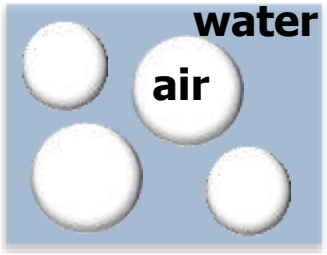
INRAE
la science pour la vie, l'humain, la terre

UMET
Unité Matériaux Et Transformations

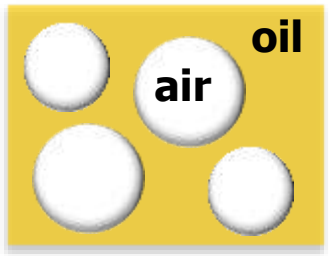
Edible oil foams stabilized by crystalline particles

Dr. Anne-Laure Fameau

Outline



1. Aqueous foams



2. Differences between aqueous & non-aqueous foams

3. Formulation rules for edible oil foams

4. Effect of co-crystallization on oil foam properties

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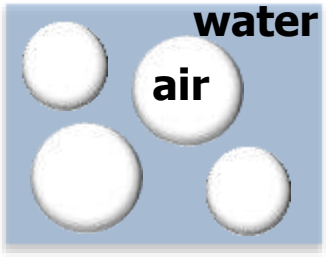

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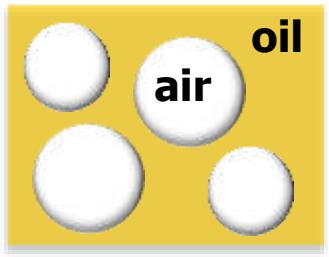

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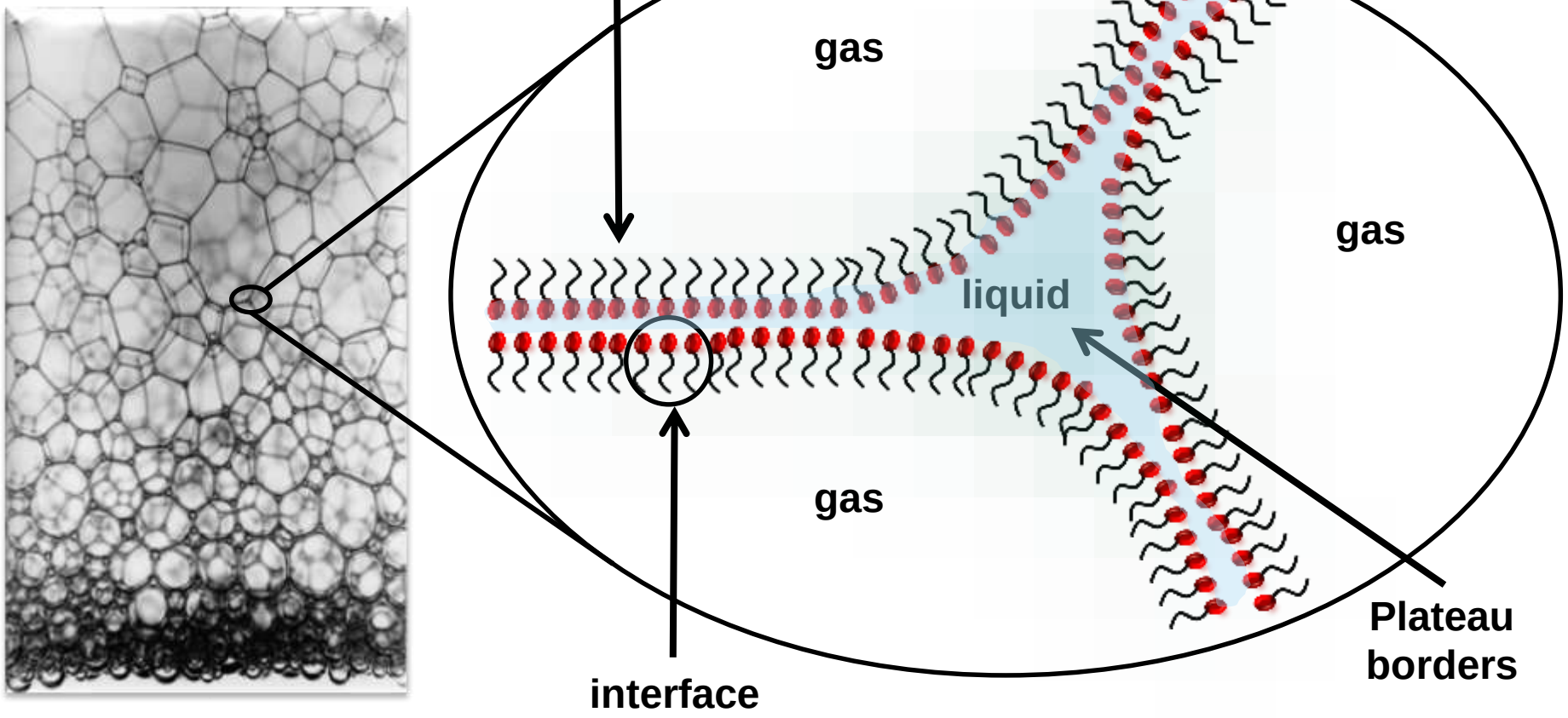
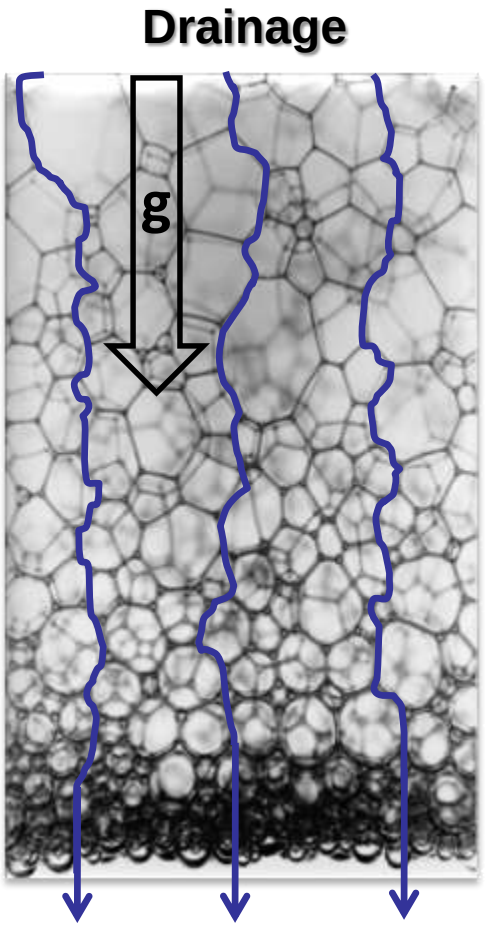
Aqueous Foams for what?

What is an Aqueous Foam?

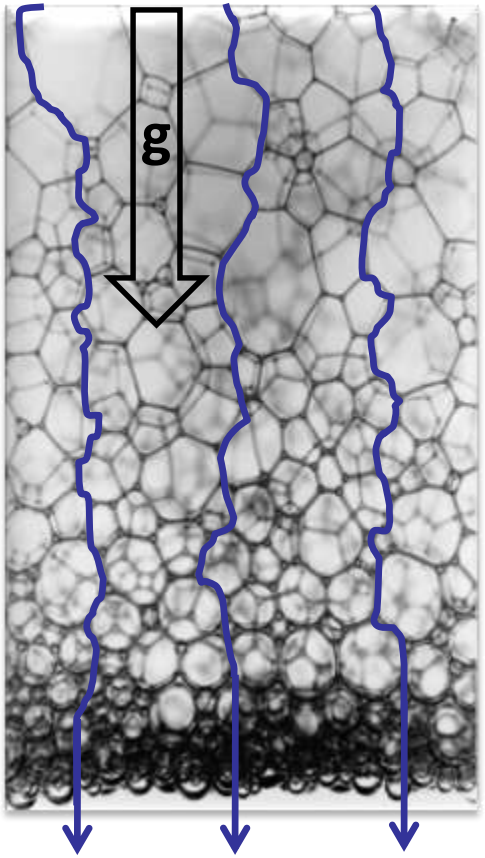


Mechanisms of foam destabilization

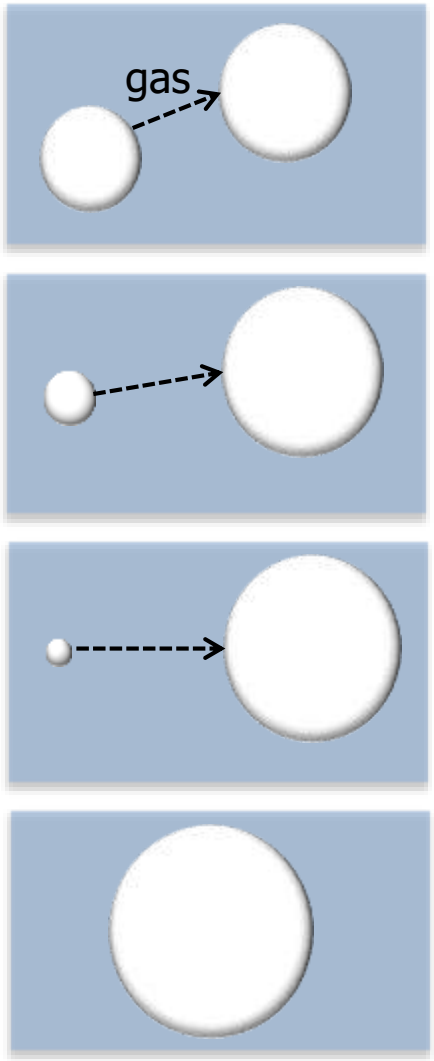


Mechanisms of foam destabilization

Drainage



Coarsening



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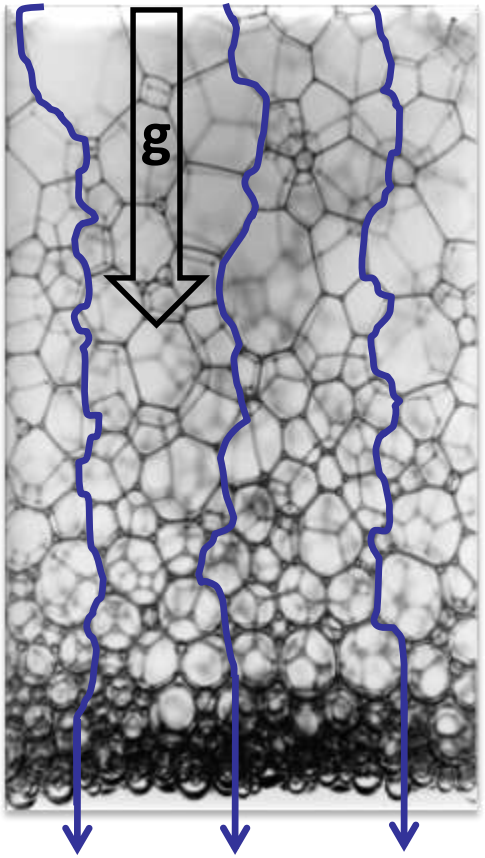

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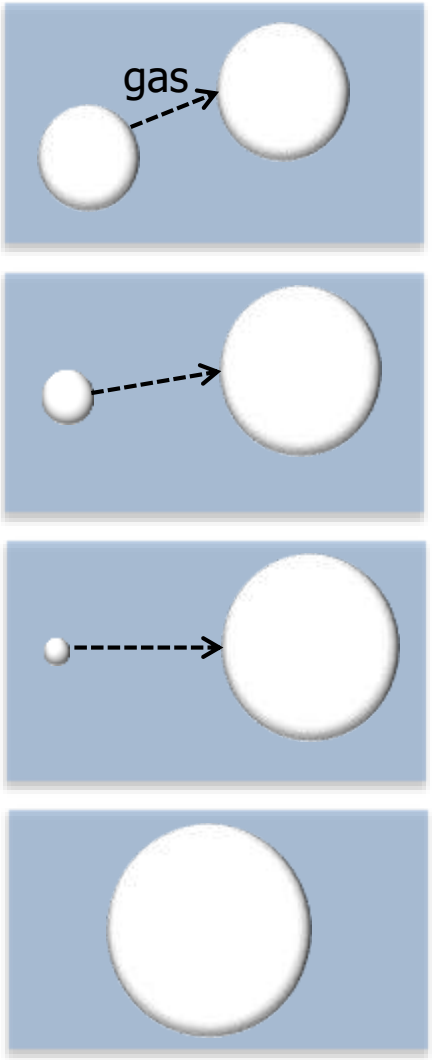
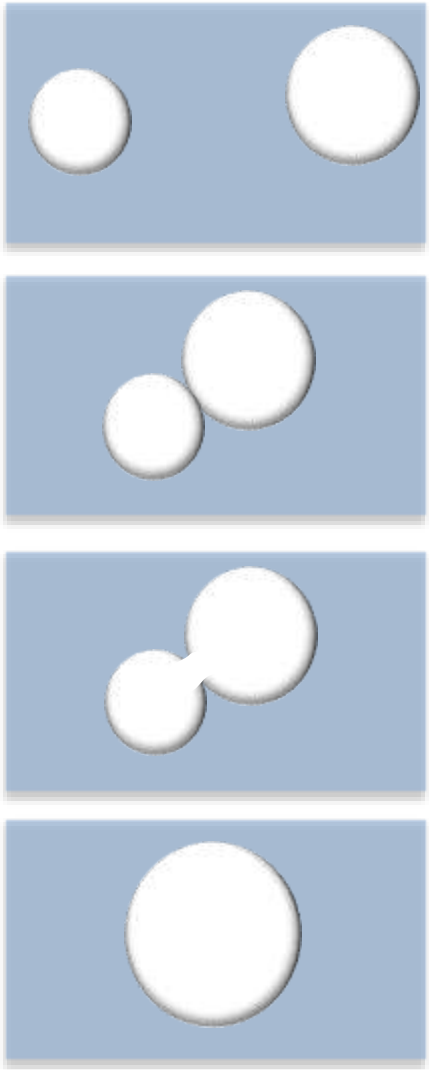


Coalescence



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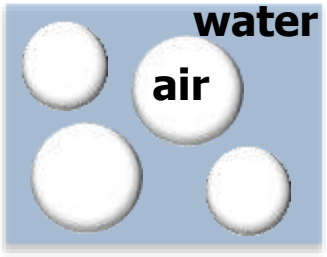

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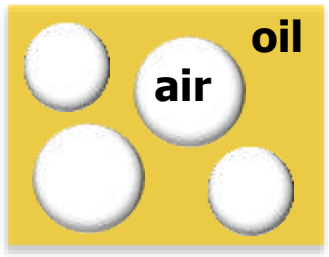

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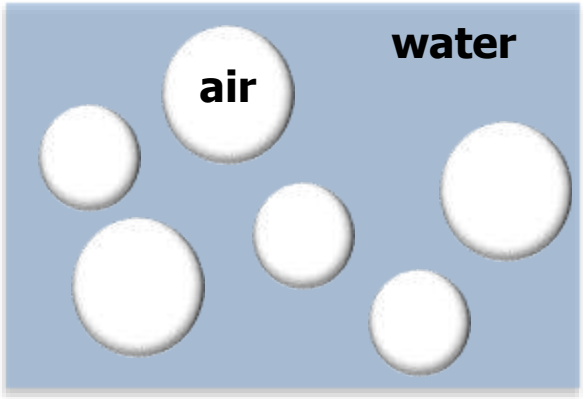
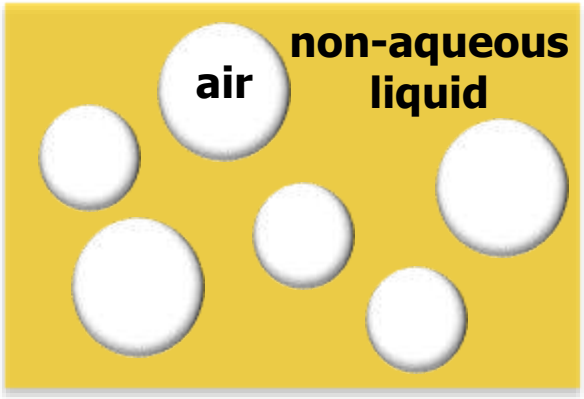
What is a non-Aqueous Foam?

