The Brave New World of Oils
Where are we going?

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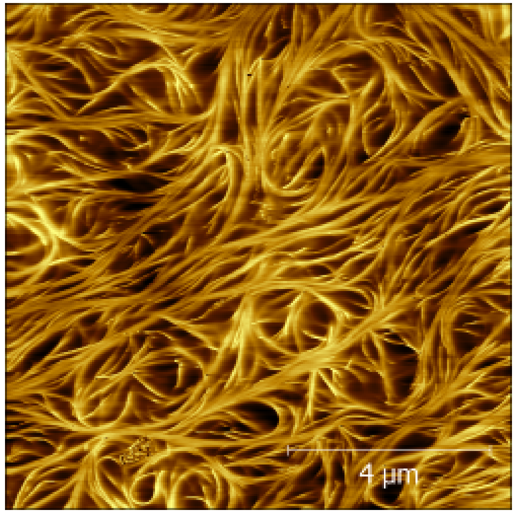


Where are we going?

To hell?


HITACHI


Credit: Kertu Saarits / Alamy Stock Photo

What can we do about it?

The future of fats and oils

- Highly sustainable production (low energy, low water, organic, crop rotation, soil conservation) – low carbon footprint
- Very low to zero habitat destruction – uses marginal lands
- Green extraction and minimal processing – low carbon footprint
- Enhanced nutritional properties
- Animal-free, including possibly dairy-free
- New, fully integrated supply chains – no “middle-men”
- Efficiency judged by a combination of factors, not only cost
- Higher margins due to integration of production and distribution and legally mandated environmental considerations

The writing is on the wall, even for dairy!

Animal fats are not an option……

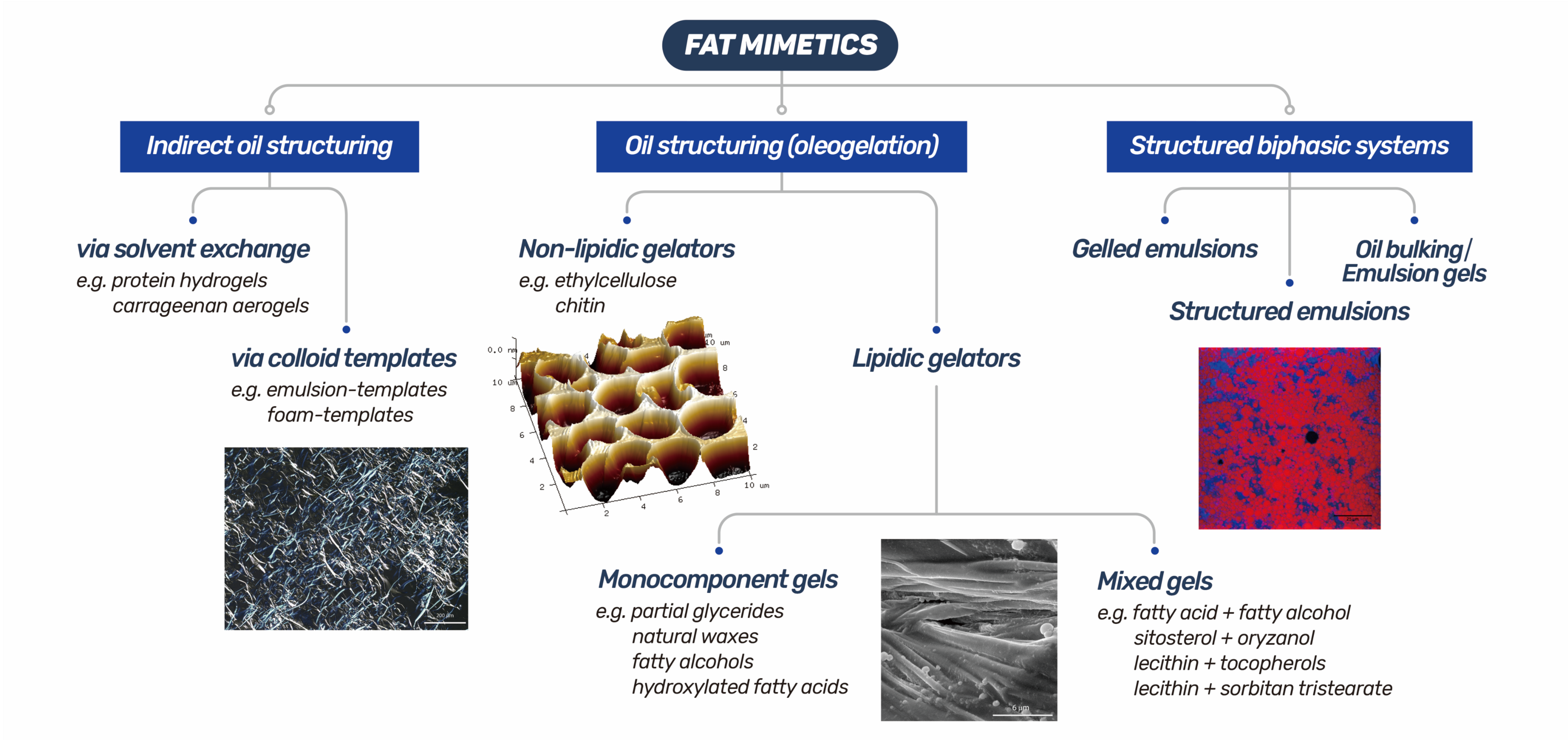
The problem with fats

- There is ample supply of plant-based oils which can fulfill modern economic and ethical requirements
- There are very few fats than can fulfill economic and ethical requirements
    - Cocoa butter – limited supply, high cost, limited functionality
    - Shea butter – not nearly enough supply, high cost, limited functionality
    - Coconut oil – limited supply, high cost and limited functionality
    - Palm oil – enormous supply, good functionality, low ethical score
    - Animal fats – forget it

Let’s explore fat mimetics?

