

We will begin momentarily at 2pm ET



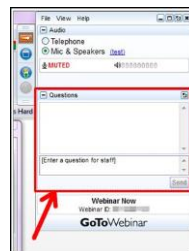
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Michel Philippe, Senior Research Associate and Sustainable Innovation Manager, L'Oréal
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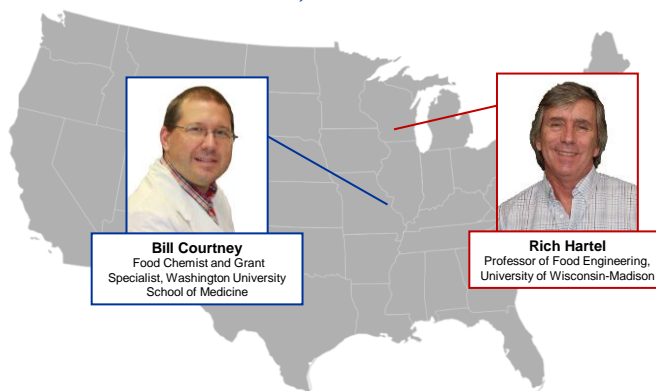
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CHOCOLATE



RICH HARTEL
UNIVERSITY OF WISCONSIN-MADISON



CACAO PRODUCTION

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- **Cacao trees grown in tropical climates**
 - Within 15° of equator
- **Sources**
 - Africa: Ivory Coast, Ghana
 - Indonesia/Malaysia
 - Brazil
- **Cocoa beans grow inside pods**
 - Harvested, beans removed, fermented, dried



COCOA BEAN

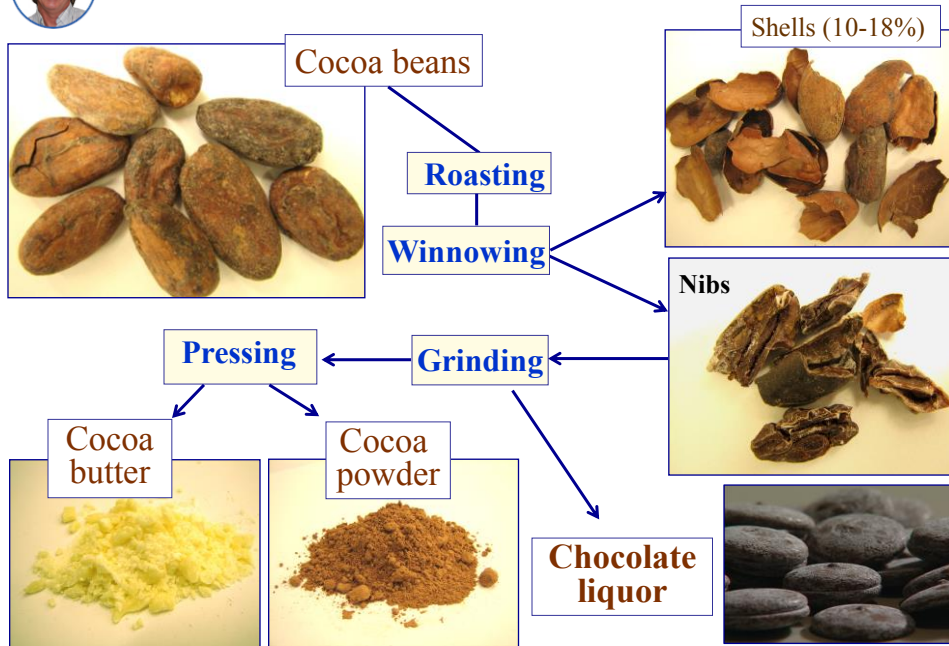
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COCOA BEAN PROCESSING

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CHOCOLATE LIQUOR: FOOD OF THE GODS

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- Ground cocoa nibs containing a mixture of cocoa solids and cocoa butter
- The primary ingredient for making chocolate





