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Todd Smeltz,  
High School Math & Chemistry Teacher,  
Upper Dauphin Area School District



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**Heather Sheardown**, Professor, Department of Chemical Engineering, McMaster University

**Mark Jones**, Executive External Strategy and Communications Fellow, Dow Chemical



**Thursday, July 14, 2016**

**Insulation Chemistry on Earth and Beyond: Polyimide and Polyamide Aerogels**

**Mary Ann Meador**, Senior Scientist, Materials Chemistry and Physics Branch of the Materials and Structures Division, NASA Glenn

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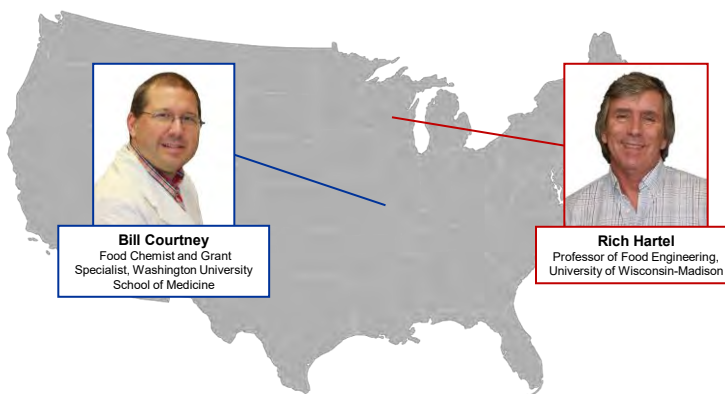


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## Ice Cream Chemistry



**Bill Courtney**  
 Food Chemist and Grant  
 Specialist, Washington University  
 School of Medicine



**Rich Hartel**  
 Professor of Food Engineering,  
 University of Wisconsin-Madison

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# ICE CREAM CHEMISTRY



Dr. Rich Hartel

University of Wisconsin-Madison



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## Outline

- **What is ice cream and how is it made?**
  - Even though there is a Standard of Identity, there is plenty of variation in commercial brands
- **Ice cream structure**
  - A complex multi-phase system
- **Ice cream melting**
  - What factors affect melt-down rates?

*If you're following along by eating ice cream, put a scoop of each product on a plate and watch what happens when it melts.*



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## Ice Cream - Defined

- **Product that meets the Standard of Identity according to the Code of Federal Regulations**
  - Minimum of 10% fat
  - Maximum of 100% overrun

$$\text{Overrun}(\%) = \text{Volume ice cream} / \text{Volume mix}$$

- So 100% overrun means the volume of mix is doubled by addition of air
  - Cheaper ice creams tend to have close to 100% while super-premium brands are closer to 40%



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## Ice Cream Sandwiches That Don't Melt?

- You've all heard that certain brands of ice cream sandwiches don't melt?
- Walmart ice cream under scrutiny when Cincinnati mom says it doesn't melt.

**What causes that?**

**Walmart says:**

*"Ice cream melts based on the ingredients including cream. Ice cream with more cream will generally melt at a slower rate, which is the case with our Great Value ice cream sandwiches."*



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## Ice Cream & the OJ Trial

- Prosecutors say the murders happened about 10:15 p.m. But police found a container of melting Ben & Jerry ice cream at the crime scene about 12:15 a.m. Defense attorneys are suggesting that, because the ice cream wasn't totally melted by 12:15, the murders had to have happened after 11 p.m. - when O.J. was already on his way to the airport.



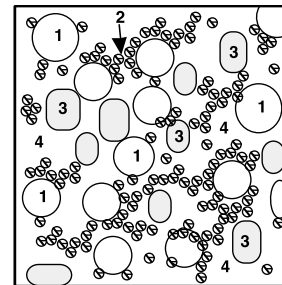
**Is it possible to tell time by ice cream “melting”?**



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## Ice Cream at a Structural Level - A Multi-Phase Product

- Ice crystals**
  - Provide cooling effect and hardness
- Air cells**
  - Reduce density
- Partially-coalesced fat globule network**
  - Affects melt-down rate and hardness of ice cream
- Proteins and hydrocolloids**
  - Network in serum phase
- Serum phase**
  - Dissolved sugars, minerals, proteins, etc.
  - Some liquid even at very low temperature



- 1 Air cells
- 2 Fat globules
- 3 Ice crystals
- 4 Continuous phase

Goff &amp; Hartel, 2013

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## Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



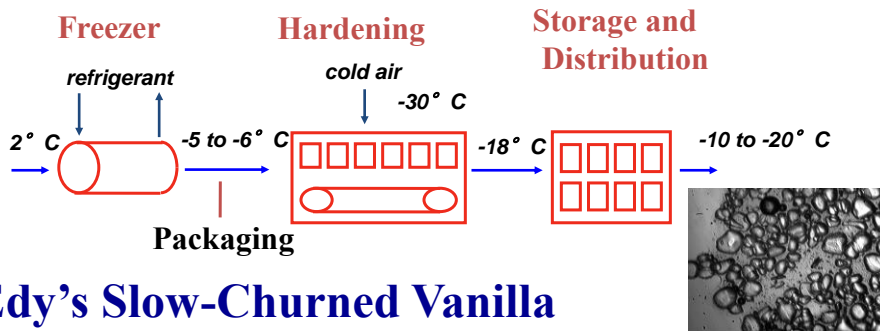
What's the difference between Edy's/Dreyer's regular and Slow-Churned?



