Redesigning Fat Phases for Various Product Applications

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Block 1 | Research & Product Design: A deeper dive into novel technologies & ingredients

Introduction

Eckhard Flöter - Chair Food Process Engineering at the Technical University Berlin

15 years of Unilever experience in applied research

composition - process - microstructure – functionality

fat crystallization, oleogelation – products and processes

The department of Food Process Engineering aspires to deliver sustainable yet industrially relevant solutions which are based on scientific insights.

- Institute Food Technology and Food Chemistry
  - Food Bio- and Processtechnology
  - Food Material Science and Food Technology
  - Brewing and Beverage Technology
  - Food Chemistry Analytics
  - Food Chemistry Toxicology

Embedded in the School of Process Technology

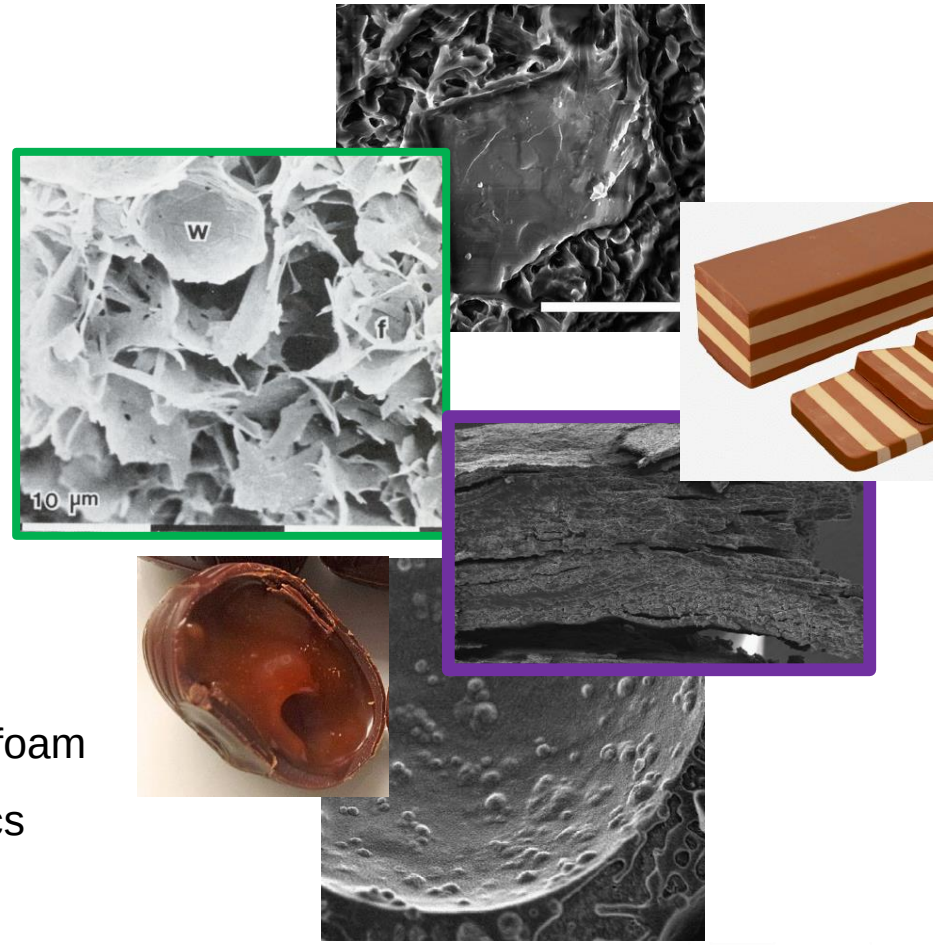
Functionailty of fats

Lipids and Foods – ‚Low Fat' and ‚Low Calory'

- Nutrition - fatty acid composition
  - Energy, essential fatty acids, carrier for fat solubles
- Heat transfer – frying, chemical stability, .. - mainly fatty acids
- <u>Structure</u>