CHOCOLATE LIQUOR COMPOSITION

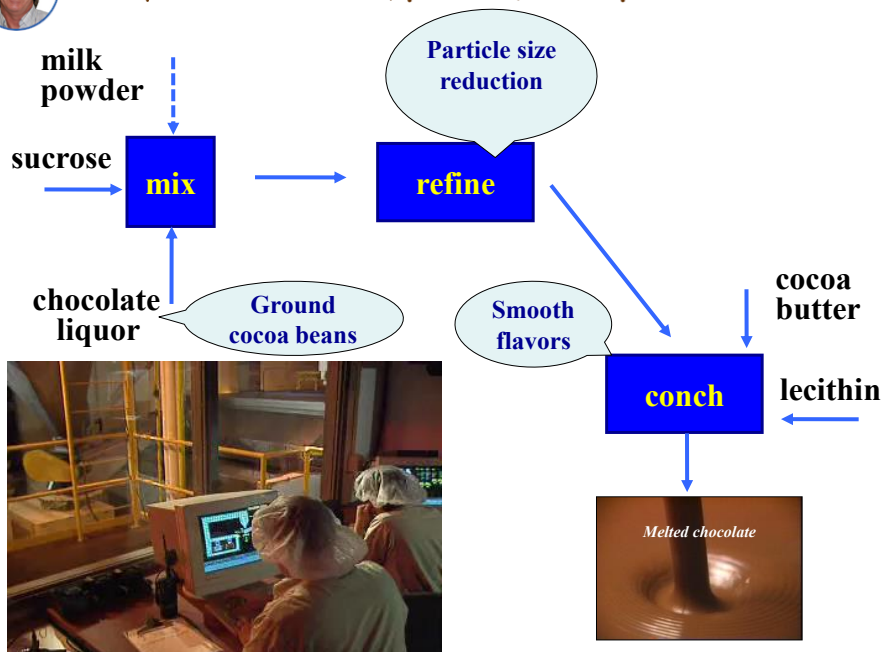
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- **Nibs (ground)**
 - 48-57% fat - cocoa butter
 - 2-3.5% water
 - 40-50% cocoa solids
 - starch, fiber and gums, etc.
- **Alkaloids**
 - 0.8 - 1.3% theobromine
 - ≈0.2% caffeine (some people say there is no caffeine in chocolate)



CHOCOLATE PROCESSING

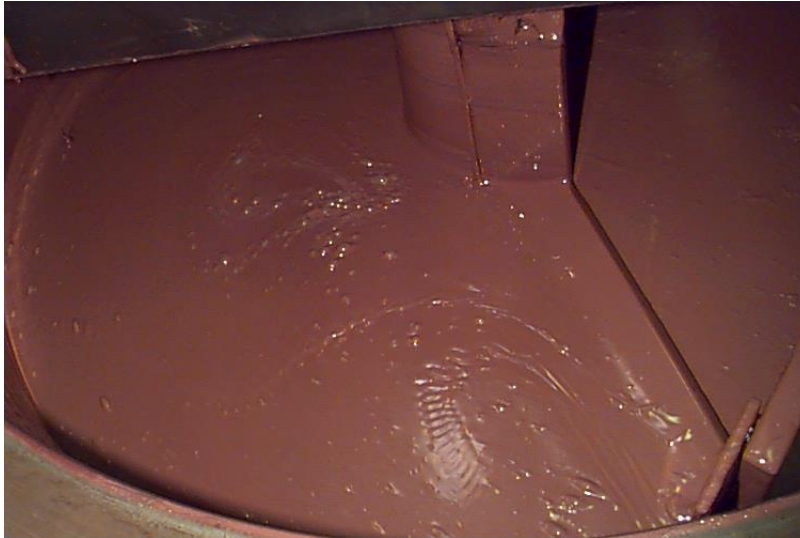
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LIQUID CHOCOLATE

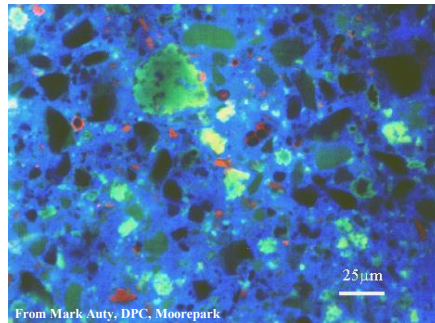
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CHOCOLATE STRUCTURE

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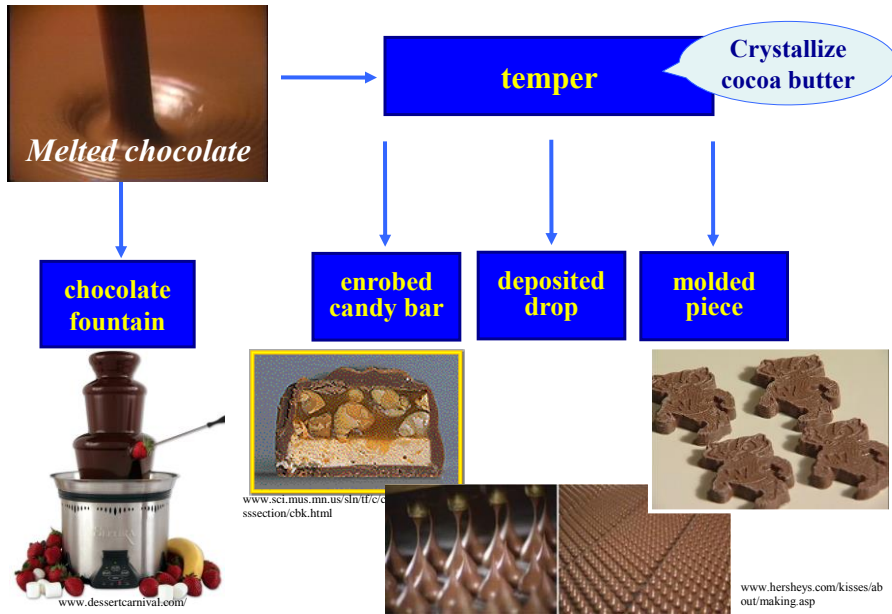
- About 60-70% particles
 - ◆ Sugar crystals,
 - ◆ Cocoa solids,
 - ◆ Milk powder
- 30-35% cocoa butter
 - ◆ *Melted chocolate*, cocoa butter is liquid
 - ◆ *Solidified chocolate*, cocoa butter is partially crystalline
- About 0.5% water in normal chocolate
 - ◆ Probably associated with sugar crystals and cocoa solids
- About 0.2-0.3% lecithin
 - ◆ Coats sugar particles and cocoa solids, the hydrophilic components