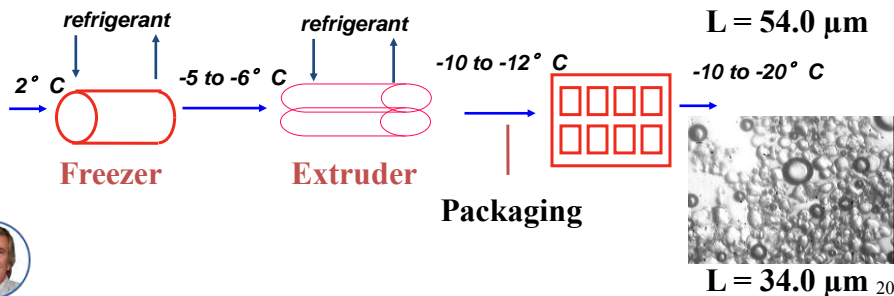
- Slow-churned has half the fat but tastes just as creamy
- Slow-churned costs more
- They have different formulations and different manufacturing processes
- All of the above

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### Edy's Full Fat Vanilla

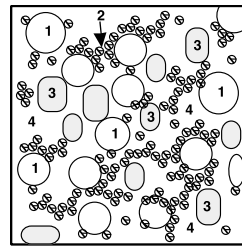


### Edy's Slow-Churned Vanilla



## Factors that Influence Meltdown

- **Heat transfer**
  - Overrun, number and size of air bubbles
  - Outside temperature, convective factors
- **Ice content**
  - Thermal diffusivity – insulation effect
- **Viscosity of serum phase**
  - Diluted by melted ice
- **Gravity**
  - Ability of serum phase to flow
- **Fat globule clusters**
  - Number and size



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## Ice Cream Melting

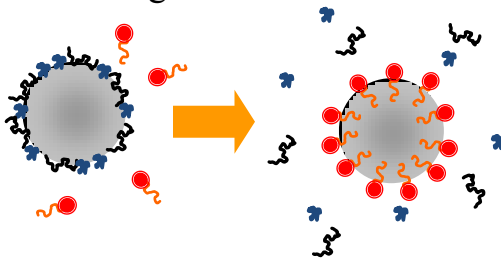
Not all ice creams are created equal – or melt in the same way



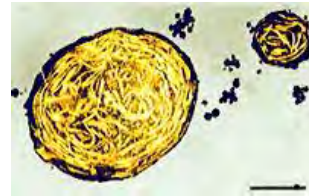
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## Fat Globules in Ice Cream Mix

- **Emulsion droplets in mix**
  - Coated with protein/emulsifier surface after homogenization
  - Emulsifier replaces protein during ageing
  - Partially crystalline milk fat network within globules



Courtesy: J McClements

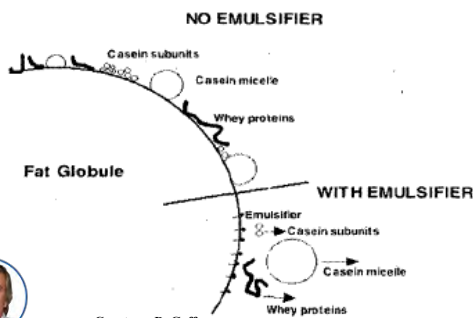


Ice cream mix fat globules  
(Doug Goff, University of Guelph)

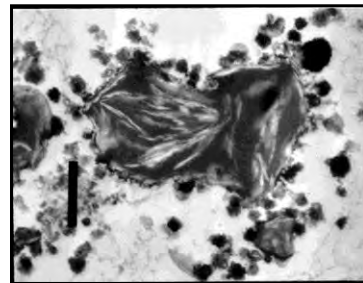
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## Emulsifier Addition

- Destabilizes the emulsion
  - Reduces interfacial tension, and reduces the interfacial viscosity
  - During freezing, emulsion droplets are forced together under shear and coalescence is initiated



Courtesy: D. Goff



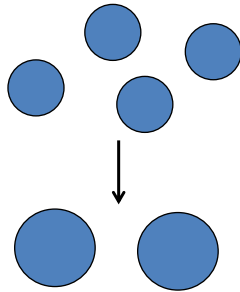
Cryo-TEM from D. Goff

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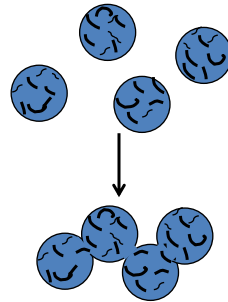