Motivation for developing fat mimetics

- Decreased saturated fat content
- Control of lipid digestion?
- Removal of hydrogenated fat (partially and fully hydrogenated)
- Veganism / Cruelty-free food products
- Religious beliefs (muslims-no lard, hindus-no tallow, vegans-no animal fat)
- Palm oil free (sustainability, natural forest habitat destruction)
- Use locally grown oils
- Small scale manufacture


FAT MIMETICS
Indirect oil structuring
Oil structuring (oleogelation)
Structured biphasic systems
via solvent exchange
e.g. protein hydrogels
carrageenan aerogels
via colloid templates
e.g. emulsion-templates
foam-templates
Non-lipidic gelators
e.g. ethylcellulose
chitin
Lipidic gelators
Monocomponent gels
e.g. partial glycerides
natural waxes
fatty alcohols
hydroxylated fatty acids
Mixed gels
e.g. fatty acid + fatty alcohol
sitosterol + oryzanol
lecithin + tocopherols
lecithin + sorbitan tristearate
Gelled emulsions
Oil bulking/
Emulsion gels
Structured emulsions

Engineering fat structure and texture: case study of ethylcellulose

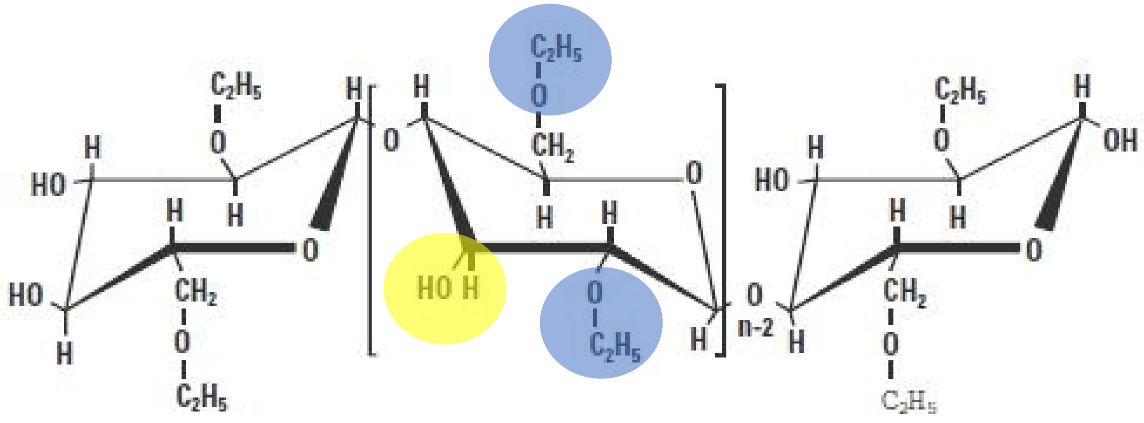
GRAS Ethylcellulose UCM360908

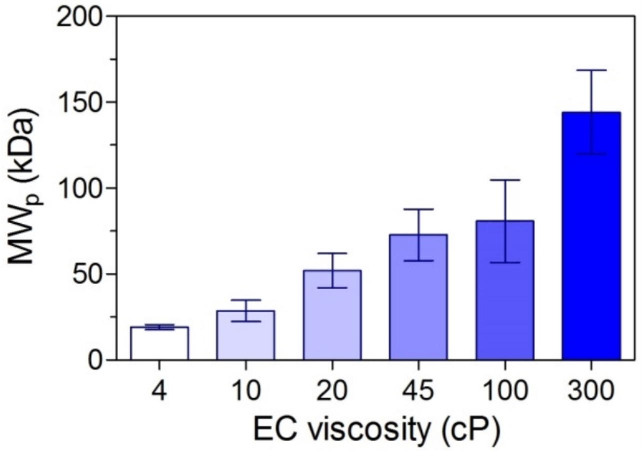
Conditions of Use: Ethyl cellulose, prepared from wood pulp or cotton, is intended for use as a food ingredient in Grain Products; Vegetables; Fruits; Milk and Milk Products; Legumes; Nuts and Seeds; Fats and Oils; Sugars and Sweet; and Beverages at a level ranging from 0.0075 to 5.0% of ethyl cellulose. The intended use of ethyl cellulose in the above mentioned food categories is estimated to result in a mean intake of 4.95 g/person/day. The high (90th percentile) intake is estimated as 9.90 g/person/day. For an individual weighing 60 kg, the mean and 90th percentile intakes are estimated as 0.082 and 0.165 g ethyl cellulose/kg body weight (bw)/day, respectively. Ethyl cellulose is not intended to be marketed for use in infant and toddler foods.