CHOCOLATE PROCESSING

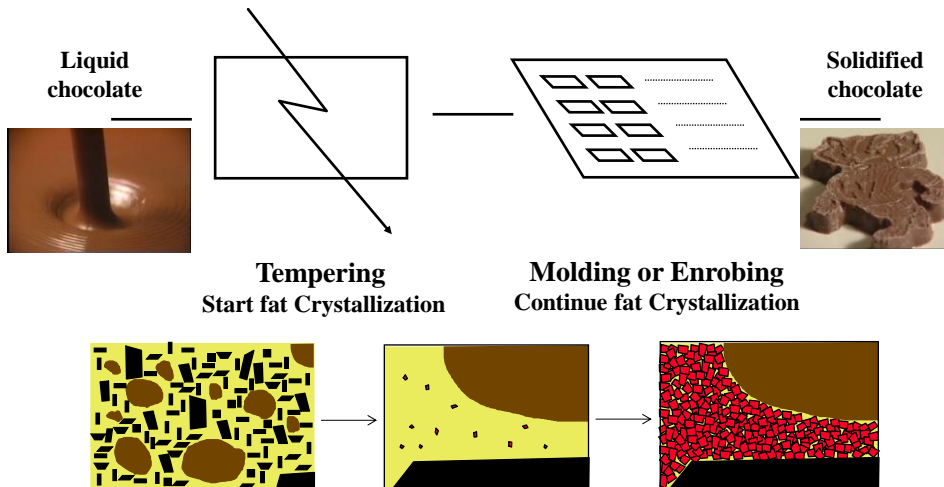
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TEMPERING

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- Controlled crystallization of the triglycerides in cocoa butter



Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



What happens if you don't temper chocolate?
(multiple possible answers)

- It doesn't solidify very well
- Molded pieces don't contract from the mold
- It isn't glossy
- It develops unsightly spots within hours to days

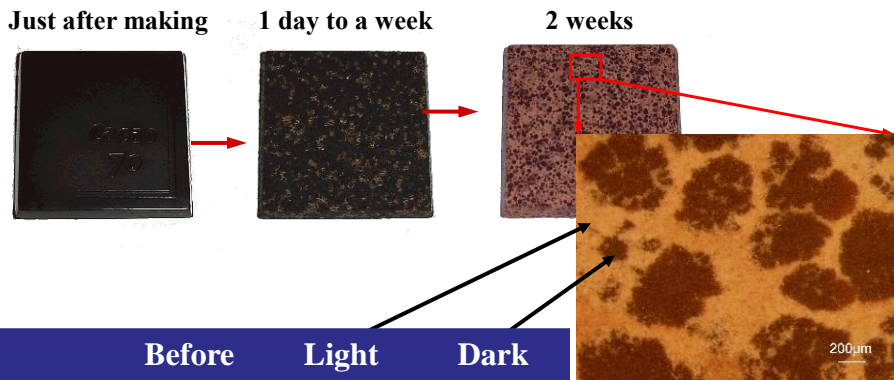
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Cocoa Butter Crystallization

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What happens if you don't temper chocolate?