# Coalescence or Partial Coalescence

**Coalescence**  
Liquid droplets

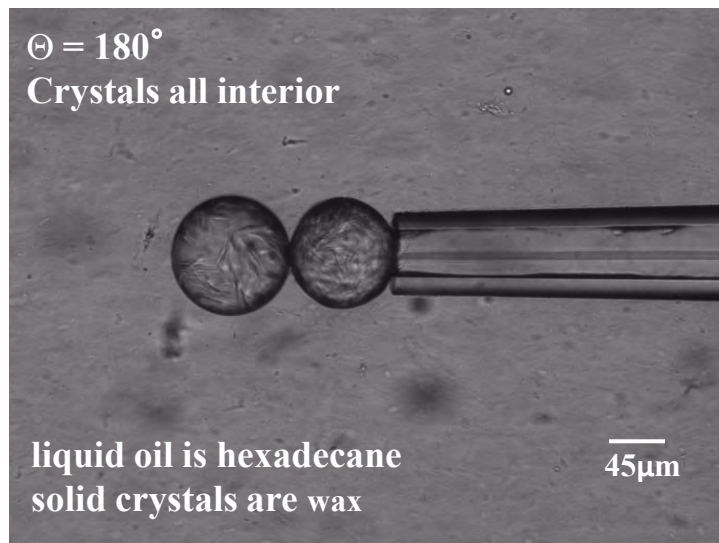


**Partial Coalescence**  
Semi-crystalline



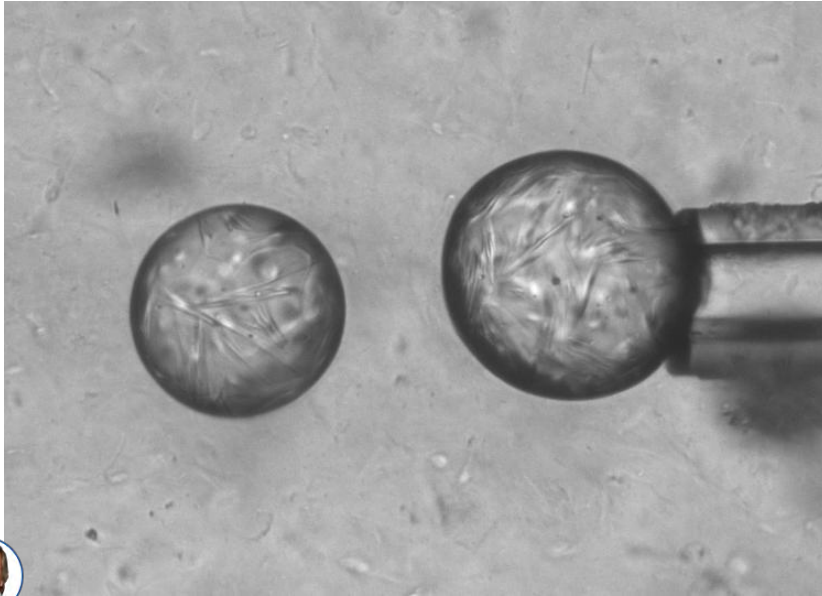
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## Partial Coalescence



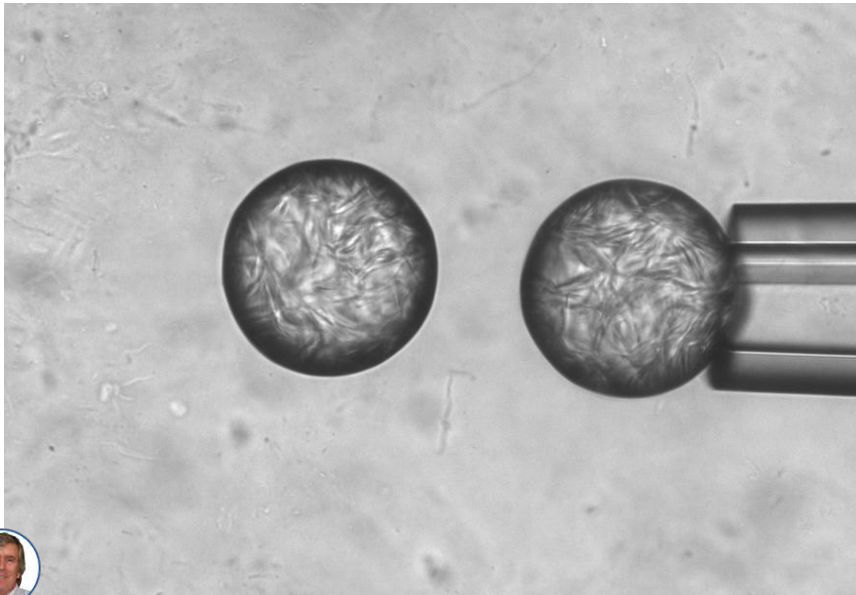
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### 30% Solid Fat Content (SFC)



