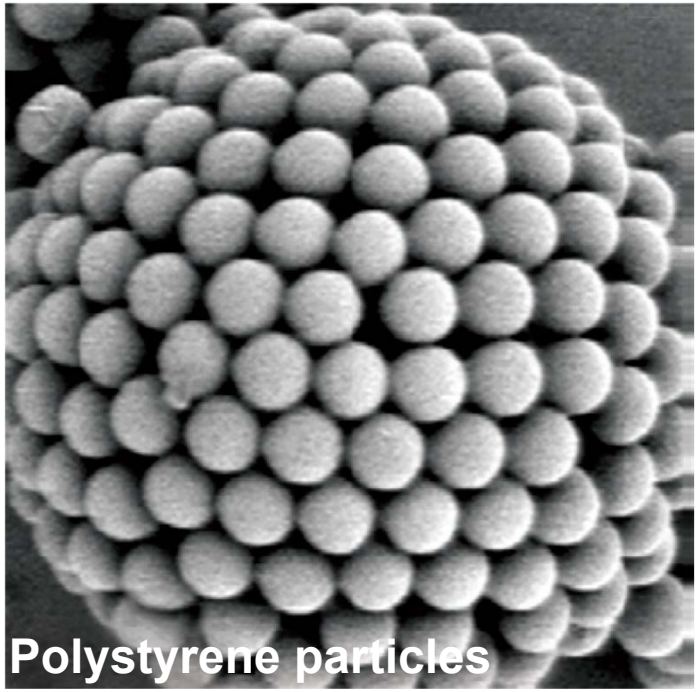
Interfacial stabilization - Emulsifier *vs* Pickering stabilizer

Conventional emulsifier: diffuse to interfaces and adsorb spontaneously

Particle stabilizer: non-spontaneous, requiring energy



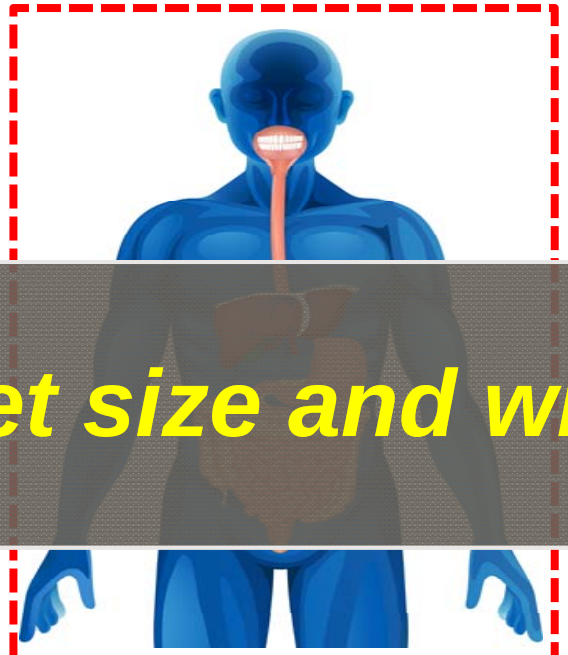


Annu. Rev. Food Sci. Technol. 2015. 6, 263.

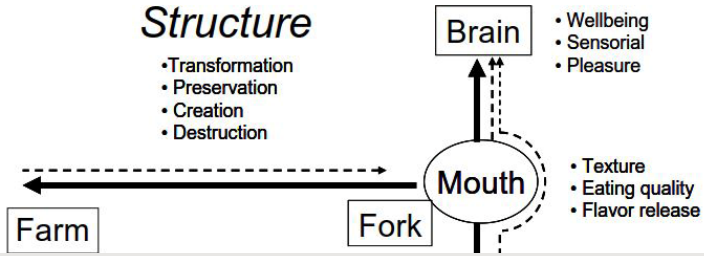
Particle type: non-spherical is possible

Pickering emulsions are attractive in functional foods

➢ **Why control lipid digestion *via* foods**



Digestion control



Lillford, Aguilera. Food Materials Science: Principles and Practice, Springer: 2007.

Large droplet size and wide size distribution

Protection & delivery

➢ **Polysaccharides nanoparticles**

Cellulose nanocrystals (CNC)

