Article:
Sarkar, A orcid.org/0000-0003-1742-2122, Zhang, S, Holmes, M et al. (1 more author) (2019) Colloidal aspects of digestion of Pickering emulsions: Experiments and theoretical models of lipid digestion kinetics. Advances in Colloid and Interface Science, 263. pp. 195-211. ISSN 0001-8686

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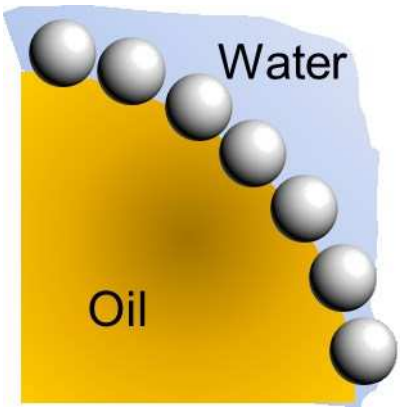
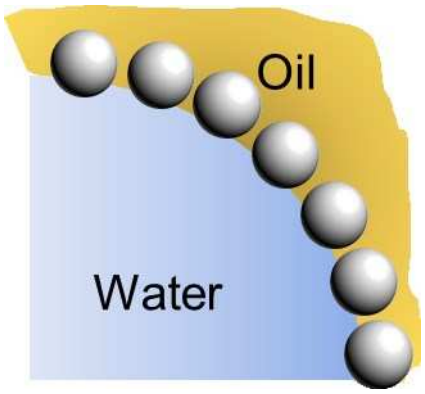
Figure 1.

(a)



(b)



(c)

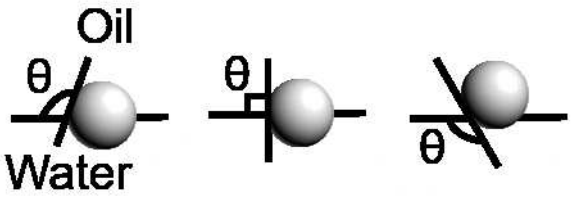


Figure 2.

