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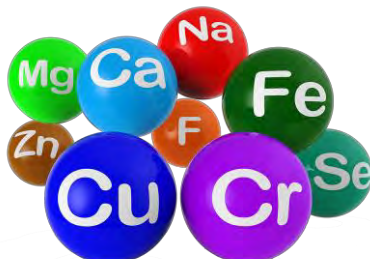
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Amy Naylor,
Professor of Chemistry
Mitchell Community College



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Thursday, February 19, 2015

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Did you miss Dr. Hartel's "Ask Me Anything" on Reddit yesterday?



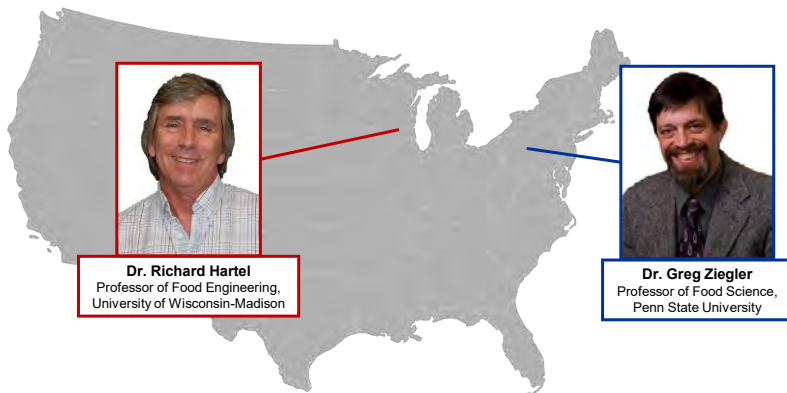
<http://redd.it/2vizlq>

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"Sweet Science: Chocolate Chemistry for Valentine's Day"



Dr. Richard Hartel
Professor of Food Engineering,
University of Wisconsin-Madison

Dr. Greg Ziegler
Professor of Food Science,
Penn State University

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Chocolate Chemistry

Dr. Rich Hartel
Professor of Food Engineering
UW-Madison



With Thanks To:

Ed Seguire
Mars, Inc.

Adam Lechter
ADM Cocoa

Chocolate: Food of the Gods

- **Interactive session with chocolate**
 - Where does chocolate come from?
 - How is it made?
 - How are chocolates different?
 - Some of the science in chocolate
- **Taste the Hershey Kiss**
 - Describe what you taste.
 - What memories does it invoke?
 - How do you know it's chocolate?



www.hershey.com/trickortreats/activities/costume-kiss.asp

Chocolate Standard of Identity

- **Must meet FDA Standard of Identity**
 - Must contain a minimum amount of components from the cocoa bean
- **Controlled ingredients**
 - Only cocoa butter and butter oil permitted fats
 - Chocolate flavor from chocolate liquor only
 - Only “nutritive carbohydrate sweeteners” permitted
 - No flavors simulating chocolate or dairy permitted