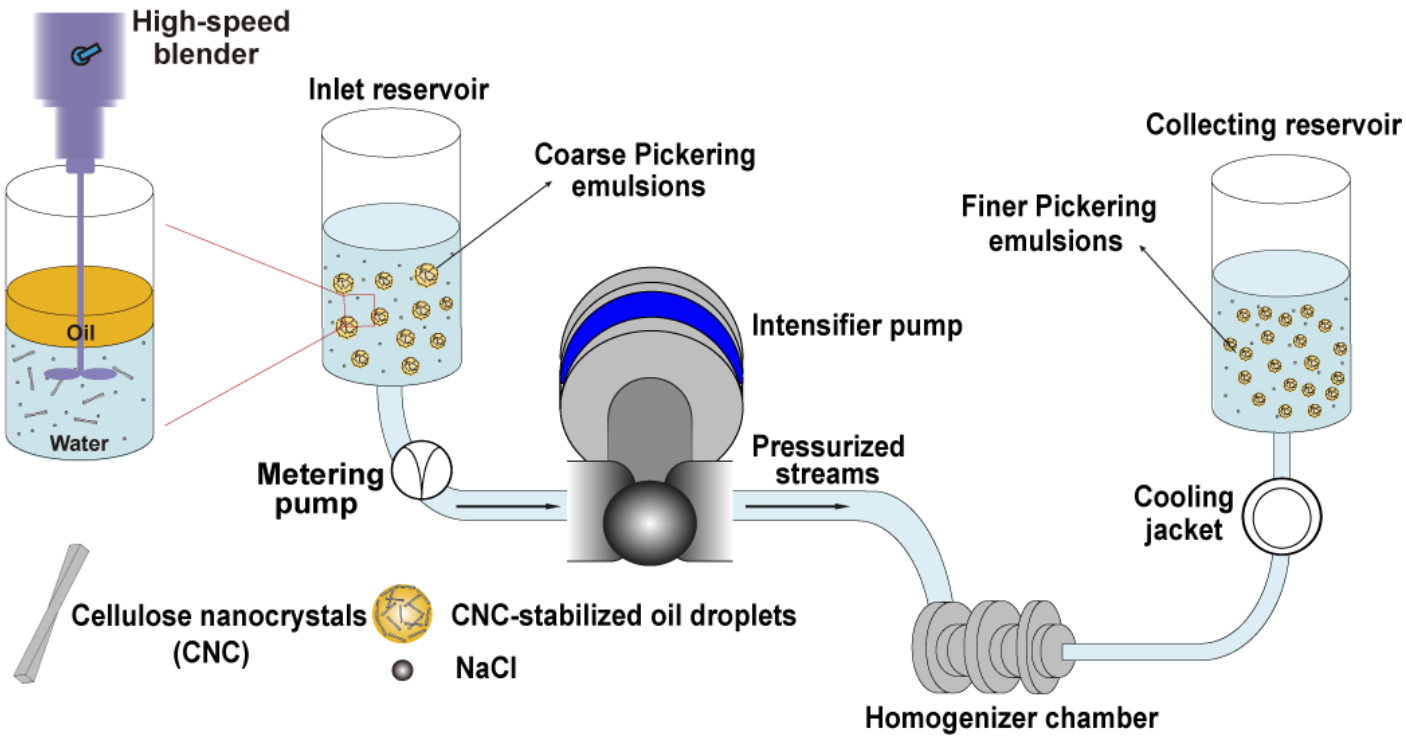
Green Chem. 2018, 20, 1571. Annu. Rev. Food. Sci. T. 2017, 8, 205. *Food Hydrocolloids 2016, 57, 178.*
J. Food Eng. 2017, 207, 35. *Food Hydrocolloids 2019, DOI: https://doi.org/10.1016/j.foodhyd.2019.04.038.*
Food Hydrocolloids 2019, DOI: https://doi.org/10.1016/j.foodhyd.2019.04.039

Can an approach achieve small, uniform CNC-stabilized Pickering droplets for controlling lipid digestion?

Photo by Long Bai

- **Microfluidization *vs* ultrasonication**
  - Higher energy
  - Tunable production
  - Large-scale batch

Emulsion preparation *via* microfluidization



- **Emulsion formulation**

  Aqueous phase: 90 wt% water of 0.05-2.0 wt% CNC and NaCl

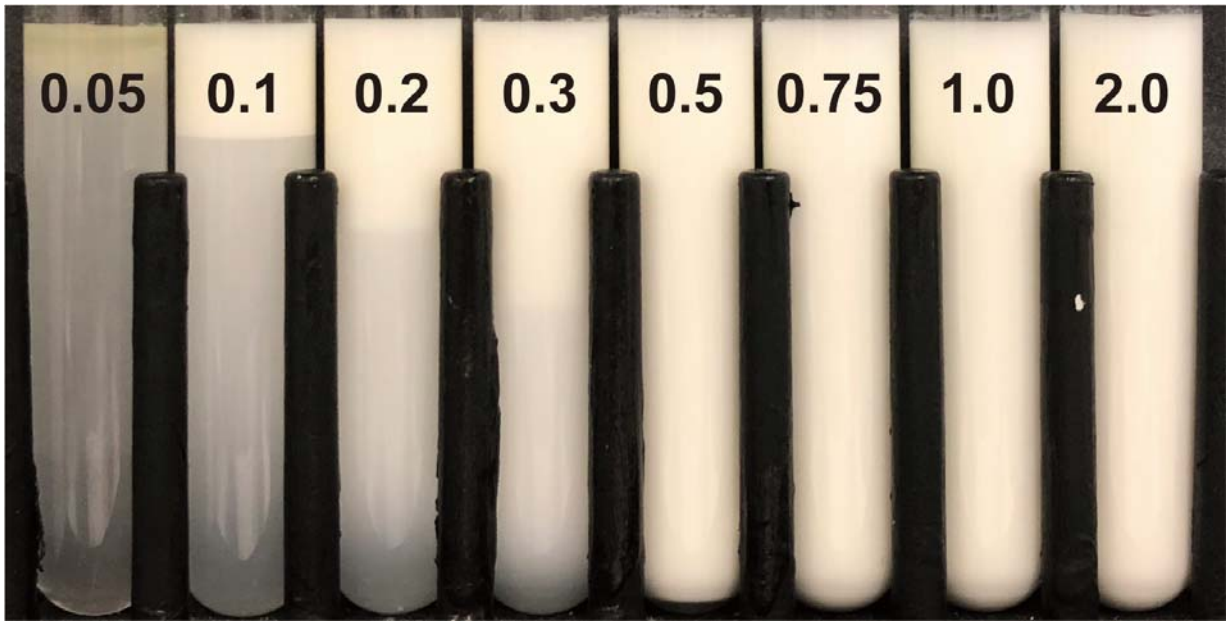
  Oil phase: 10 wt% corn oil

J. Colloid Interf. Sci. 2016, 466, 206.
Food Hydrocolloids 2019, DOI: https://doi.org/10.1016/j.foodhyd.2019.04.038
Food Hydrocolloids 2019, DOI: https://doi.org/10.1016/j.foodhyd.2019.04.039