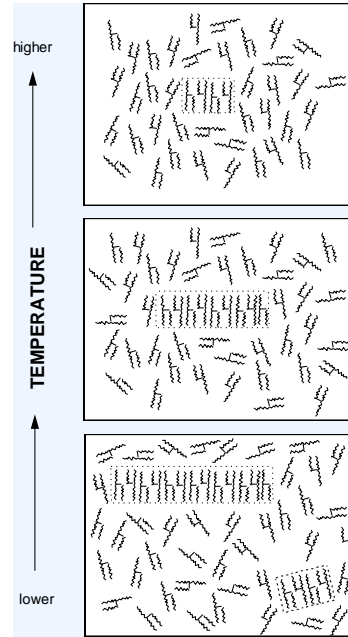
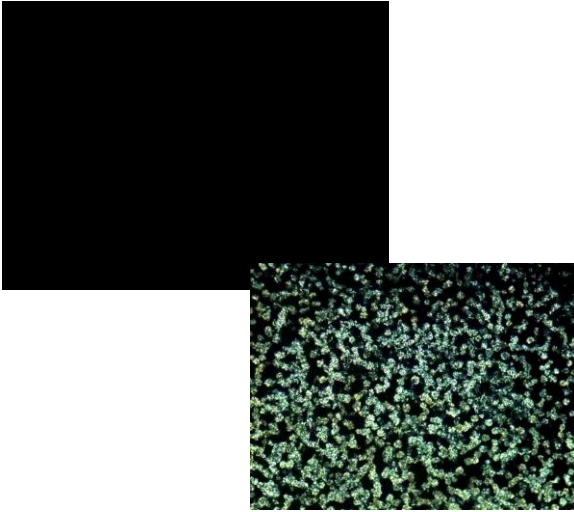
	Before Bloom	Light Brown	Dark Brown
Sugar (%)	34	43	34
Fat (%)	38	21	39



LIPID CRYSTALLIZATION

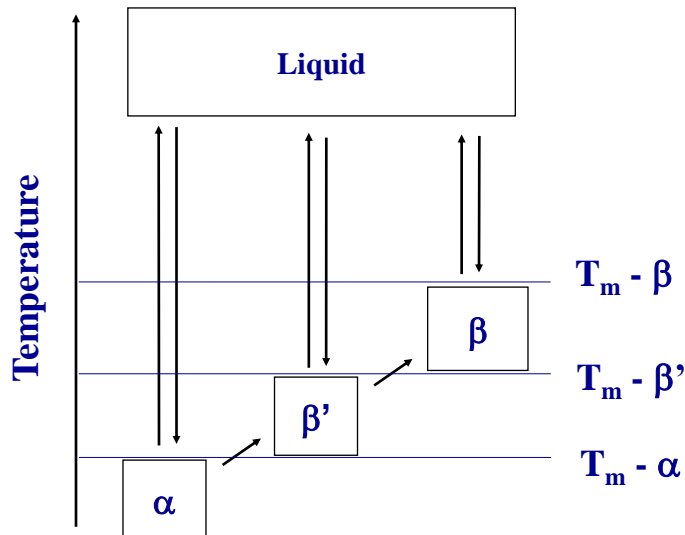
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Liquid structures form in lipid melts as temperature decreases below melting point



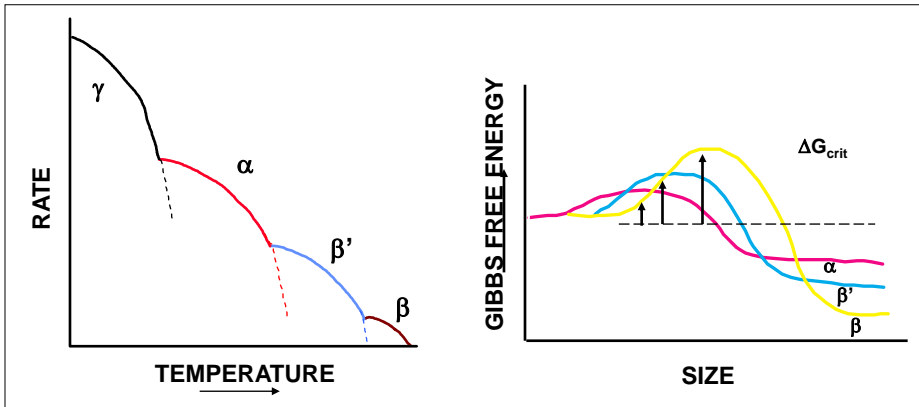
MONOTROPIC POLYMORPHISM

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- Different polymorphs form at different temperatures, with rates of formation dependent on temperature.



Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



What is the melting point in degrees Celsius of cocoa butter?

- 23.3 C
- 25.5 C
- 27.5 C
- 33.8 C
- 36.3 C



COCOA BUTTER POLYMORPHISM

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Polymorph	Melting Point (° C)	ΔH (cal/g)
γ I	17.3	-
α II	23.3	20.6
β ₂ III	25.5	26.9
β ₁ IV	27.5	28.1
β ₂ V	33.8	32.7
β ₁ VI	36.3	35.4

(Wille and Lutton, 1966)