Ethylcellulose (EC)

- Commercially available, range of viscosities (molecular weights)
- Utilized in a variety of industrial applications
- Degree of substitution: ~2.5
  - T_g ~135 °C
  - CGC in oil ~6 wt%

Cosmetic
Pharmaceutical
Food Packaging
Edible labels





Davidovich-Pinhas et al., *Ann. Rev. Food Sci. Technol.* (2017) **7**(1), 11544

EC Oleogels

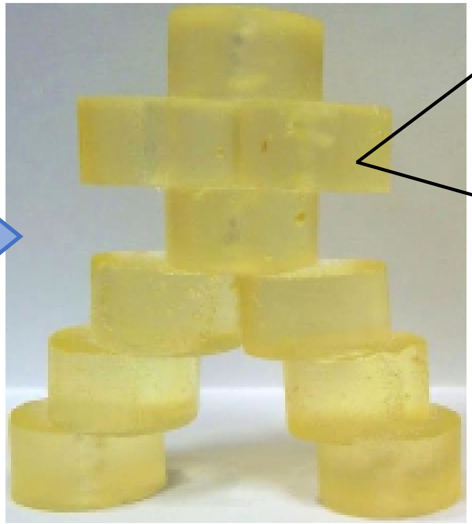
- EC can be dispersed in oil above T_g
- Upon cooling, physical gel formed by intermolecular hydrogen bonds
- Gel matrix appears as a pocketed, coral-like network

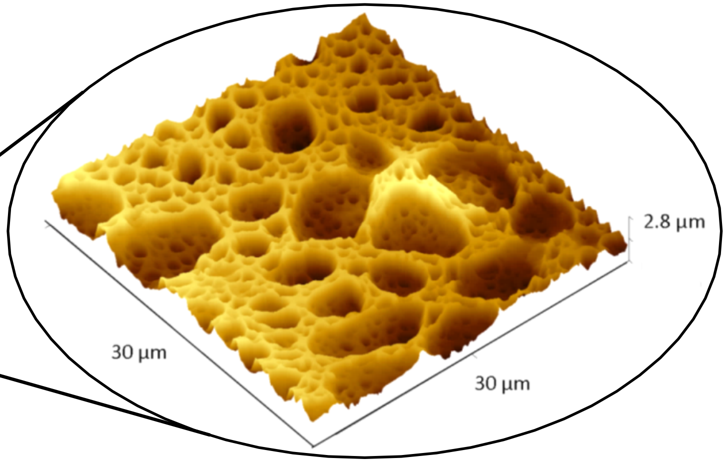
Liquid oil

+ EC

+ heat

Oleogel





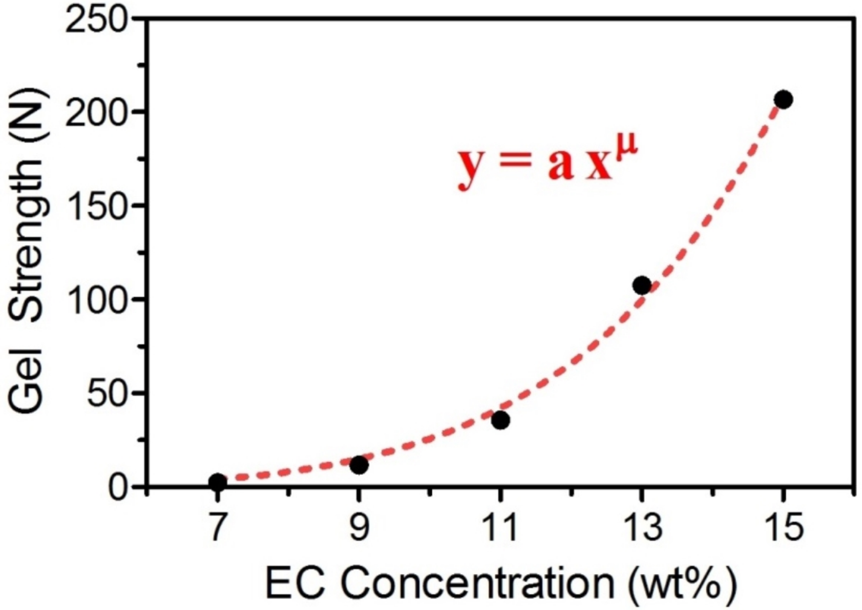
Tailor lipid profile
Optimize physical properties
Incorporate lipid-soluble nutraceuticals

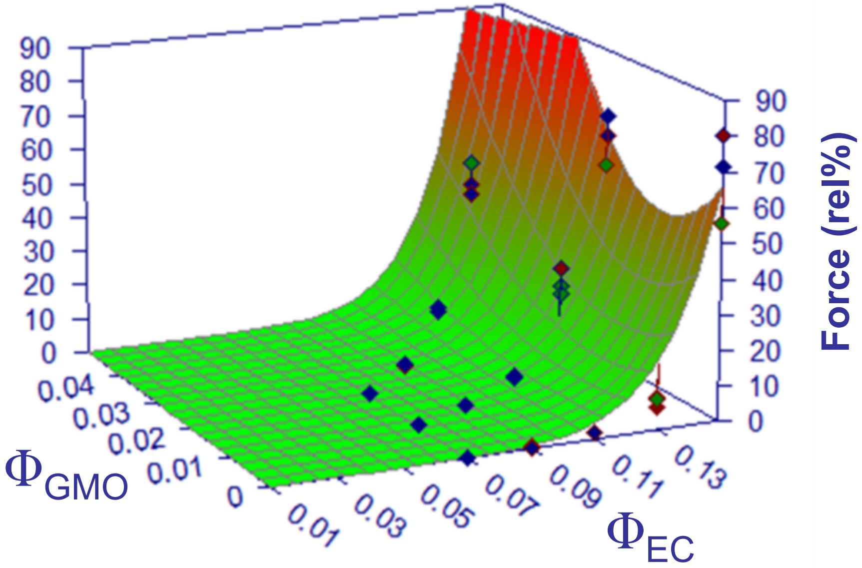
O’Sullivan et al., *Food & Function* (2017) **8**(4), 1438-1451