Aqueous Foams



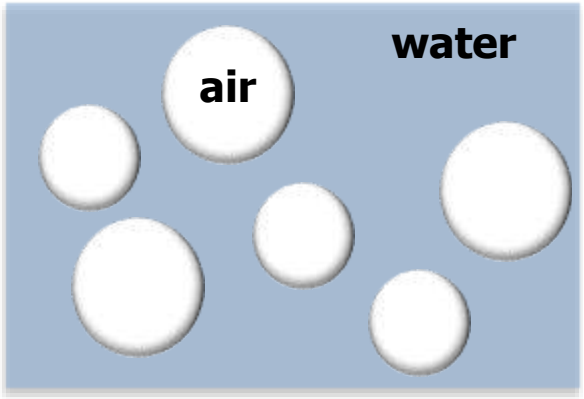
Non-Aqueous Foams



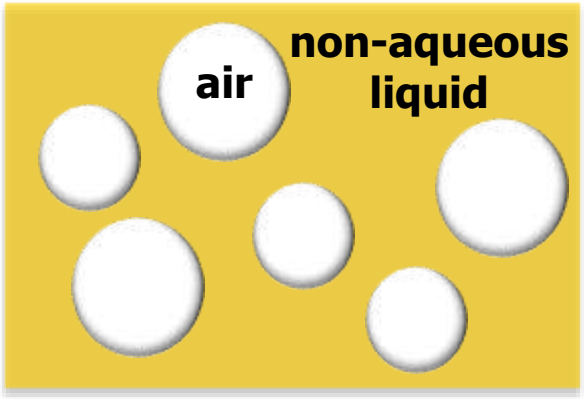
S. E. Friberg, Curr. Opinion Coll & Int Sci., 2010.

What is a non-Aqueous Foam?

Aqueous Foams



Non-Aqueous Foams



Where can we find Non-Aqueous Foams?

Cosmetic industry

Petroleum industry

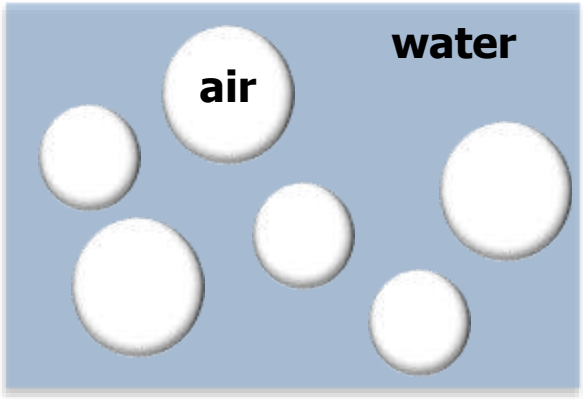
Food industry

Few data available on the formulation, production and characterization of Non-Aqueous Foams

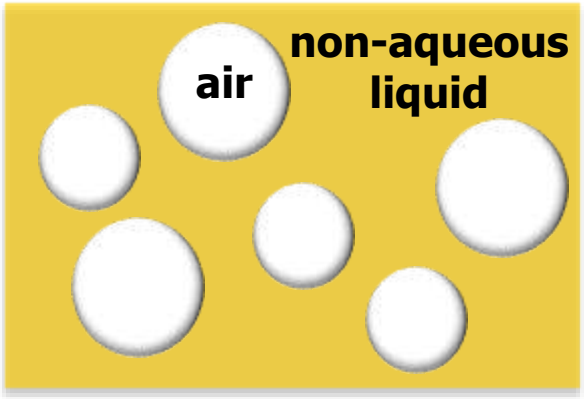
S. E. Friberg, Curr. Opinion Coll & Int Sci., 2010.

Aqueous/Non-Aqueous Foams: Differences

Aqueous Foams



Non-Aqueous Foams

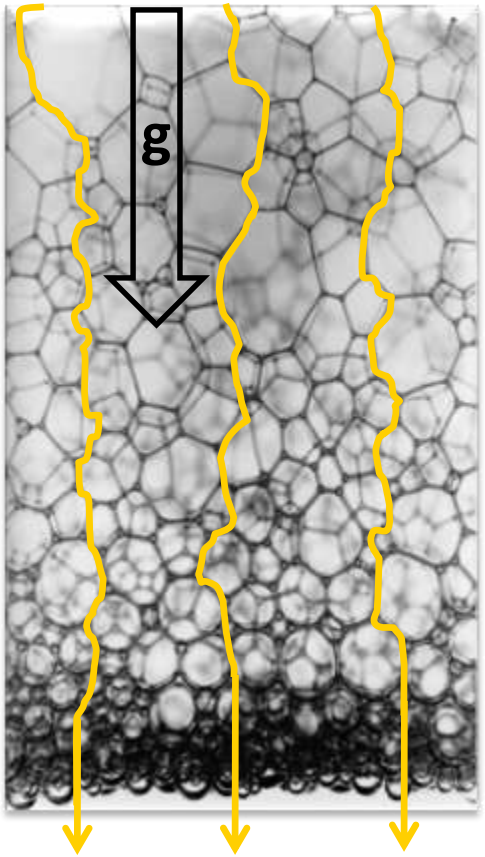


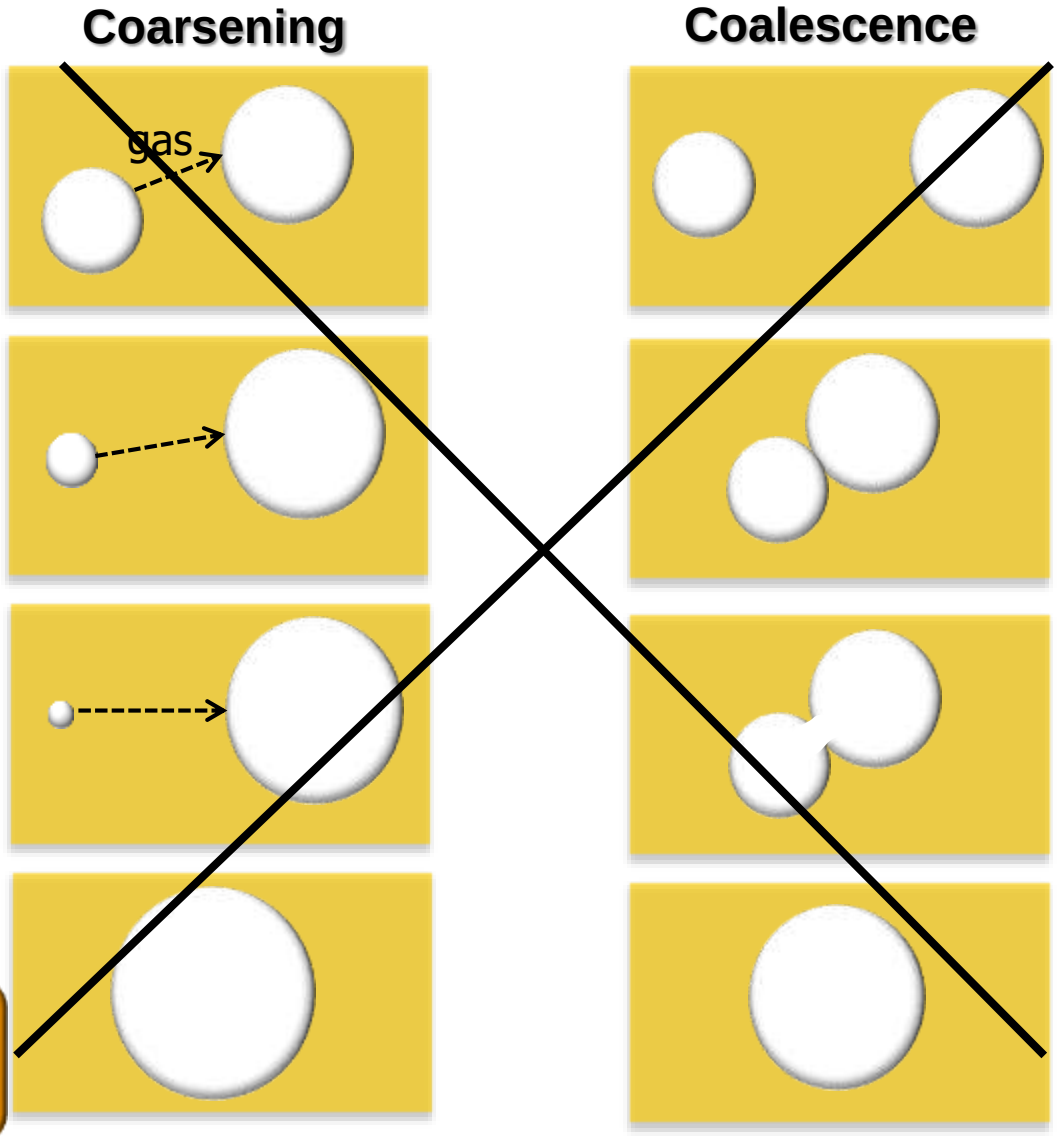
Maximum Liquid fraction < 1 %

Maximum Liquid fraction around < 10-20%

Large difference in the liquid fraction inside the foam

Aqueous/Non-Aqueous Foams: Differences



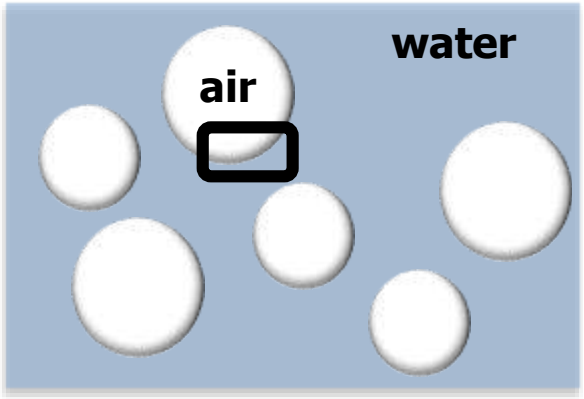


Drainage most important destabilization mechanism

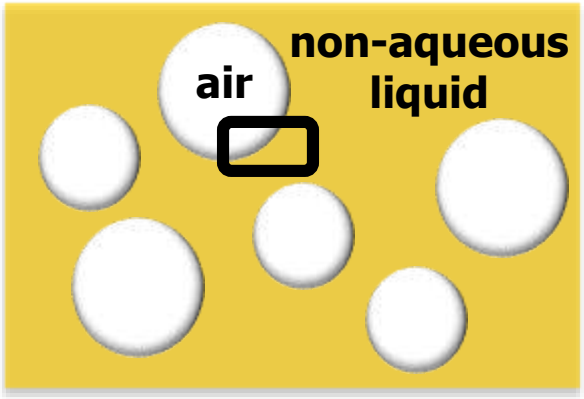
A-L. Fameau, Book chapter. Handbook of Molecular Gastronomy, 2021

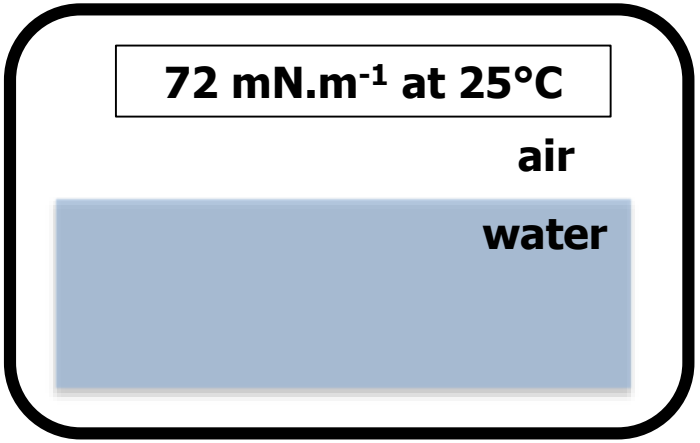
Aqueous/Non-Aqueous Foams: Differences

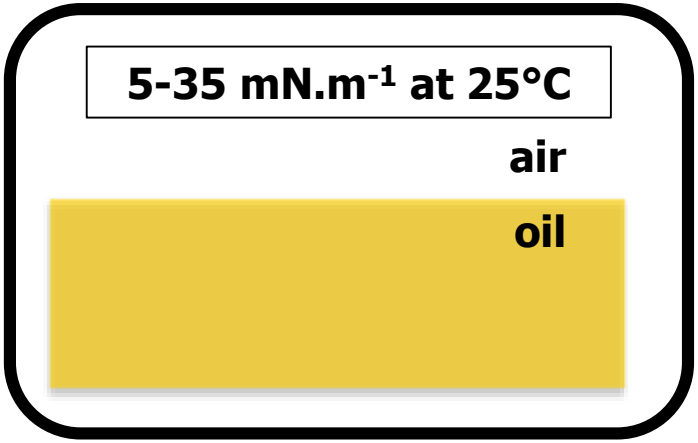
Aqueous Foams



Non-Aqueous Foams







Large difference in the surface tension of the solvents

A-L. Fameau, Book chapter. Handbook of Molecular Gastronomy, 2021

Aqueous/Non-Aqueous Foams: Differences

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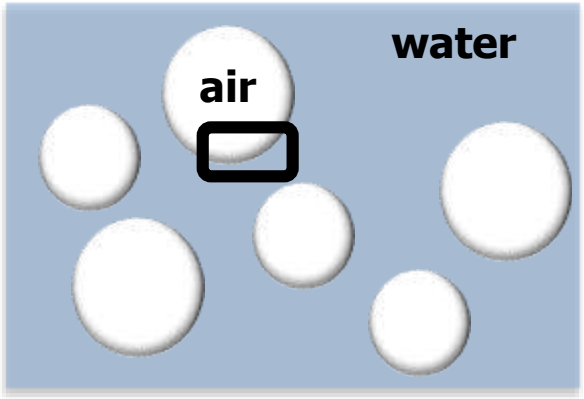

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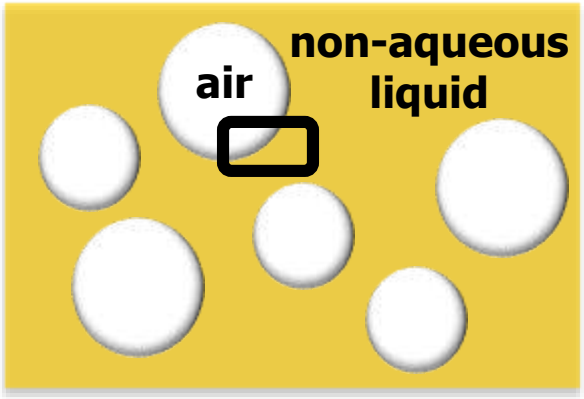
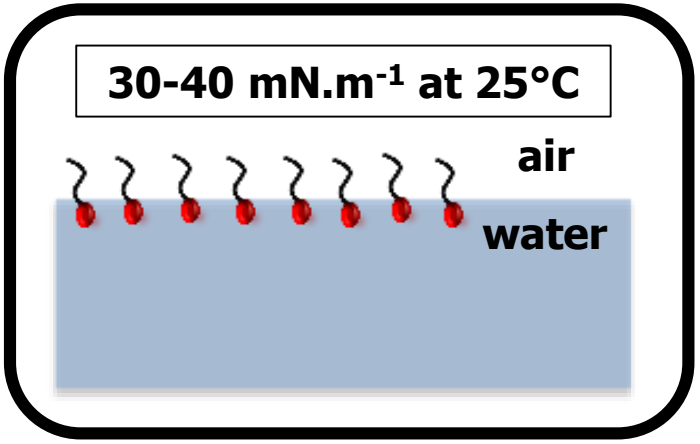
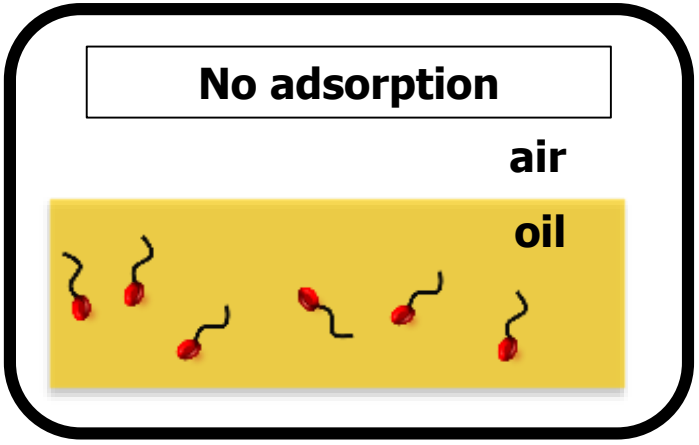
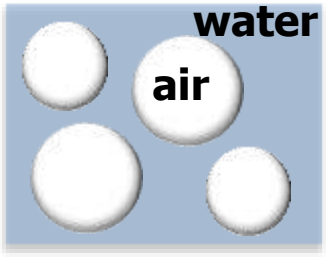






For oil systems, the low surface tension makes the adsorption of hydrocarbon-based surfactants energetically unfavourable.

Outline



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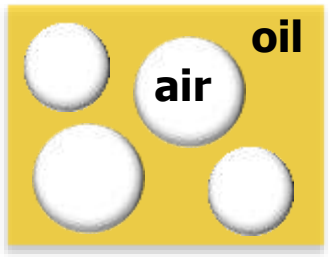

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How to obtain Oil Foams?