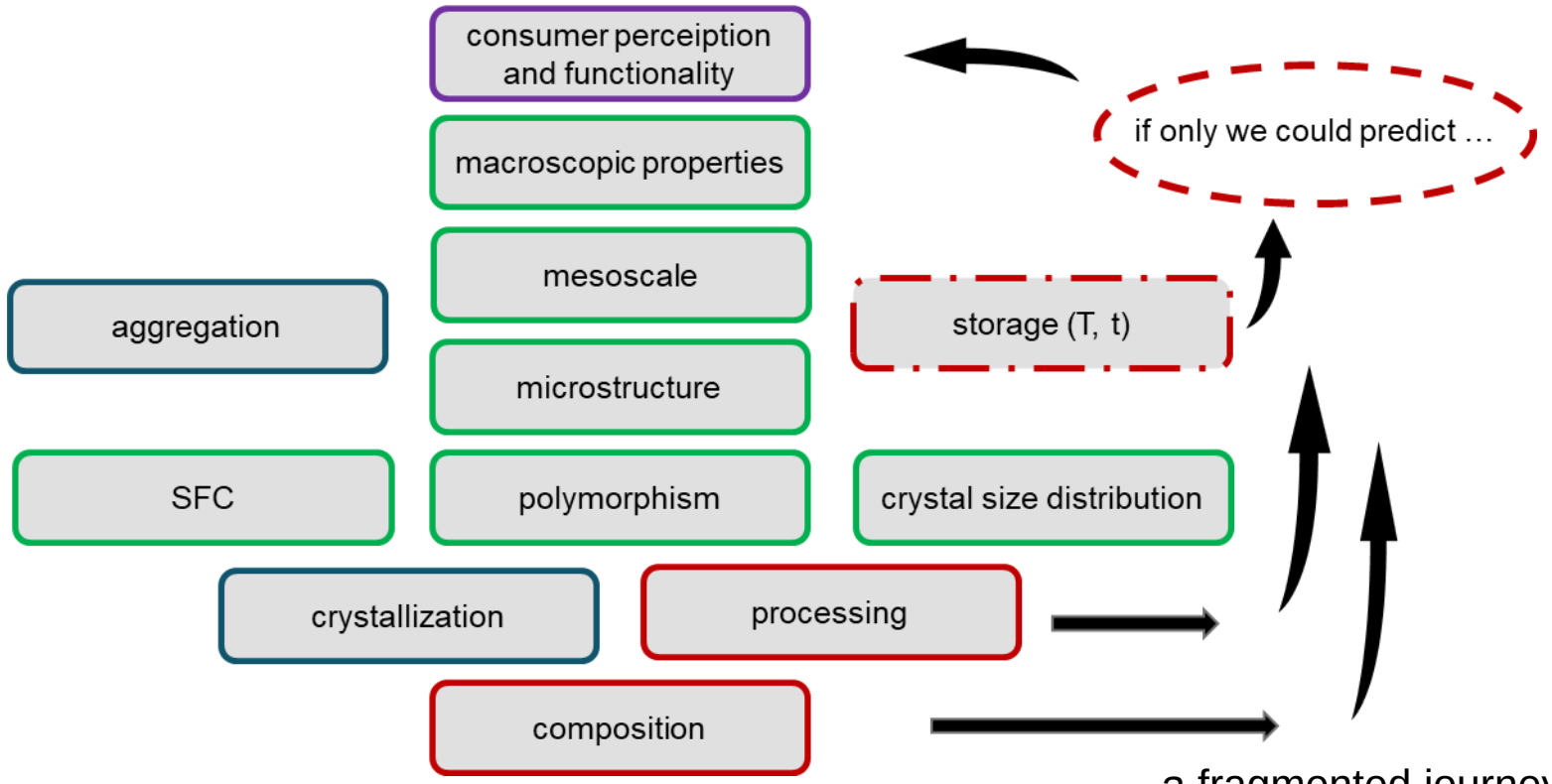
Structured – dispersed phases

- Barrier, film function, preservation
- Macroscopic structure: hardness, plasticity
- Microscopic structure: stabilization of suspension, emulsion, and foam
- Product disintegration: emulsion inversion, flavour release, kinetics
- Organoleptic: cooling, smoothness, creaminess, lubrication



The hierachy of structure

A view on the mechanism of functionality of traditionally structured lipid phases ….



…. a fragmented journey through the scheme

Role of characterization and specification in re-designing

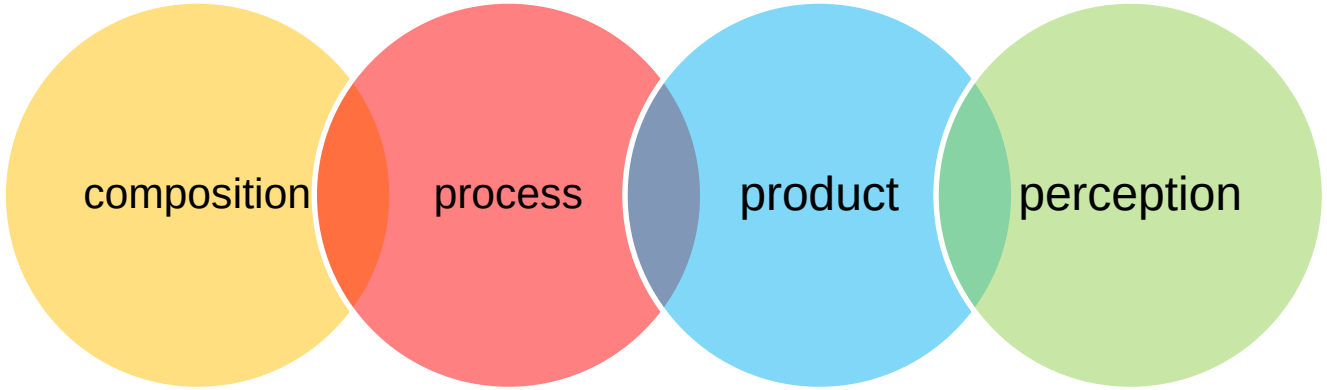
- do we know why certain fats work in certain applications ?