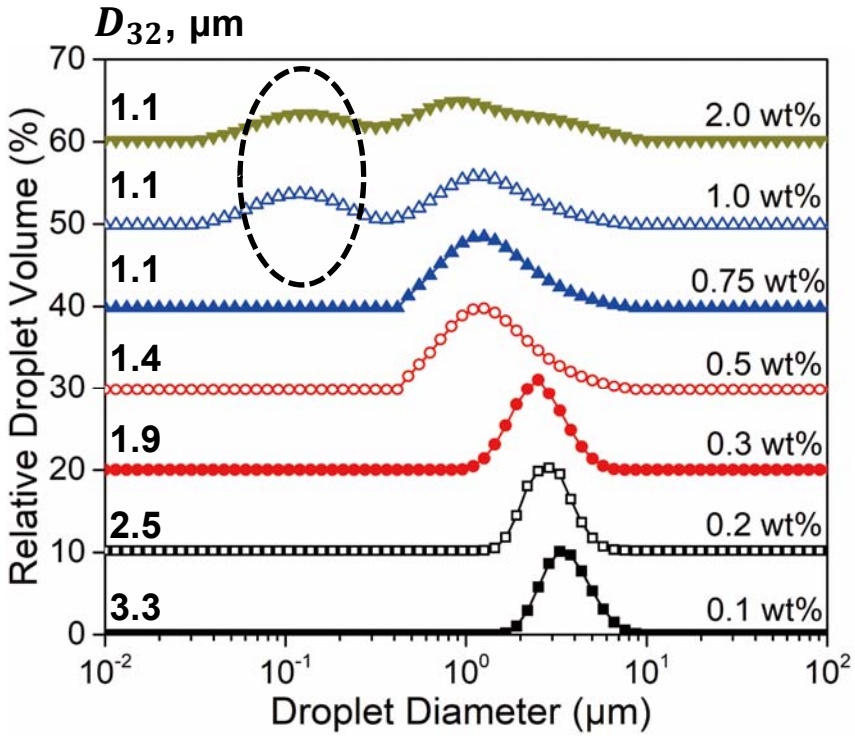
NaCl was used to partially screen the surface charge of CNCs, promoting their pack at the interfaces. Microfluidization condition was set as 3 pass at 13 kpsi pressure for all samples.