Fluorocarbon-based surfactants

Low Foam Stability

B. Binks, et al., Coll Surf A, 2010.

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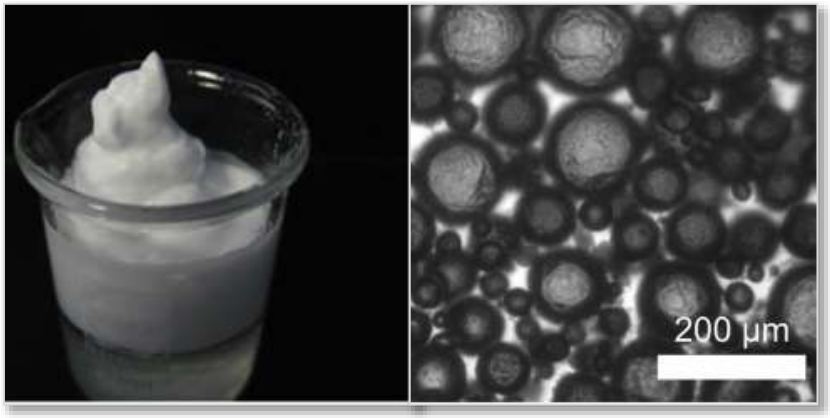
Partially Oleophobic Particles (Surfaces coated with Fluoro groups)



Ultrastable Foam

R. Murakami, et al. Advanced Functional Materials, 2010.

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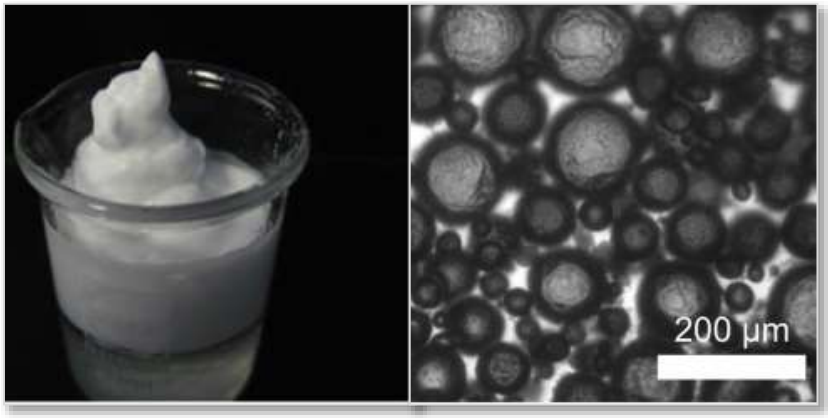

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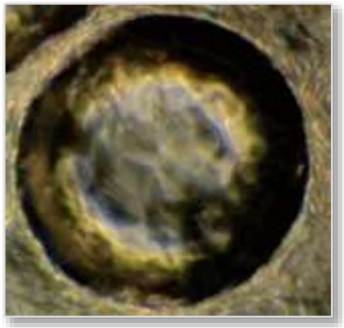
Crystalline particles of fatty components (Mono-, Di-, Triglycerides, fatty acids, fatty alcohol & sucrose esters)



Ultrastable & based on Food grade components

L. K. Shrestha, et al., Langmuir, 2006.
A-L. Fameau et al., Langmuir, 2015.
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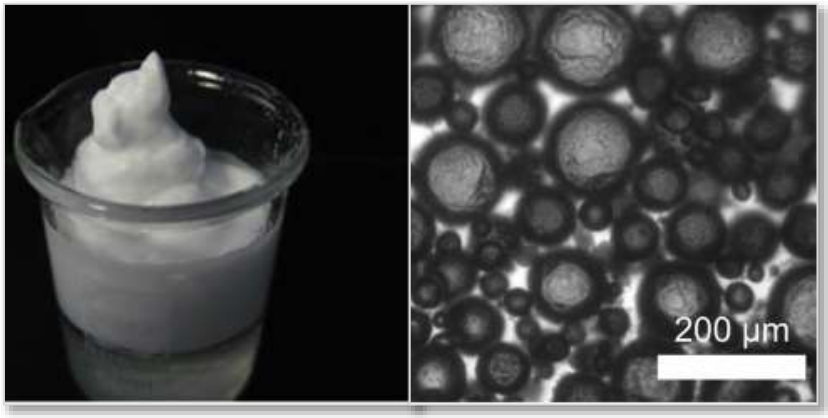

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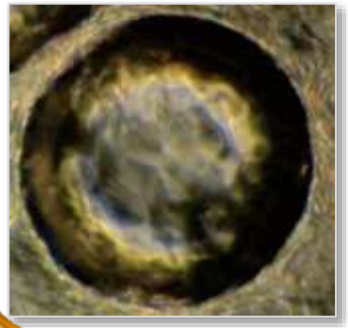

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How to obtain crystalline particles?

Vegetable oils

+

Fatty components

- **Mono-, Di-, Triglycerides**
- **Fatty acids**
- **Fatty alcohol**
- **Sucrose esters**

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Vegetable oils

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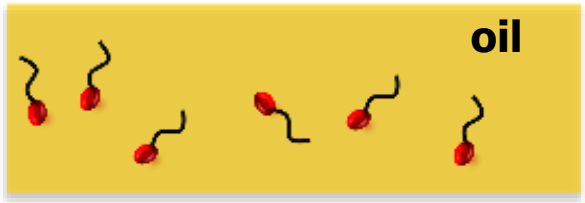

Fatty component soluble at high temperatures

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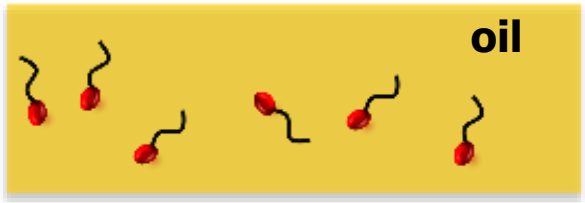

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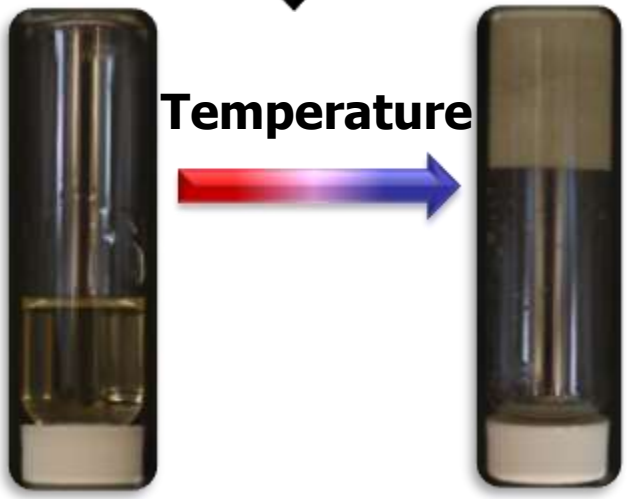
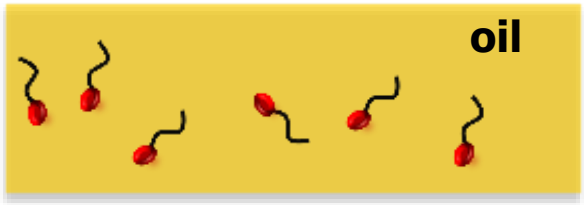


Crystalline particles

Oleogel formation due to the formation of crystalline particles

How to obtain crystalline particles?



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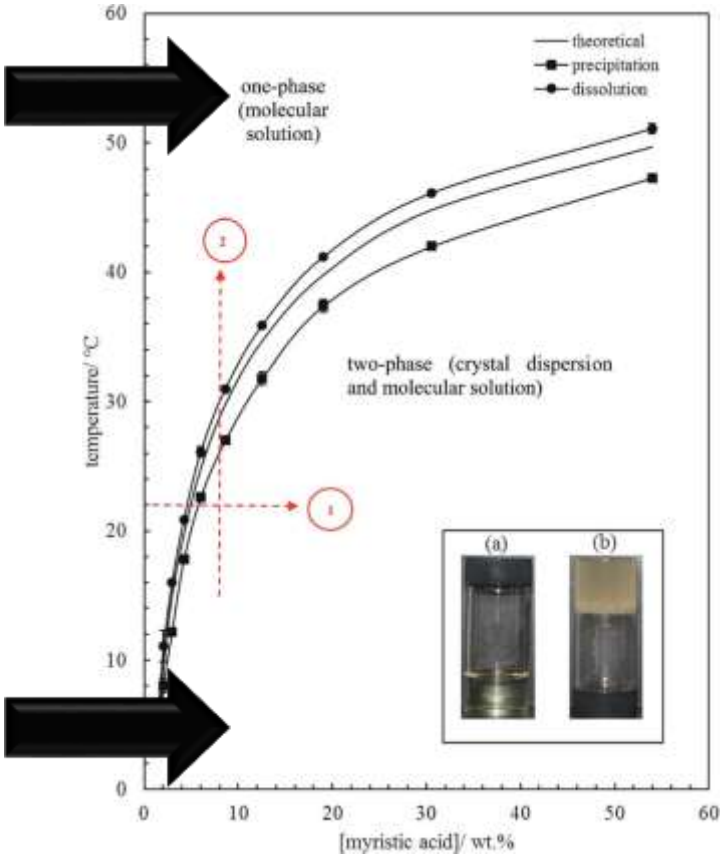
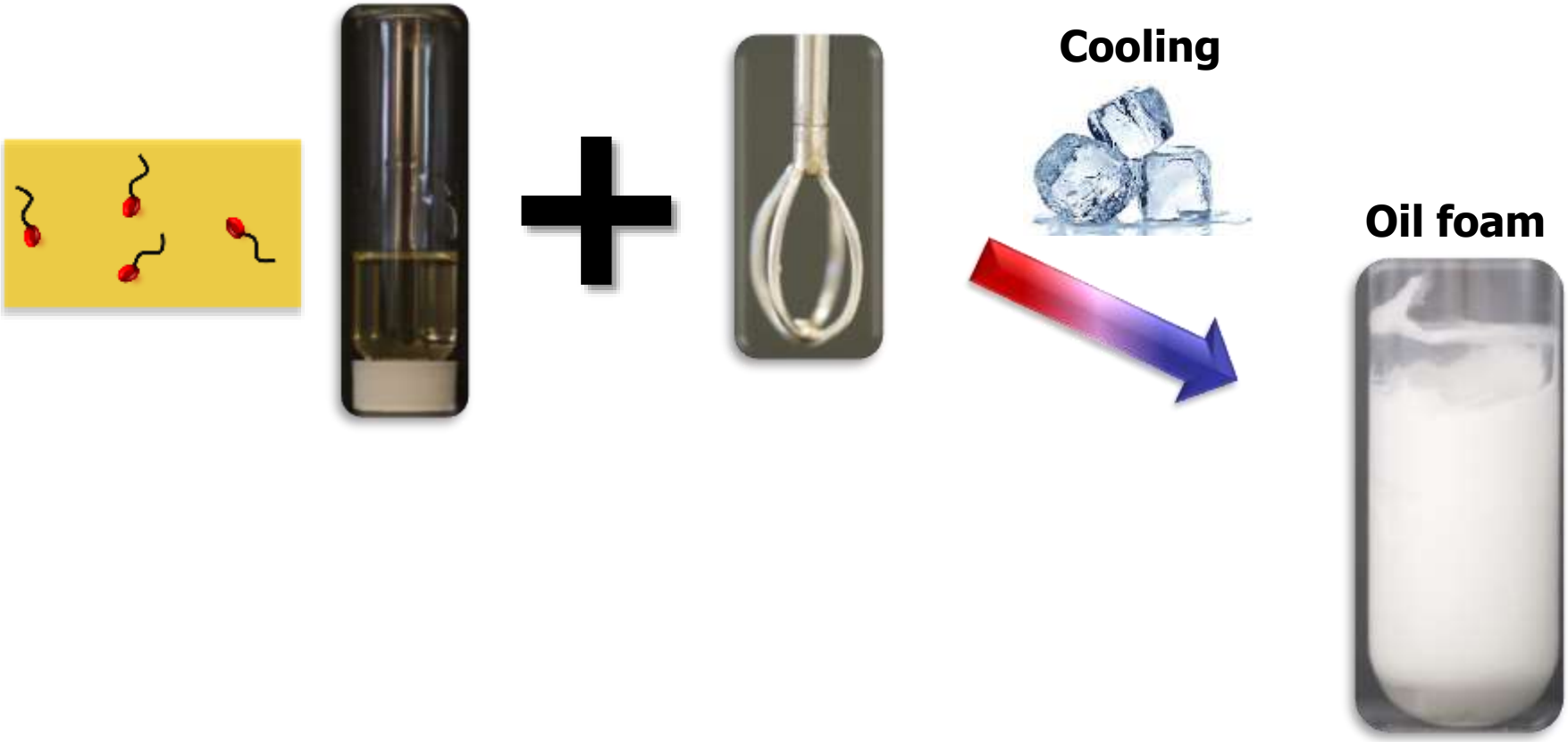


To produce crystalline particles: determination of the solubility limit for each fatty component in a given oil.

B.P. Binks., Chemical Science 2016.

How to produce Oil foam?



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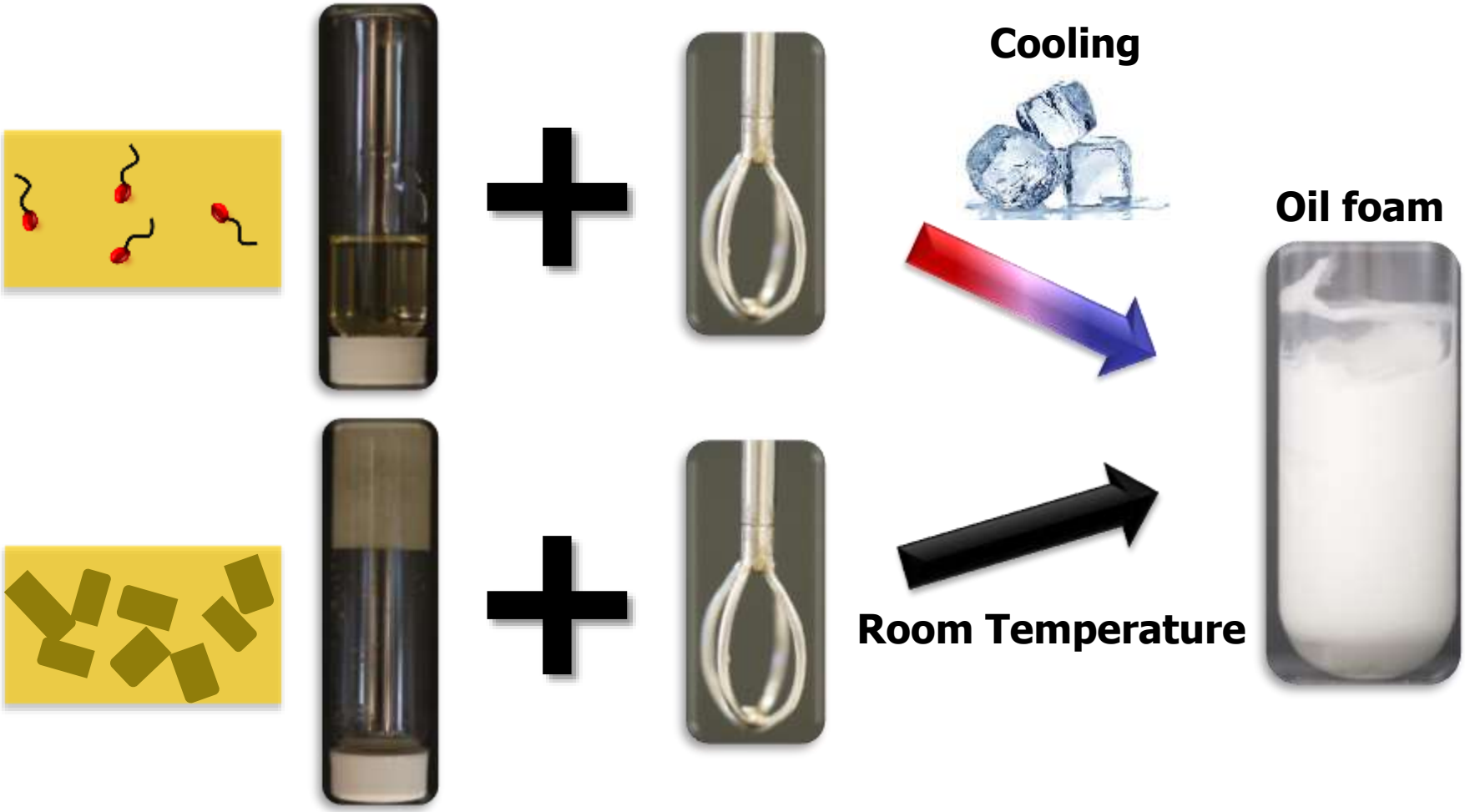