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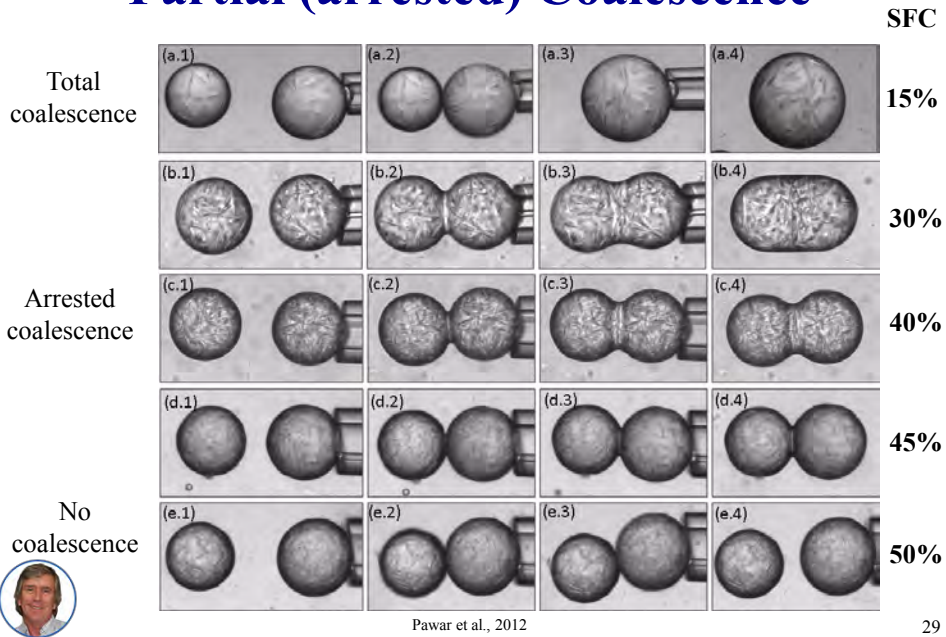
### 40% Solid Fat Content (SFC)



28

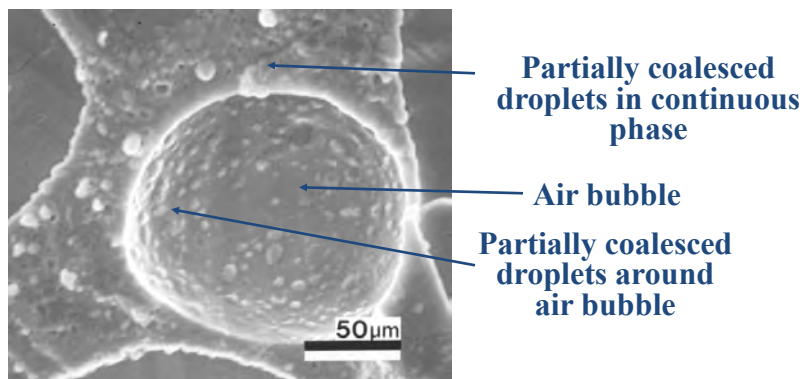


## Partial (arrested) Coalescence



## Partial Coalescence in Ice Cream

- In ice cream, emulsion droplets partially coalesce and cover the air cell interface
  - Provide structural support for air cells

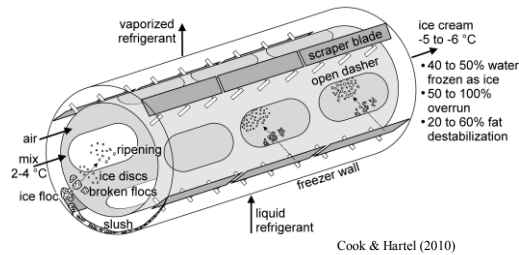


Ice cream viewed by cryo-SEM (D. Goff, Guelph)

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## Partial Coalescence in Ice Cream

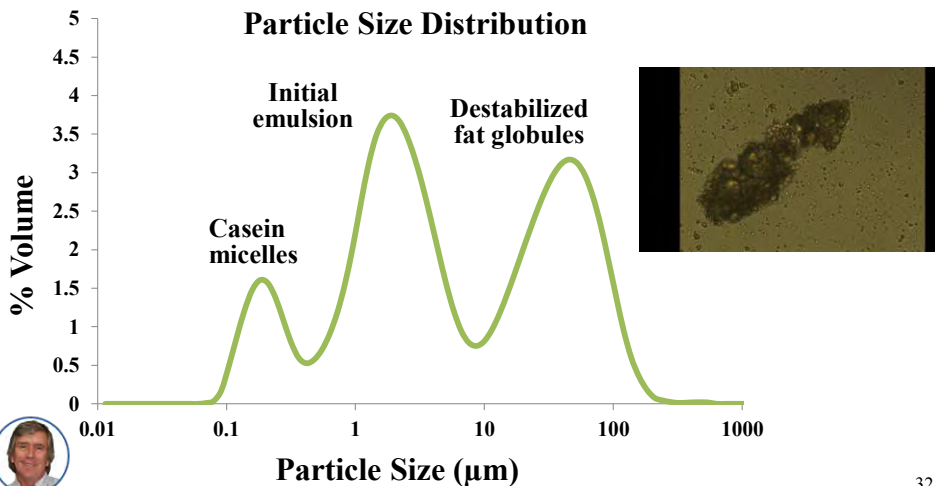
- In the short time the ice cream spends in the freezer, the fat globules (with 50-60% solid fat content) must come together to form 3-D clusters that subsequently support and help stabilize the air cells
  - Extensive shear forces at work to disrupt the O/W interface and allow the coalescence process to begin
  - The rigidity of crystal network within the fat globules prevents complete coalescence



