Stability of crystallizing emulsions

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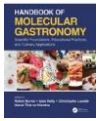
Launching event for the publication of the Handbook of Molecular Gastronomy



Thomas A. Vilgis
soft matter food physics
Max-Planck-Institute for Polymer Research
Mainz

Emulsions

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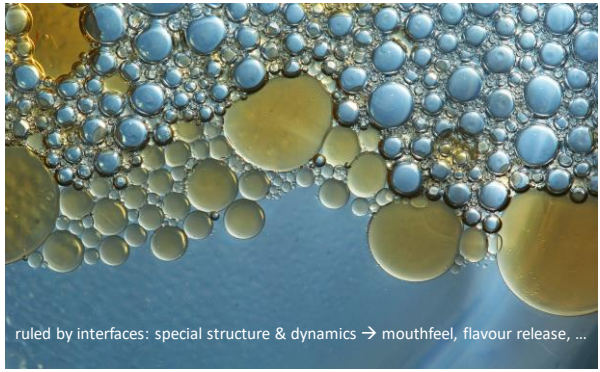
Interface dominated systems

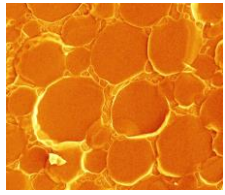


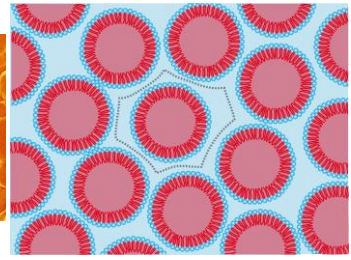
stable for low shear, low tempererature, and sufficient surfactant properties

Droplet density and dynamics

discrete phase oil: aroma release

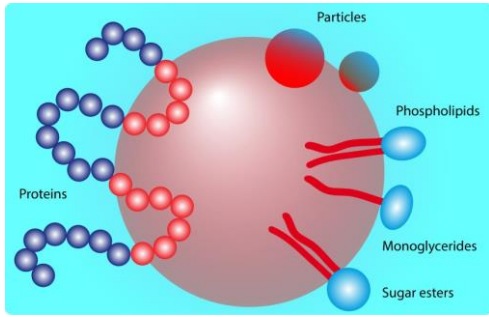
continuous phase water: taste release





Small droplets in a cage: texture, mouthfeel

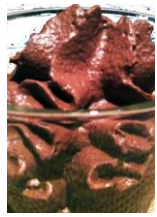
Different types of emuslifiers



What about “soy milk”?

many useful kitchen applications





Fat content

Why does ot work with chocolate

Hot soy milk → add chocolate → emulsify → cool down → chocolate becomes solid

but how does the cocoa butter crystallize in emulsion droplets?

What happens when fat crystallizes?

Chocolate cream / soy milk

bulk

emulsion (confined geometry)

Kinetics matters, morphology & polymorphs

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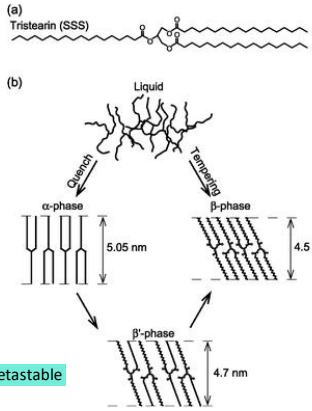

very unstable

stable

metastable

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Vilgis, T. A. (2015). Soft matter food physics—the physics of food and cooking. *Reports on Progress in Physics*, *78*(12), 124602.

Cocoa butter: many polymorphs

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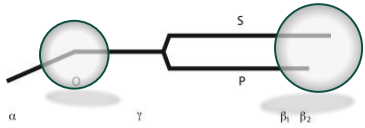
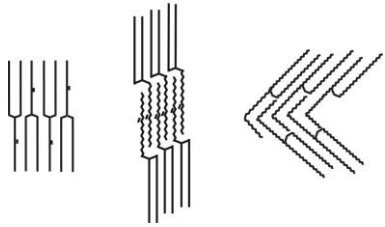
mainly POS



various polymorphs



You feel it in the mouth

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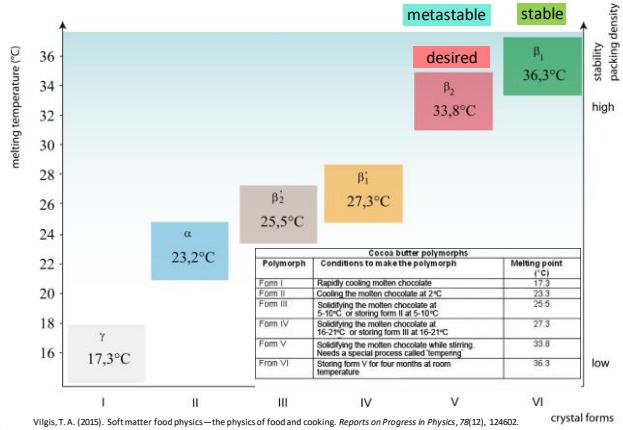
Melting & mouthfeel: chocolate science