• Crystallizes rapidly

• Crystallizes slowly
• Desired form in chocolate

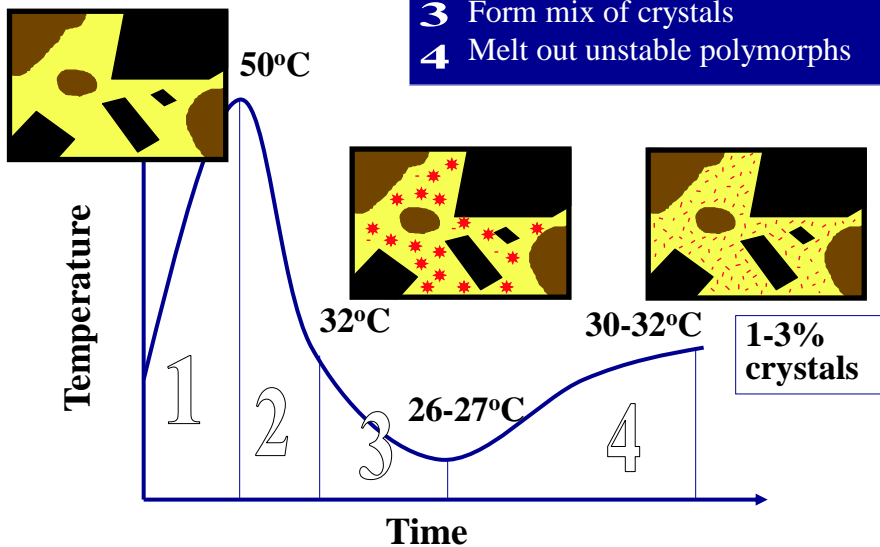
• Form associated with bloom



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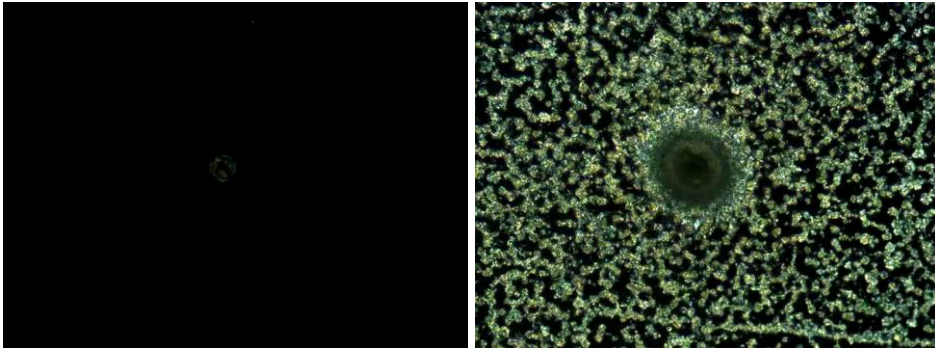
Tempering

- 1 Melt
- 2 Cool - no crystallization
- 3 Form mix of crystals
- 4 Melt out unstable polymorphs

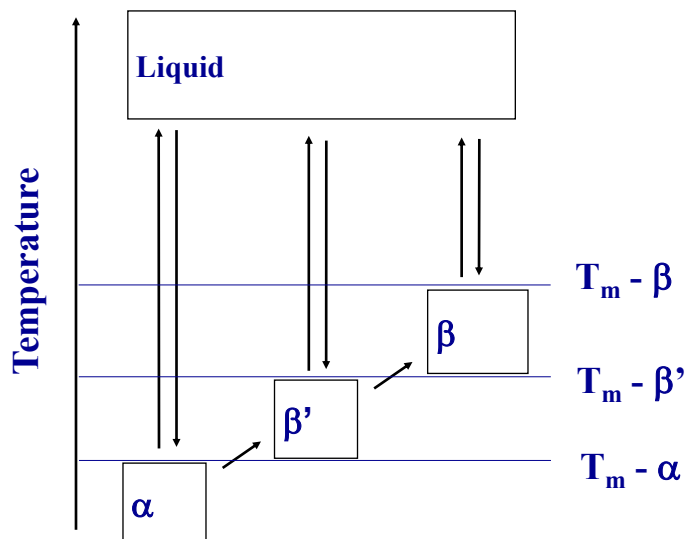




One stable β seed



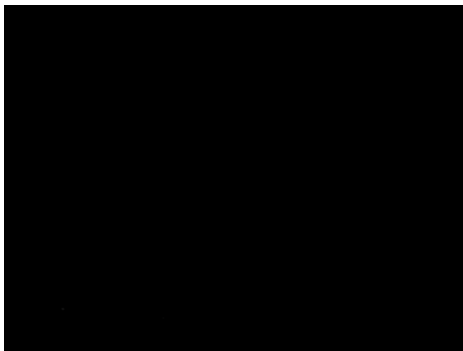
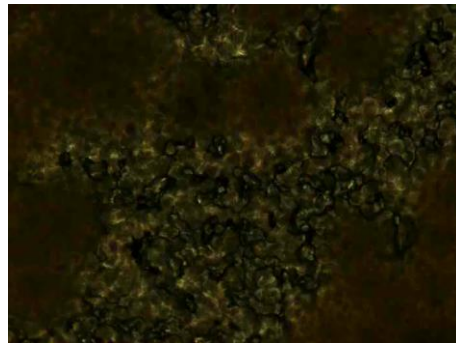
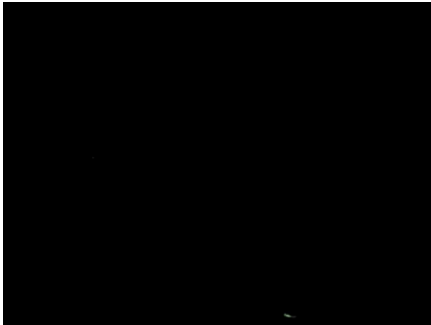
MONOTROPIC POLYMORPHISM