CNC stabilizes Pickering emulsions

Day-1

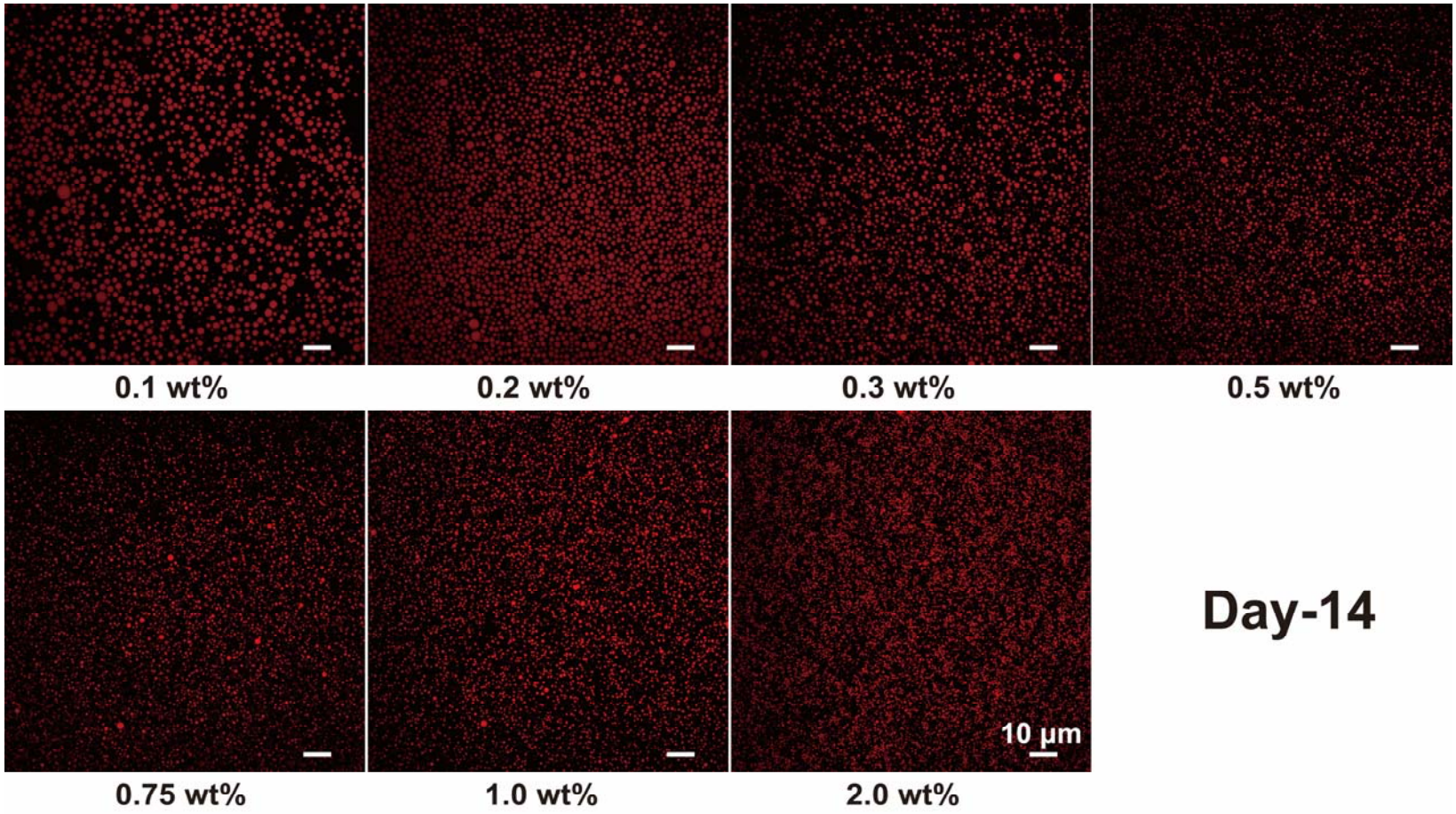


Oiling-off



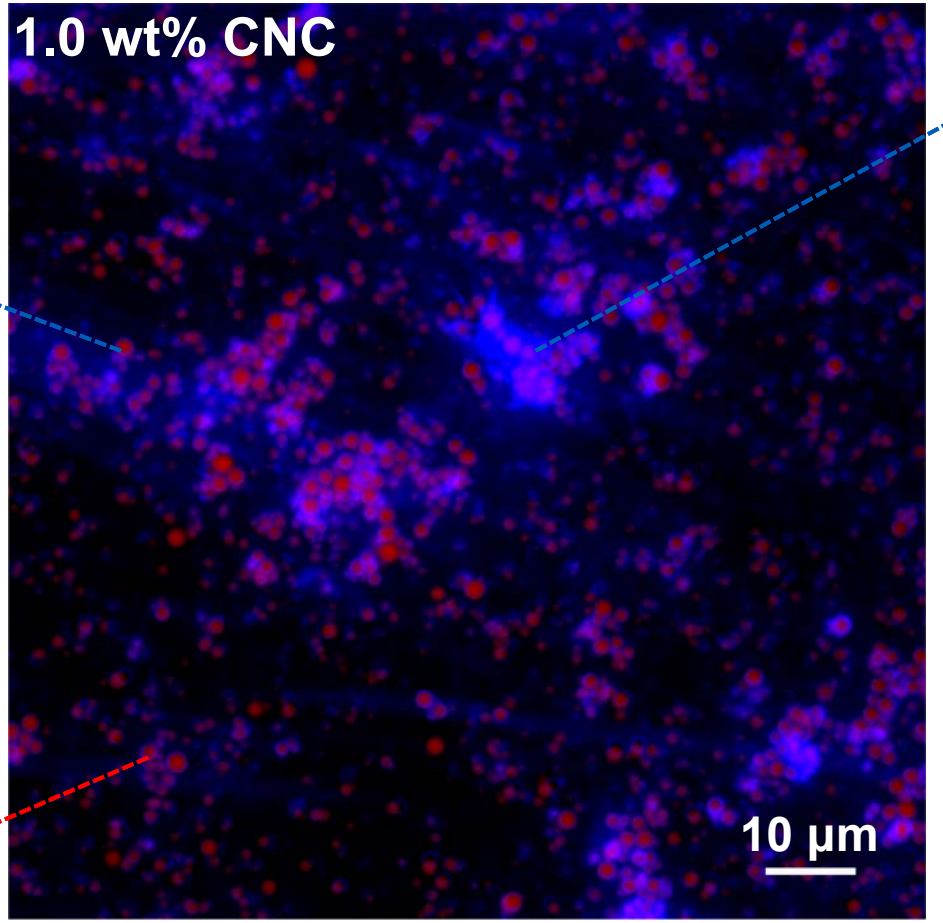
Droplets at micron size were produced over 0.75 wt% CNC

Uniform droplet distribution



Corn oil was dyed by Nile red prior to observation.