Cocoa butter polymorphs

Polymorph	Conditions to make the polymorph	Melting point (°C)
Form I	Rapidly cooling molten chocolate	17.3
Form II	Cooling the molten chocolate at 2°C	23.3
Form III	Solidifying the molten chocolate at 5-10°C or storing form II at 5-10°C	25.5
Form IV	Solidifying the molten chocolate at 16-21°C or storing form III at 16-21°C	27.3
Form V	Solidifying the molten chocolate while stirring. Needs a special process called Tempering	33.8
From VI	Storing form V for four months at room temperature	36.3

Vilgis, T. A. (2015). Soft matter food physics—the physics of food and cooking. *Reports on Progress in Physics*, *78*(12), 124602.

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Bulk crystallization of cocoa butter

CB_90°C_24Hrs_at room temperature

Joshi, B. L., Zielbauer, B. I., & Vilgis, T. A. (2020). Comparative Study on Mixing Behavior of Binary Mixtures of Cocoa Butter/Tristearin (CB/TS) and Cocoa Butter/Coconut Oil (CB/CO). *Foods*, *9*(3), 327.

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Physicist: make life simple

More controlled: soy storage proteins + cocoa butter

Jüngling I. (2020) Stability of protein stabilized cocoa butter emulsion under crystallization, Thesis, MPI-P / University Mainz.