- is there flexibility in raw materials if we do understand what we do ? flexibility is money
- if we have a catalogue of solutions – choose the cheapest one ….. ok, ok supply chain
  - in chemically interesterified hardstocks BlendFlexibility at level 1 was easy – make sure the FA mix is the same
  - enzymatic interesterification more complicated – but current practise should potentially be similar
  - natural instead of modified

- are specifications anything more than the fingerprint of a solution that was ‚randomly' found to work ?
  - might just be right for the supplier-manufacturer transaction
  - ‚the fingerprint make sure that it is what I used to have and that will work' – quick verification on delivery

  - I doubt the commercial people have specs on diglycerides in palm oil based fats ?
  - science tells us significance but it does not matter? Or are systems/processes designed too robust ?

Redesigning and designing



new ingredients	processes	product	perception
- cheaper	- conversion cost	- cost effective	- image
- regional	- GHG efficient	- safer	- valuable
- sustainable	- traditional	- more robust	- better
- functional	- more effective	- performance	- ……
- …	- less harmful	- …..	

- No palm, regional, less saturated, less seed oils, more essential fatty acids, less rancid, vegetable, …

Substitution of structured lipid phases in established products

- substitution of TAG-structured fat phases that deliver established functionality
  - is the functionality of the fat phase understood ?
  - understanding interaction of process-fat phase interactions necessary
    - where in the process is increased viscosity necessary ? If at all
    - is solid-like behaviour necessary at intermediate states ?
    - can solidification/geling occur on storage ?
    - is the new structure/gel destroyed by high shear ?
    - can straight oil do the trick as well ?

      - ‚Re-Engineering‘ of the process to identifiy
        - fat functionality
        - define requirements

          - Or re-engineer for simpler process
            - no cooling crystallization
            - crystallization in pack without cooling

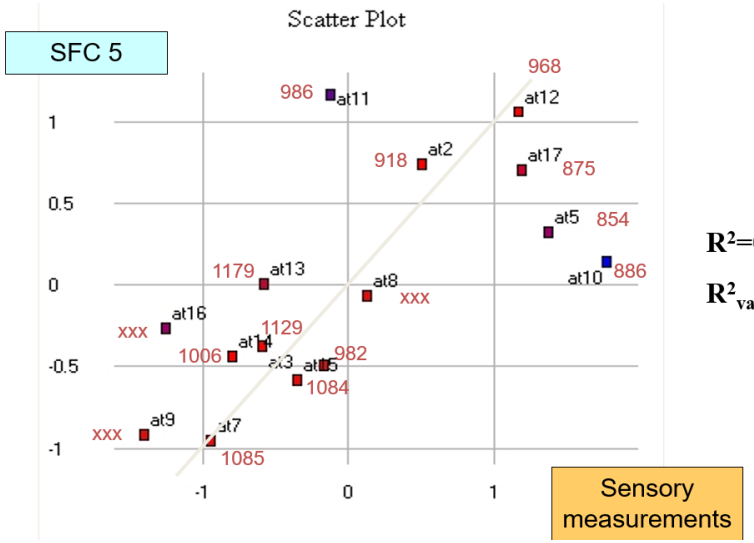
Revisiting conditions for successful oleogelator systems

According to Co & Marangoni (2012)

1. Food-grade
2. Economical - costs and availability
3. Efficient
4. Matching physical pr… alternative structurant must have a similar rheological and sensory (melting) properties as the fa… is aiming to replace.
5. Preferentially versatile
6. Consumer acceptance

IT SHOULD JUST WORK

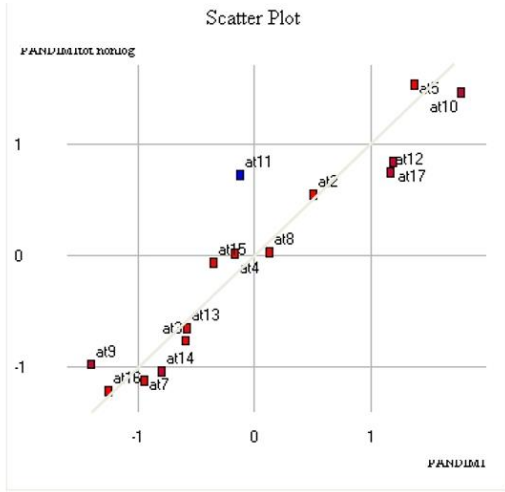
Can we measure the relevant properties ?



R^2=0.45

R^2_{val}=0.26

Instrumental measurements (TPA)