CNC locates at the interface



CNC

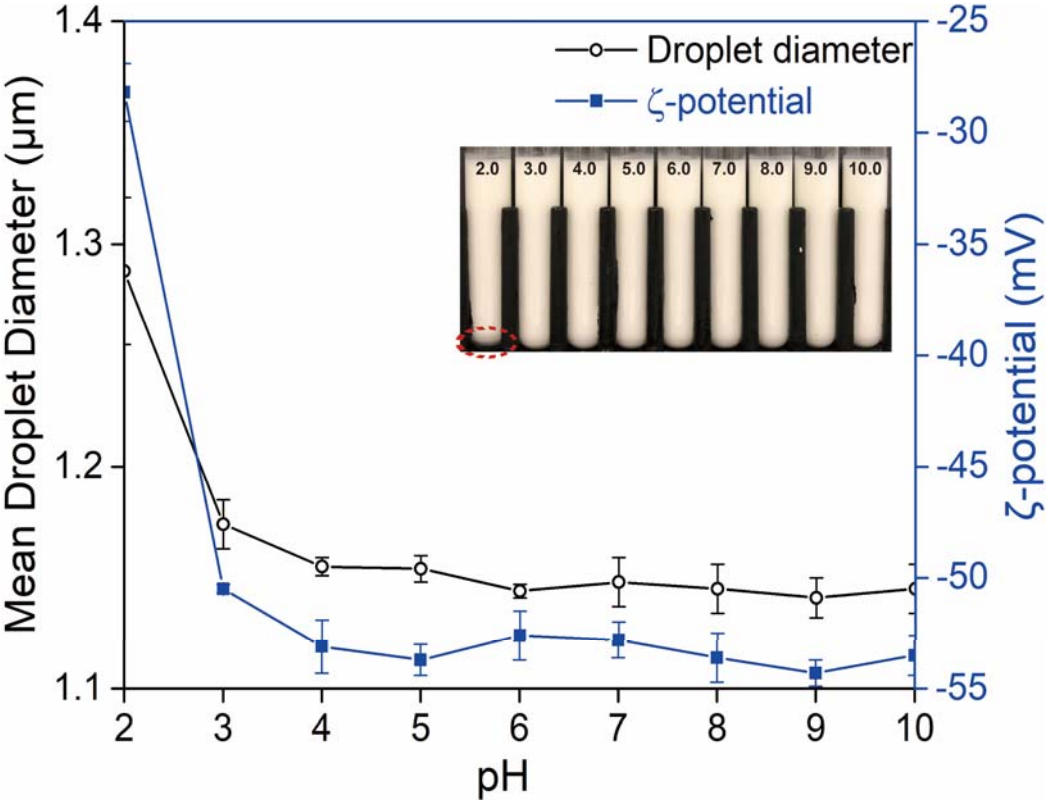
CNC

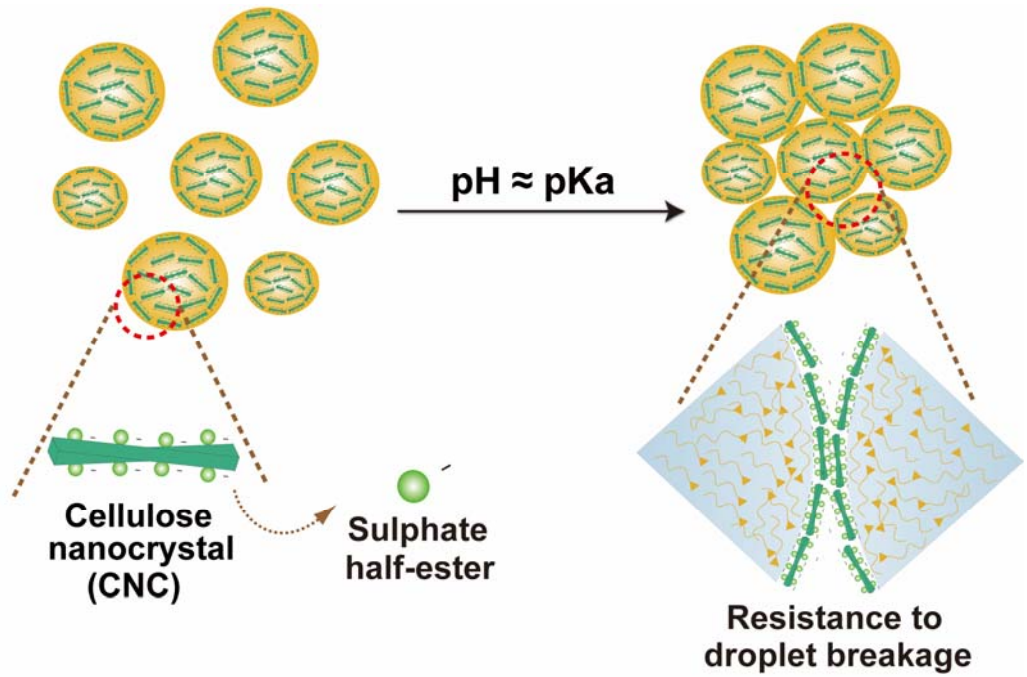
Oil phase

- CNC covers droplet surfaces (blue contour)
- CNC exists in aqueous phase at high level

Corn oil was dyed by Nile red, and CNC was stained by Calcofluor white.