Chocolate: *Theobroma Cacao* *Food of the Gods*



Cacao Production

- 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



Ready for Harvest



Harvesting



Pod Opening



Pod and Beans



Fermenting



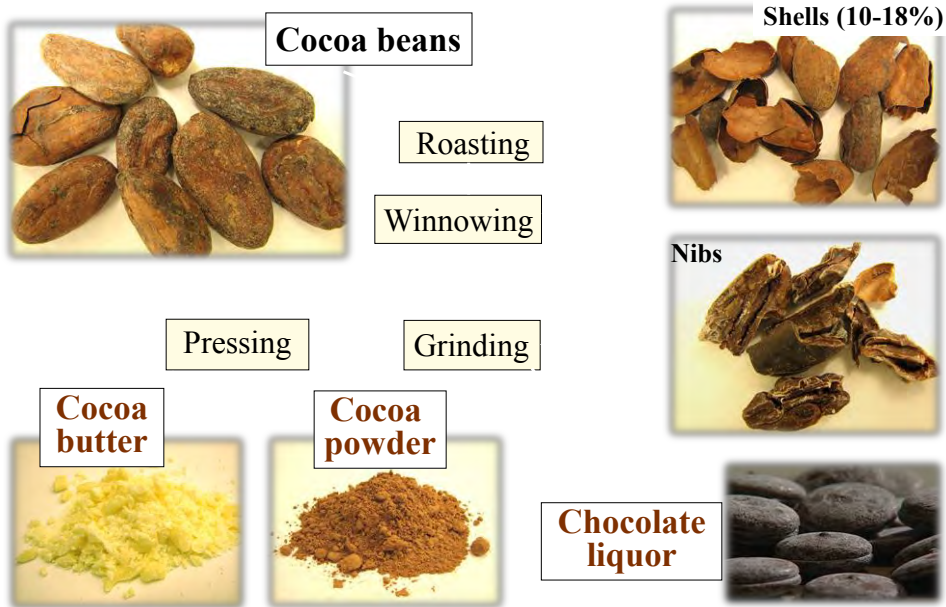
Drying



Cocoa Beans



Cocoa Bean Processing



Chocolate Liquor: Food of the Gods

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

**Taste the chocolate liquor
(Baker's chocolate)**



Chocolate Liquor Composition

- **Nibs (ground)**

- 48-57% fat - cocoa butter
- 2-3.5% water
- 40-50% cocoa solids
 - starch, fiber and gums, etc.



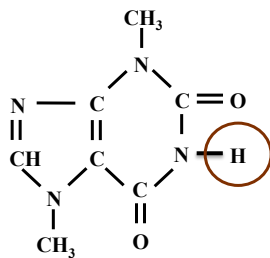
- **Alkaloids**

- 0.8 - 1.3% theobromine
- ≈0.2% caffeine (some people say there is no caffeine in chocolate)

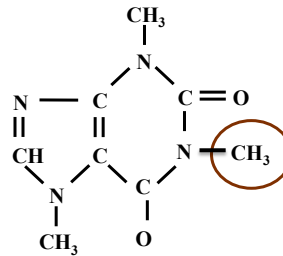


Alkaloids

- Theobromine and caffeine are related methylxanthine compounds



Theobromine



Caffeine

- But they have very different physiological effects

Alkaloids

- **Theobromine**

- Gentle, mild effect
- Long lasting (6 hr.)
- Increases well-being
- Mild anti-depressant
- Stimulates cardiovascular and muscular systems
- Mild effect on central nervous system
- Not addictive
- Mild diuretic

- **Caffeine**

- Strong, intense effect
- Short term (2-3 hr.)
- Increases alertness
- Increases emotional stress
- Stimulates cardiovascular and respiratory systems
- Strong effect on central nervous system
- Addictive
- Strong diuretic

www.xocoatl.org/caffeine.htm

Audience Survey Question

ANSWER WITH THE CORRECT LETTER IN THE QUESTIONS BOX



Why shouldn't you let your dog eat chocolate?

- a) It causes them to become seriously ill
- b) That's less chocolate for us
- c) Dogs metabolize theobromine very slowly
- d) All of the above

www.hersheys.com/nutrition/theobromine.asp

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Chocolate

“In 1847, an English company introduced the first solid eating chocolate made by combining melted cocoa butter with sugar and cocoa powder. This chocolate had a smooth, velvety texture and quickly replaced the old coarse-grained chocolate ...”



Chocolate liquor
Cocoa butter
Sucrose
Milk source (optional)
Lecithin
Vanillin

Dark Chocolate Example Compositions

- | | |
|------------------------|------------------------|
| • Minimum Semi-sweet | • 70% Bittersweet |
| 50.4% Sugar | 29.4% Sugar |
| 35.0% Chocolate liquor | 70.0% Chocolate liquor |
| 14.0% Cocoa butter | -- Cocoa butter |
| 0.3% Lecithin | 0.3% Lecithin |
| 0.1% Vanillin | 0.3% Vanilla |