Mechanical properties

- Various strategies to modify gel strength
  - Polymer concentration, MW, oil type
  - Food-grade surfactants
  - Addition of polar compounds

$$Z = X^{\mu}(a + bY + cY^2)$$

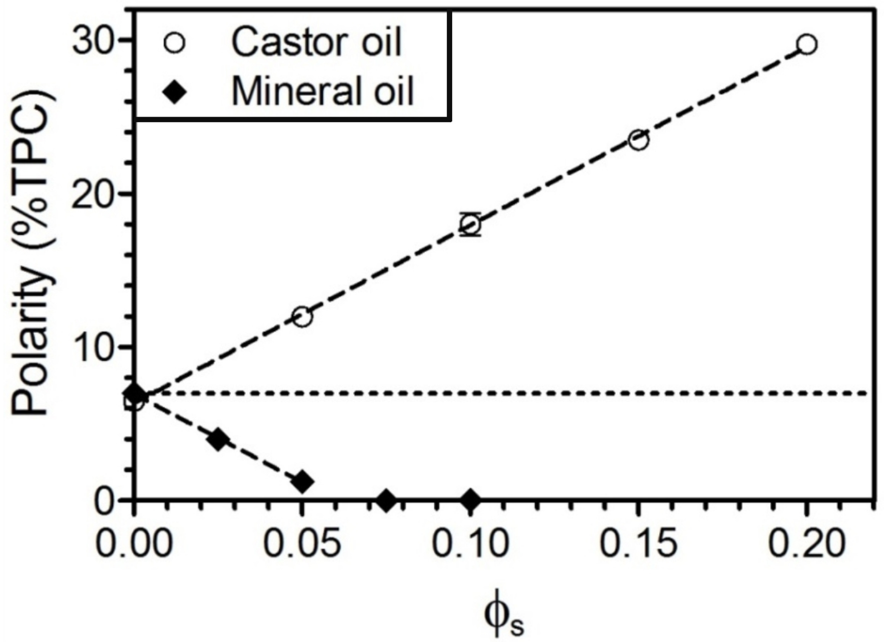


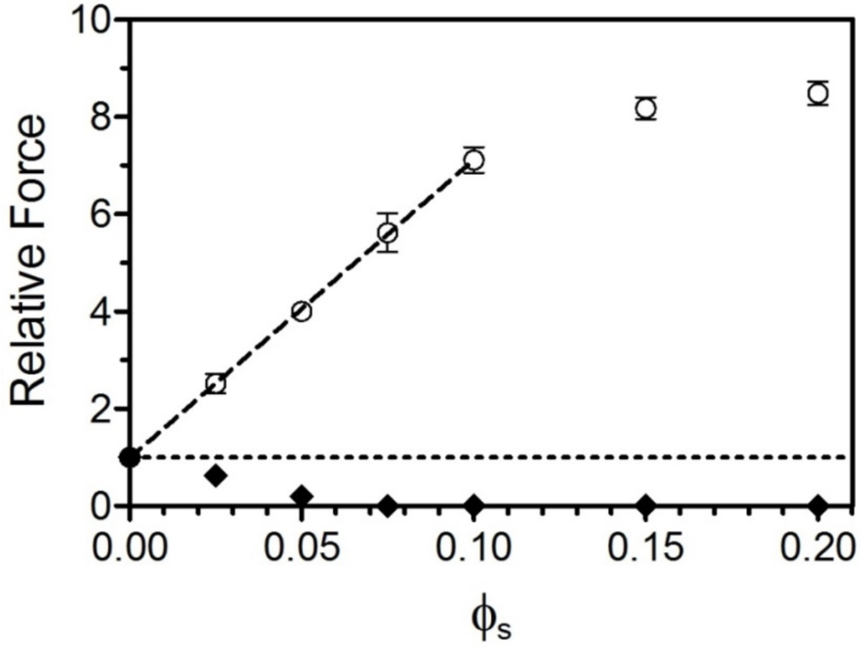


Gravelle et al., *Journal of Food Engineering* (2014) **143**, 114-122

Solvent polarity

- Functionality can be altered via interactions with polar molecules
  - Castor oil, mineral oil used to modify oil polarity
  - Miscible oils followed polymer/solvent blending laws