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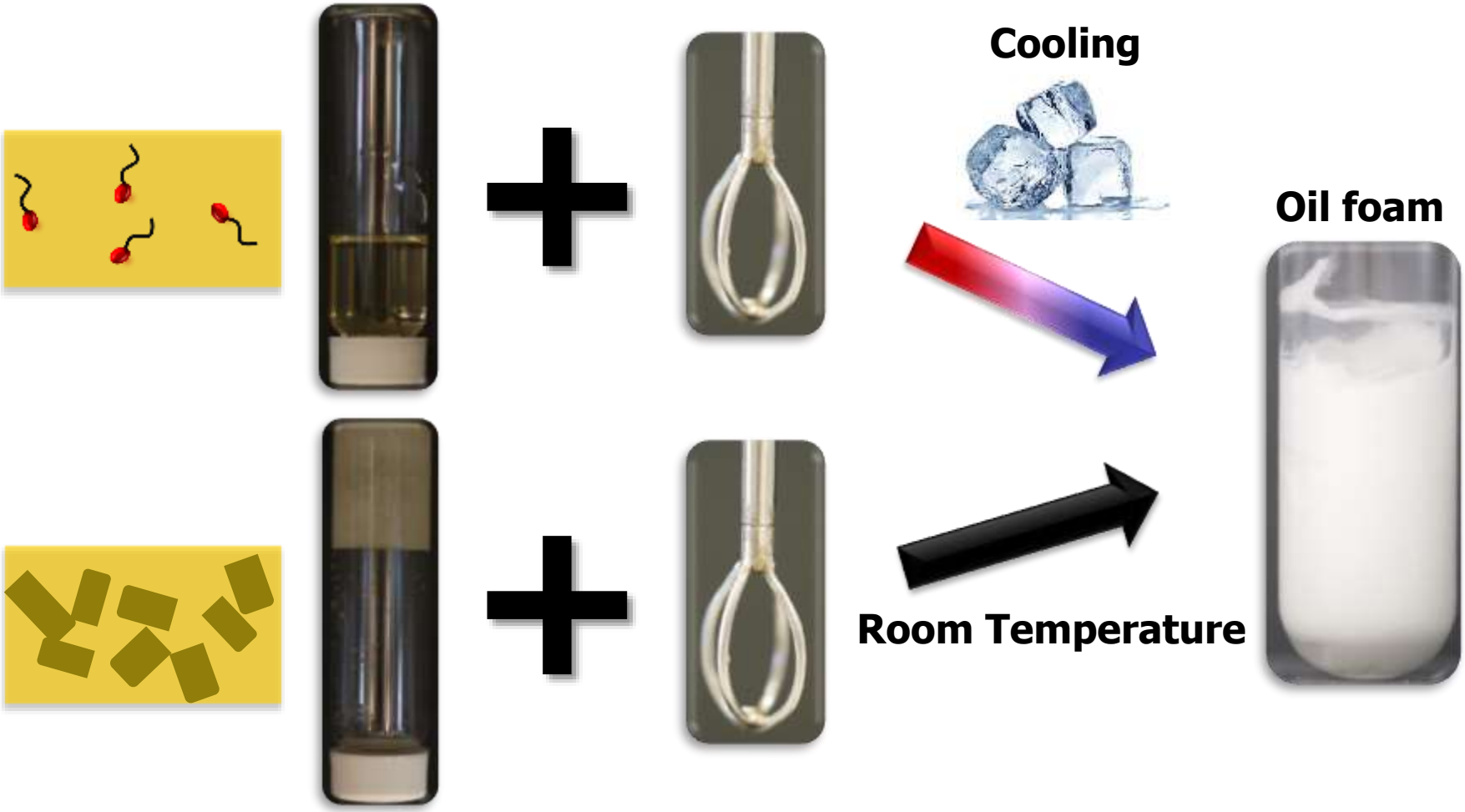
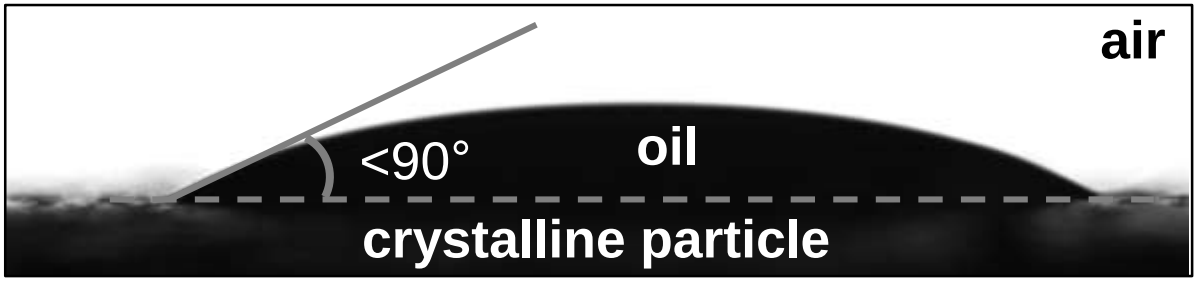


Two ways to produce oil foams by whipping: (1) by cooling during the oleogel formation or (2) directly from the oleogel

How to stabilize Oil foam?

How to stabilize Oil foam?



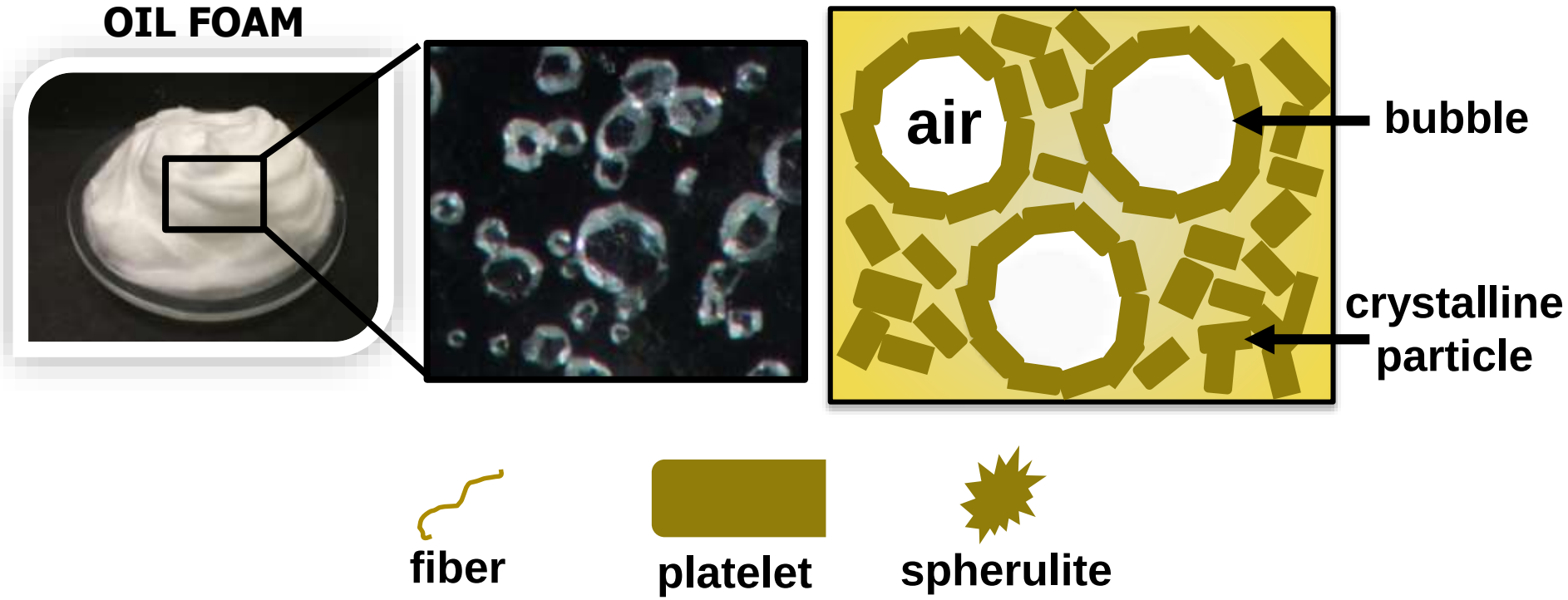
Key parameter for crystals to adsorb at the air-oil surface is to exhibit a suitable contact angle < 90°.

B.P. Binks., Chemical Science 2016.

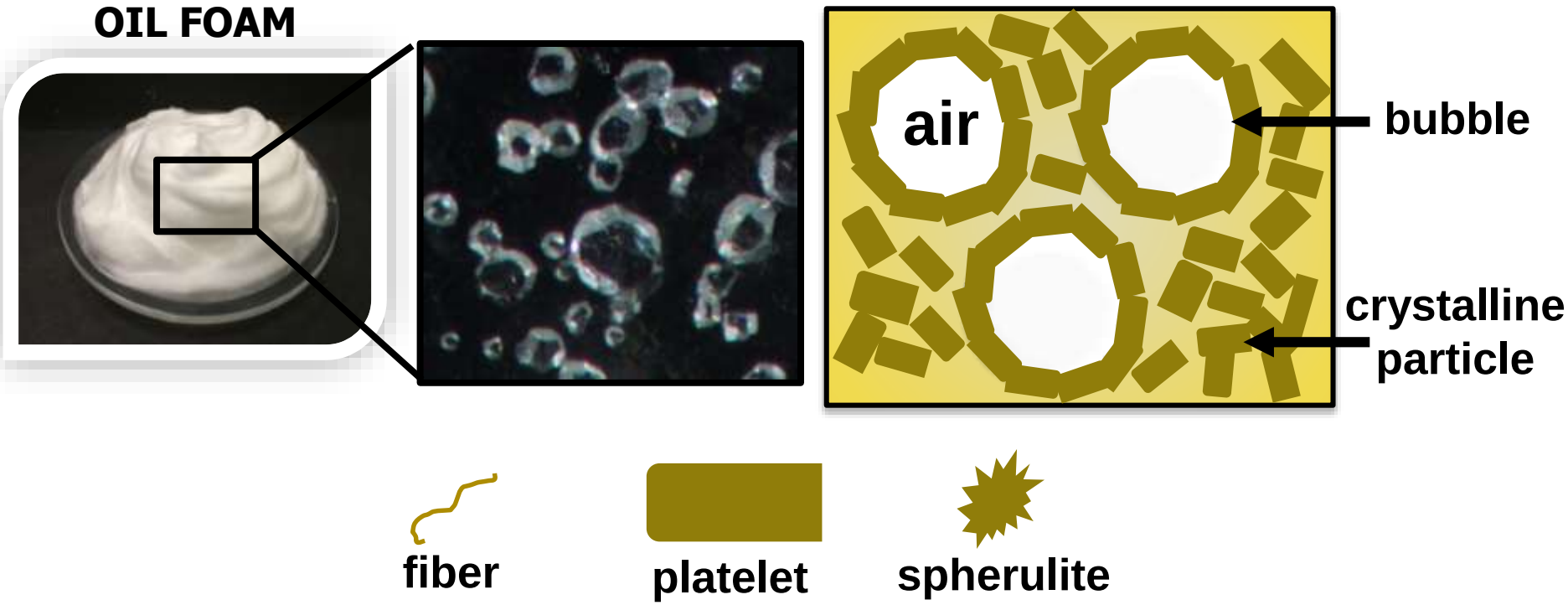
How to stabilize Oil foam?

Size & shape of crystalline particles depend on: cooling rate, shearing rate & nature of fatty component.

Effect of the particles shape?



Effect of the particles shape?



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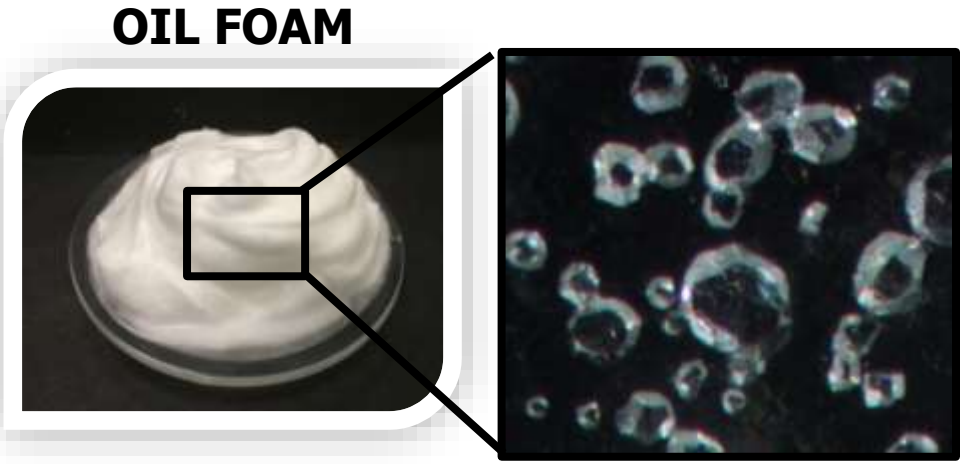
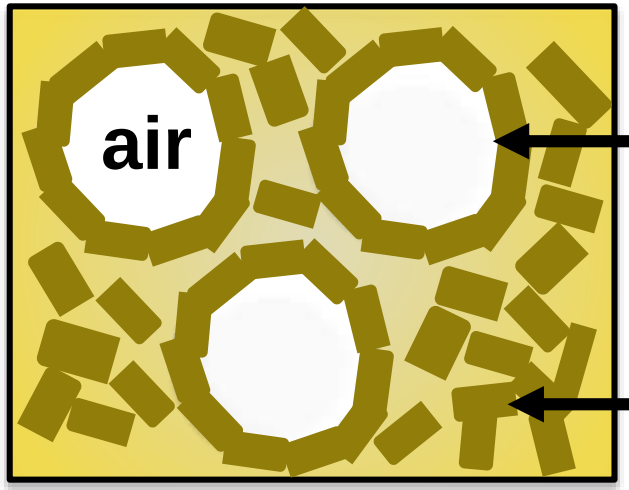
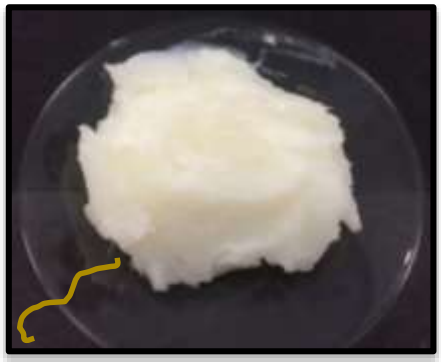
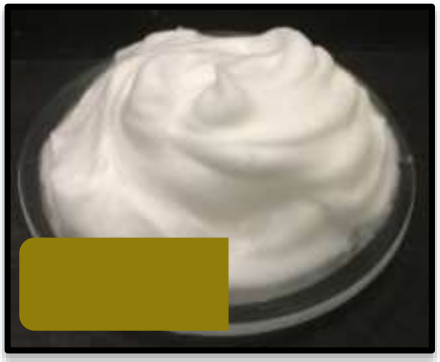




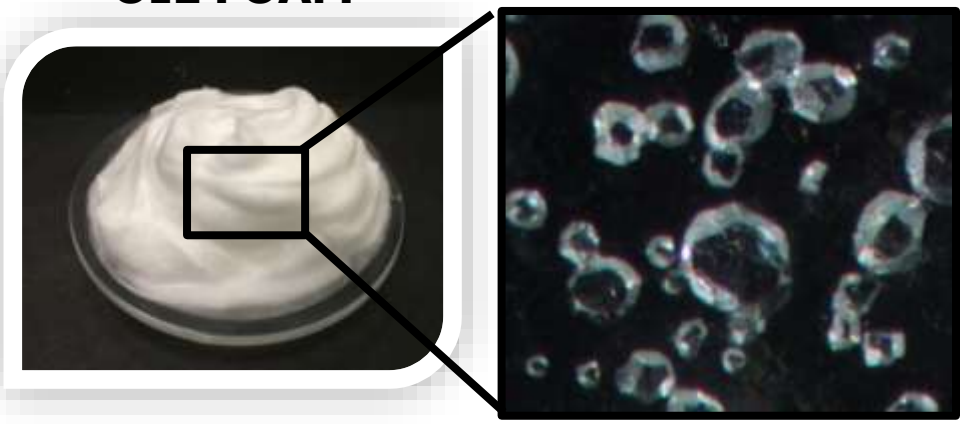

12-hydroxystearic acid

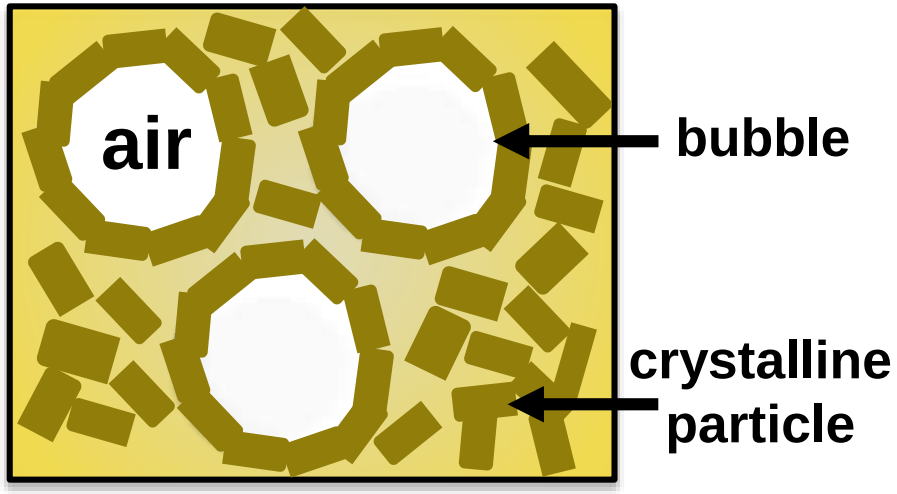

stearic acid


trihydroxystearine

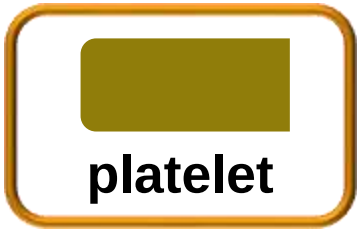
Effect of the particles shape?