**Compare Hershey Special
Dark vs. Lindt 70%
(save half the Lindt for later)**

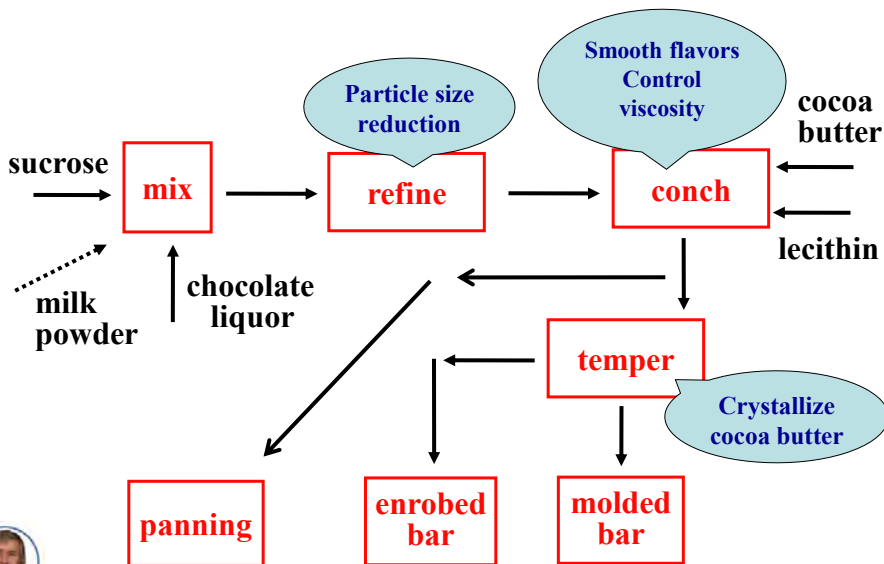


70% Cocoa

- By cocoa, manufacturers are counting all the chocolate liquor and extra cocoa butter added to the bar.
- 70% cocoa means that there's only about 29.5% sugar in the bar (the rest is vanilla and lecithin)
- It tastes really chocolatey

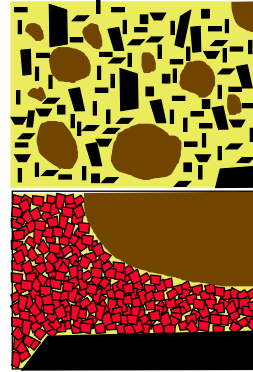


Chocolate Processing



Chocolate/Coating Structure

- **About 60-70% dispersed particles**
 - Sugar crystals, cocoa solids, milk powder
- **30-35% fat (cocoa butter or PKO)**
 - Melted chocolate, fat is liquid
 - Solidified chocolate, fat is partially crystalline
- **About 0.5% water**
 - Probably associated with sugar crystals and cocoa solids
- **About 0.2-0.3% lecithin**
 - Coats sugar particles and cocoa solids, the hydrophilic components



Composite Image of Chocolate

Confocal Microscopy

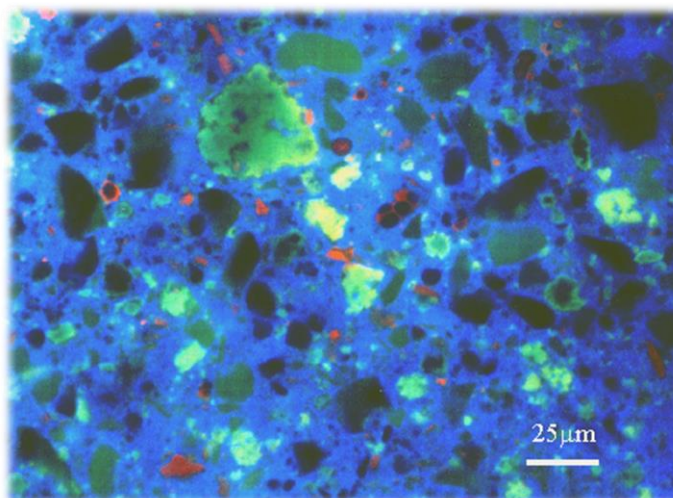
Dark green
- sugar crystals

Bright green
- milk protein

Red
- cocoa solids

Blue
- liquid fat

Black
- sugar crystals



From Mark Auty, DPC, Moorepark

Audience Survey Question

ANSWER WITH THE CORRECT LETTER IN THE QUESTIONS BOX



What is White Chocolate?

- a) Dark chocolate gone incognito
- b) Dark chocolate with white color added
- c) Chocolate without nonfat cocoa solids
- d) Milky milk chocolate

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White Chocolate

- Contains everything except the cocoa liquor
- Chocolate flavor comes only from the cocoa

What is predominant flavor?