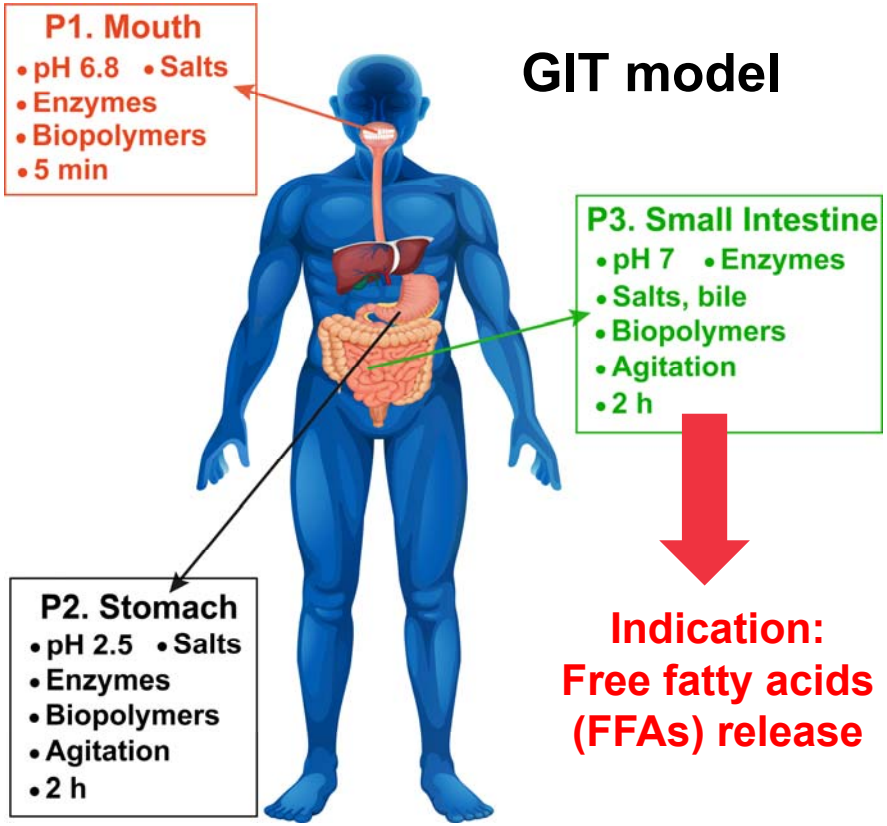
Stability against pH change





Droplets were stable against acidic condition

In vitro lipid digestion *via* gastrointestinal tract (GIT) model



GIT model

Indication: Free fatty acids (FFAs) release

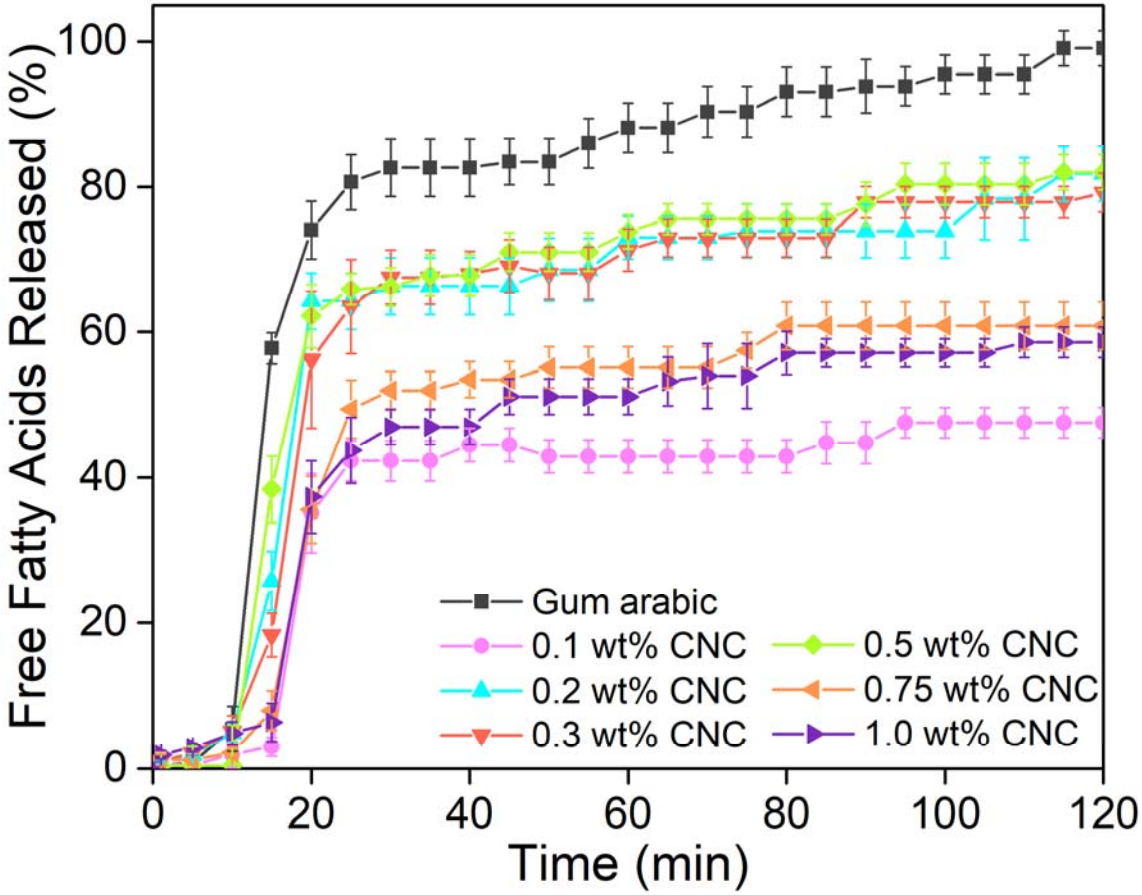
Adv. Colloid Interf. Sci. 2010, 159, 213.

Monitor FFAs release *via* pH-stat

Photo by Long Bai

The GIT model and corresponding procedure were developed in Prof. McClements lab, Umass Amherst, USA.

