HEAT RESISTANT CHOCOLATE

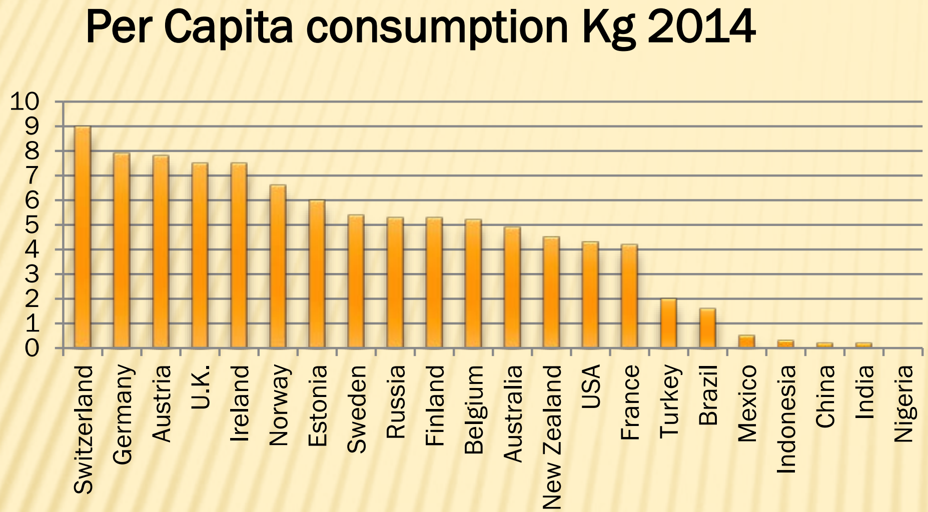
WHAT IS GOING TO BE COVERED IN THIS PRESENTATION?

- The commercial opportunity for Heat Resistant Chocolate
- What is chocolate?
- What is Heat Resistant Chocolate?
- How to produce it.
- Practical issues in the manufacturing process
- Intellectual property
- Information resources

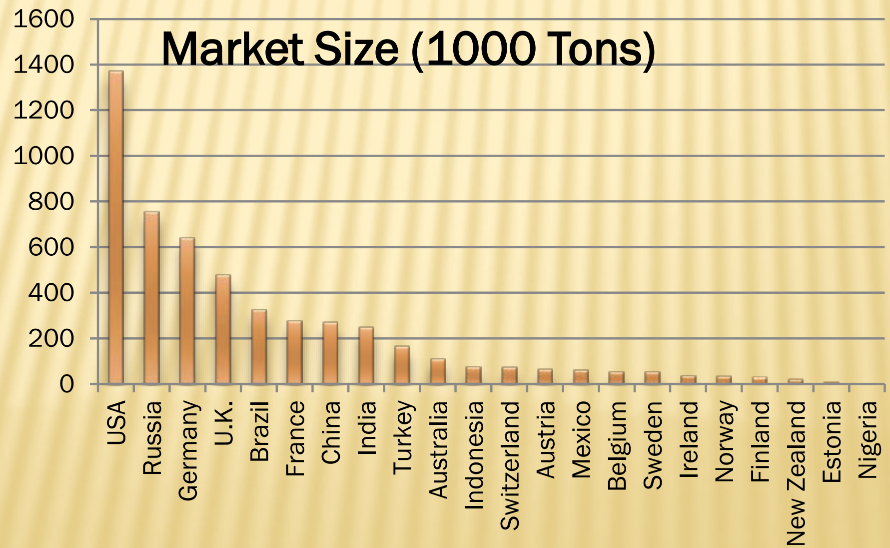
WHY IS IT IMPORTANT?

- Normally, chocolate starts to melt at about 77°F (25°C) and is pretty much fully molten at 91°F (33°C)
- Many countries have ambient temperatures above that range, for large parts of the year.
- Let us be reminded that the ‘actual’ environmental temperatures can exceed the ambient shade temperatures greatly.
- Many of those hot regions have large populations and rapidly expanding economies, which could sustain good emerging markets in the chocolate sector.
- Although the potential for expanding the chocolate markets in these regions is there economically, the infrastructure to deliver non-heat-damaged chocolate to the consumer is often not.
- This last point is important as the heat resistance may well be required for the initial distribution chain, rather than for the Point of Sale, and for the journey from the shop to the actual product consumption.