OIL FOAM





- **Shape of the crystalline particles:**



Effect of the particles size?

Size & shape of crystalline particles depend on: cooling rate, shearing rate & nature of fatty component.

Callau et al. Food Chemistry, 2020

Effect of the particles size?

Size & shape of crystalline particles depend on: cooling rate, shearing rate & nature of fatty component.

Fatty alcohol & Fatty acid
(stearic acid/stearyl alcohol)

platelet

Fast cooling

platelet

Callau et al. Food Chemistry, 2020

Effect of the particles size?

Fatty alcohol & Fatty acid
(stearic acid/stearyl alcohol)

Slow cooling

Fast cooling

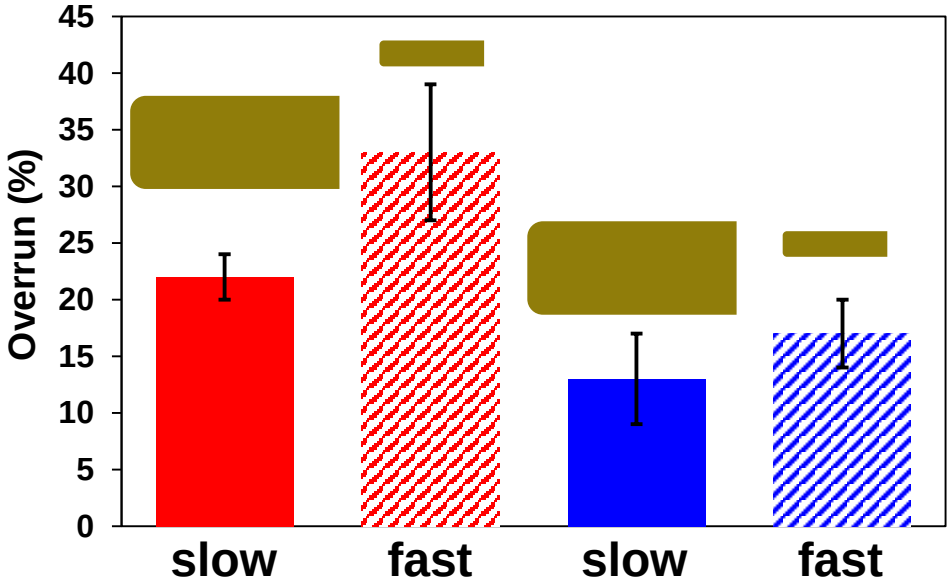
Effect of the particles size?

Fatty alcohol & Fatty acid
(stearic acid/stearyl alcohol)

Slow cooling

Fast cooling

$$Overrun\ (\%) = \frac{V_{foam} - V_{oil}}{V_{foam}} \times 100$$



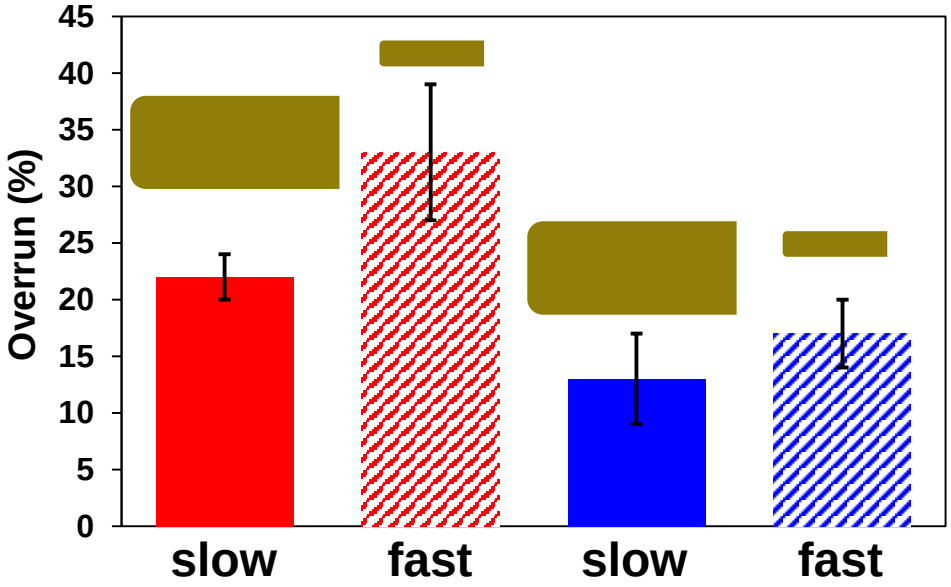
Effect of the particles size?

Fatty alcohol & Fatty acid
(stearic acid/stearyl alcohol)

Slow cooling

Fast cooling

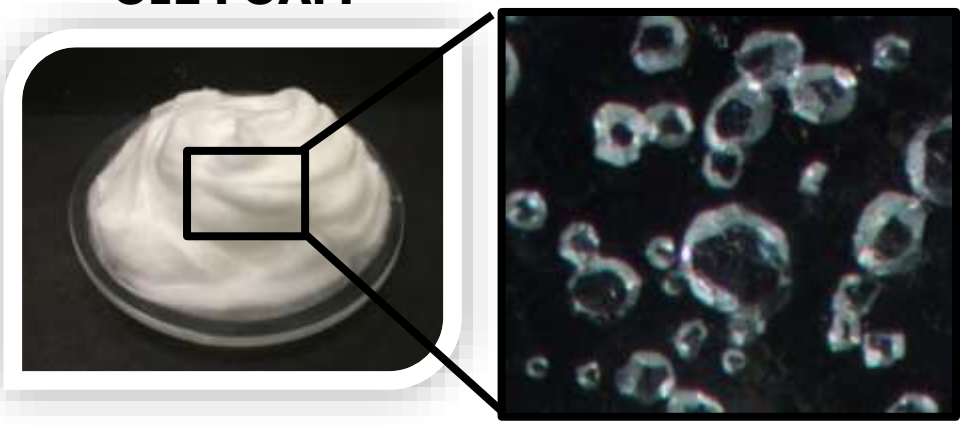
$$Overrun\ (\%) = \frac{V_{foam} - V_{oil}}{V_{foam}} \times 100$$

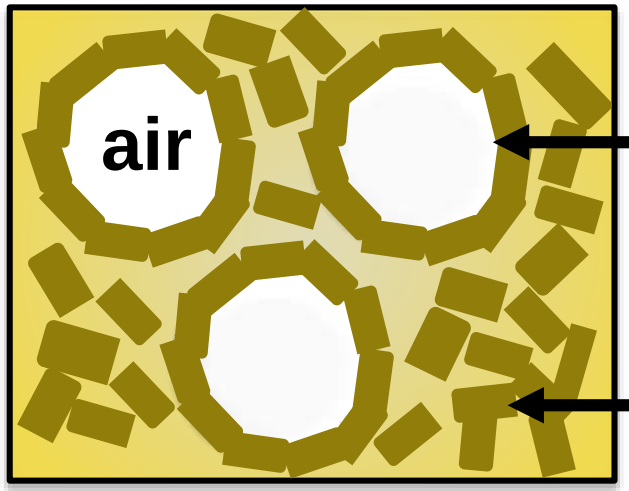


Size, important parameter: small crystals higher overrun & foam stability

Formulation rules

OIL FOAM



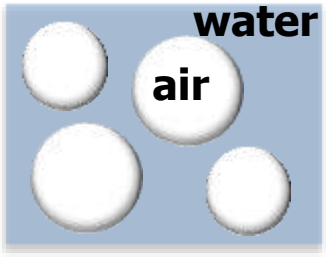


- Crystalline particles with suitable **contact angle < 90°**
- Shape of the crystalline particles:

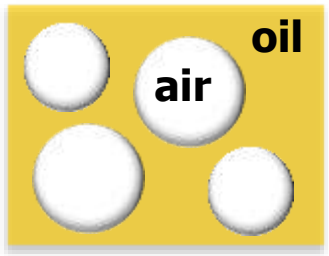
- Size of the crystalline particles:

Key parameters for crystalline particles depend on: cooling rate, shearing rate & nature of fatty component.

Outline



1. Aqueous foams



2. Differences between aqueous & non-aqueous foams

3. Formulation rules for edible oil foams

4. Effect of co-crystallization on oil foam properties

Effect of co-crystallization?

90 wt.%
Sunflower oil

Stearyl alcohol

Stearic acid

10 wt. %
R = SO:SA

Oleogel

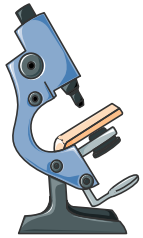
Oil foam

Callau et al. JCIS, 2020
Callau et al. Food Chemistry, 2020

Effect of co-crystallization?

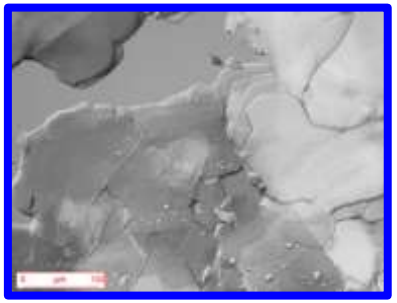
R= 10:0

Fatty Alcohol



DIC
x20

R = 0:10



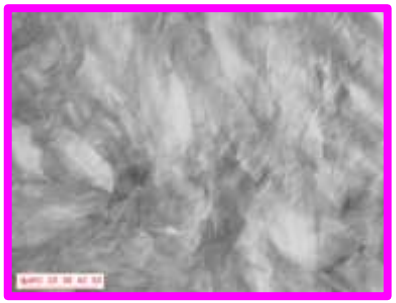
Fatty Acid

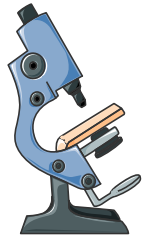
Effect of co-crystallization?

R= 10:0

Fatty Alcohol

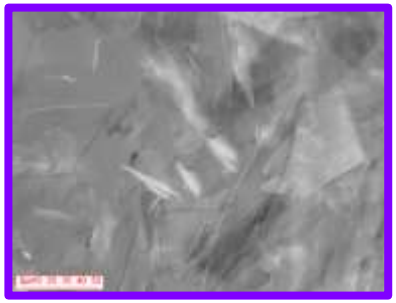
R = 5:5



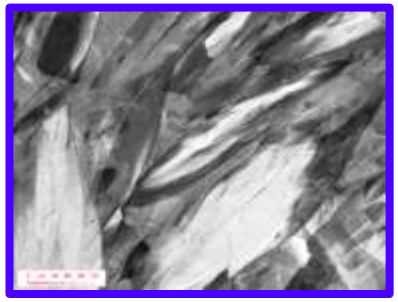


DIC
x20

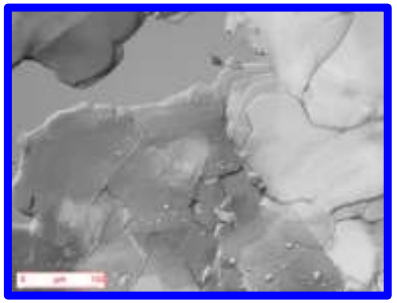
R = 3:7



R = 2:8



R = 0:10



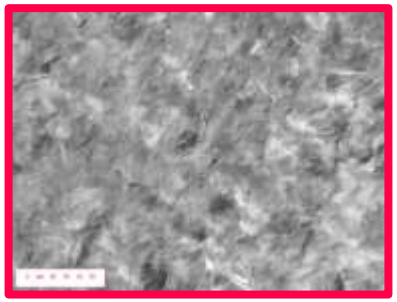
Fatty Acid

Effect of co-crystallization?

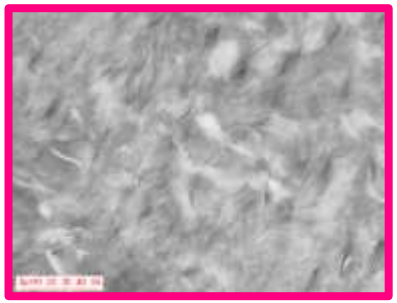
R= 10:0

Fatty Alcohol

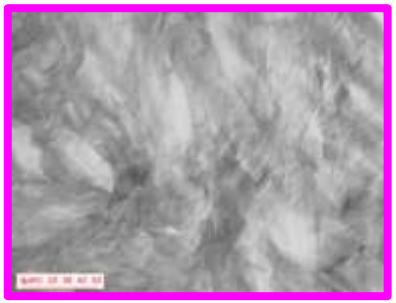
R= 8:2

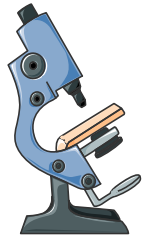


R = 7:3



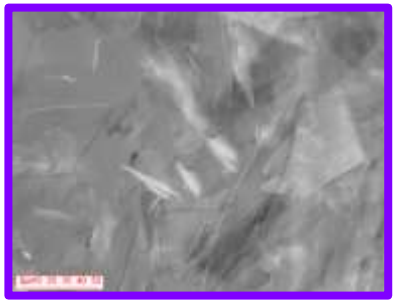
R = 5:5



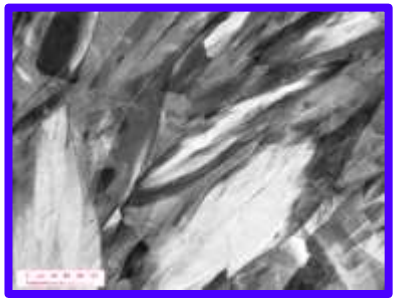


DIC
x20

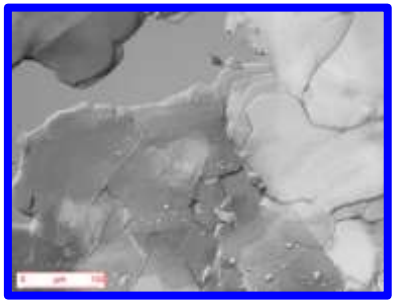
R = 3:7



R = 2:8



R = 0:10



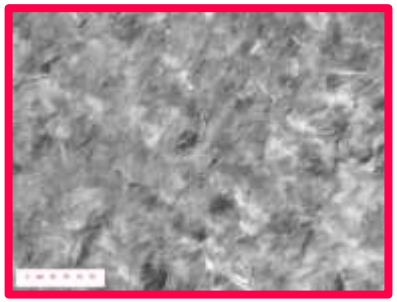
Fatty Acid

Effect of co-crystallization?

