Food-grade particles for emulsion stabilisation: Developing trends and challenges

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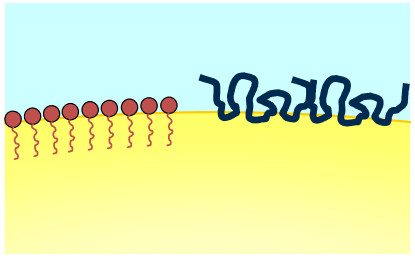
Introduction

- Food emulsions?

O/W emulsions

W/O emulsions

- Droplet size: < 1 μm to 100 μm
- Interface-dominated materials
- Conventional emulsifiers: LMWEs and/or proteins



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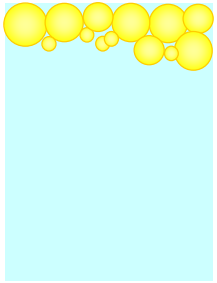
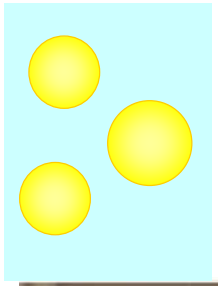
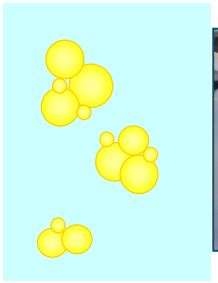
Introduction

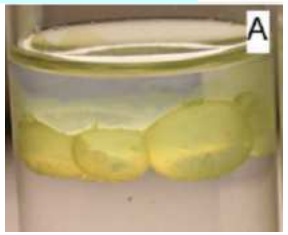
- Instability issues in food emulsions

Physical destabilisation





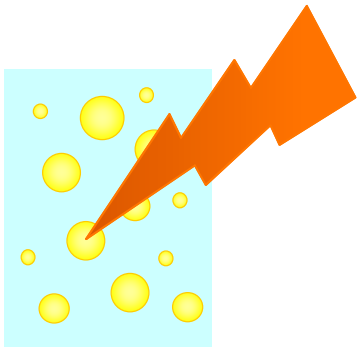




- Gravitational separation
- Droplet-droplet attractive interactions dominate
- Interfacial film ruptures easily

→ Texture, appearance defects

Chemical destabilisation



- Oxidation of unsaturated lipids and/or other labile lipophilic molecules

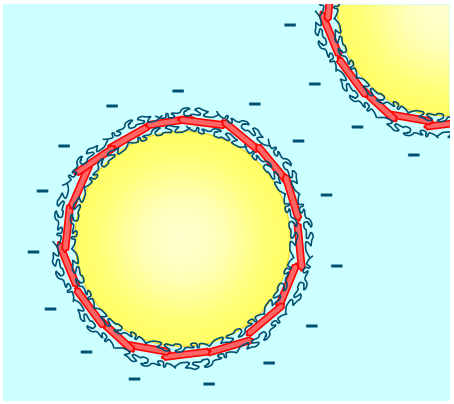
→ Degradation of sensory quality (rancidity)

→ Degradation of nutritional quality

Introduction

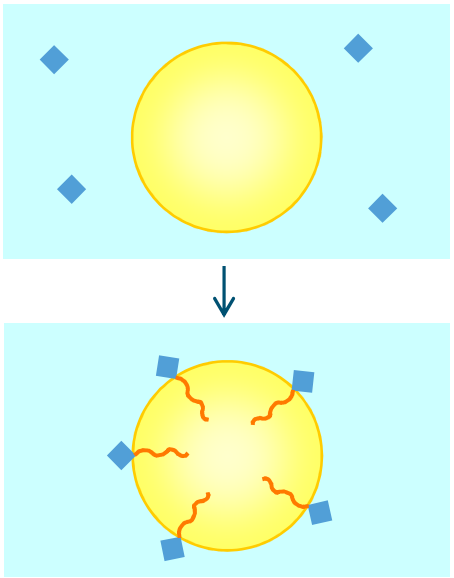
- There is a need to develop strategies to improve the stability of food emulsions

- Controlled interfacial design?