CURRENT CONSUMPTION OF CHOCOLATE

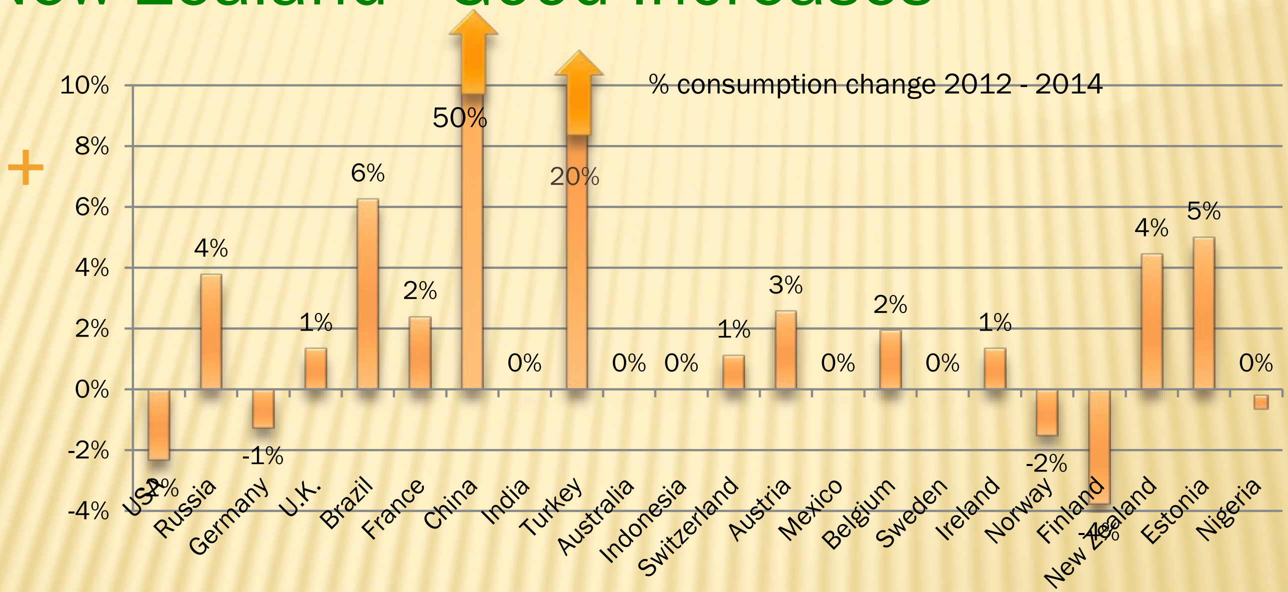


World cocoa production 4.8 million tons (2012)



CHOCOLATE MARKETS 2014 VS 2012

- China, Turkey, Brazil, Russia, Austria, Estonia, New Zealand - Good Increases



- Most of Europe treading water
- U.S., Germany and most of Scandinavia down

MARKET OPPORTUNITIES FOR CHOCOLATE

Brazil, Russia, India and China

Mexico, Indonesia, Nigeria and Turkey

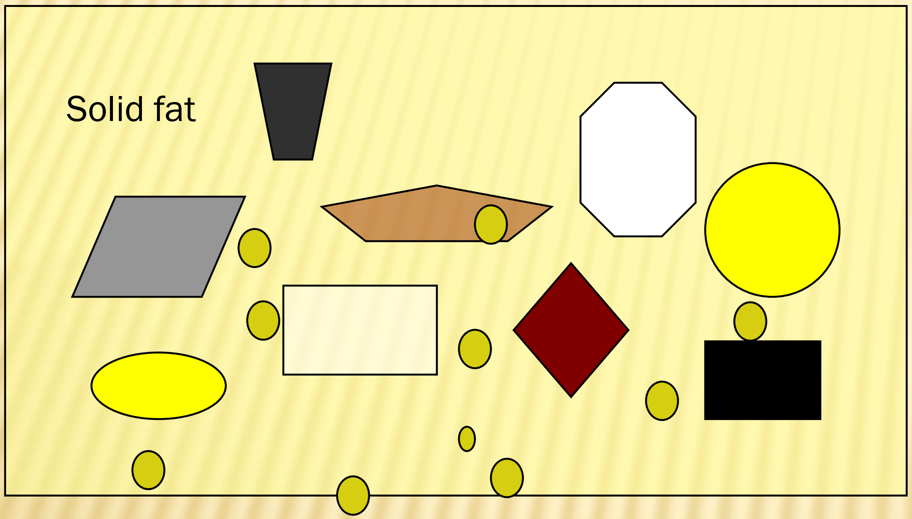
WHAT IS THE PROBLEM?