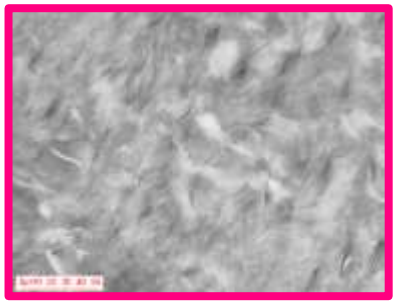
R= 10:0

Fatty Alcohol

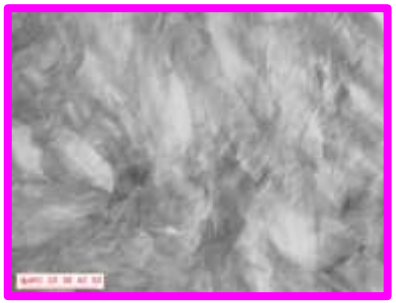
R= 8:2

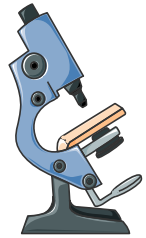


R = 7:3



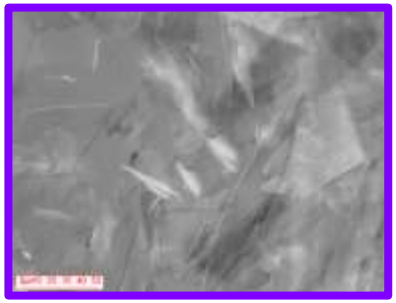
R = 5:5



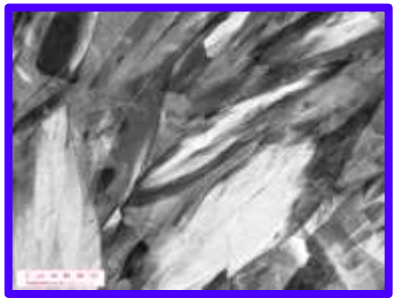


DIC
x20

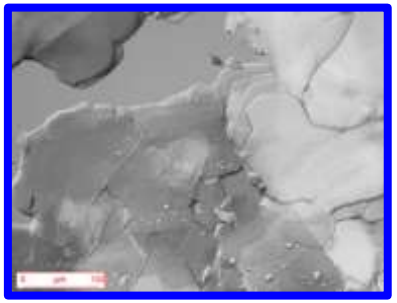
R = 3:7



R = 2:8



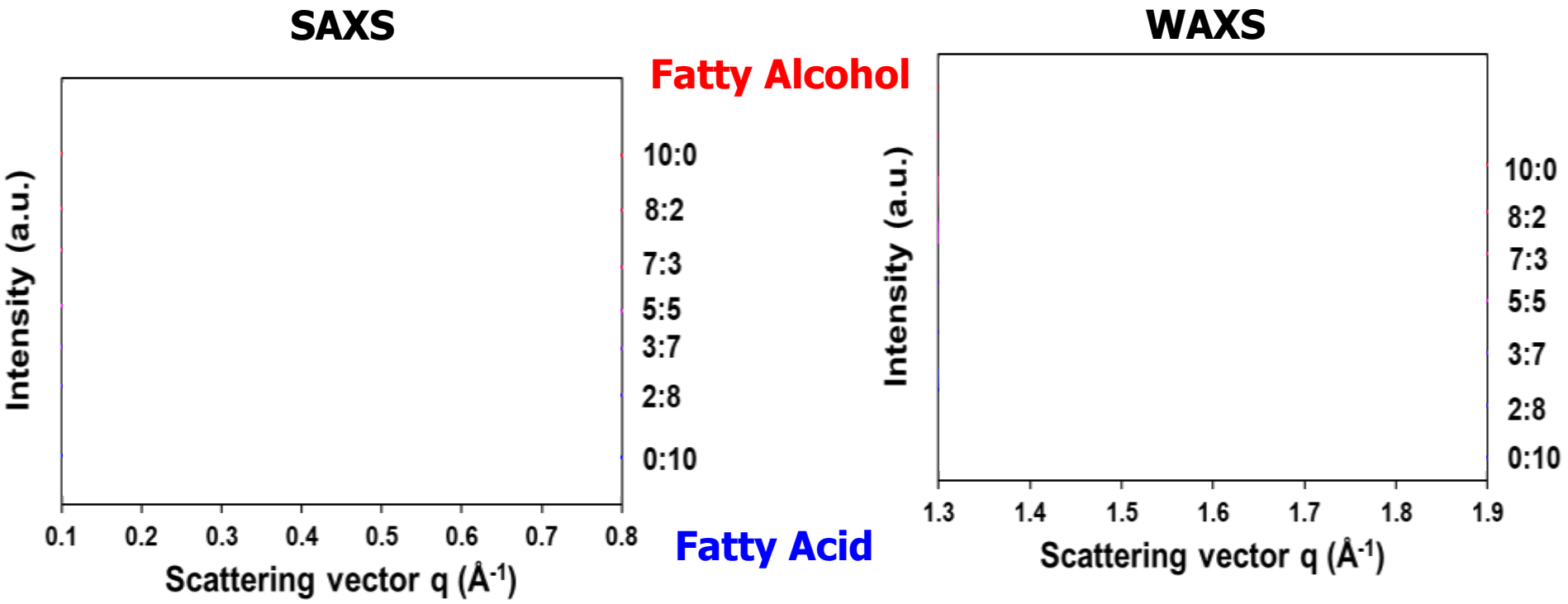
R = 0:10



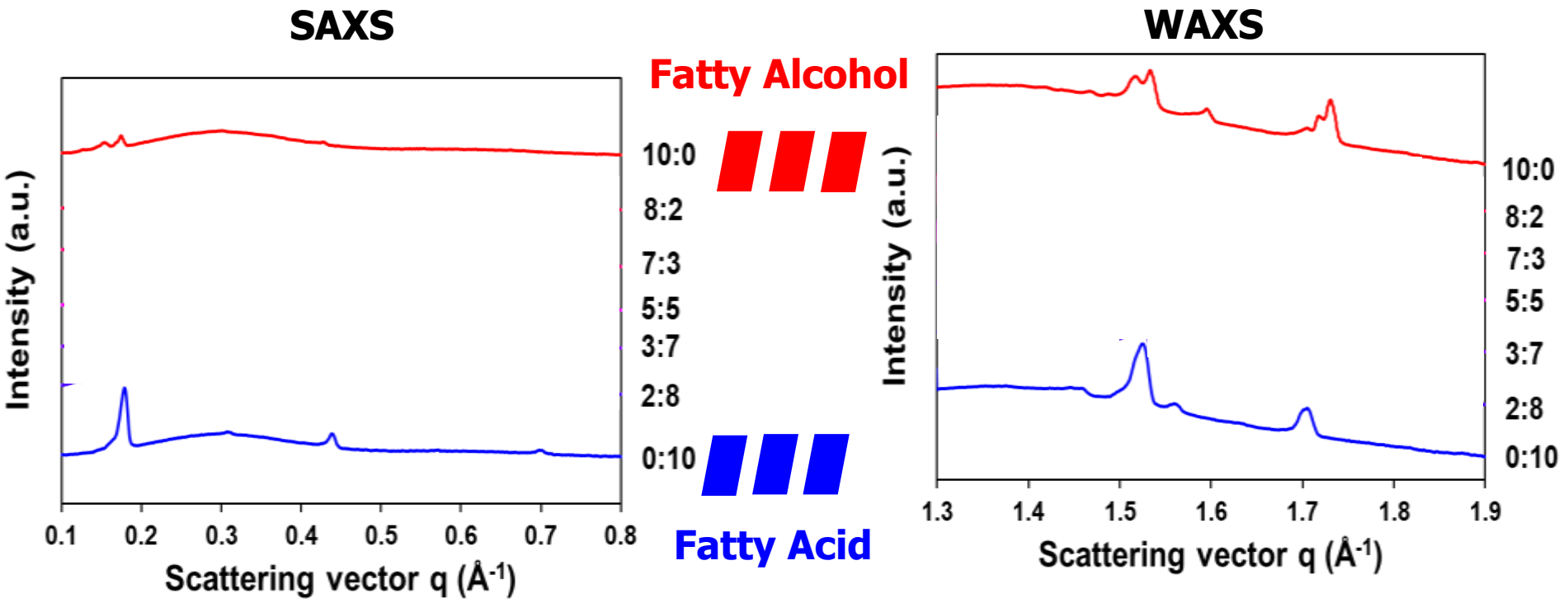
Fatty Acid

Platelet-shape for all R, but the size of crystals varies with R: two R with very small crystals

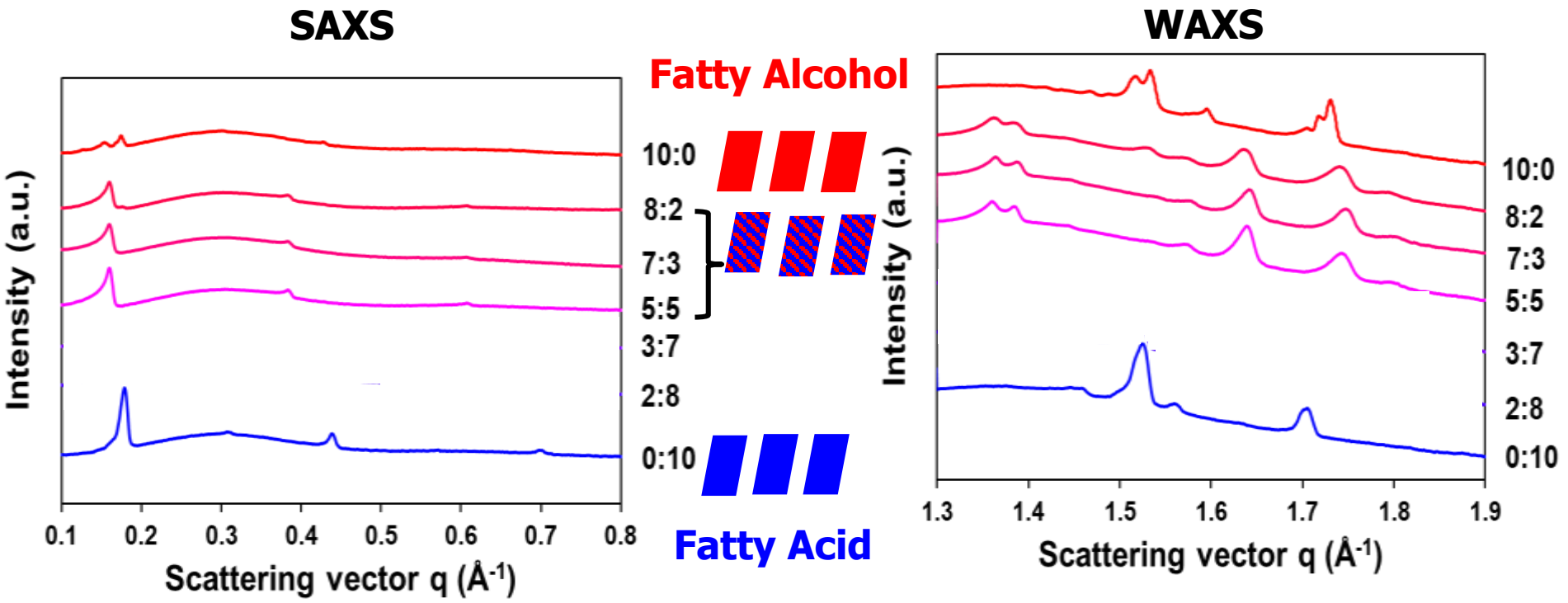
Effect of co-crystallization?



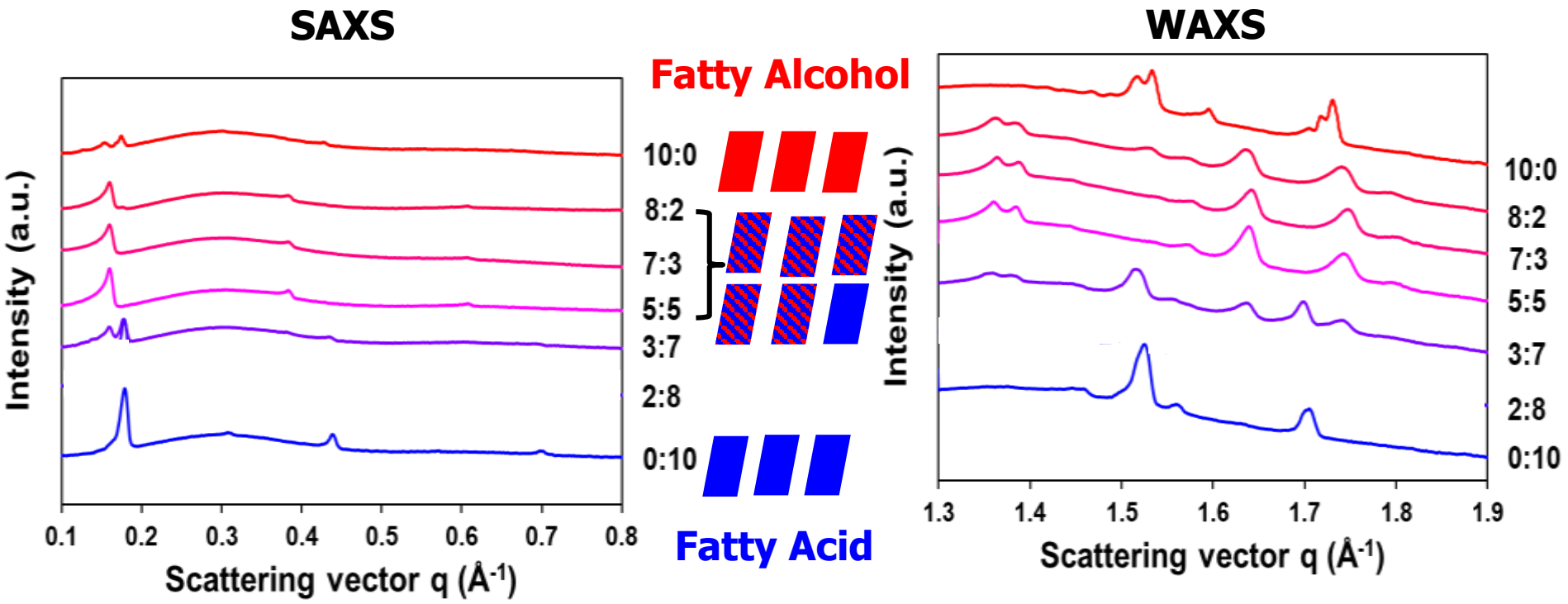
Effect of co-crystallization?



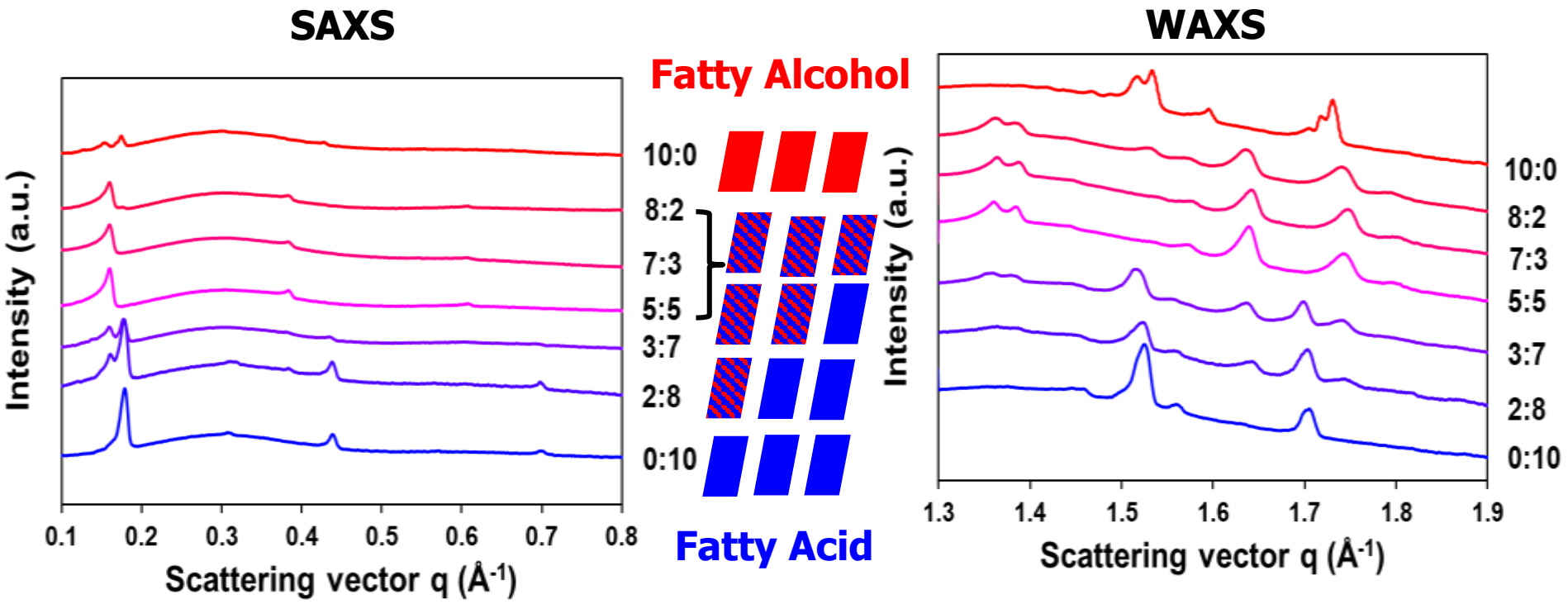
Effect of co-crystallization?