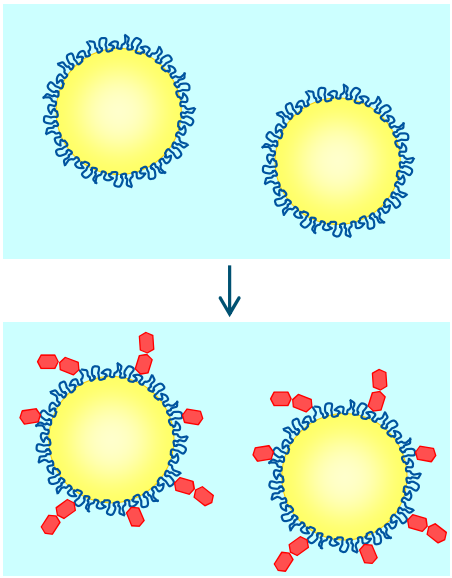
Multilayered emulsions

Guzey & McClements 2006, *Adv. Coll. Int. Sci.* 128, 227



Lipophilised antioxidants

Laguerre et al. 2015, *Crit. Rev. Food Sci. Nutr.* 55, 183



Glycated proteins

Delahaije et al. 2013, *Langmuir* 29, 15201

Introduction

- What about particles??

2010 Food emulsions and foams: Stabilization by particles

Eric Dickinson *

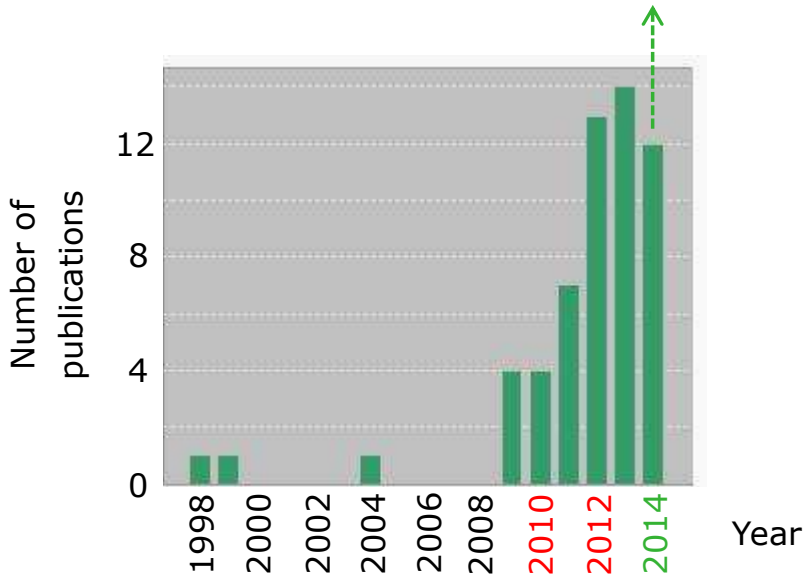
"the proportion of this research that is directly applicable to foods is necessarily small"

2012 **Use of nanoparticles and microparticles in the formation and stabilization of food emulsions**

Eric Dickinson*

"for Pickering stabilization of food-grade O/W emulsions, various kinds of dispersed particles of biological origin have recently been demonstrated as useful"

Web of Science, "Pickering, food, emulsion" as topic (Sept. 2014):



Dickinson 2010, *Curr. Opin. Coll. Int. Sci.* 15, 40

Dickinson 2012, *Trends Food Sci. Technol.* 24, 4

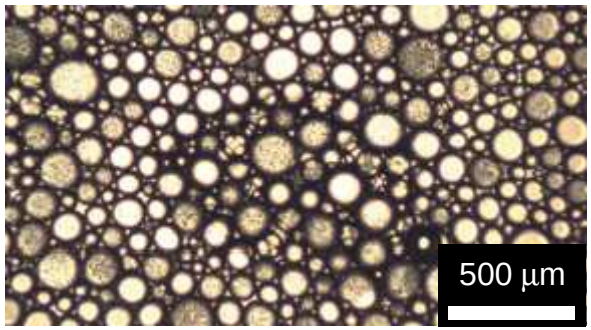
Food-grade particles

- Inorganic (yet food-grade) particles:
  - Silica-based particles (SiO_2) E 551
  - Titanium-based particles (TiO_2) E 171
  - Calcium carbonate particles ($CaCO_3$) E 170