COCOA BUTTER

1. Without Seeds
2. One seed
3. 0.00055% seeds
4. 0.027% seeds
5. 0.137% seeds



1. Without Seeds
2. One seed
3. 0.00055% seeds
4. 0.027% seeds
5. 0.137% seeds

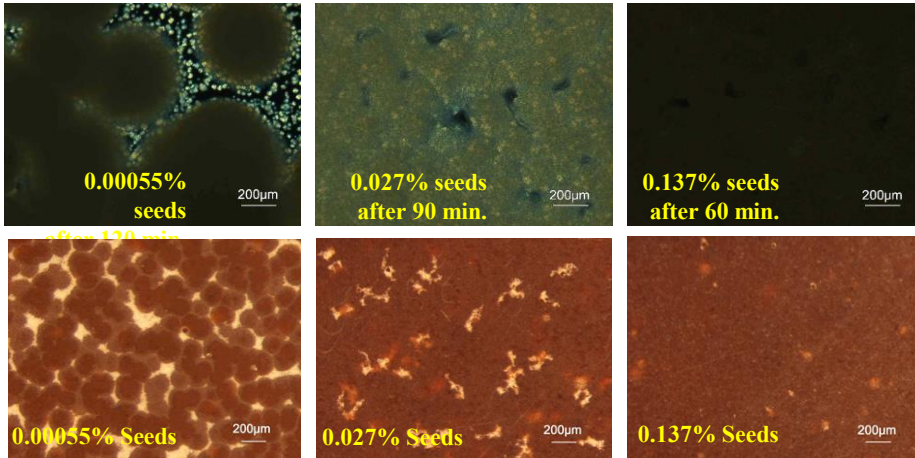




CRYSTALLIZATION VS. BLOOM

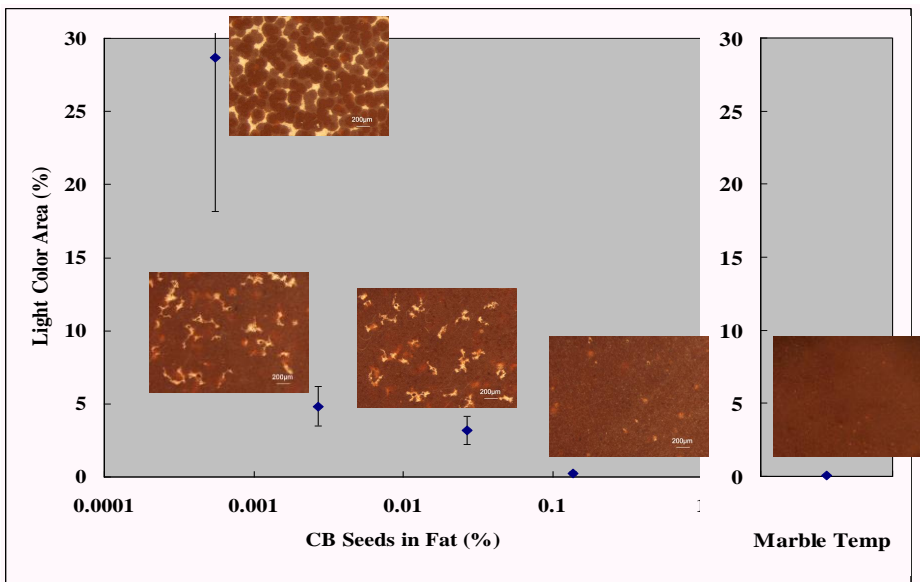
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As seeds amount increased, β crystallization took less time to reach upper level of solid fat content and the size became smaller – the result, a smooth surface.



POORLY TEMPERED CHOCOLATE

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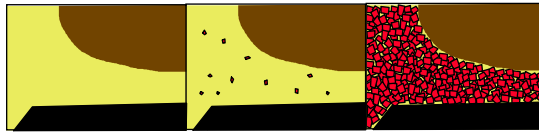




Tempering

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- In order to develop the desired crystalline structure in chocolate, the crystallization process must be carefully controlled
 - **tempering**
 - formation of proper number of seed crystals of correct size and polymorph (β V form desired)
 - first cool to low temperature (26-27° C) to form unstable polymorphs and then warm up to higher temperature (32° C) to promote formation of desired crystal structure
 - **cooling tunnel**
 - maintain desired crystal size and polymorph



Tempered Chocolate?