Soy proteins as surfactants

Storage protein: Glycine, very long protein, effective emulsifers

```
P04776 GLYG1_SOYBN    1  MAKLVFSLCFLLFSGCCFAFSSREQFQQNEQCQCQKLNALKPDNRIESEGGLIETWNPNNK  60
P04405 GLYG2_SOYBN    1  MAKLVLSLCFLLFSGCF---AAREQAQNEQCQCQKLNALKPDNRIESEGGFIETWNPNNK  57
                         *****:*********       : *** ********************:*********

P04776 GLYG1_SOYBN   61  PFQCAGVALSRCTLNRNALRRPSYTNGPQEIYIQQGRGIFGMIYPGCPSTFEEPQQPQQR  120
P04405 GLYG2_SOYBN   58  PFQCAGVALSRCTLNRNALRRPSYTNGPQEIYIQQGNGIFGMIFPGCPSTYQEPQESQQR  117
                         ***************************************:******.***:  ***

P04776 GLYG1_SOYBN  121  GQSSRPQDRHQKIYNFREGDLIAVPTGVAWWMYNNEDTPVVAVSIIDTNSLENQLDQMPR  180
P04405 GLYG2_SOYBN  118  GRSQRPQDRHQKVHRFREGDLIAVPTGVAWWMYNNEDTPVVAVSIIDTNSLENQLDQMPR  177
                         :.*.*********:.*************************************************

P04776 GLYG1_SOYBN  181  RFYLAGNQEQEFLKYQQEQGGHQSQKGRHQQEEENEGGSILSGFTLEFLEHAFSVDKQIA  240
P04405 GLYG2_SOYBN  178  RFYLAGNQEQEFLKYQQQQQGGSQSQKGKQQEEENEGSNILSGFAPEFLKEAFGVNMQIV  237
                         ****************:* * ...: :********..*****: ***:.**:* **.

P04776 GLYG1_SOYBN  241  KNLQGENEGEDKGAIVTVKGGLSVIKPPTDEQQQRPQEEEEEEEEDEKPQCRGKDKHCQRP  300
P04405 GLYG2_SOYBN  238  RNLQGENEEEDSGAIVTVKGGLRVTAPAMRKPQ---QEEDDDDEEEQPQCVETDKGCQRQ  294
                         :******* **.********** *  *  :  *  ***:::::*:*:**  .** ***

P04776 GLYG1_SOYBN  301  RGSQSKSRRNGIDETICTMRLRHNIGQTSSPDIYNPQAGSVTTATSLDFPALSWLRLSAE  360
P04405 GLYG2_SOYBN  295  ----SKRSRNGIDETICTMRLRQNIGQNSSPDIYNPQAGSITTATSLDFPALWLLKLSAQ  350
                             **  ***********:*:*:**.*************:*******  *:****:

P04776 GLYG1_SOYBN  361  FGSLRKNAMFVPHYNLNANSIIYALNGRALIQVVNCNGERVFDGELQEGRVLIVPQNFVV  420
P04405 GLYG2_SOYBN  351  YGSLRKNAMFVPHYTLNANSIIYALNGRALVQVVNCNGERVFDGELQEGGVLIVPQNFAV  410
                         :*********.*****:*:*:*****:*****:*********:*********** ***.*

P04776 GLYG1_SOYBN  421  AARSQSDNFEYVSFKTNDTPMIGTLAGANSLLNALPEEVIQHTFNLKSQQARQLKNNNPF  480
P04405 GLYG2_SOYBN  411  AAKSQSDNFEYVSFKTNDRPSIGNLAGANSLLNALPEEVIQHTFNLKSQQARQVKNNNPF  470
                         **:*********** * **.*************:*****:*****:*********:*****

P04776 GLYG1_SOYBN  481  KFLVPPQESQKRAVA  495
P04405 GLYG2_SOYBN  471  SFLVPPQESQRRAVA  485
                         *******:****
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Varying cocoa butter content