R^2=0.89

R^2_{val}=0.69

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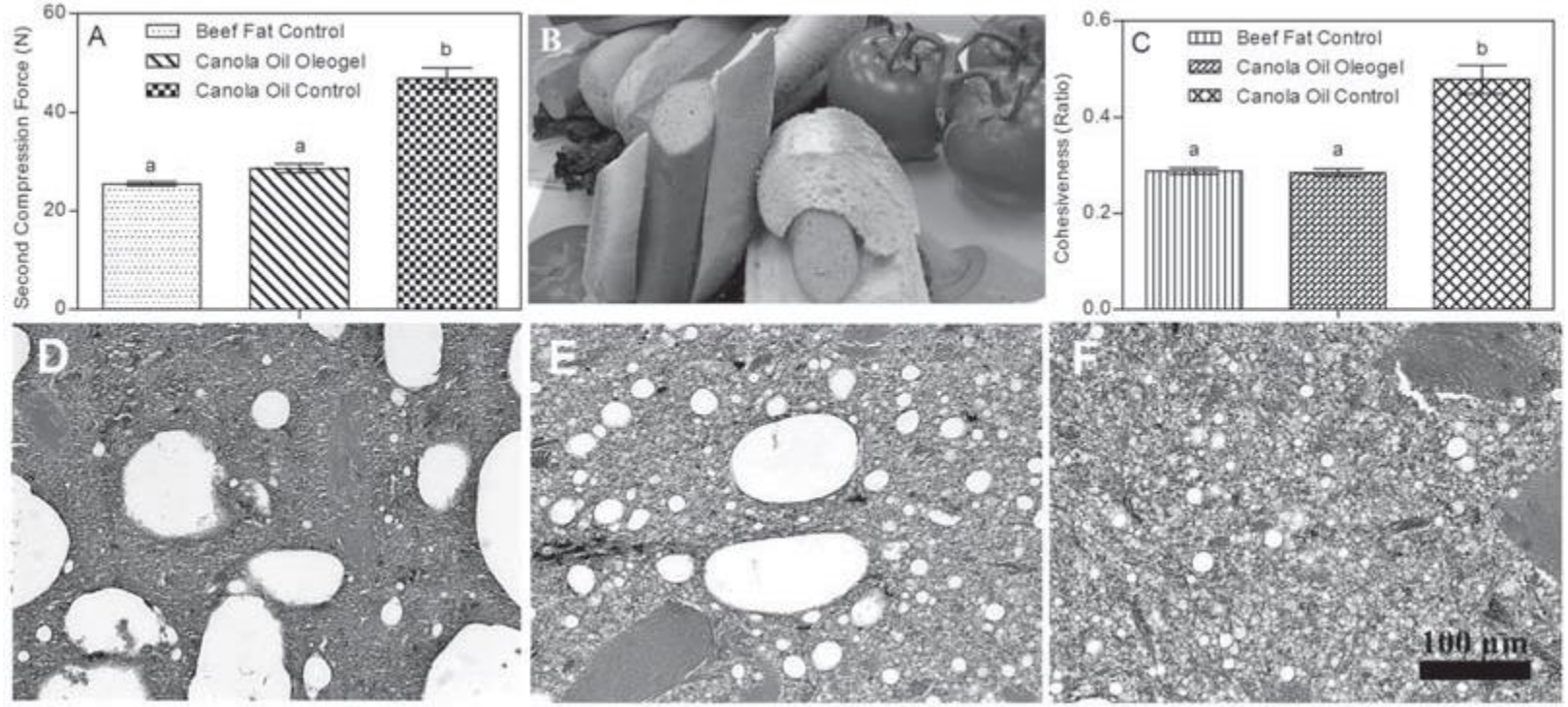
Example I – Frankfurters: Application of ethylcellulose (Zetzl et al.)

- substitution of animal fat in Frankfurters (Zetzl et al)
  - solid state during minzing is must
    - microstructure design – coarse vs fine composite material
- substitution of TAG-structured fat phases that deliver established functionality