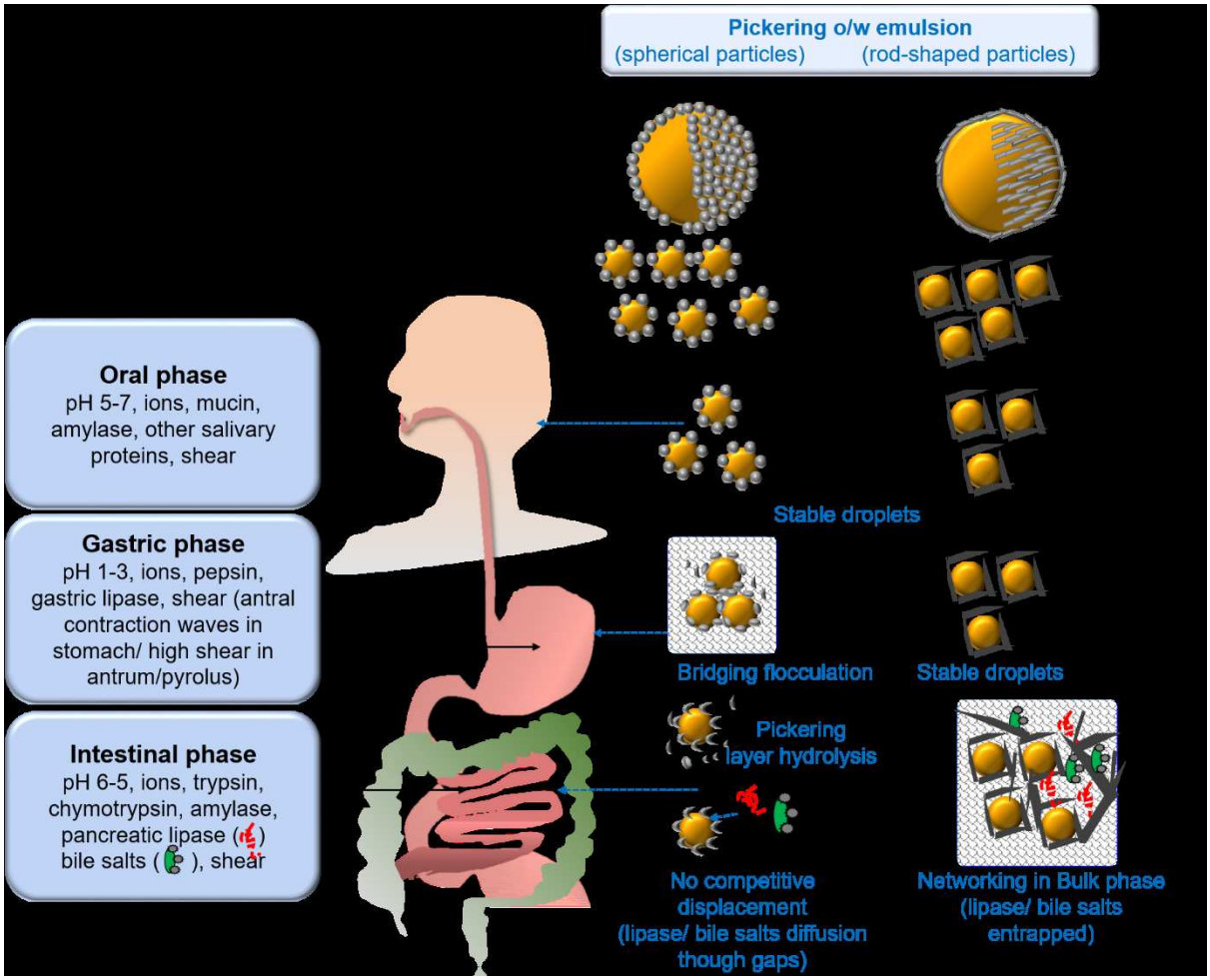
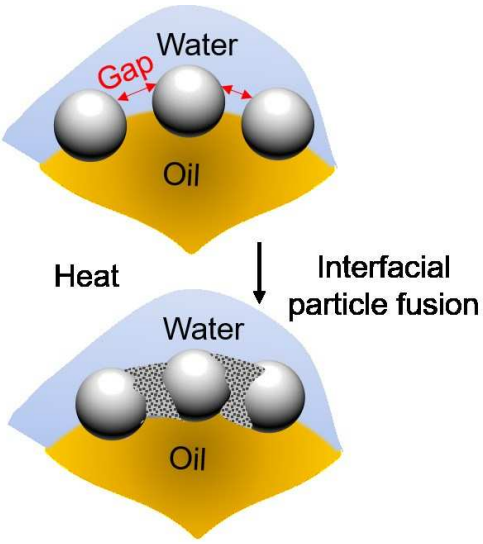
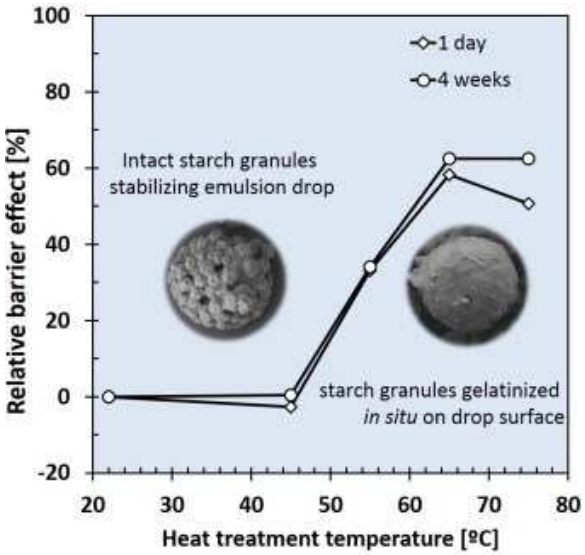

Pickering o/w emulsion
(spherical particles)
(rod-shaped particles)
Oral phase
pH 5-7, ions, mucin, amylase, other salivary proteins, shear
Gastric phase
pH 1-3, ions, pepsin, gastric lipase, shear (antral contraction waves in stomach/ high shear in antrum/pyrolus)
Intestinal phase
pH 6-5, ions, trypsin, chymotrypsin, amylase, pancreatic lipase
bile salts
, shear
Stable droplets
Bridging flocculation
Stable droplets
Pickering layer hydrolysis
No competitive displacement (lipase/ bile salts diffusion though gaps)
Networking in Bulk phase (lipase/ bile salts entrapped)

Figure 3.