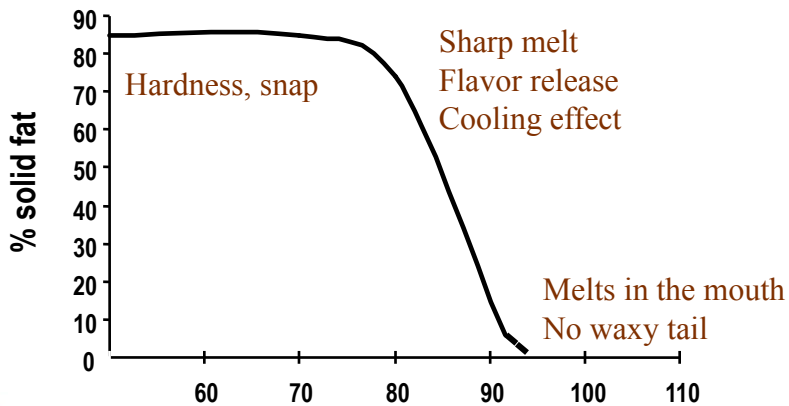
Important Properties of Chocolate

- 1 Particle size (fineness)
- 2 Flavor
- 3 Viscosity
- 4 Fat phase properties
 - Tempering
 - **Melting properties**
- 5 Polyphenols



Cocoa Butter Melting

- Draw the melting profile of cocoa butter



Wax in your Chocolate?

- Why do some chocolates have a waxy aftertaste? Is it because chocolate makers add wax to their chocolate

- Wax is not allowed in chocolate under the Standard of Identity!!
- There are NO chocolate manufacturers that add wax to their chocolate!!

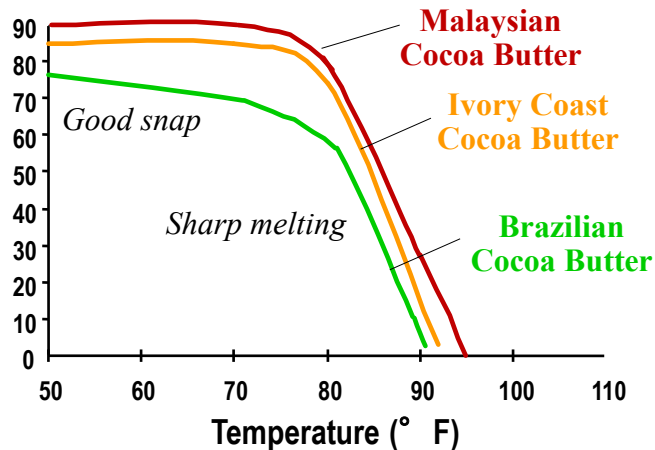


Paraffin wax is mostly found as a white, odorless, tasteless, waxy solid, with a typical melting point between about 47° C to 64° C (116.6° F to 147.2° F).

en.wikipedia.org/wiki/Paraffin

Cocoa Butter Melting Profiles

- Cocoa butters from different sources have slightly different melting profiles



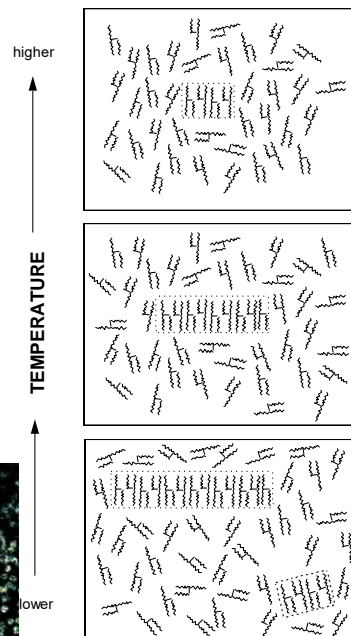
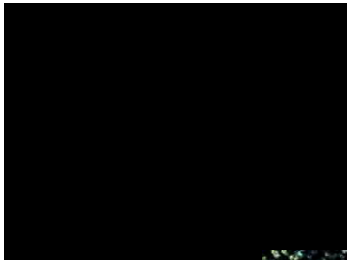
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Lipid Crystallization