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Good tempering

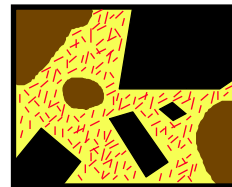
- proper flow properties of tempered mass
- rapid setting upon cooling
- high gloss in final product
- maximum contraction (mold release)
- resistance to fat migration and bloom

Under tempering

- insufficient seed to crystallize mass
- low gloss in final product
- less contraction
- rapid bloom formation

Over tempering

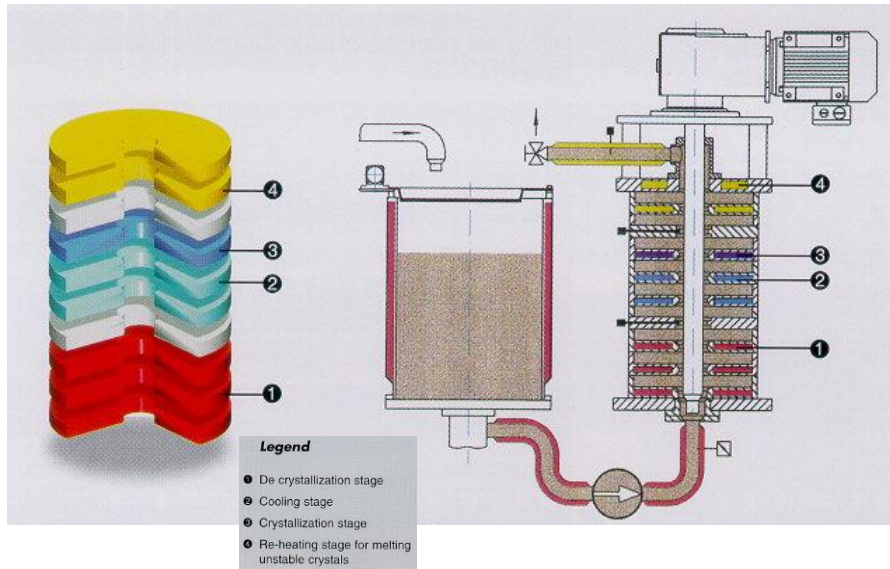
- higher viscosity
- less gloss in final product
- less contraction





CONTINUOUS TEMPERING COMMERCIAL

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KETTLE TEMPERING

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- Automated tempering cycle
 - Melt chocolate in kettle, heat to 110° F
 - Cool to 85-90° F and add more chocolate in back side of kettle
 - The fresh chocolate partially melts, seeding the cooled chocolate with appropriate cocoa butter crystals



Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



When hand tempering, what temperature, in Fahrenheit, is needed for dark chocolate?

- 75-77 F
- 81-83 F
- 85-87 F
- 88-90 F
- 91-93 F

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HAND TEMPERING

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- Pour a portion of melted chocolate onto slab and work with spatulas
- Return crystallized mass back to bowl
- Check temperature
 - If $\approx 88-90^\circ$ F, it's tempered
 - If $>92^\circ$ F, repeat marble work
- Mold chocolate, dip strawberries, etc.

- | | |
|---|------------------------------|
| 1 | Melt |
| 2 | Cool - no crystallization |
| 3 | Form mix of crystals |
| 4 | Melt out unstable polymorphs |





TEMPERING

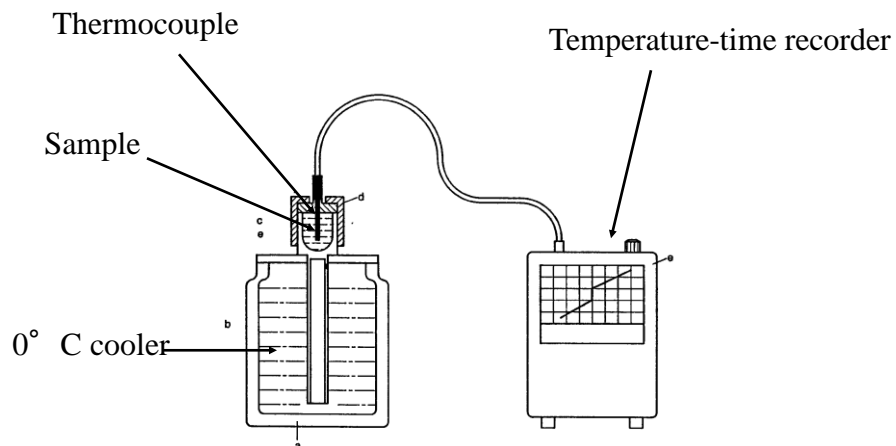
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- Did you get your chocolate or tempered or not?
- Well tempered chocolate:
 - Solidifies to the touch in a minute or so.
 - Releases easily from the mold
 - Good contraction
 - Has glossy surface
 - Small crystals reflect light
 - Good snap
 - Fine internal structure
 - Resistant to bloom
 - Retains gloss for long time