- But, concerns have been raised, e.g.:
  - Biopersistence, potential toxicity
  - Not environment-friendly
  - Synthetic food additives

Food-grade particles

- Protein-based particles:

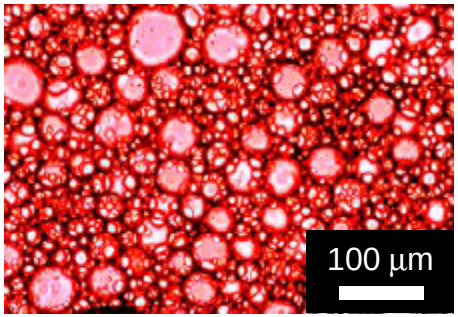


Sunflower O/W emulsion

Zein particles (from corn)

Particle size ~ 80 nm, droplet size ~ 100 µm

de Folter et al. 2012, *Soft Matter* 8, 6807



Soybean O/W emulsion

Soy protein nanoparticles

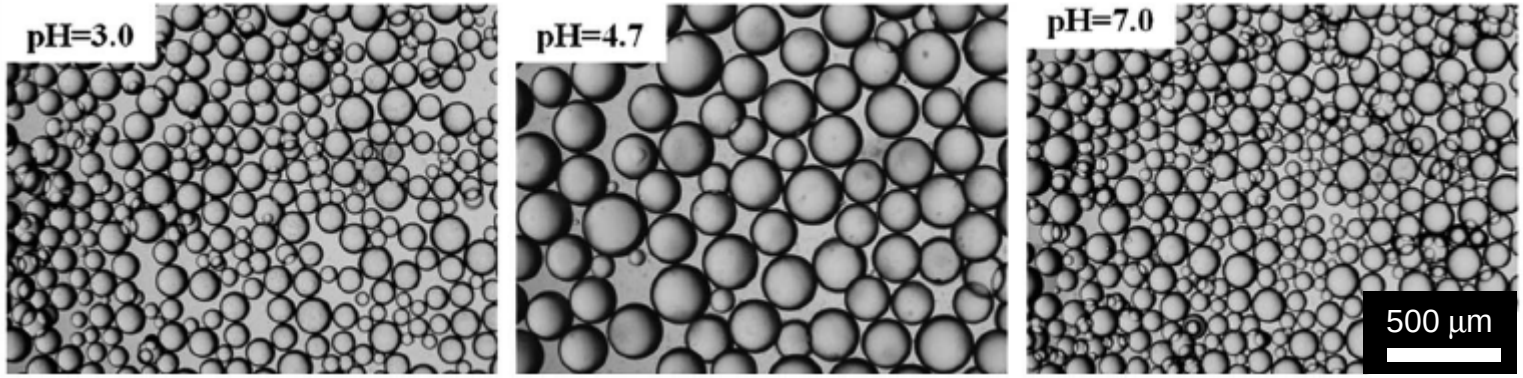
Particle size ~ 50-200 nm, droplet size ~ 50 µm

Liu & Tang 2013, *J. Agric. Food Chem.* 61, 8888

Medium chain triglyceride O/W emulsion

Whey protein microgels

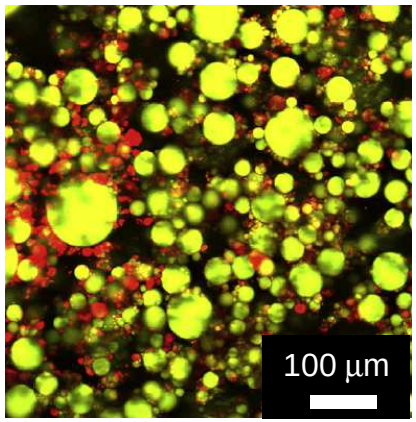
Particle size ~ 200 nm, droplet size ~ 100-200 µm