D: reference

E: gelled oil

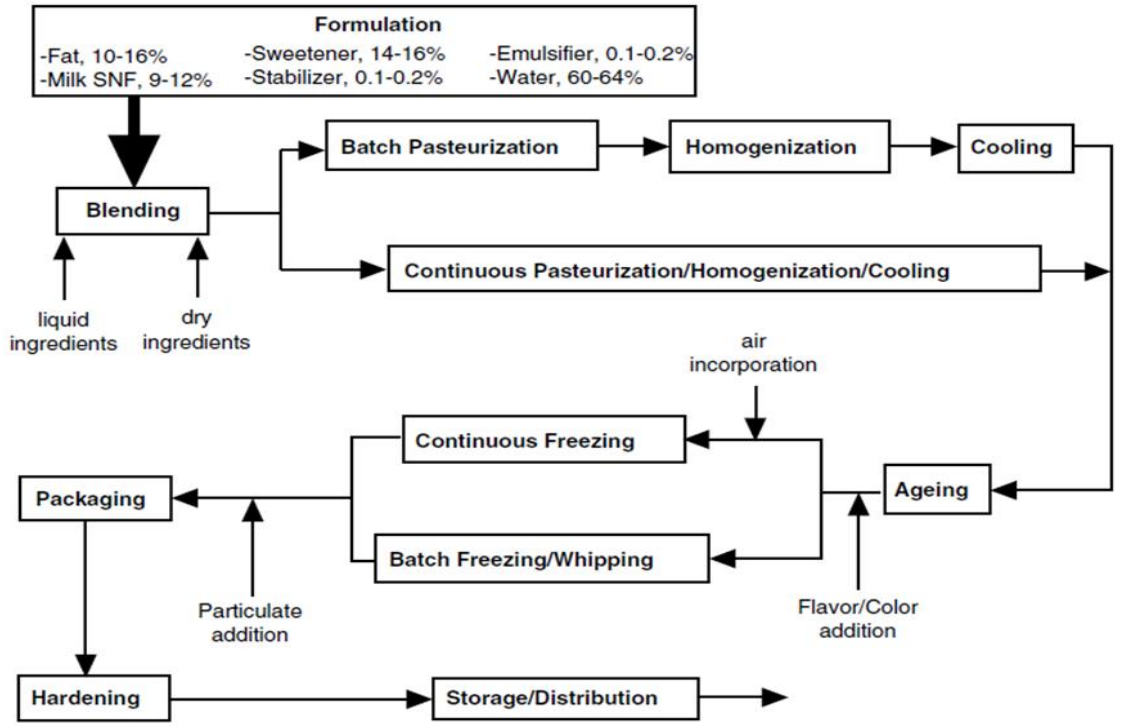
F: oil



Example II – ‚low' fat oil in water emulsions

Icecream

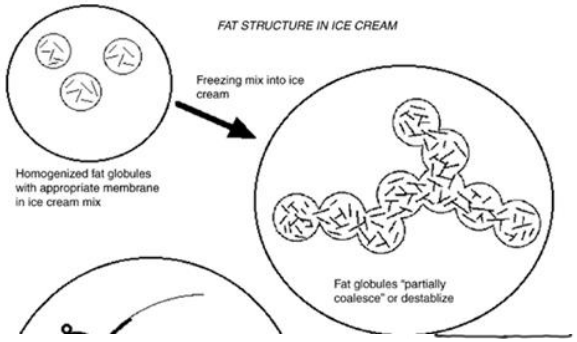
- aging necessary to allow for flocculation of droplets
  - semi-solid state or other emulsifier-based solution
    - ultimate reference milk fat
    - semi-solid state after aging is must



whipping cream, dairy alternatives

- stabilization of bubbles on whipping be flocculation
  - ‚analogous' to ice cream
  - semi-solid in final product on usage necessary
  - emulsion stability is must

  - no network through protrusion – liquid
  - richness, hardness, perception depending on crystalline state (tribology)

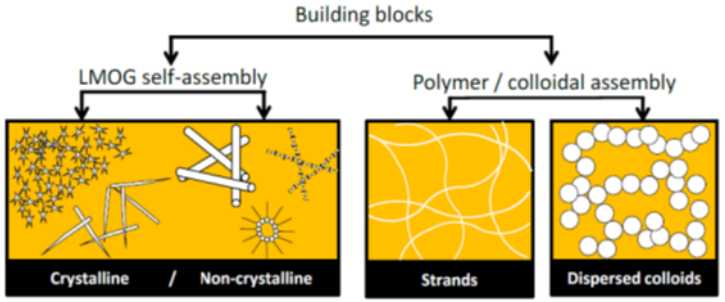


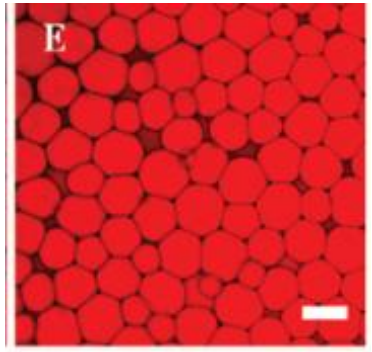
Disclaimer: Smart alternative solutions are always possible

Basic routes of non-TAG structuring

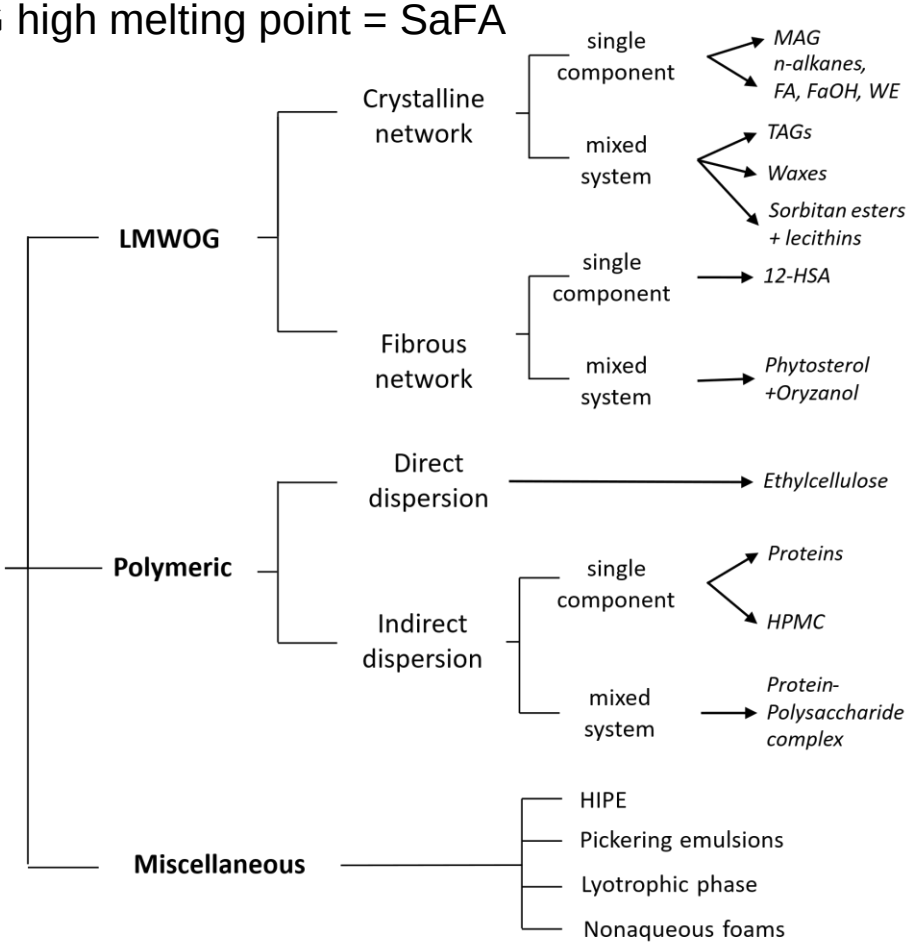
Not everything can be solved with coconut ……