(a)


Water
Gap
Oil
Heat
Interfacial particle fusion
Water
Oil

(b)


1 day
4 weeks
Intact starch granules stabilizing emulsion drop
starch granules gelatinized in situ on drop surface
Relative barrier effect [%]
Heat treatment temperature [ºC]

(c)

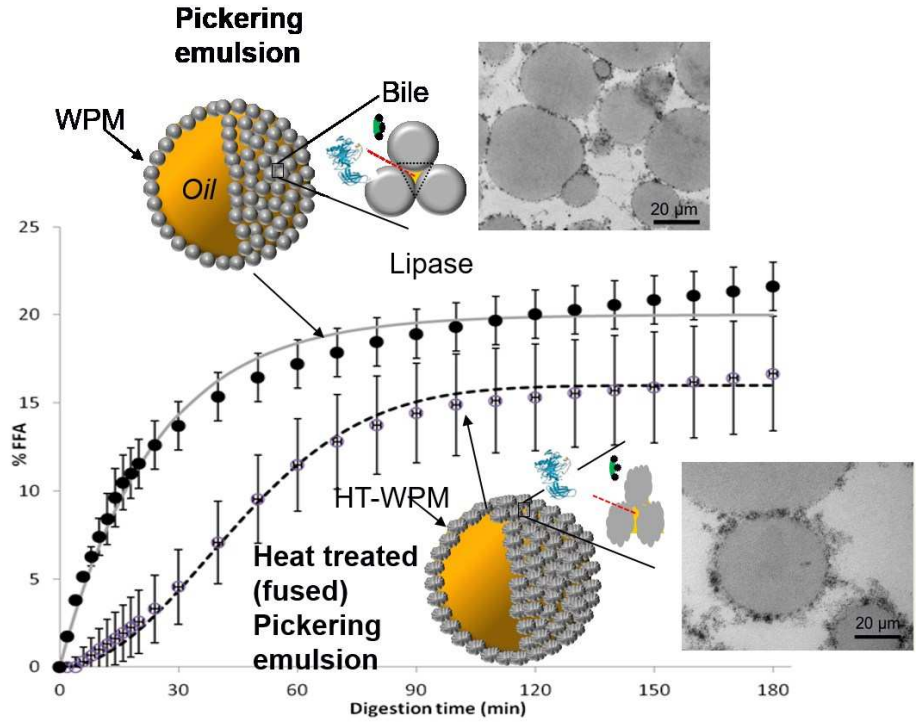

Pickering emulsion
WPM
Oil
Bile
20 µm
Lipase
HT-WPM
Heat treated (fused) Pickering emulsion
20 µm
% FFA
Digestion time (min)

Figure 4.