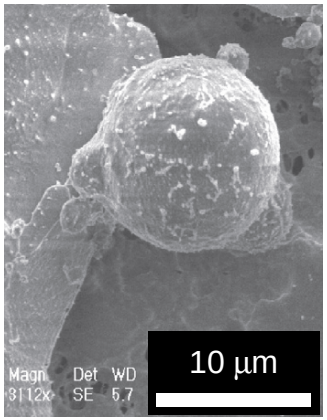
Destribats et al. 2014, *Soft Matter* 10, 6941

Food-grade particles

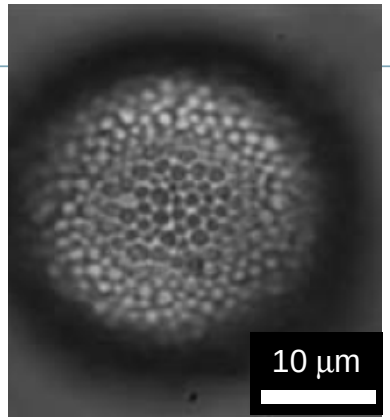
- Carbohydrate-based particles:



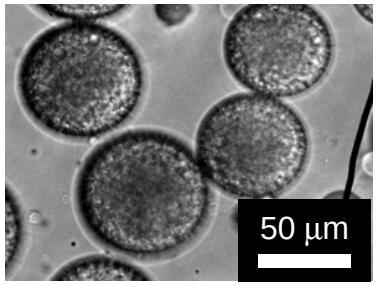
Tetradecane/W emulsion
OSA starch particles
Particle size ~ 1-20 µm, droplet size 20-30 µm
Murray et al. 2011, *Food Hydrocoll.* 25, 627



Sunflower O/W emulsion
OSA starch particles
Particle size ~ 120 nm, droplet size ~ 5-20 µm
Kargar et al. 2012, *J. Colloid. Int. Sci.* 366, 209



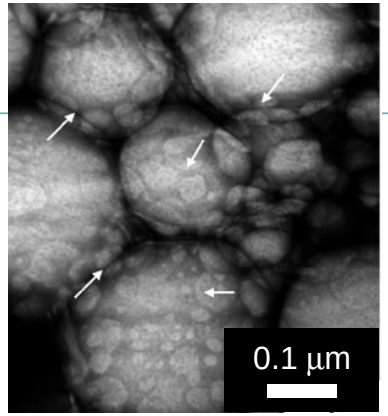
Medium chain triglyceride O/W emulsion
OSA starch particles
Particle size ~ 0.6-10 µm, droplet size ~ 10-100 µm
Rayner et al. 2012, *Faraday Disc.* 158, 139



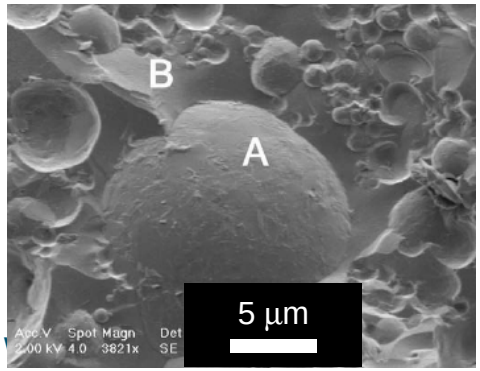
Corn O/W emulsion
Chitin nanocrystals
Particle size 240x20 nm, droplet size ~ 10-100 µm
Tzoumaki et al. 2011, *Jfood Hydrocoll.* 25, 1521