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



Polymorphism

- **Polymorphic structures**

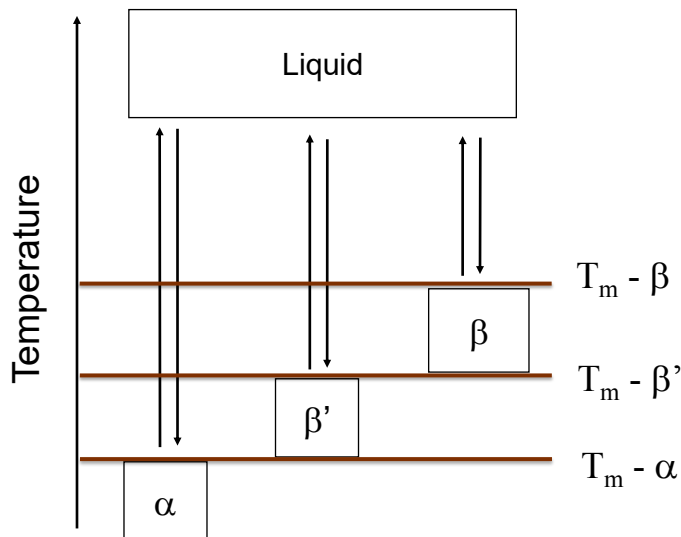
- molecules may take more than one crystal form
- different lattice structures
 - TAG can be oriented at different angles



- Or in different lengths (double or triple)



Monotropic Polymorphism



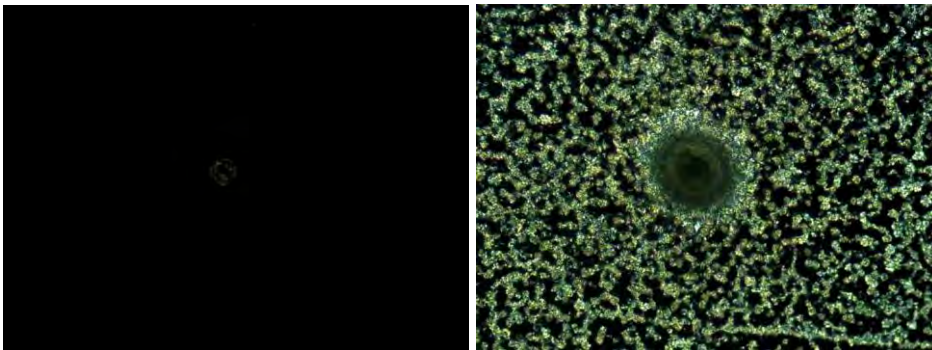
Cocoa Butter Polymorphism

Polymorph	Melting Point	ΔH (cal/g)	
γ I	17.3° C	-	
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	Desired form in chocolate
β_1 VI	36.3	35.4	Form associated with bloom

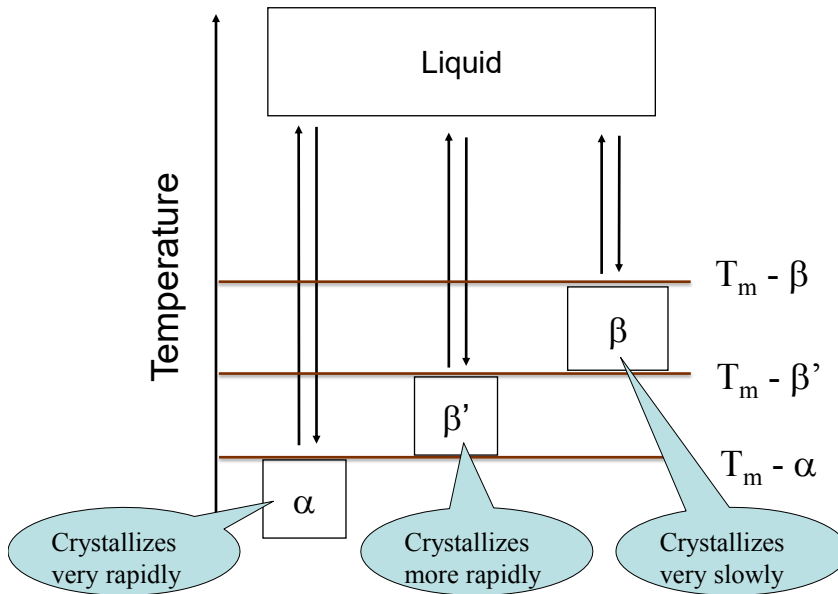
Wille and Lutton, 1966)