Non-TAG based structurants – TAG high melting point = SaFA





HIPE o/w emulsion



LMWOG =
Low molecular weight oleogelator

MAG = Monoacylglyceride

FA = Fatty acid

FaOH = Fatty alcohol

WE = Wax ester

TAG = Triacylglyceride

12-HSA = 12-Hydroxystearic acid

HPMC =
Hydroxy-Propyl-Methyl-Cellulose

HIPE =
High internal phase emulsion

Fig. 1: Classification of different types of oleogelators

Basic routes of non-TAG structuring

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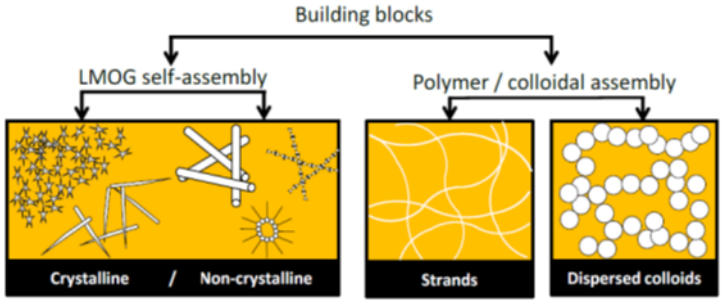

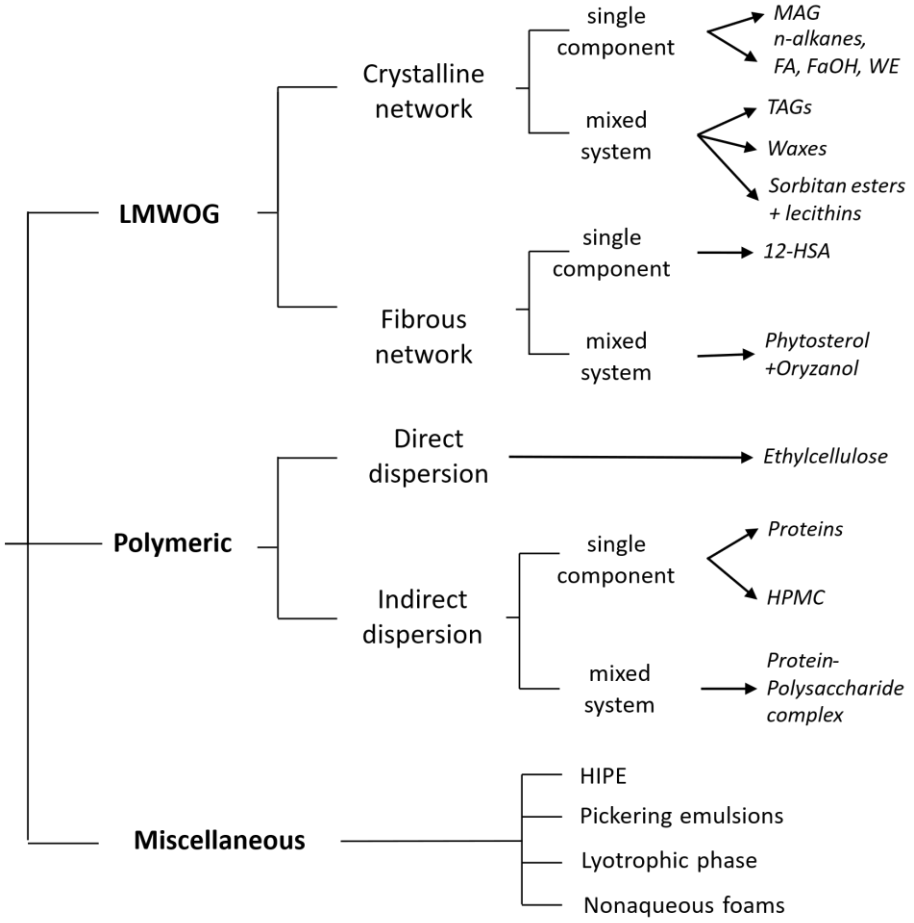

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Processing

- system specific
  - incompatible?
  - beneficially simple?

Fig. 1: Classification of different types of oleogelators

Own examples of long list of academic applications

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Baked goods

- muffins
- stollen
- pound cake
- soft cake
- laminated doogh !