Food-grade particles

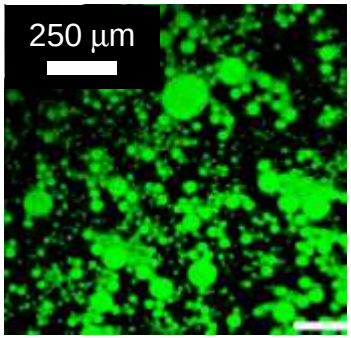
- Lipid-based particles:



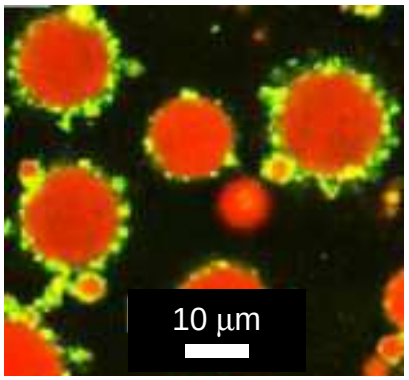
Canola O/W emulsion
Solid lipid nanoparticles (Citrem)
Particle size 25x150 nm, droplet size ~ 0.5 µm
Gupta & Rousseau 2012, *Food Funct.* 3, 302



W/Sunflower oil emulsion
Triglyceride crystals
Submicron sintered crystals, droplet size ~ 3-10 µm
Frasch-Melnik et al. 2010, *J. Food Eng.* 98, 437



Soybean O/W emulsion
Phytosterol-based particles
Particle size ~ 0.04-30 µm,
droplet size ~ 50-250 µm
Liu & Tang 2014, *J. Agric Food Chem.* 62, 5133

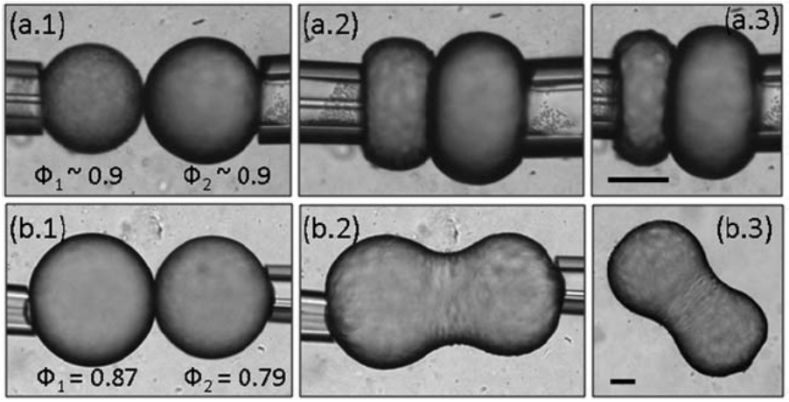


Hexadecane/W emulsion
Hexadecane nanodroplets (stabilised with casein)
Particle size ~ 150 nm, droplet size ~ 2-25 µm
Ye et al. 2013, *Langmuir.* 29, 14403

Potential benefits for food emulsions

- Interfacial barrier:
  - Against physical destabilisation

Pawar et al. 2011, *Soft Matter* 7, 7710



  - Against chemical degradation?

Lipid oxidation in emulsions stabilised with:
- Tween 20 > Silica particles > Caseinate
- OSA starch particles > MCC particles

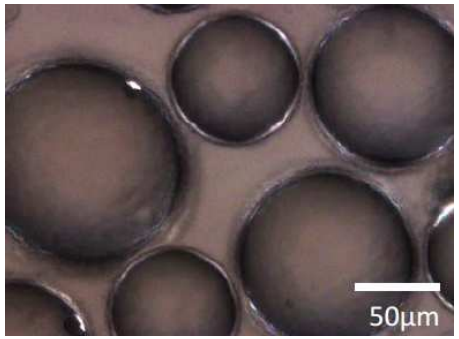
Kargar et al. 2011, *J. Colloid Int. Sci.* 357, 527

Kargar et al. 2012, *J. Colloid Int. Sci.* 366, 209

  - Controlled fate in the GI tract?