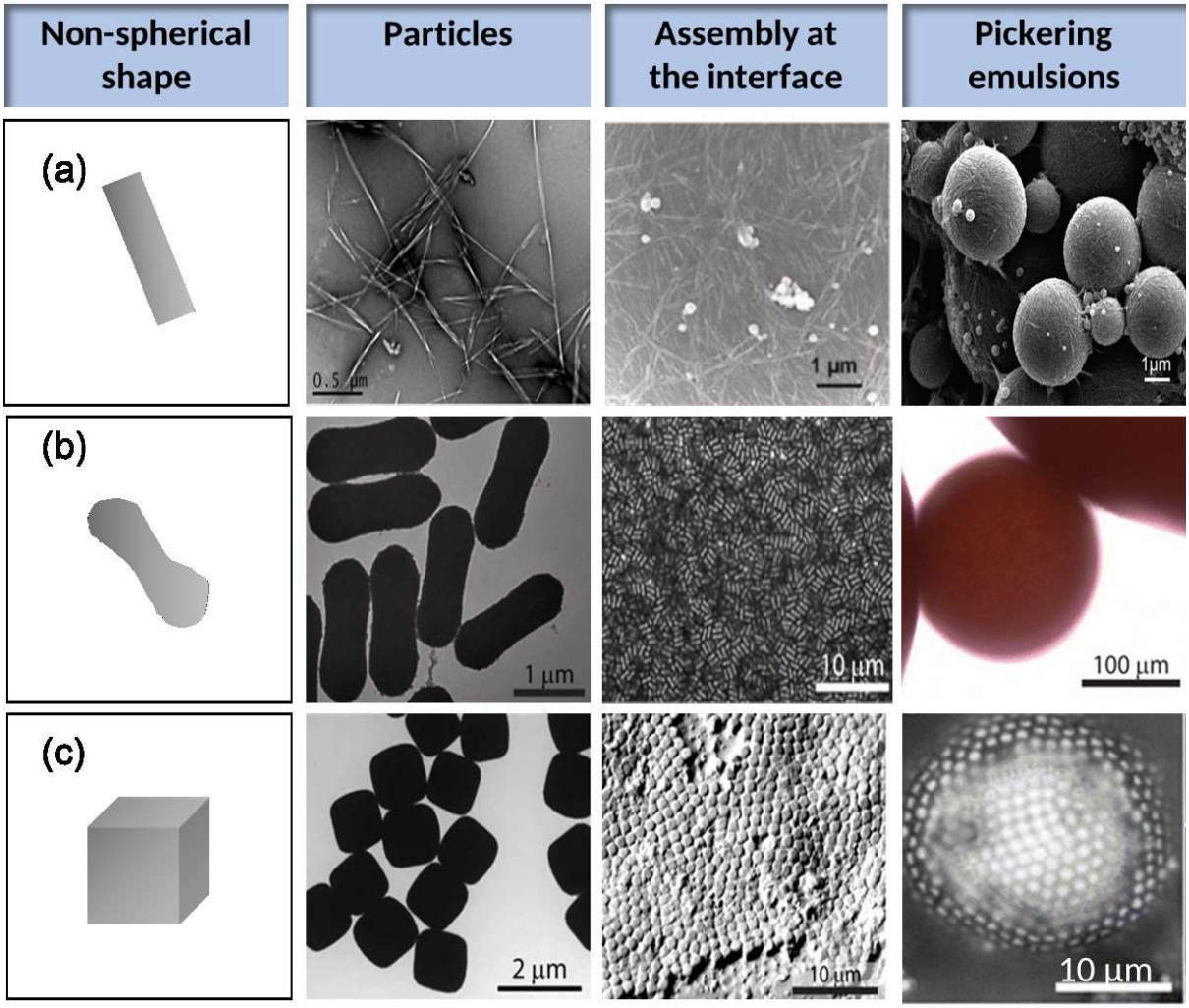
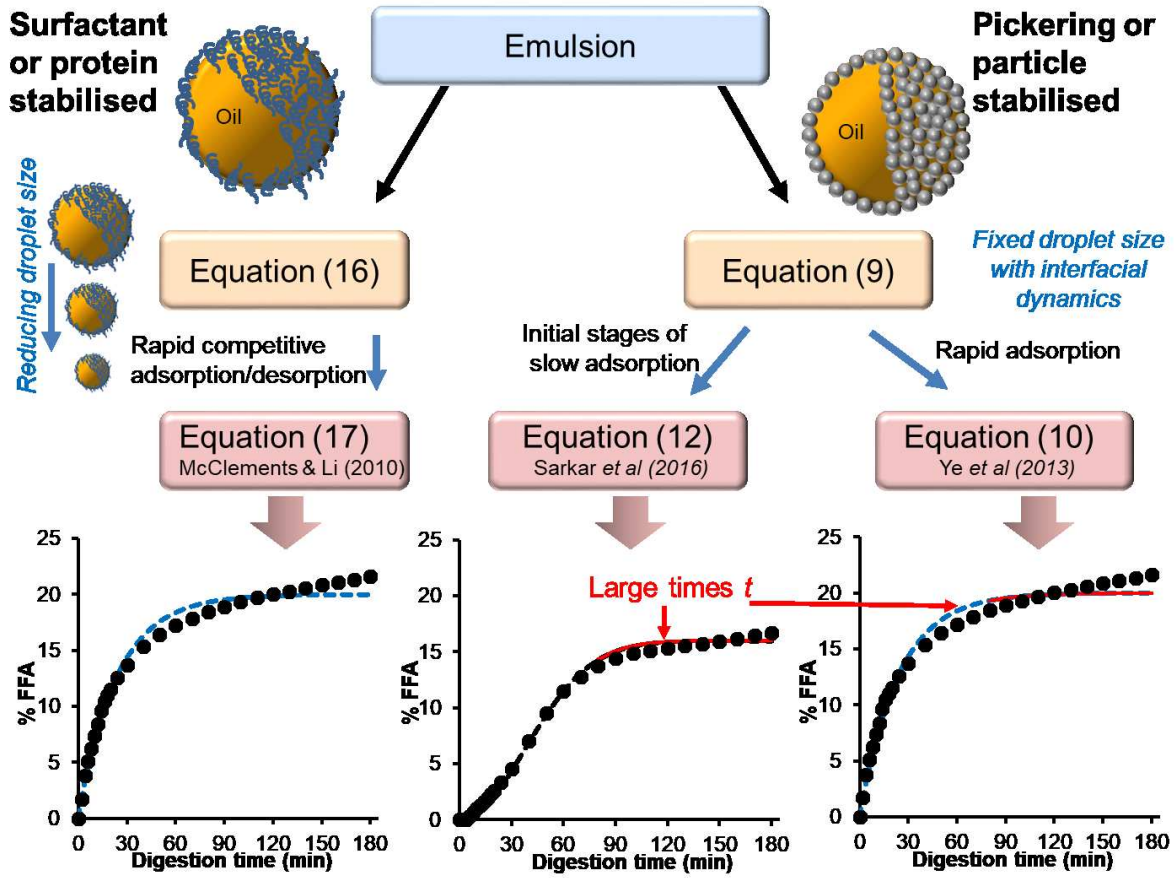