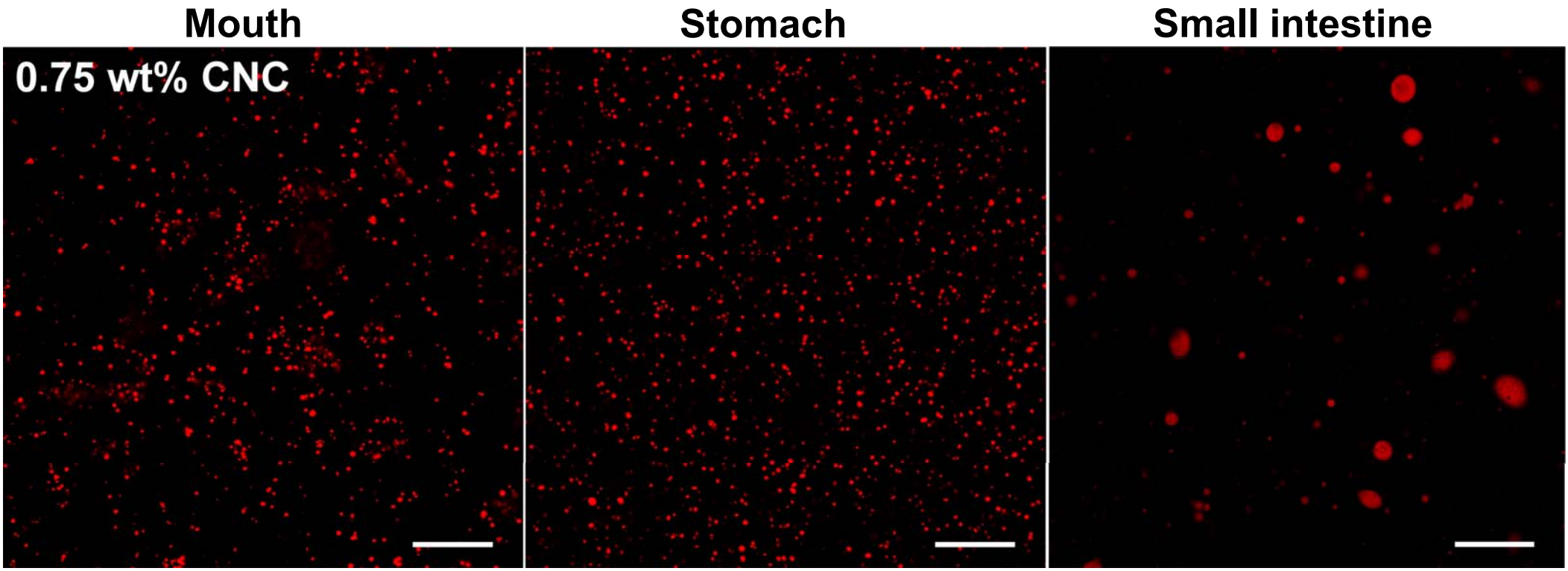
CNC-stabilized emulsions inhibit lipid digestion



- 40% reduction of FFAs release over 0.75 wt% CNC
- Droplet size influences FFAs release

Polysaccharides emulsifier, gum arabic, was used as a reference through the digestion test.

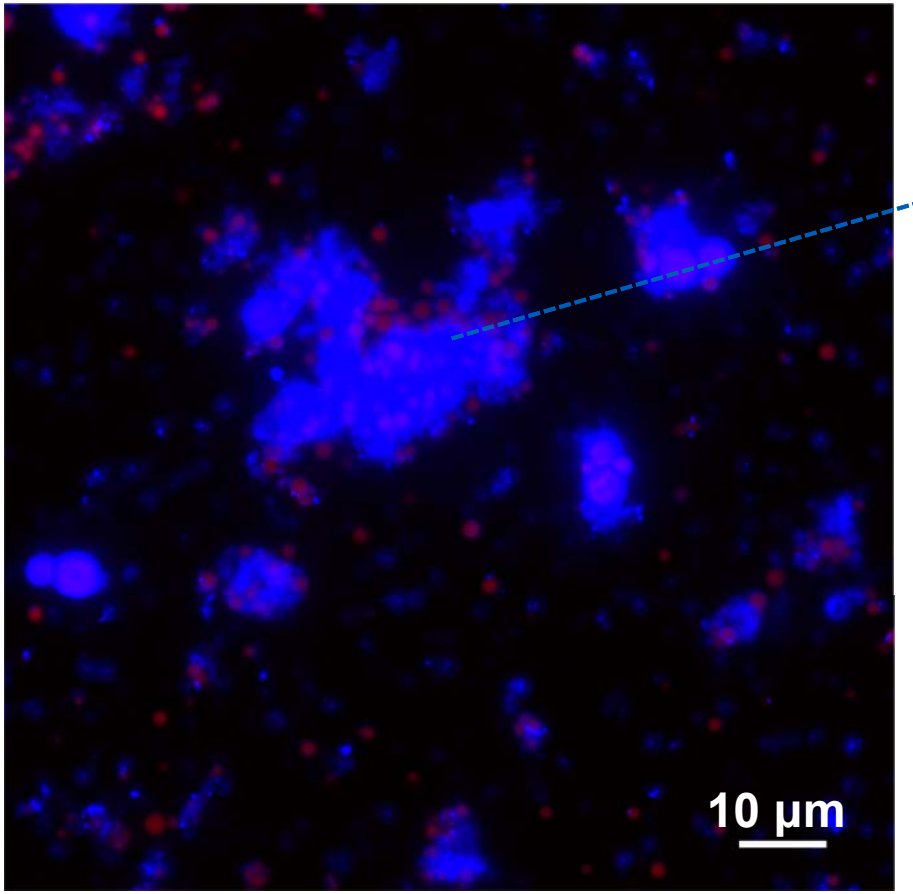
Droplets after digestion



Droplets retained original shape after 3-phase digestion

Corn oil was dyed by Nile red prior to observation.