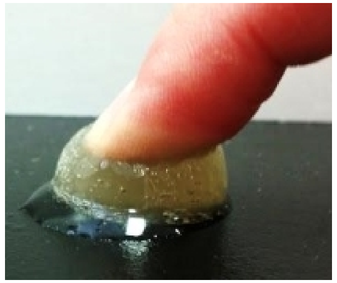


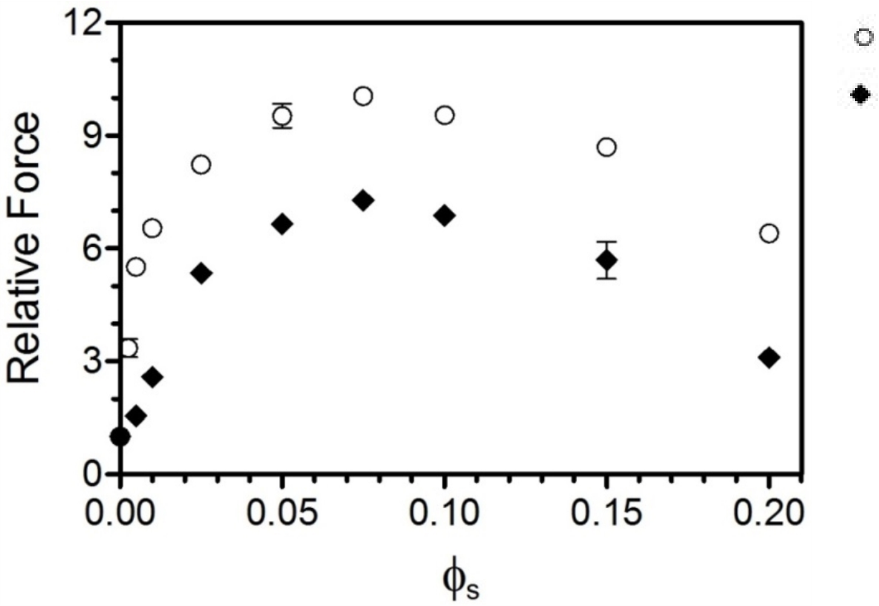
Gravelle et al., *Carbohydrate Polymers* (2016) **135**, 169-179

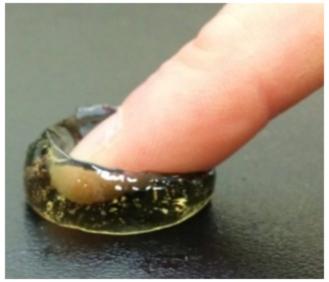
Surface-active small molecules

- Amphiphilic molecules produced sharp increase in gel strength
  - Displayed site-specific interaction kinetics ($\phi_s \leq 0.10$)
  - Relative influence depends on structure of head-group

$$F_{rel} - 1 = F_{rel}^{max}\left(\frac{\phi_s}{K_d + \phi_s}\right)$$



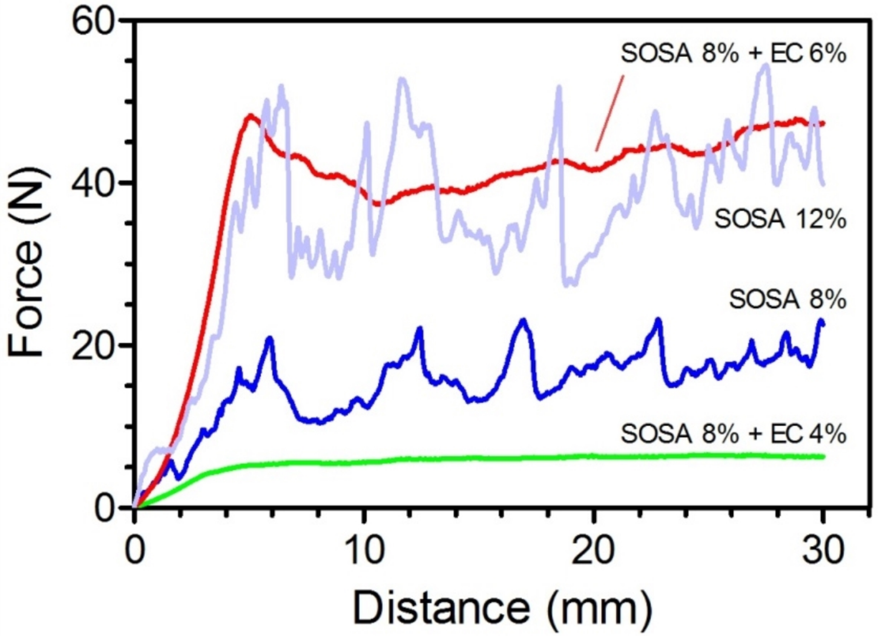


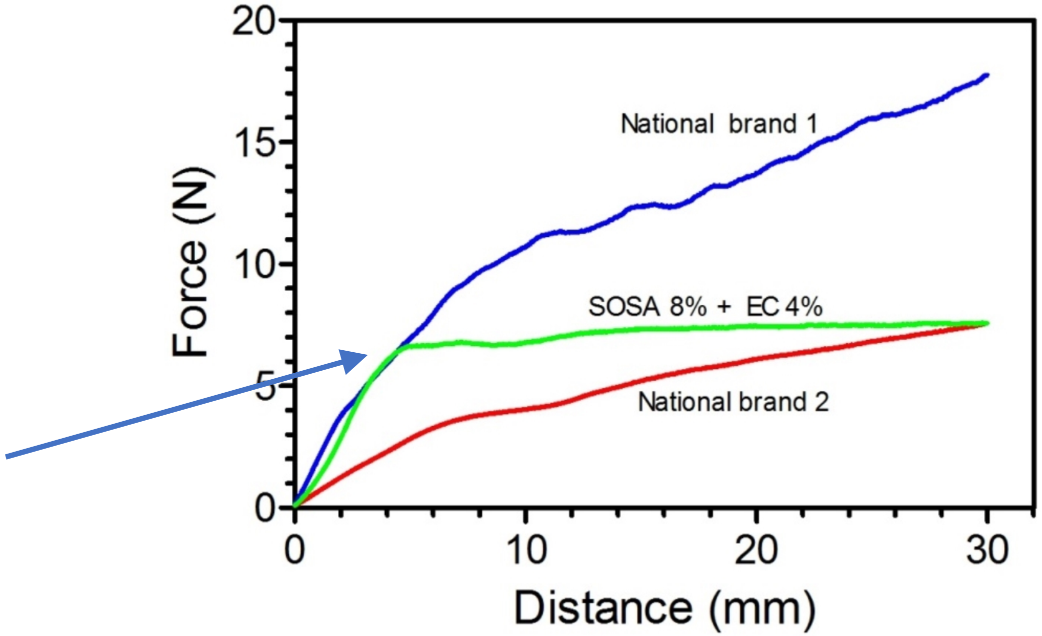


Gravelle et al., *Carbohydrate Polymers* (2016) **135**, 169-179

Functionality of EC/SOSA hybrid systems

- Sharp melting profile → characteristic of fat
- Flow properties of EC/hybrid less brittle, synergistic increase in gel strength
- Below CGC of EC, plastic flow analogous to commercial fat spreads