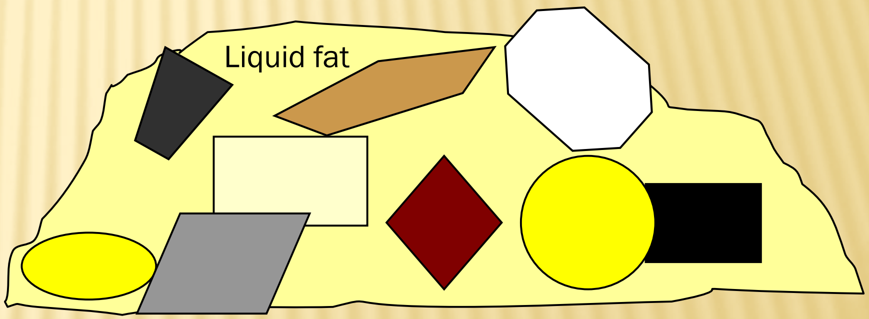
- Chocolate consists of a finely divided mixture of sugar, cocoa beans and sometimes milk particulates, dispersed in a continuous fat matrix.
- The fat matrix is holding everything together so when the fat is mainly solid, the chocolate will be too.
- Conversely, when the fat melts, the chocolate will become deformed, sticky and ultimately liquid.

THE SCHEMATIC STRUCTURE OF CHOCOLATE

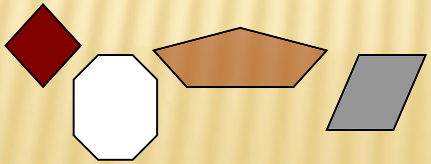
Solid chocolate held in shape by solid fat