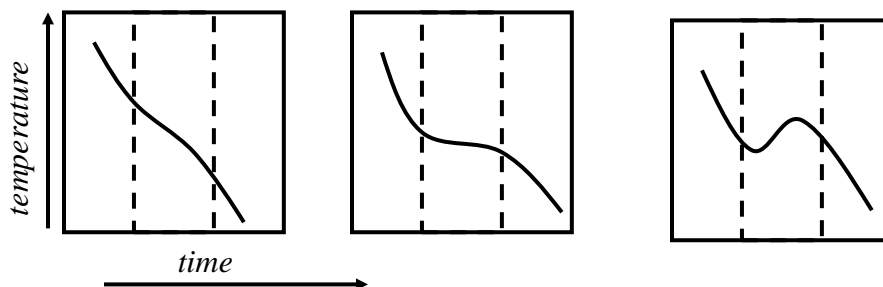
TEMPER METERS

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TEMPERMETER COOLING CURVES



Over tempered

GOOD TEMPER

Under tempered



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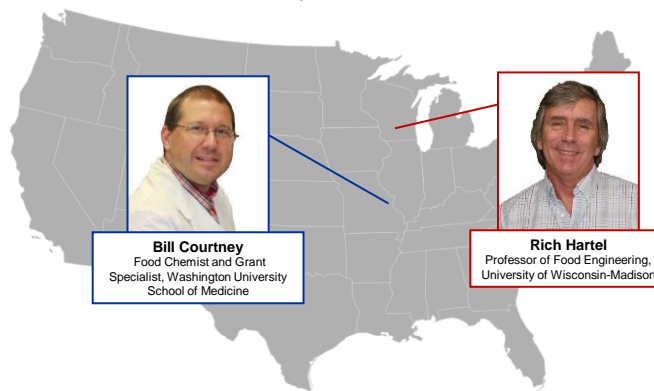
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**“How to Make Chocolate for your Special Valentine:
Flowers Bloom, Chocolate Shouldn’t”**



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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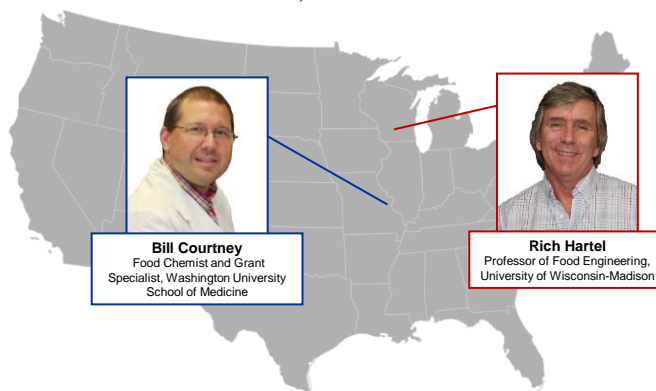
Stuart Conway, Professor of Organic Chemistry, University of Oxford

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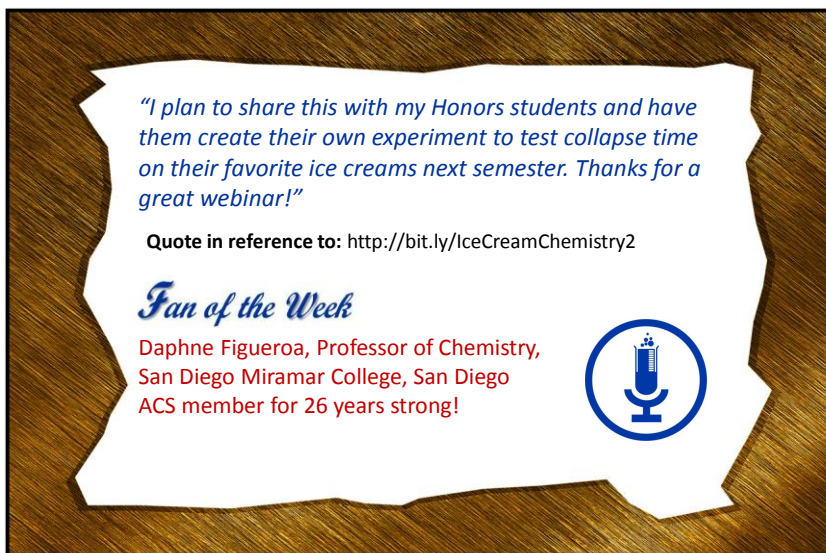
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