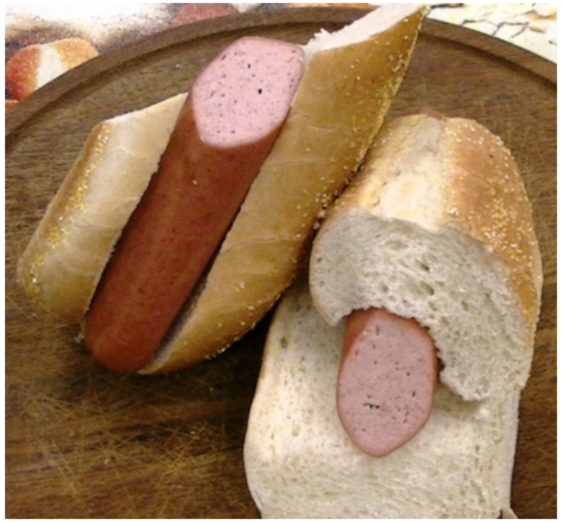
<u>Brittleness factor</u>: RMSD of linear or second order polynomial of latter stages of curve
<u>Stress Overshoot</u>: energy accumulation and catastrophic release

Gravelle et al., *Food Research International* (2017) **91**, 1-10

Food applications of EC oleogels

Cream fillings

Processed Meat



Shortening

Heat-resistant chocolate

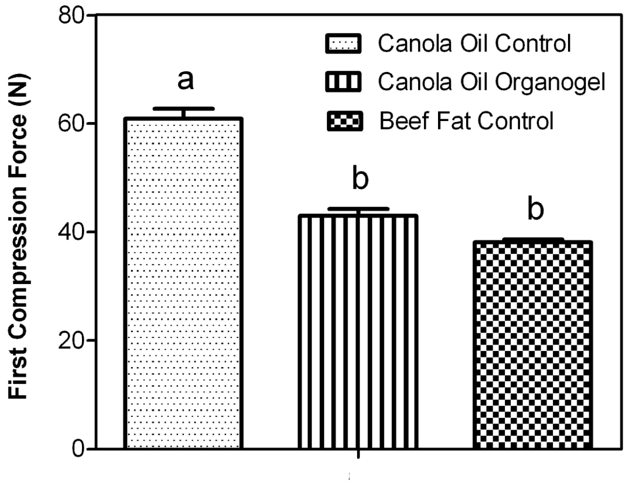
Meat products

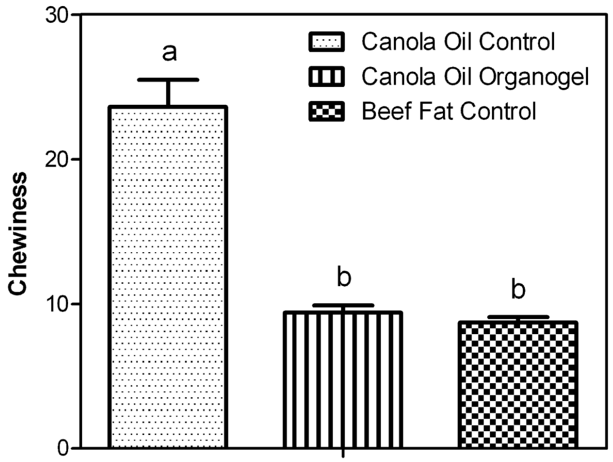
- Frankfurters
  - Finely comminuted (emulsified) meat

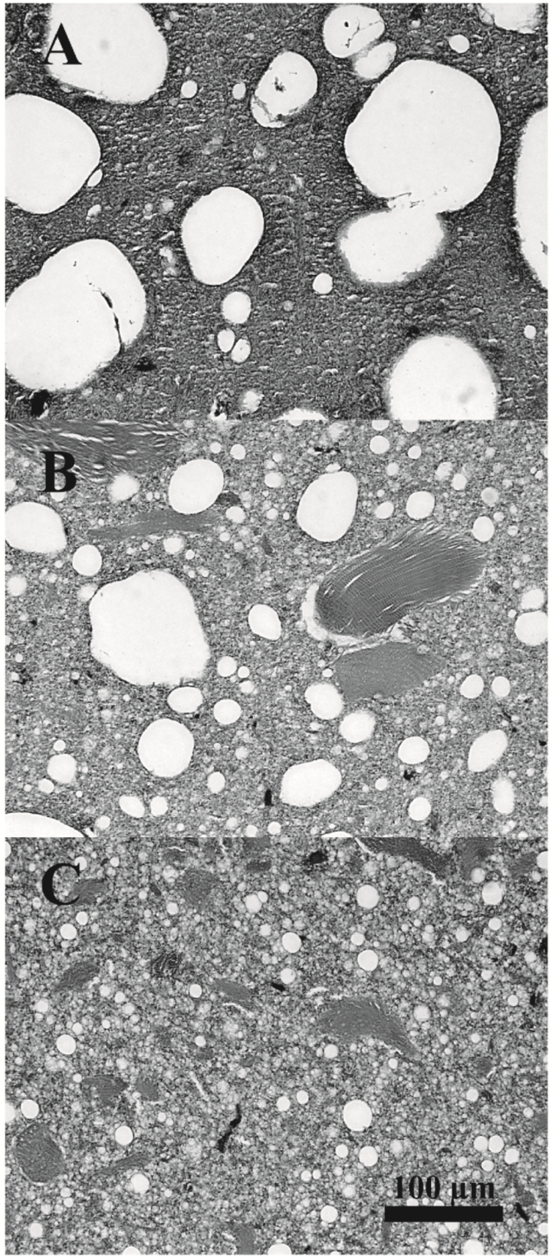
- Pâté
  - Liver-based (poor gelator), high fat product (40-50%)