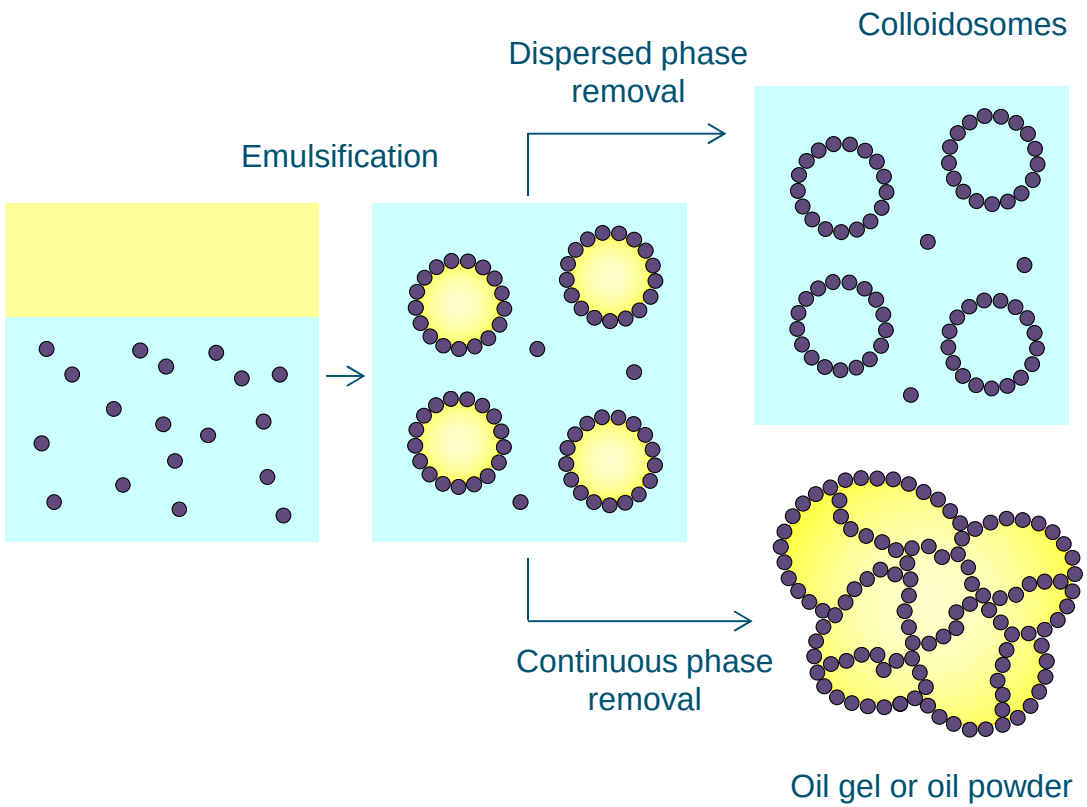
Heat-induced gelatinisation of adsorbed starch particles → interfacial layer that resists digestion

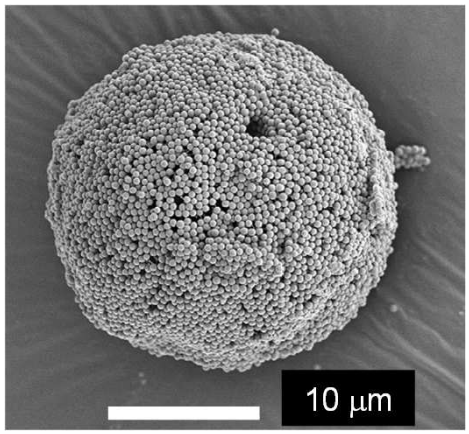
Timgren et al. 2011, *Proc. Food Sci.* 1, 95

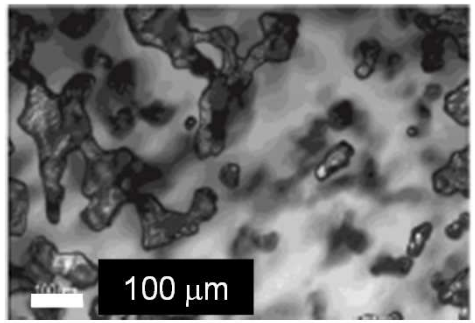


Potential benefits for food emulsions

- Templates for new food materials







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Rossier-Miranda et al. 2009, *Colloids Surf. A* 343, 43

Adelmann et al. 2012, *Langmuir* 28, 1694

Challenges

- (Nano)particles in food?