Cocoa Butter

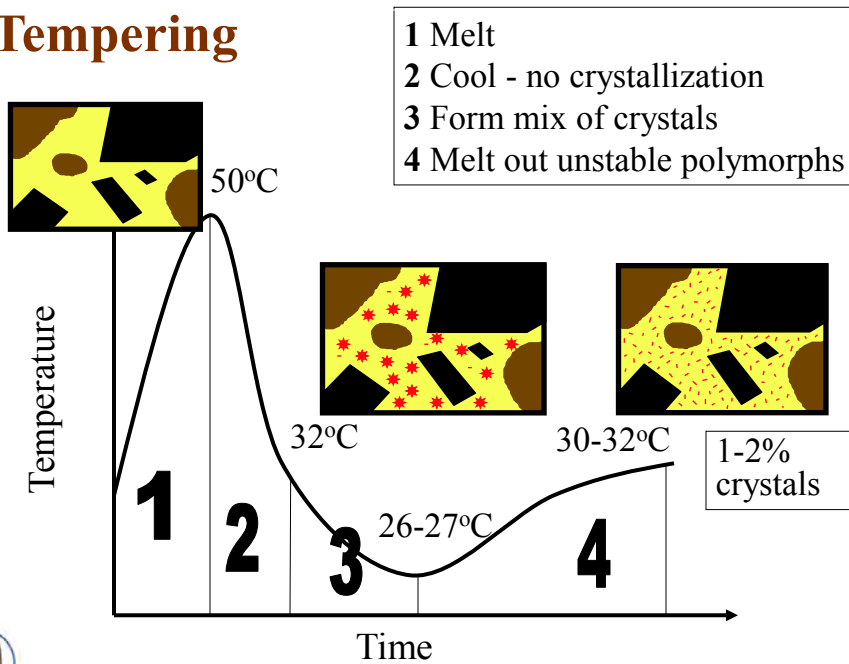
One stable β seed



Monotropic Polymorphism



Tempering

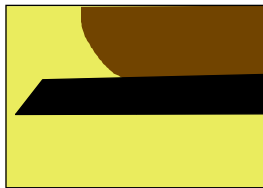


Tempering

- **Critical to making fine chocolate**
 - Provides numerous stable β polymorph seeds to set the remaining cocoa butter as it solidifies
 - Typically thought that 1-2% of the cocoa butter mass should be seed crystals