CNC protects oil droplets from digesting enzyme

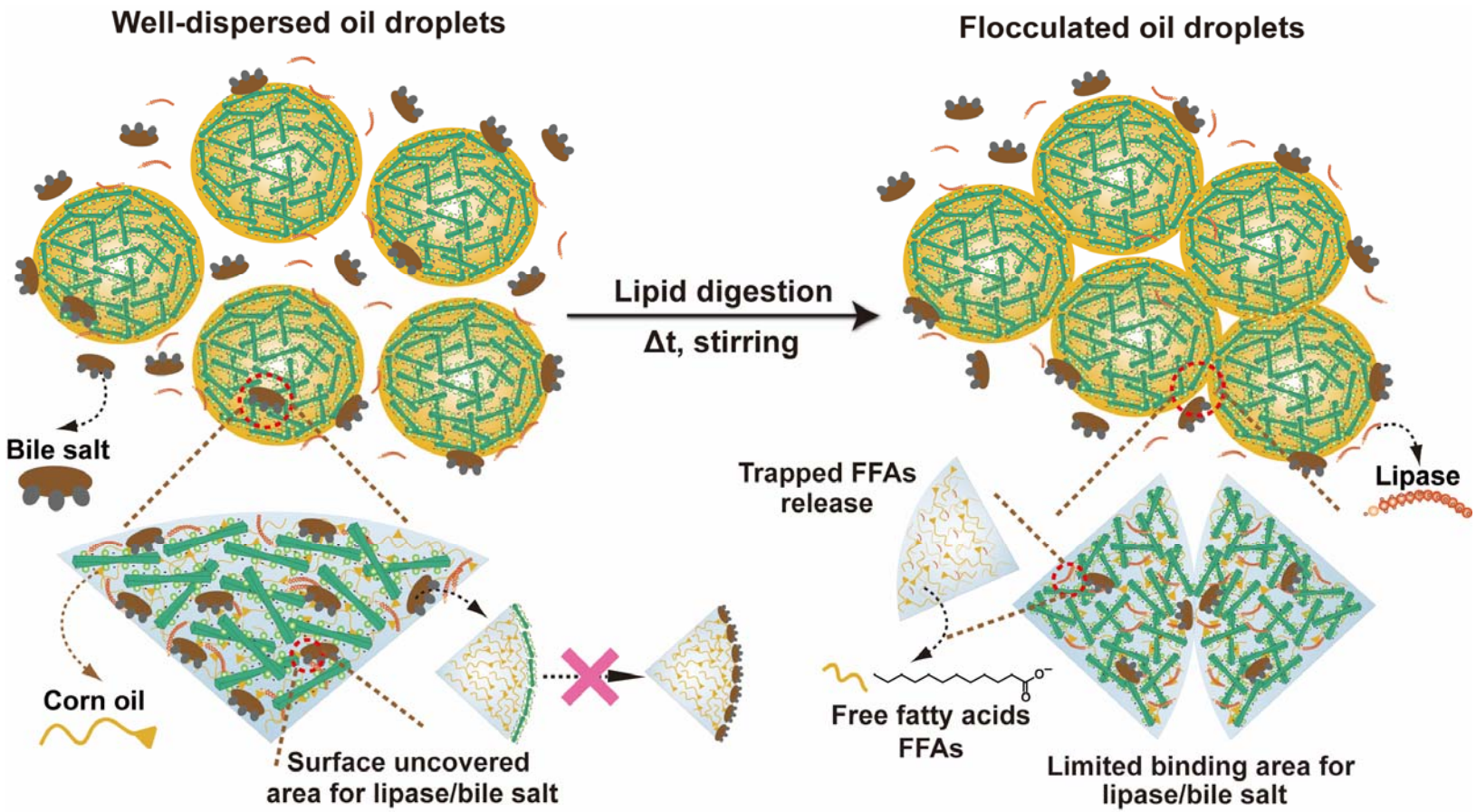


CNC surrounds flocculated droplets

- CNC covers oil droplets after digesting
- Total surface area of oil phase was reduced by CNC

Corn oil was dyed by Nile red, and CNC was stained by Calcofluor white.

Mechanism for controlling digestion in Pickering system



Conclusions

- Small-sized, uniformly-distributed CNC-stabilized Pickering emulsions were produced *via* microfluidization
- Droplets are stable at acidic condition
- Lipid digestion is reduced by approximately 40% over 0.75 wt% CNC
- Irreversible Pickering adsorption of CNC and reduced surface area of droplets ensure inhibition of digestion

Food Hydrocolloids 2019, DOI: https://doi.org/10.1016/j.foodhyd.2019.04.038
Food Hydrocolloids 2019, DOI: https://doi.org/10.1016/j.foodhyd.2019.04.039

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