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## Measuring Partial Coalescence

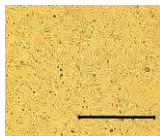
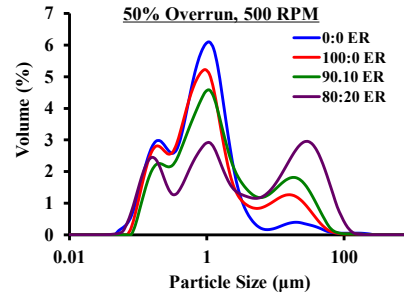
- Measured with light scattering technique



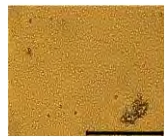
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# Controlling Partial Coalescence

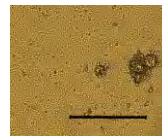
- **Addition of emulsifiers**
  - Polysorbate 80 (PS80)
  - Mono & diglycerides (MDG)
  - Ratio (ER=MDG:PS80)
- **Shear stress in the freezer**
  - Ice phase volume
    - Freezing point depression
  - Overrun
  - Dasher speed



0:0 ER, 5.9%



100:0 ER, 19.6%



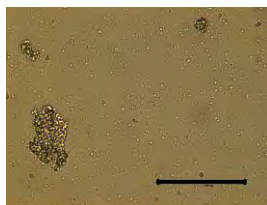
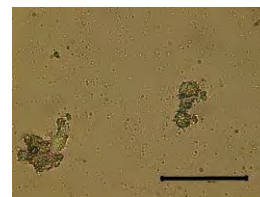
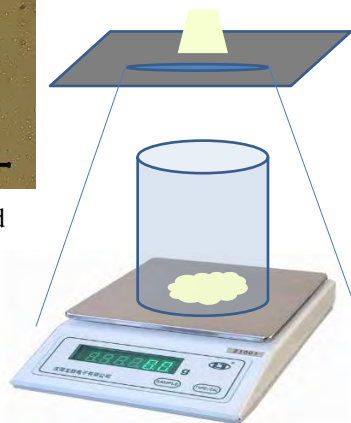
90:10 ER, 28.3%



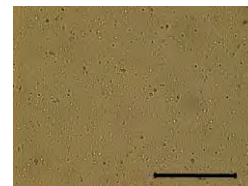
80:20 ER, 56.2%

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## Meltdown/Drip-through Test *The Role of Fat Globule Clusters*

Whole melt/melted  
ice cream

Top/remnant foam





Drip-through

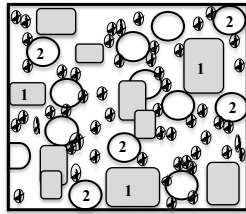


Up to 2 hrs at room temp  
Plot weight vs time, take slope to obtain rate of melt

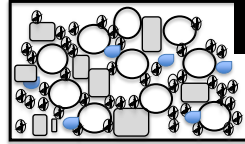
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# Low Fat Destabilization, Full Collapse and Drip-Through

1	- Ice crystals		- Fat/destabilized fat
	- Free water	2	- Air cells
	- Serum phase		



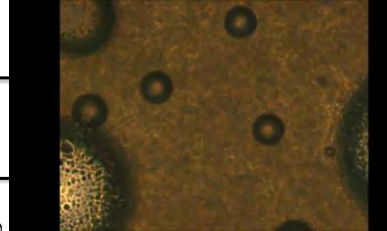
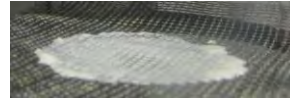
t = 0 minutes



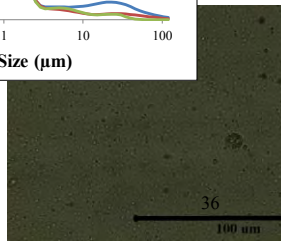
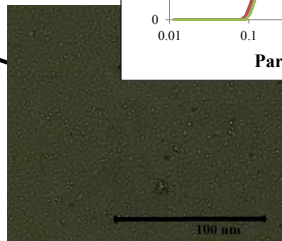
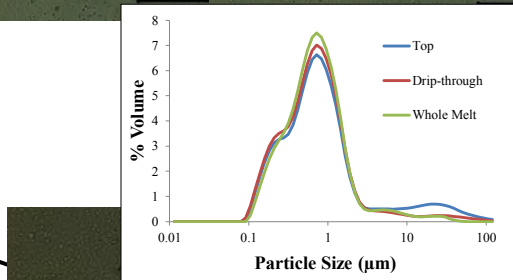
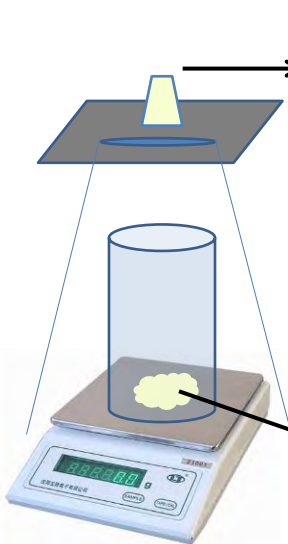
t = 60 minutes