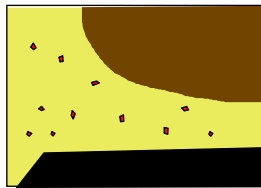
Tempering

Start fat crystallization

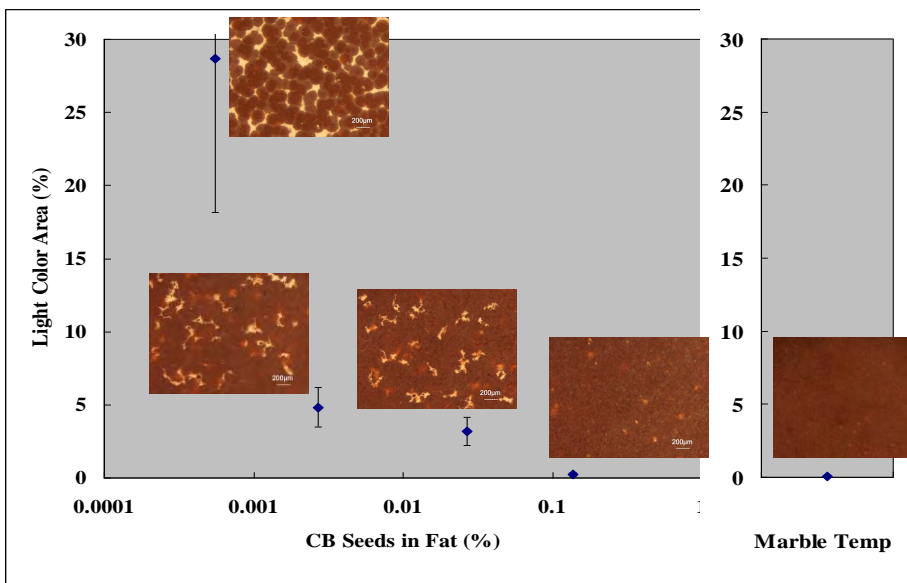


Cooling Tunnel

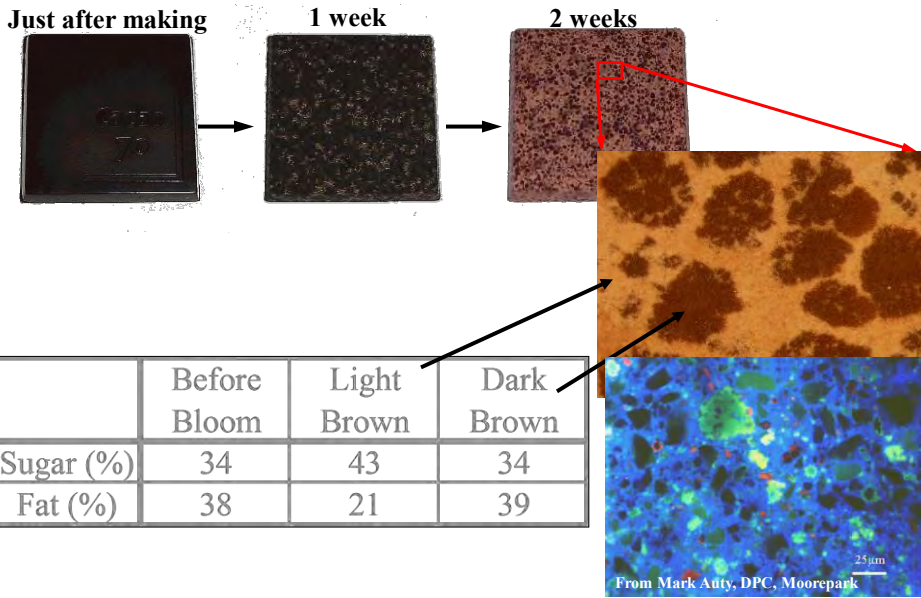
Continue fat crystallization



Poorly Tempered Chocolate

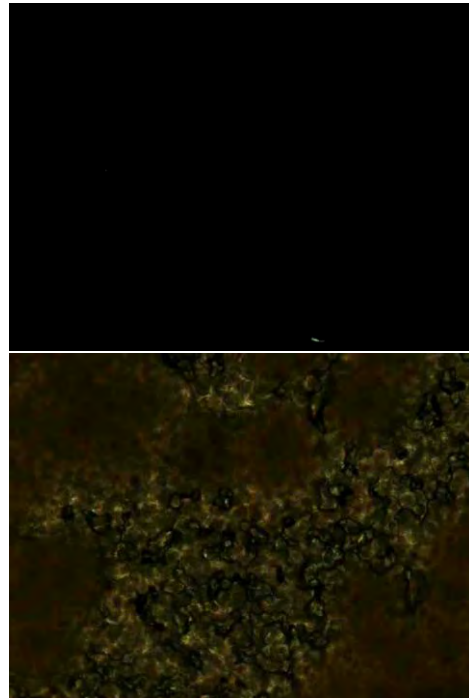


Bloom Development w/o Tempering



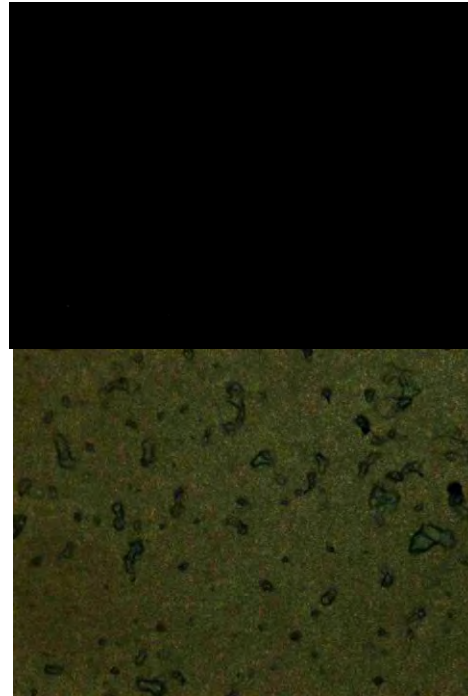
Cocoa Butter

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



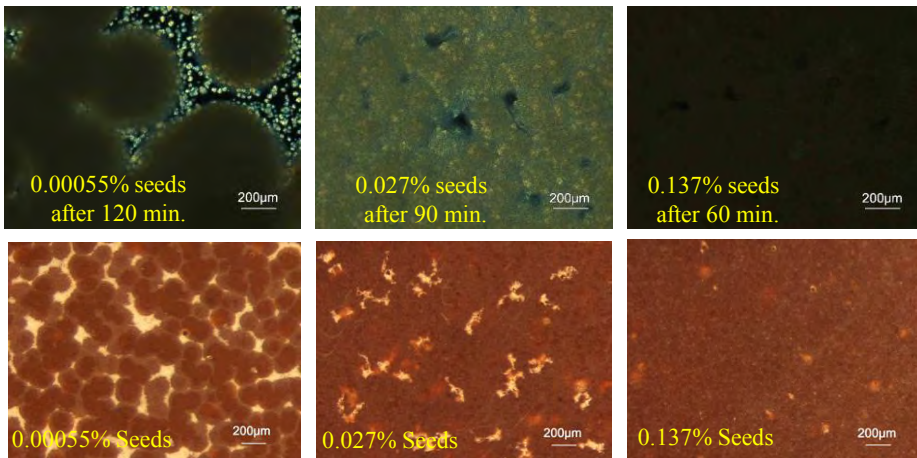
Cocoa Butter

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



CB Crystallization vs Bloom