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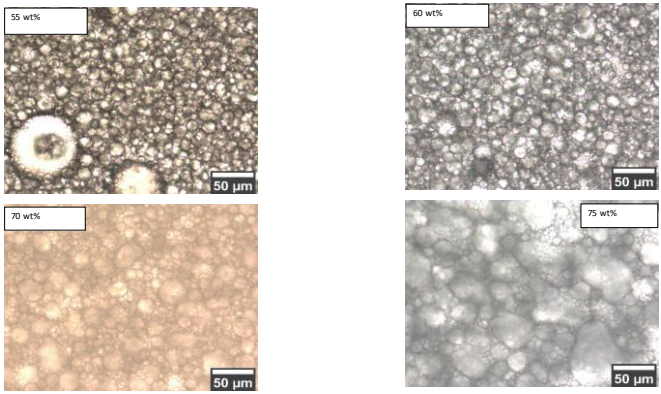
Prepared With a 4 wt% soy protein-dispersion



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Varying soy protein content

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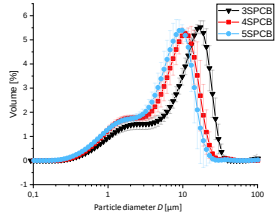
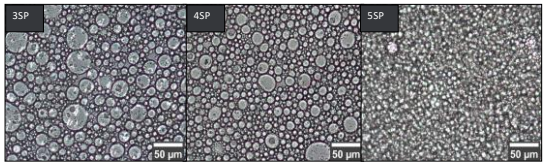




3 % 4 % 5 %

From liquid to creamy to “solid”

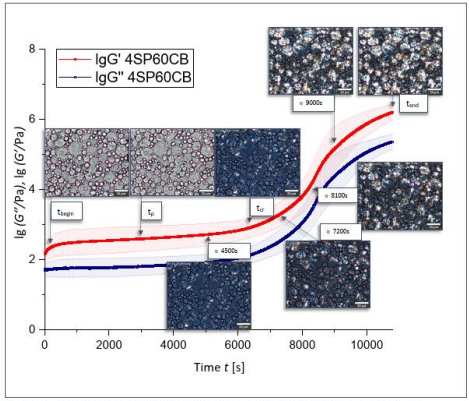
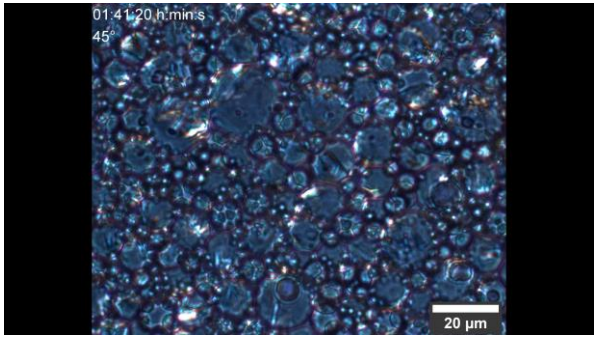


Figure 40: time-dependent rheological measurement, displaying the storage modulus G' and the loss modulus G'' of a 4SP60CB emulsion complimented by microscope pictures taken seperatly during the same time frame, showing the change in emulsion after time. τ_{begin} = measurement start , τ_g ≈ 3000s, τ_{cr} ≈ begin of rapid crystallization, τ_{end} ≈ end of measurement.

Jüngling I. (2020) Stability of protein stabilized cocoa butter emulsion under crystallization, Thesis, MPI-P / University Mainz.

Crystallization under the microscope



Jüngling I. (2020) Stability of protein stabilized cocoa butter emulsion under crystallization, Thesis, MPI-P / University Mainz.

What is going on an meso / micros scales?

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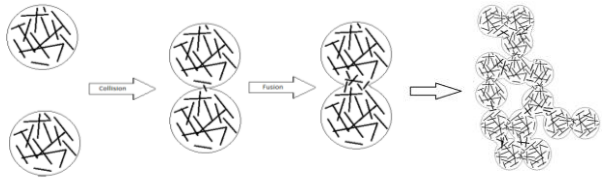
1. Secondary heterogenous nucleation → secondary crystallization process
2. Induce/supports partial coalescence



form particle gel

Result: Phase inversion induced through fat-crystallization

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What is going on at nano scales?

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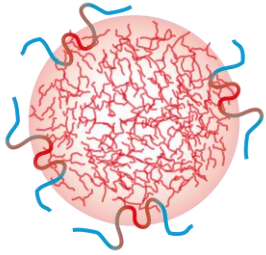
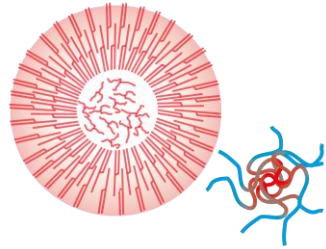


liquid oil phase $T > T_c$



solid fat phase $T > T_c$

What can do real soy milk and real chocolate better?

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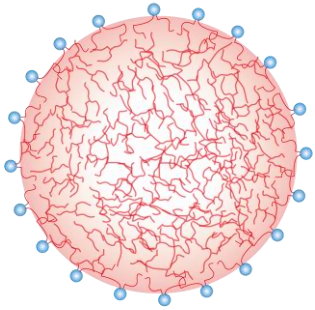
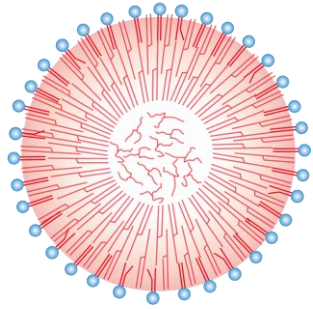
Lecithin (phospholipids) from soy and chocolate help differently





- C 18:0 crystallizes early
- lipids remain in interface

What can do real soy milk and real chocolate better?

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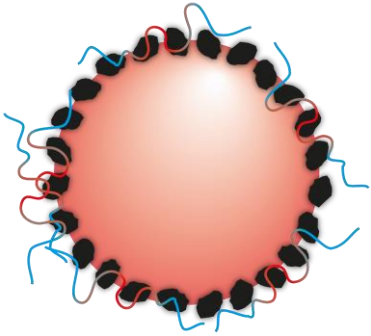
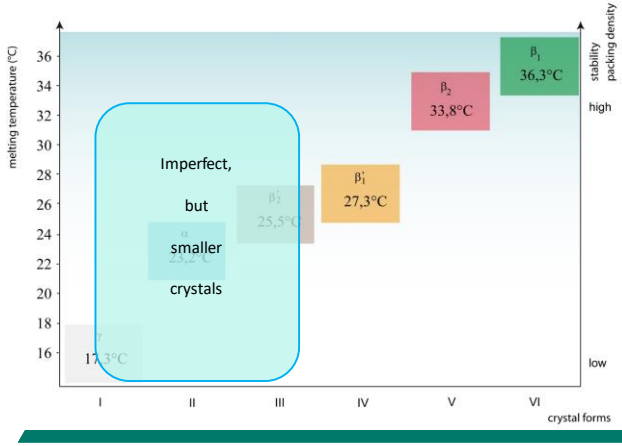


- Cocoa particles, (polyphenols)
- Pickering emulsion
- Funktional surfaces
- Keep soy proteins close to interfaces

Suggestion: cool chocolate emulsion rapidly



Thank you for the invitation

Thank you Mainz – Foodies