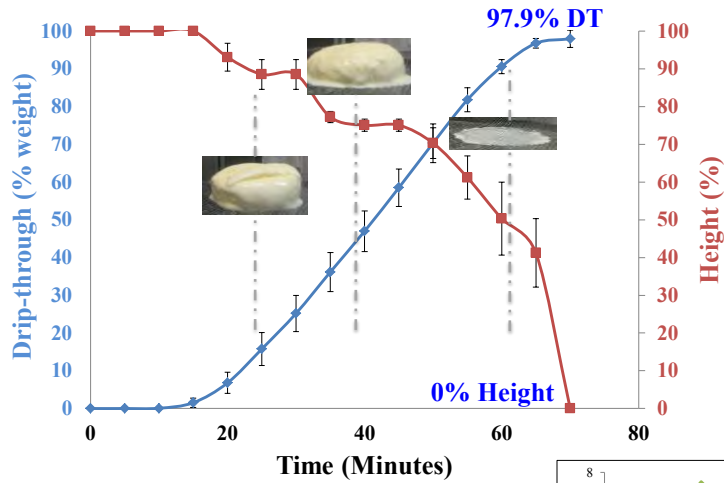
t = 70 minutes



## Fast Drip-638: 5% FD

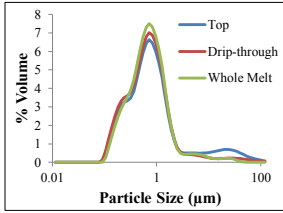


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**Sample 638**

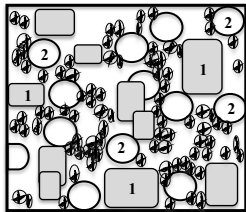
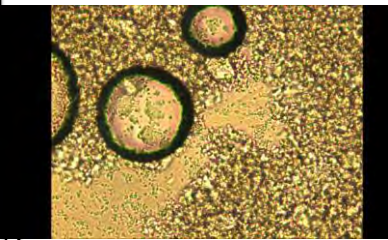
- Fast drip-through rate
- Minimal partial coalescence
- No stand-up properties



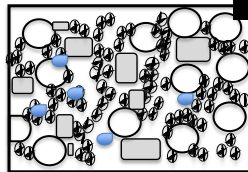
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## High Fat Destabilization, Minimal Collapse

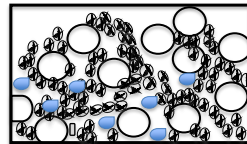
1	- Ice crystals	⊙	- Fat/destabilized fat
●	-Free water	②	- Air cells
	-Serum phase		