Culinary

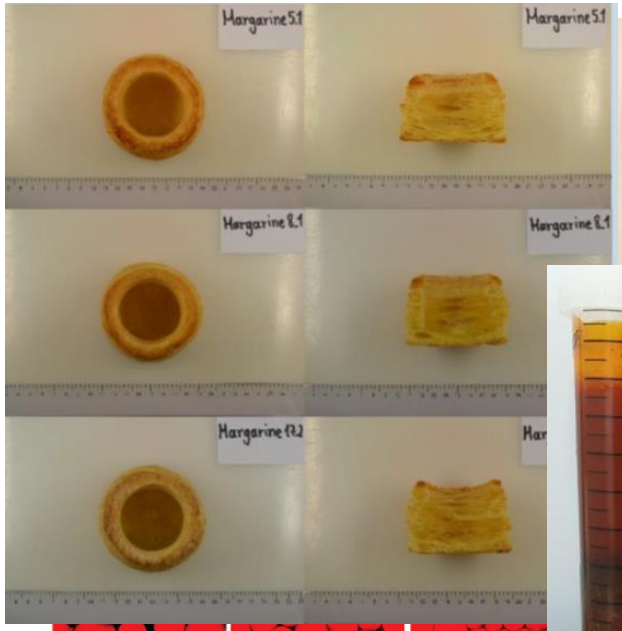
- boullion cubes
- marinades

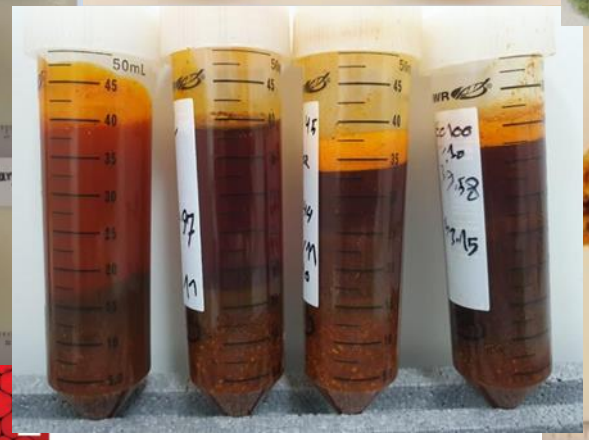
Dairy alternartves

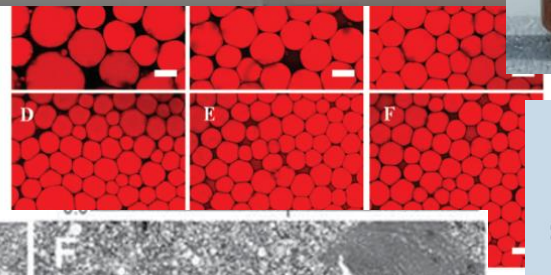
- yogurt

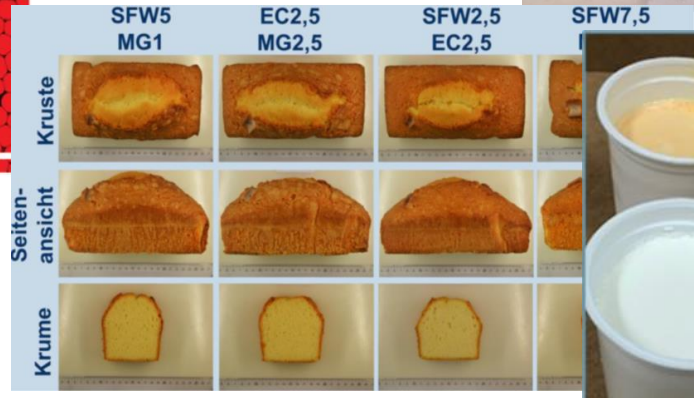
Meat alternatives…

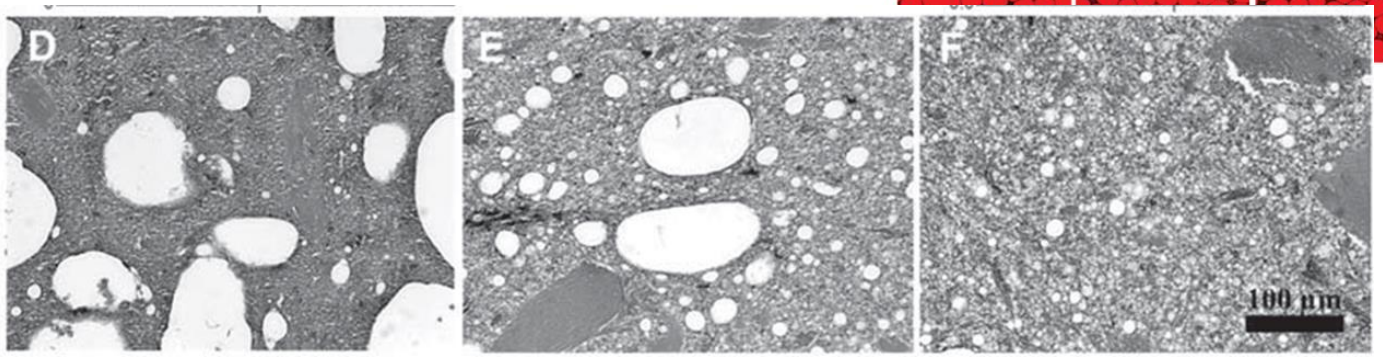
Example substitution strategy











Selection of claims on product-structuring system matches

category	Fat function	Product/problem	Oleogel system
Confectionary products	snap, appearance, melting sensation	Heat resistant chocolate	EC
		Reduced-fat chocolate	EC
		Oil migration/ Confectionary fillings	12-HSA
			Sterol/sterol-ester
			Wax
Meat products	Snap, texture	Sausages (Frankfurter-, Breakfast-, Bologna-type), Hamburger	Sterol/sterol-ester
			EC, Wax
			Pork skin emulsion
	Texture, spreadability	Pâté	EC, Wax
			EC+ MAG
Margarine+ spreads	Emulsion stabilization, hardness, melting properties, spreadability	Margarine/ spreads	Wax
Shortening for pastries	prevent adherence of gluten & starch, air cell stabilization, mouthfeel, flavour release	Cookies	EC, Wax
		(Gluten-free) cake	Wax
			EC
Dairy products	Richness, creaminess, scoopability, stabilization	Ice cream	Sterol/sterol-ester
			Wax
	Richness	Yoghurt	Sterol/sterol-ester
	Richness, spreadability	Cream cheese	Wax

Critical comments:

- realism of manufacturing
- storage time
- lack of benchmark
- no proper referencing
  - can straight oil do the trick ?

What is the benefit ?

e.g. confectionary

Plenty of options – it is the economy … and availability

List of some systems

Structuring material	Production volume [Mio t]	Price [$ t^{-1}]	Min. %wt for oil structuring	Amount of structured oil [Mio t]	Price per t structured oil [$ t^{-1}]
Palm oil	71.4[a)]	550[a)] (06.2020)	Straight	71.4	550
PPP from palm oil	5.7[b)]	750[b)]	3–4	142.7–190.3	896–903
EC	0.45–0.47[c)]	1000[d)]	3–4	11.3–15.7	903–913
SFX	0001–0005[a)]	1000[d)]	0.5–1.0	0.2–0.5	900.5–901
RBX	0.4[c)]	1000[d)]	1–5	8–40	901–905
SCX	3.8[a)]	1000[d)]	3	126.7	903
β-sitosterol/ γ-oryzanol	0.2[c)] 0.11–0.34[c)]	1000[d)] 3330[c)]	2–4 (40:60 mass ratio)	4.6–28.3	1361–1919

[a)] Actual, see respective paragraph in Section 4; [b)] Assuming 8% tripalmitate (PPP) in PO, additional costs of double dry fractionation estimated $200 t^{-1}; [c)] Potential, see respective chapter for details; [d)] Guessed to calculate the price per t structured oil, the actual price is likely much higher.

AMF (2500 $/t) at old PO price point

Are there niche markets with high benefits ? Problems preferentially solved with gels ?