Review

Edible lipid nanoparticles: Digestion, absorption, and potential toxicity

David Julian McClements *

Protein nanostructures in food – Should we be worried?

Jared K. Raynes[a,b], John A. Carver[c,d], Sally L. Gras[e] and Juliet A. Gerrard[a,f,g,h,*]

Nanodelivery of Bioactive Components for Food Applications: Types of Delivery Systems, Properties, and their Effect on ADME Profiles and Toxicity of Nanoparticles

T. Borel and C.M. Sabliov*

European commission recommendation (2011):

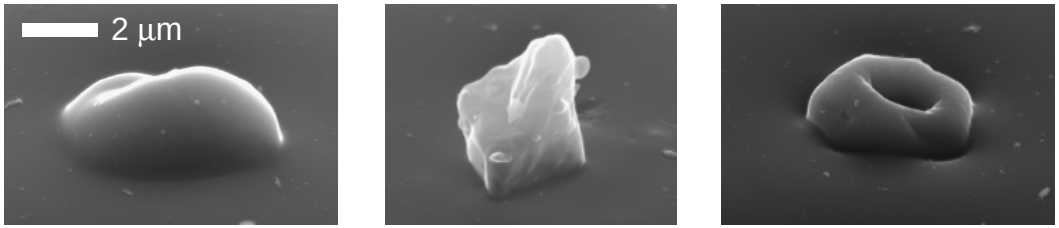
Nanomaterial = "a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm".

In foods: "all ingredients present in the form of engineered nanomaterials shall be clearly indicated in the list of ingredients. The names of such ingredients shall be followed by the word 'nano' in brackets".

Bleeker et al. 2012, RIVM letter report 601358001/2012

Challenges

- Prediction of particle performance?



Paunov et al. 2007, *J. Colloid Int. Sci.* 312, 381

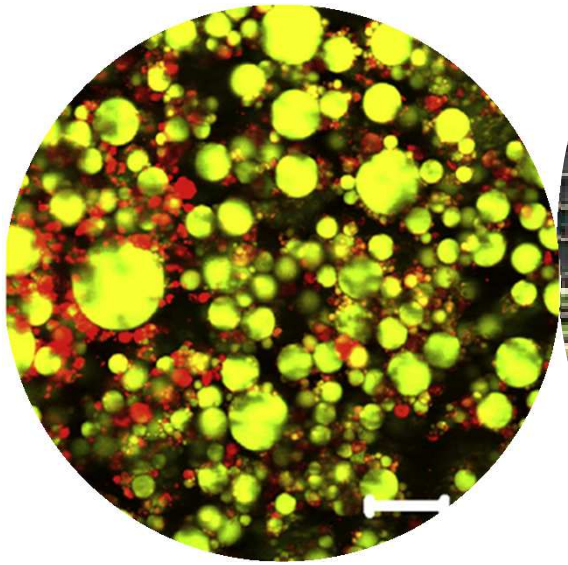
- Range of applications, effect of the emulsion composition

- Kinetic stability of biodegradable particles at fluid interfaces?

Conclusions

- Strong interest in particle-stabilised emulsions for food applications has emerged over the past 5 years
- Many advantages can be foreseen: surfactant-free label, physical stability, barrier interfaces, templates for new materials, etc.
- But... Some technological and health-related questions need to be further addressed

Thank you!



See also:

Berton-Carabin, C. & Schroën, K. (2014) Pickering emulsions for food applications: Background, trends and challenges. Accepted for publication in *Annual Review of Food Science and Technology*.

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