t = 0 minutes



t = 60 minutes

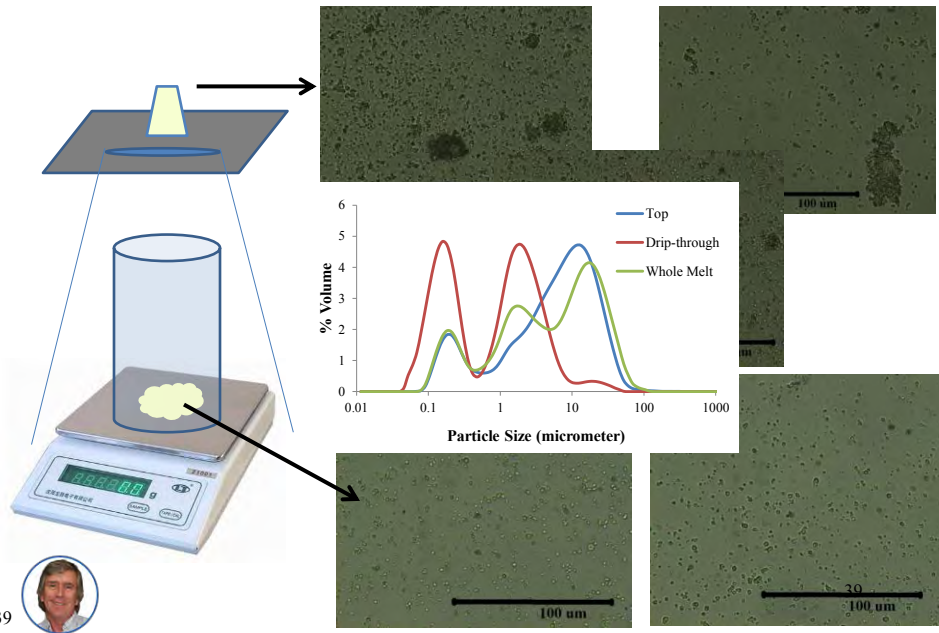


t = 120 minutes

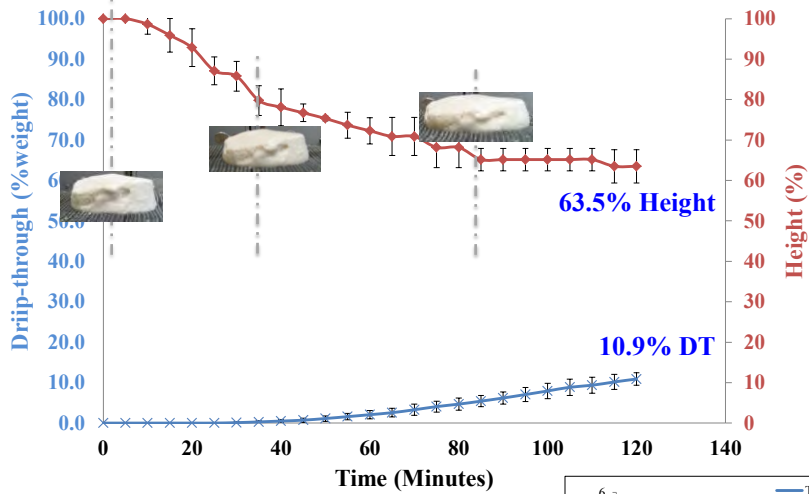


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# Slow Drip-293: 55.3% FD



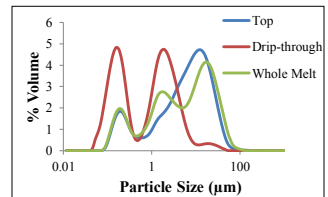
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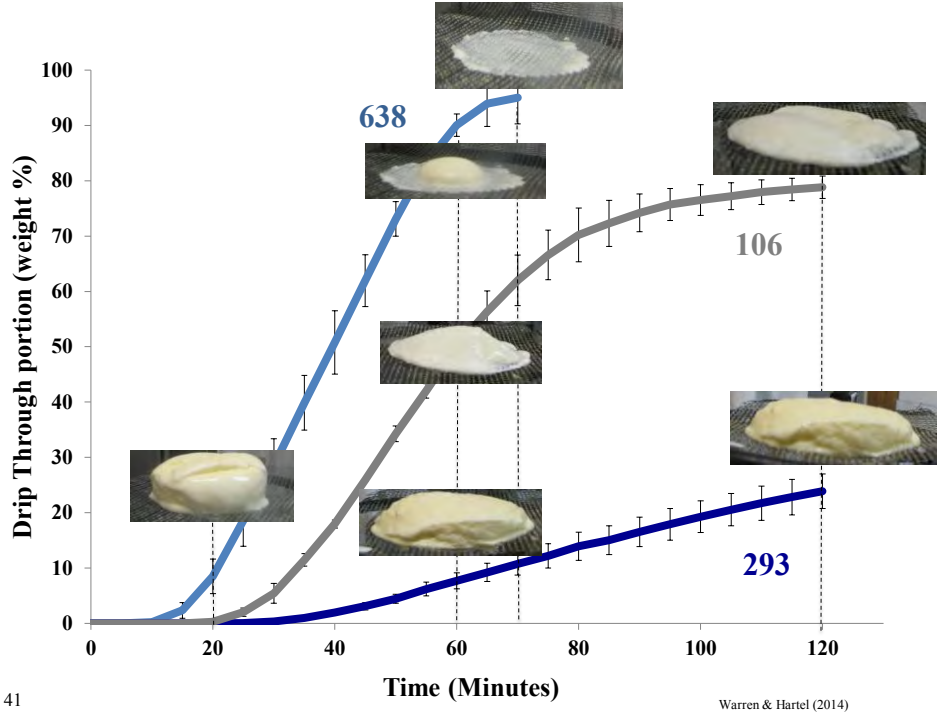
**Sample 880**

- Slow drip-through
- Large partial coalescence
- High stand-up properties

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Warren & Hartel (2014)