- Breakfast sausages
  - Coarsely ground meat, added binding agent (rusk)

Replacement of fat in beef and plant-based frankfurters?







Beef fat

EC Oleogel

Oil

Sensory

Figure 4.1 Effects of fat type replacement on TPA first compression hardness in frankfurters containing canola oil (CO) organogel with 8,10,12 & 14% ethylcellulose (EC) with 1.5% sorbitan monostearate (SMS) in replacement of beef fat.

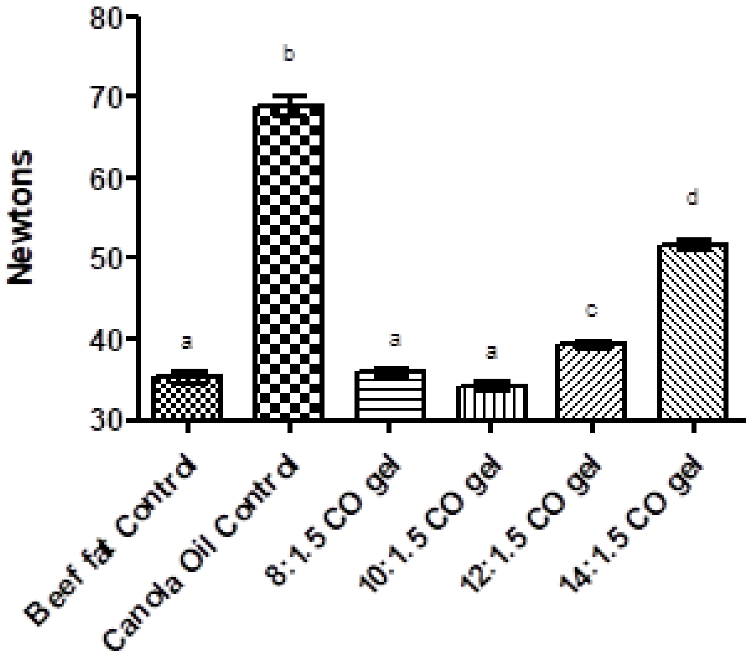
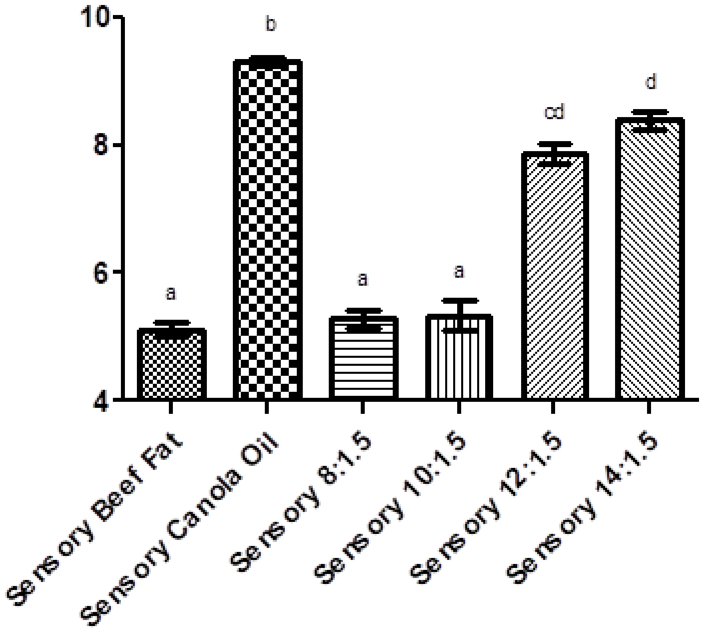
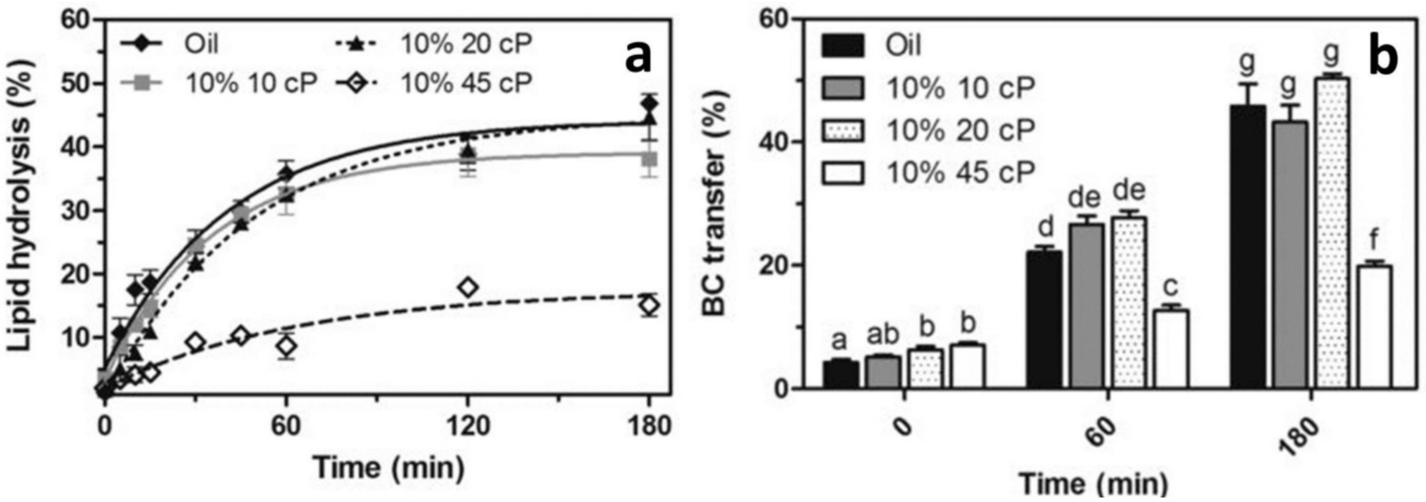