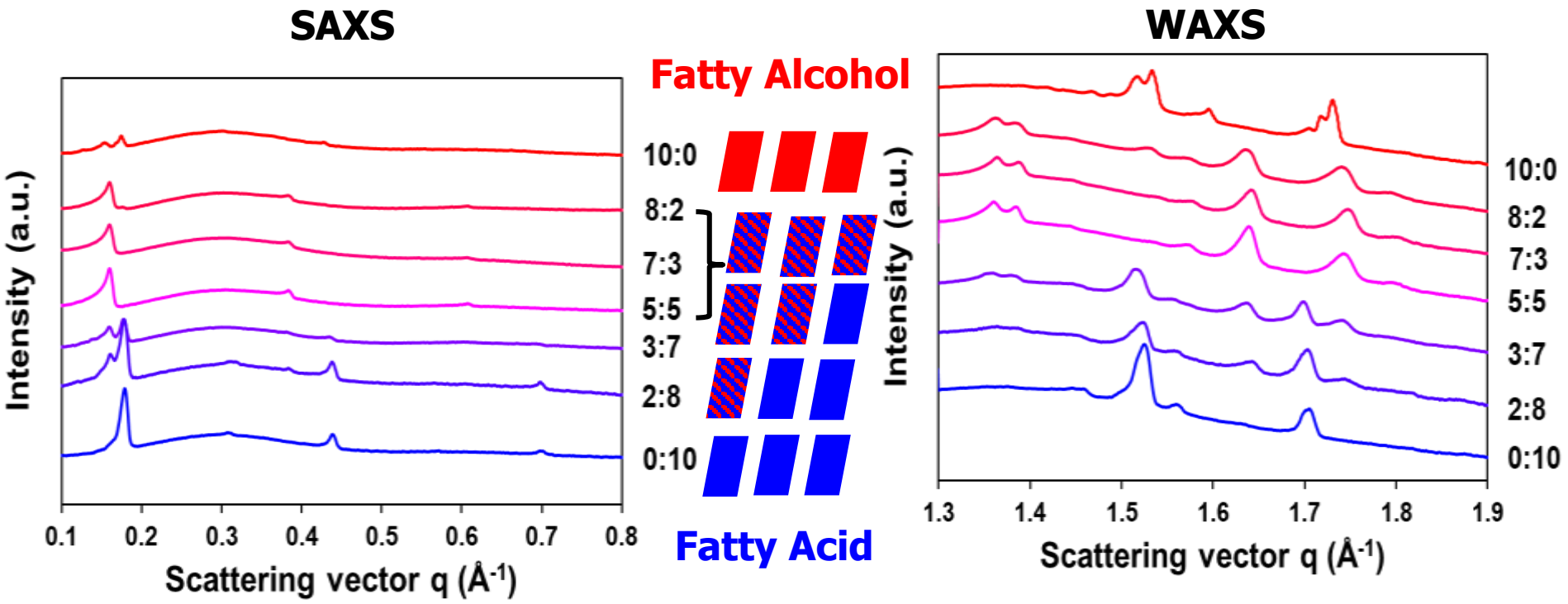
Effect of co-crystallization?



Effect of co-crystallization?



Effect of co-crystallization?

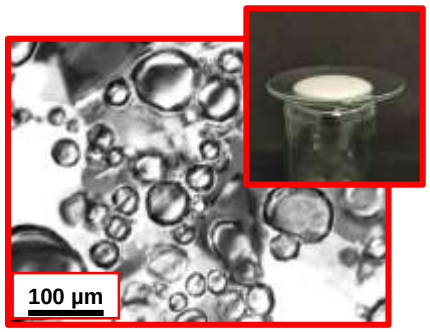


Mixed crystals for R= 8:2, R = 7:3 with the smallest crystals

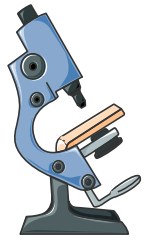
Callau et al. JCIS, 2020

Effect of co-crystallization?

R= 10:0

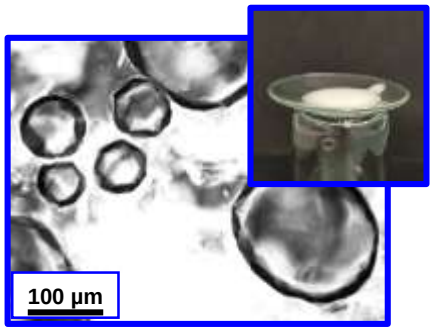


Fatty Alcohol



DIC
x20

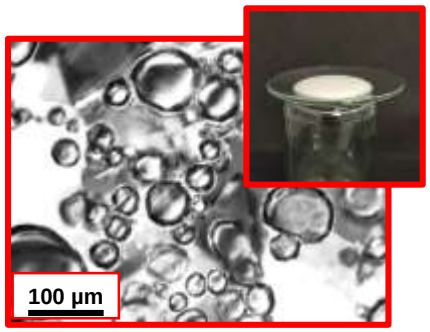
R = 0:10



Fatty Acid

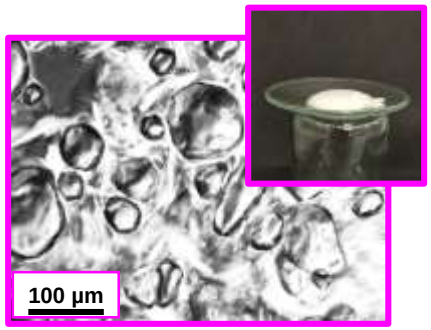
Effect of co-crystallization?

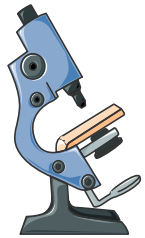
R= 10:0



Fatty Alcohol

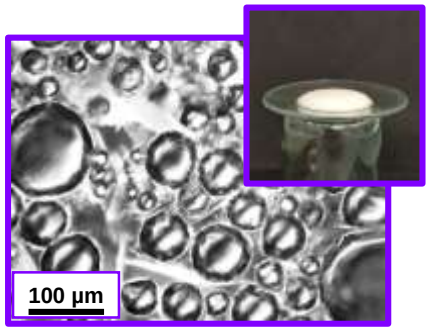
R = 5:5



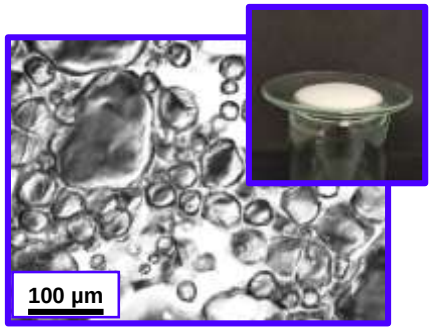


DIC
x20

R = 3:7



R = 2:8



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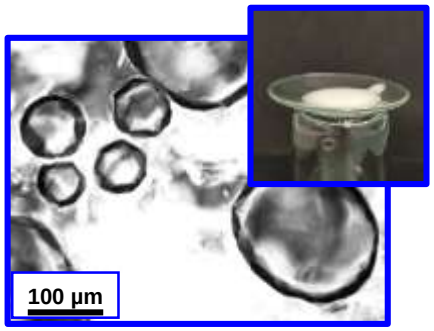
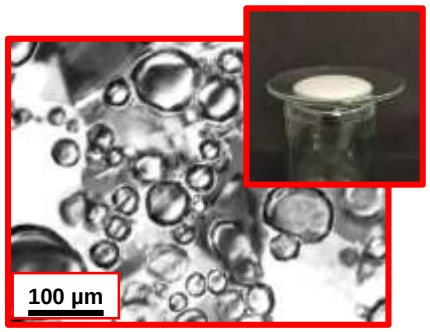


Fatty Acid

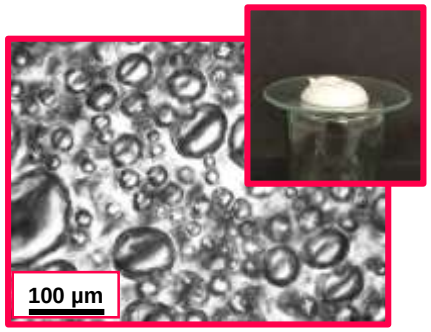
Effect of co-crystallization?

R= 10:0

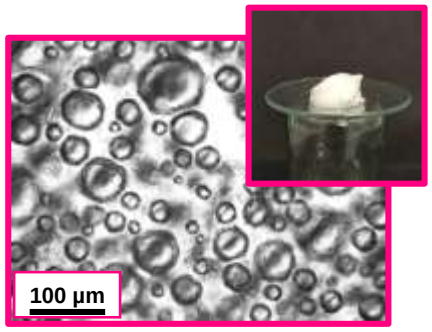


Fatty Alcohol

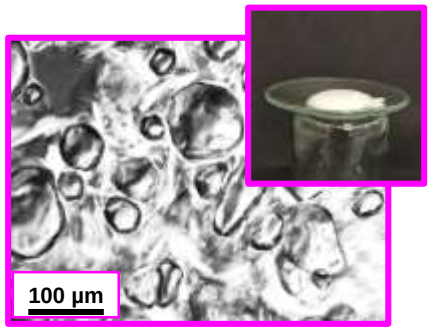
R= 8:2

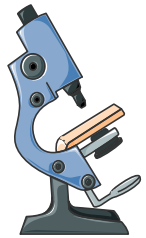


R = 7:3



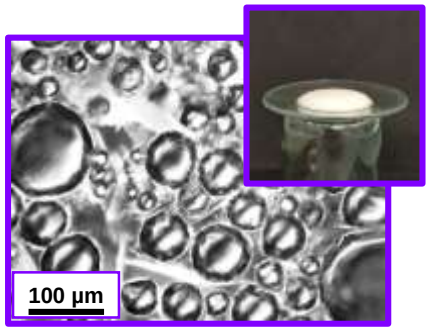
R = 5:5



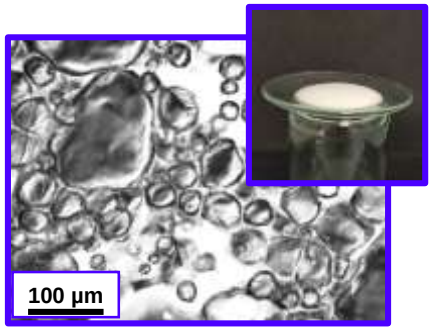


DIC
x20

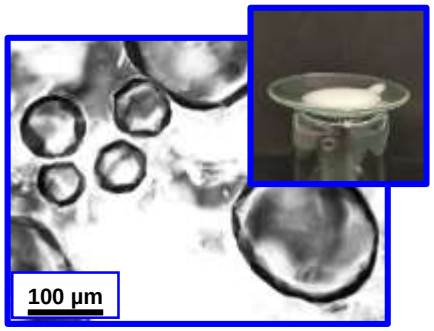
R = 3:7



R = 2:8



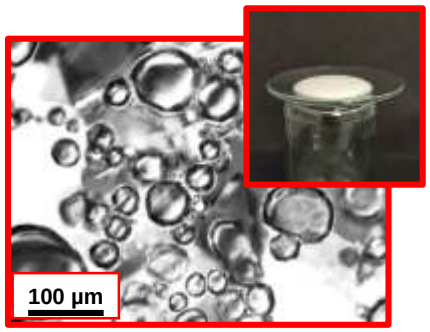
R = 0:10



Fatty Acid

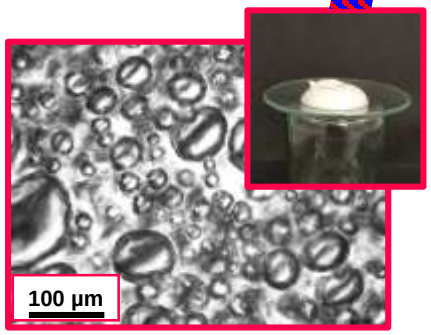
Effect of co-crystallization?

R= 10:0

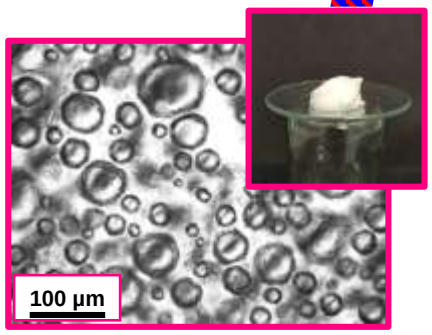


Fatty Alcohol

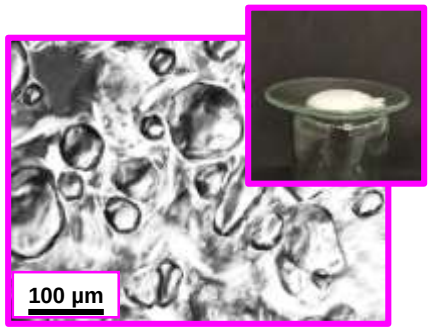
R= 8:2



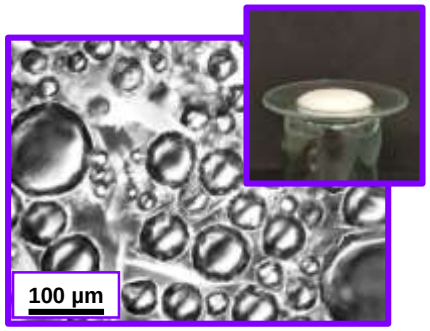
R = 7:3



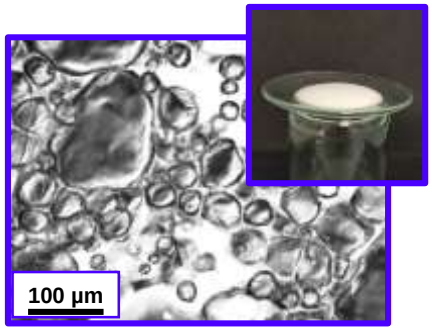
R = 5:5



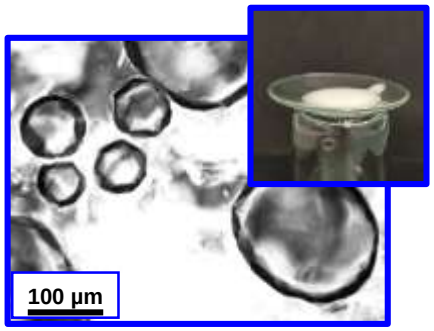
R = 3:7



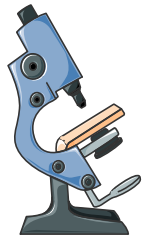
R = 2:8



R = 0:10



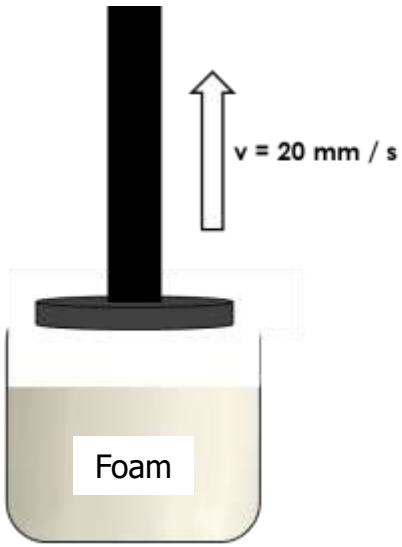
Fatty Acid

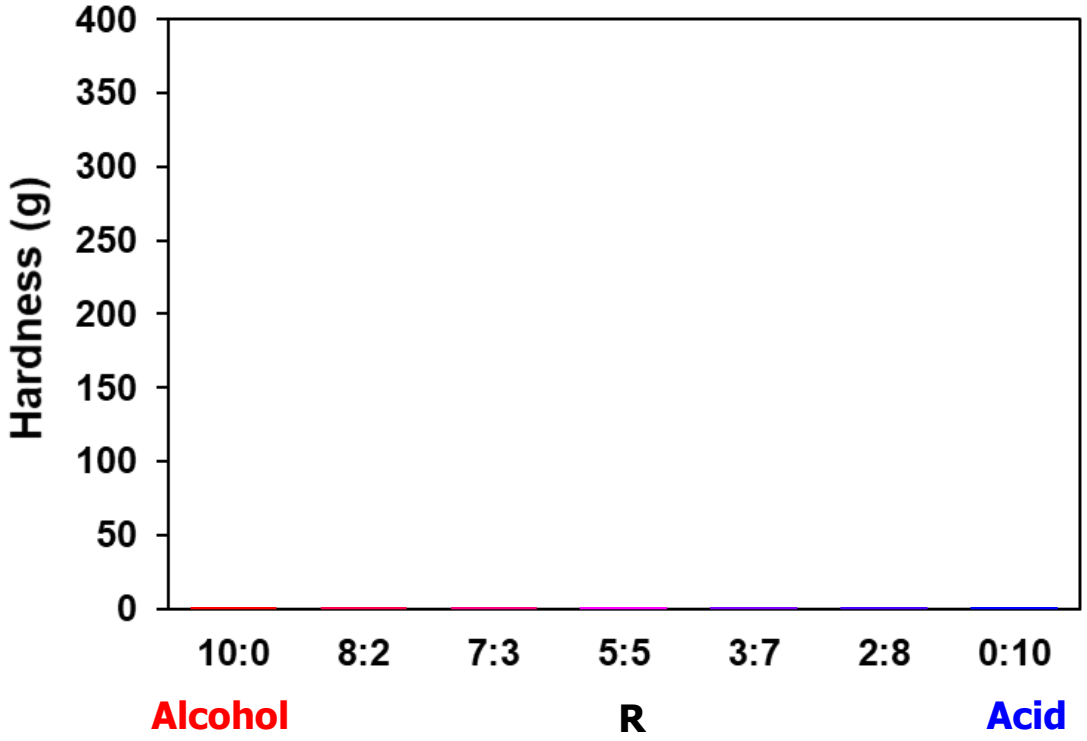


DIC
x20

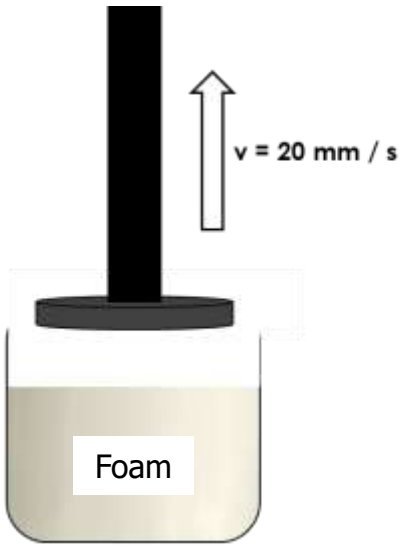
High Overrun and small bubbles for mixed crystals (R= 8:2 & R = 7:3)