### Audience Survey Question

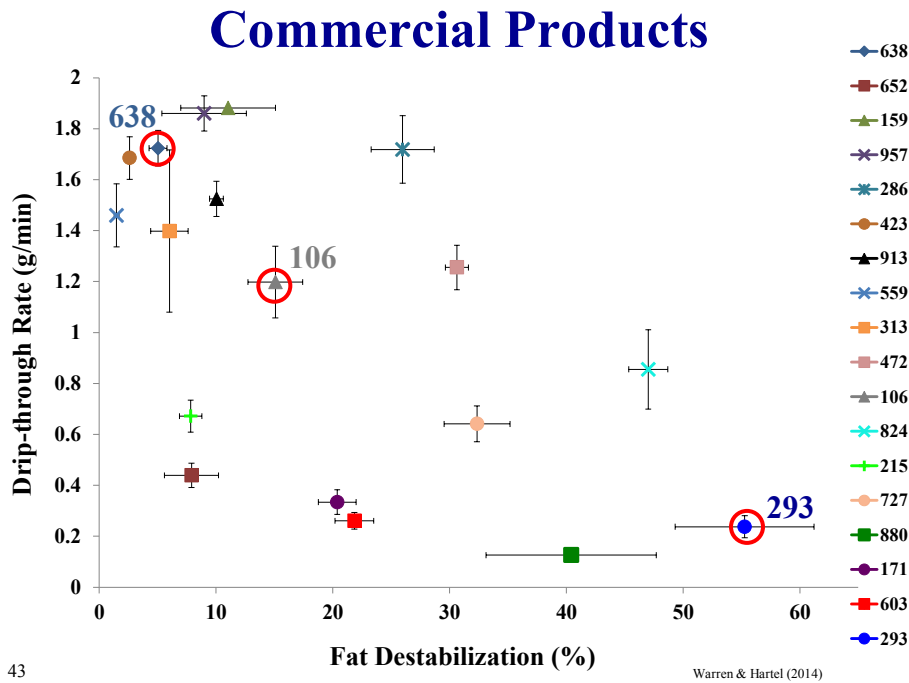
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



**Did you see a difference in melt-down of your ice cream samples and if so what was different between them?**

- Fat content
- Overrun
- Stabilizer/thickener
- Emulsifier
- All of the above

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## Wrap Up

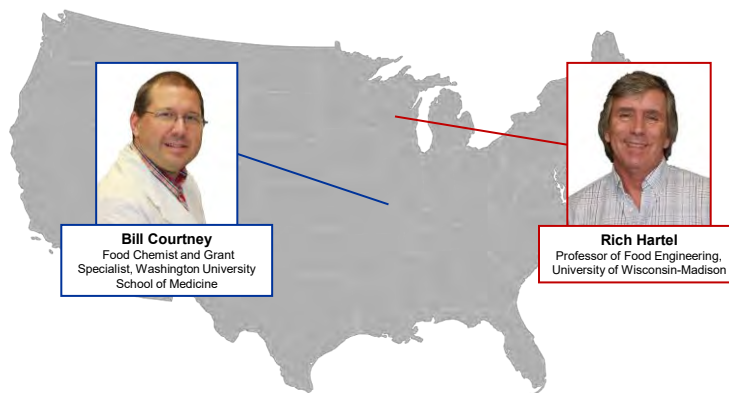
- **Walgreen's ice cream sandwiches**
  - Melting and collapse are two different phenomena, each governed by numerous parameters
  - The Walgreen's ice cream has melted, but because of the structures, it doesn't collapse – other commercial products show the same behavior
- **B&J ice cream in the OJ trial**
  - Yes, it'd be possible to predict time based on collapse (not "melting") of but control experiments would be needed

**Ice cream - one of the most complex food products**



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## Ice Cream Chemistry



**Bill Courtney**  
 Food Chemist and Grant  
 Specialist, Washington University  
 School of Medicine



**Rich Hartel**  
 Professor of Food Engineering,  
 University of Wisconsin-Madison

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## Final Thoughts?



Ice cream has been around hundreds of years but there is still plenty we don't really know about it.



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**Heather Sheardown**, Professor, Department of Chemical Engineering, McMaster University

**Mark Jones**, Executive External Strategy and Communications Fellow, Dow Chemical



Thursday, July 14, 2016

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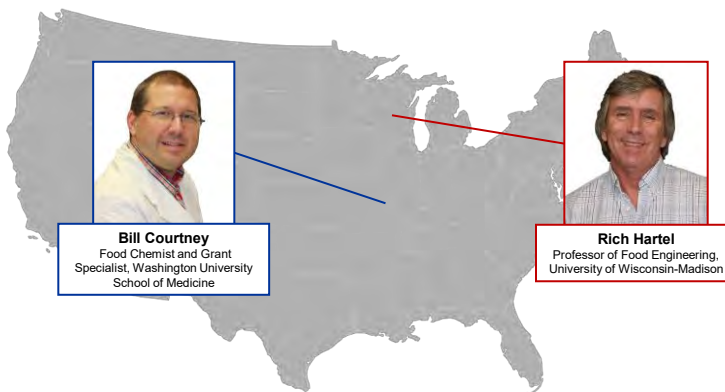
**Mary Ann Meador**, Senior Scientist, Materials Chemistry and Physics Branch of the Materials and Structures Division, NASA Glenn

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## Ice Cream Chemistry



**Bill Courtney**  
Food Chemist and Grant  
Specialist, Washington University  
School of Medicine



**Rich Hartel**  
Professor of Food Engineering,  
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Quote in reference to: <http://bit.ly/SweetChem>




### *Fan of the Week*

Todd Smeltz,  
High School Math & Chemistry Teacher,  
Upper Dauphin Area School District




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