Consumer acceptance for known ingredients (starch, proteins,…) - methylcellulose ????

Many systems proven in a vial, mockup product test – sensory, stability and disintegration superfluous

And lipids for structured vegetable protein base

Functionality and relevant properties of fat phase difficult to pinpoint

- juiciness, flavor, lubrication
  - marbling converting via caramelization

- just oil in protein matrix
- encapsulated oil
- o/w emulsion for tuning release and marbling

- structured lipid phase
  - traditional TAG melting profile (cocoa butter)
  - oleogel (non-TAG) – oil release at higher T

- process of fat phase integration:
  post dosing, co-processing, structured build-up, forced insertion, ….

The role of characterization and specification – oleogels

- Characterization and specification of gels
  - structure
    - penetration hardness, backextrusion, elasticity, recovery, ….
  - oil binding capacity
    - centrifugation, filter paper in whatever form
  - disintegration characteristics
    - thermally induced disintegration, solid ‚something‘ line

Relevance ?

- specification of structurants when gelling on site or in product
  - parameters critical for functionality identified ? Analytical methods available ?

Can new structuring benefit new products – are we ready for that ?

Concluding remarks

- Basic rules for relation of TAG composition and functionality are well established
- Non-TAG structuring offers many options with limited comprehension and application experience

- successful design TAG or non-TAG gel necessitate
  - analysis of manufacuring process to determine fat phase functionality
    - manufacturing, shelf life, usage
  - conversion of fat phase functionality into fat phase phase characteristics
  - without reference fat phase – for non-assembled products – this is difficult
    - substitution for structured lipid phase in ‚natural‘ matrix extremely difficult
    - interaction lipid phase and matrix not accessible

- redesign of fat phase based on verification of relevance of characterization methods
  - for comparability, flexibility and definition of future specifications

Oleogels at risk to remain ‘niche’ …. unless for new products accompanied by beneficial process innovation

- oleogels offer different characteristics of lipid phase
  - most relevant for hot applications

……. but novel food status doubtful

Thank you for your attention !

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