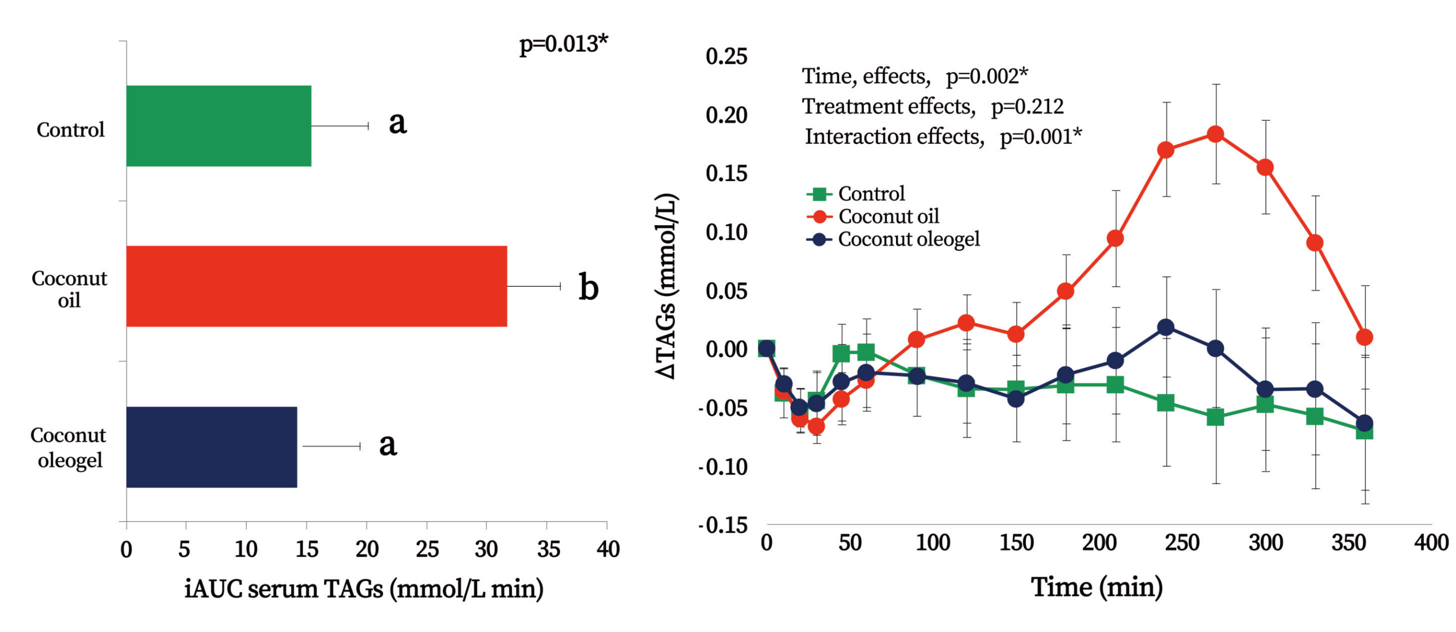
Figure 4.2 Effects of fat type replacement on hardness level (0-10 point scale; Hardness: 0 = very soft, 10 = very hard) perceived by sensory analysis panelists in frankfurters containing canola oil (CO) organogel with 8,10,12 & 14% ethylcellulose (EC) and 1.5% sorbitan monostearate (SMS) in replacement of beef fat.



Barbut et al. 2016, J. Food Science 81(9): C2183

Lipolysis & Digestion





(a,b) O'Sullivan et al., *Food & Function* (2017) **8**(4), 1438-1451; (c) Tan et al., *Food & Function* (2017) 8(1), 241-249

Final Perspectives – what we need to work on

- Mixtures of oleogelling materials with targeted functional properties
- Find a new polymer oleogelator (other than EC) from natural sources
- Force triglycerides to behave like small-molecule oleogelators (frustrated crystal growth, lower-dimensional growth)
- Find solutions that will be commercially viable – mainly enough supply
- Some regulatory approval for oleogelators
- Work on near-nature versions of fat structuring strategies

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