Non-spherical shape
Particles
Assembly at the interface
Pickering emulsions
(a)
(b)
(c)
0.5 µm
1 µm
1µm
1 µm
10 µm
100 µm
2 µm
10 µm
10 µm

Figure 5.


Surfactant or protein stabilised
Oil
Emulsion
Pickering or particle stabilised
Oil
Reducing droplet size
Equation (16)
Equation (9)
Fixed droplet size with interfacial dynamics
Rapid competitive adsorption/desorption
Initial stages of slow adsorption
Rapid adsorption
Equation (17)
McClements & Li (2010)
Equation (12)
Sarkar et al (2016)
Equation (10)
Ye et al (2013)
Large times t
% FFA
Digestion time (min)
0
5
10
15
20
25
30
60
90
120
150
180

Captions of Figures

Figure 1. Possible positions of spherical solid particle at curved liquid-liquid interface representing particles preferentially wetted by aqueous phase (particle-stabilised O/W emulsions) (a) and by oil phase (particle-stabilised W/O emulsions), respectively (b), and position of a single spherical particle at a planar oil-water interface for a contact angle (θ), measured through the aqueous phase (c), with θ < 90 °(left), = 90 ° (centre), > 90 ° (right), respectively.

Figure 2. Schematic representation of the possible fate of Pickering emulsions based as they traverse through the oral to gastrointestinal regimes based on *in vitro* digestion studies. For simplicity reason, spherical particle is shown as enzyme-responsive and rod-shaped particle is shown as enzyme-unresponsive.

Figure 3. Schematic showing particle fusion at the O/W interface by heat treatment, (a) with examples of relative barrier properties in modified starch-stabilised interface as a function of heat treatment (Reprinted with permission from [98, 107]), (b) and release of FFA in whey protein-microgel (WPM)-stabilised interface with/ without heat treatment (HT-WPM) as a function of duodenal digestion time (image redrawn with permission from [16]) (c). Insets in (b): (left) is a non-heat treated quinoa starch granule-stabilised droplet and (right) a heat treated droplet illustrating the creation of a partially gelatinized starch layer. Insets in (c): (left) is WPM-stabilised droplet with corresponding transmission electron micrograph (gray solid line – theoretical fit, solid circle – observed value) and (right) is Heat treated droplet (HT-WPM) with corresponding transmission electron micrograph (black dashed line, empty circle – observed value).

Figure 4. Examples of anisotropic particles, rod-shaped (a), peanut shaped (b) and cubic-shaped (c) with schematic, electron micrograph of the particles, arrangement of the particles at

the interface and microstructure of the Pickering emulsion droplets stabilized by the respective anisotropic particles. Microscopic images of peanut- and cube-shaped particles and corresponding emulsion droplets are reprinted with permission from [119] and those of rod-shaped particles are reprinted with permission from [120].

Figure 5. Schematic representation of the mathematical models applicable to the pathways relevant to surfactant-stabilised or particle-stabilised emulsions. Under the assumptions or rapid adsorption/desorption of surface enzymes and permissible reduction in droplet size, equations (16) and (17) are relevant where short time digestion and subsequent asymptotic equilibrium are achieved. Where droplet size remains stable, *i.e.* Pickering emulsion, equation (9) is the appropriate route and where further equation (10) selection is required for rapid adsorption and where interfacial dynamics are included, equation (12) is appropriate. Here it is notable that interfacial adsorption at short-times results in delayed digestion and that the large-time behaviour (in red) of both equations (10) and (12) are asymptotic.