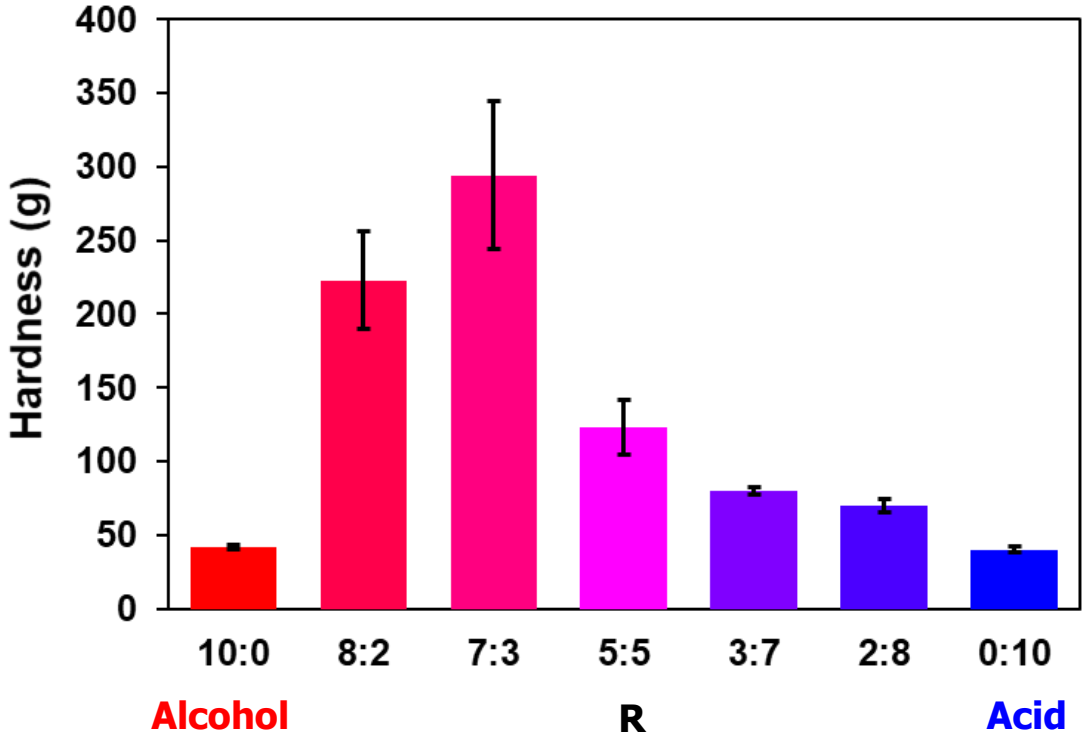
Effect of co-crystallization?



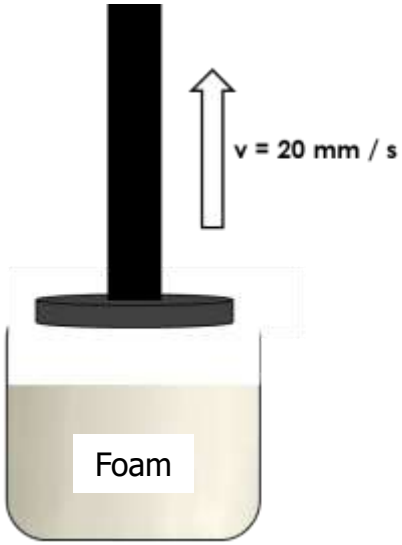


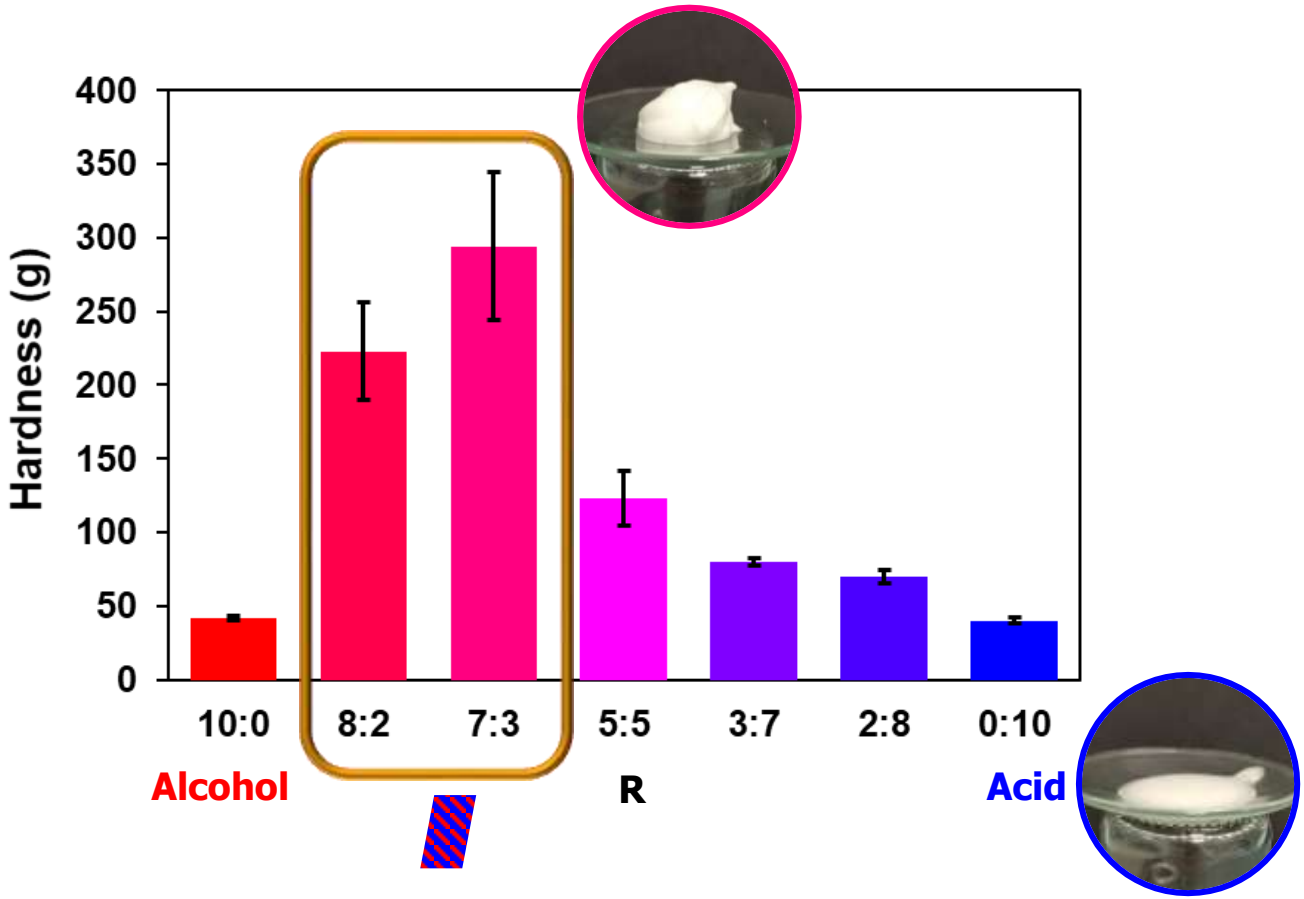
Effect of co-crystallization?





Effect of co-crystallization?

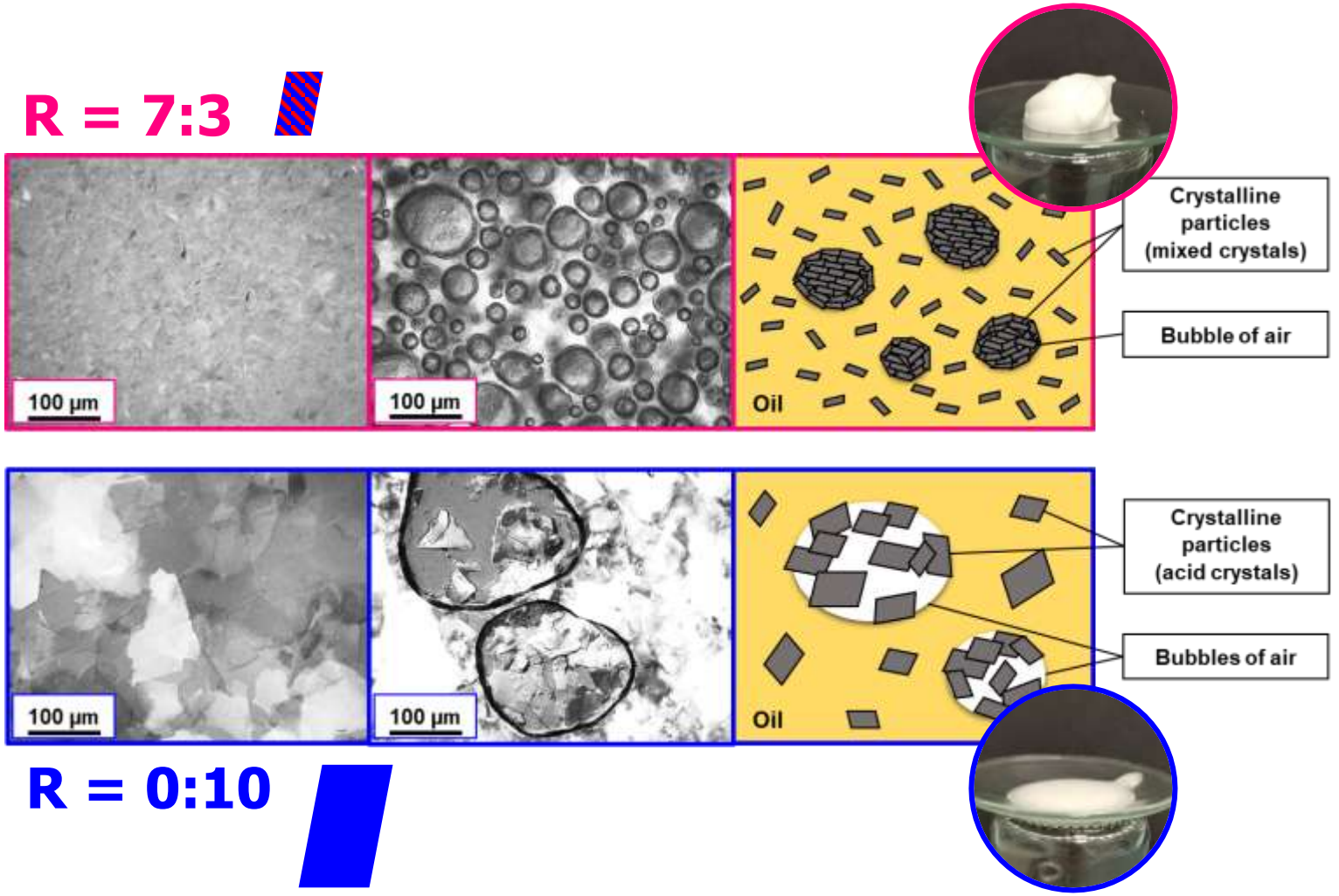




High hardness of foams for mixed crystals (R= 8:2 & R = 7:3)

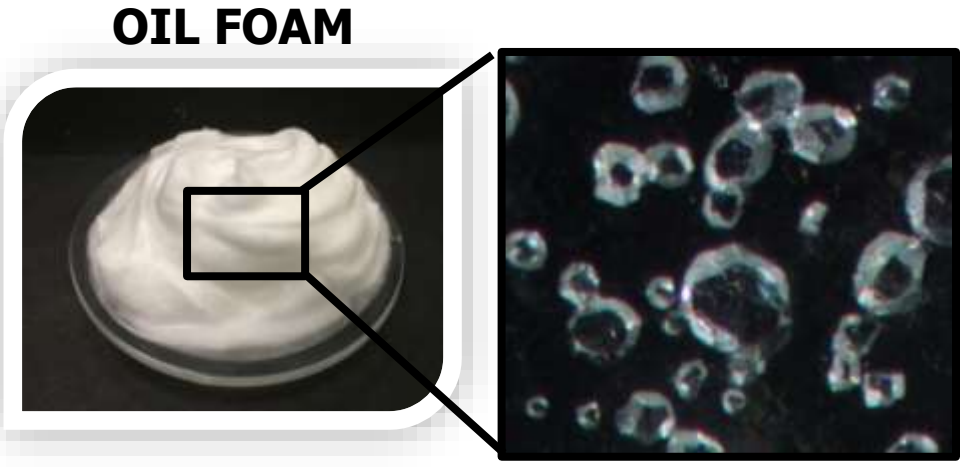
Callau et al. Food Chemistry, 2020

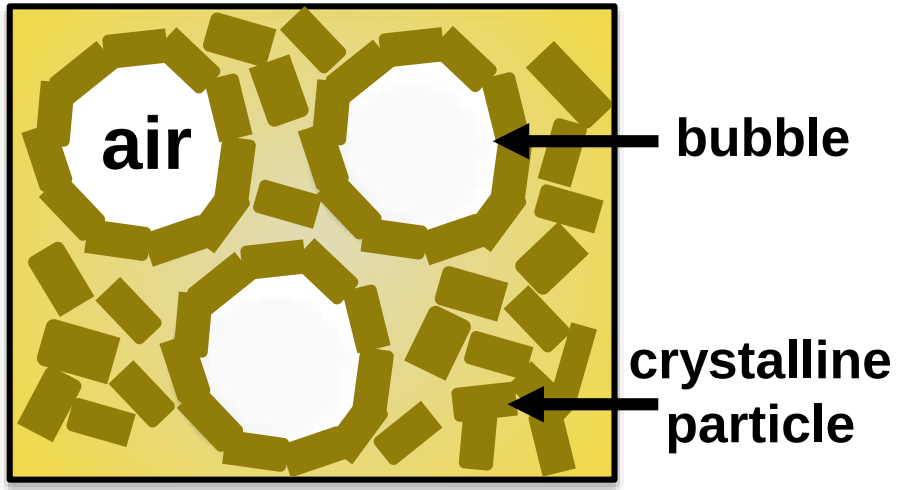
Effect of co-crystallization?



Co-crystallization of fatty acids/fatty alcohols improves foam properties by the presence of small mixed crystals in high quantity

Conclusion





- Crystalline particles with suitable **contact angle < 90°**
- Shape of the crystalline particles:

- Size of the crystalline particles:

- Co-crystallization: **increase the quantity & decrease crystals size**

Acknowledgments

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Thanks for your attention!