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.

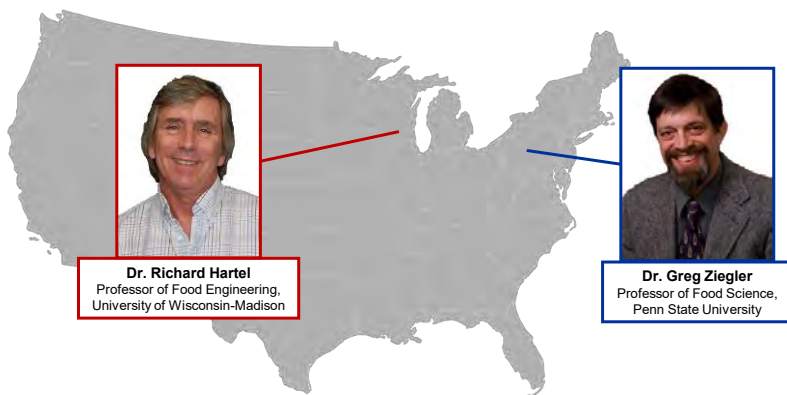


Chocolate Chemistry: Lessons Learned

- Chocolate used to be used as “money” and it grows on trees, so money really does grow on trees.
- Chocolate is a vegetable so it’s good for you.
- Be sure to temper your chocolate correctly if you want nice shiny pieces.



“Sweet Science: Chocolate Chemistry for Valentine's Day”



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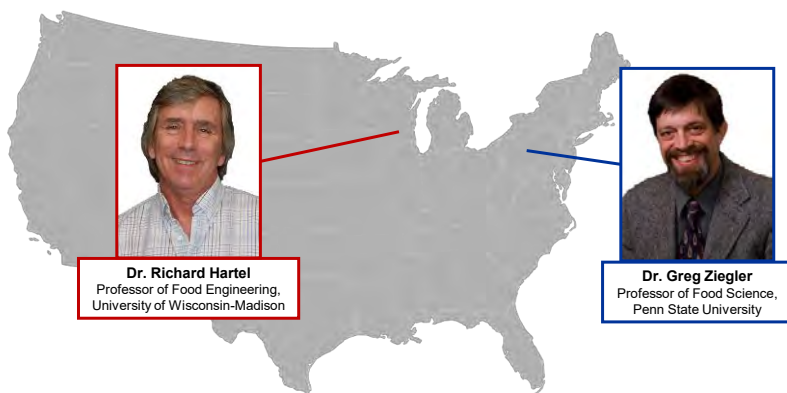
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