Molten chocolate loses shape when fat melts



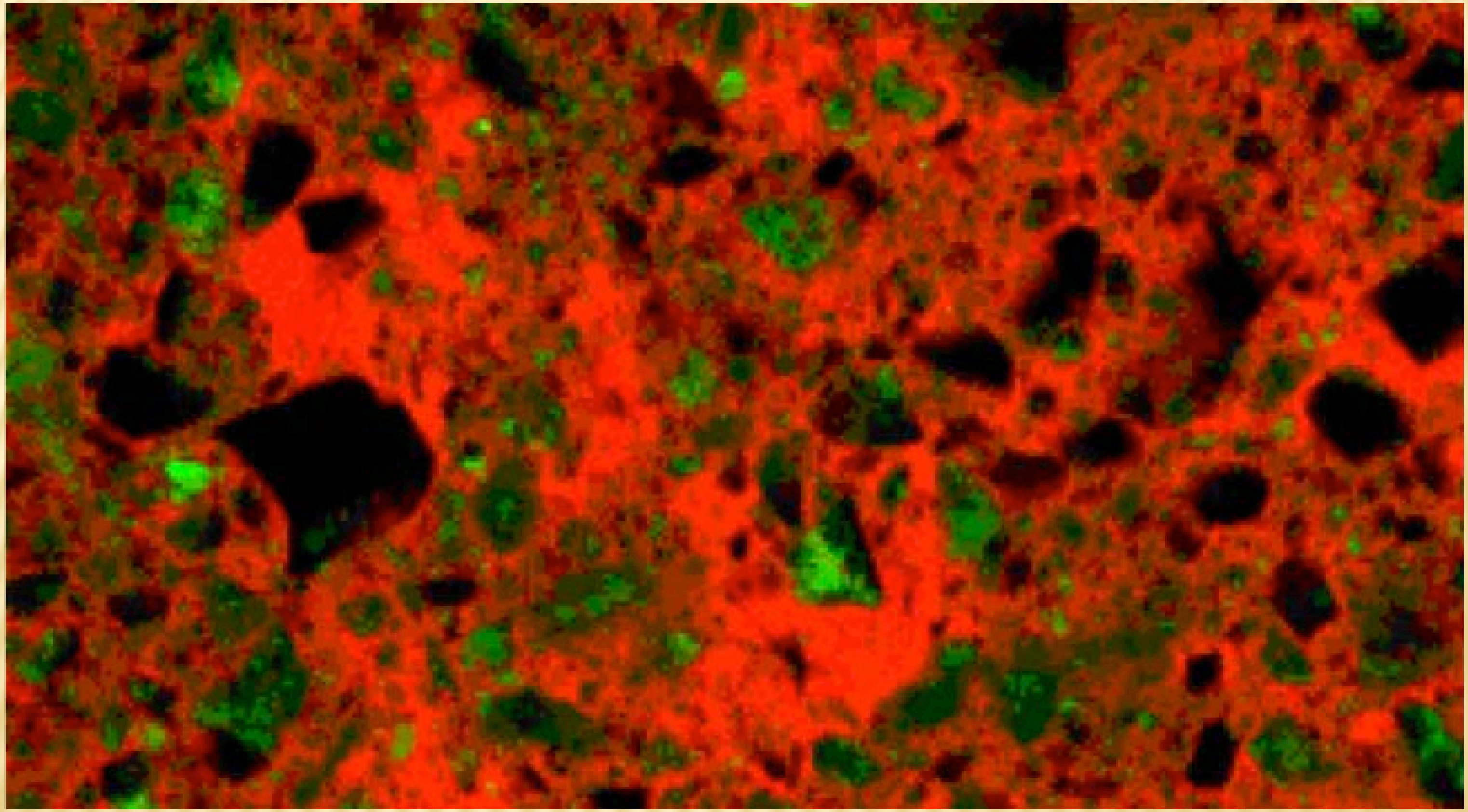


Liquid fat trapped in matrix



Solid particles sugar, cocoa, milk

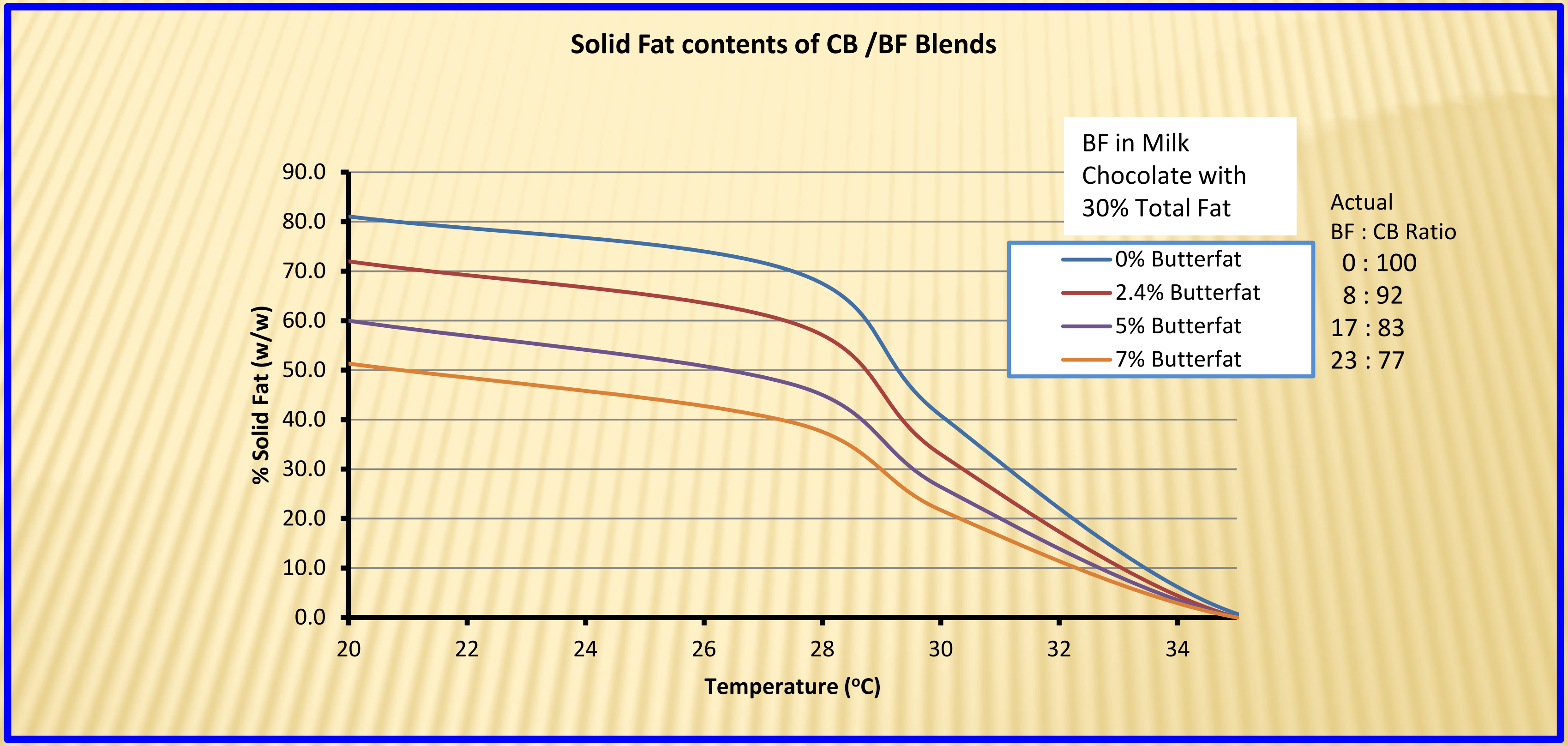
MICROSTRUCTURE OF CHOCOLATE



Optical micrograph of milk chocolate -

Courtesy of Derick Rousseau, Ryerson University, Toronto, Canada

NOT ALL THE FAT HAS TO MELT!



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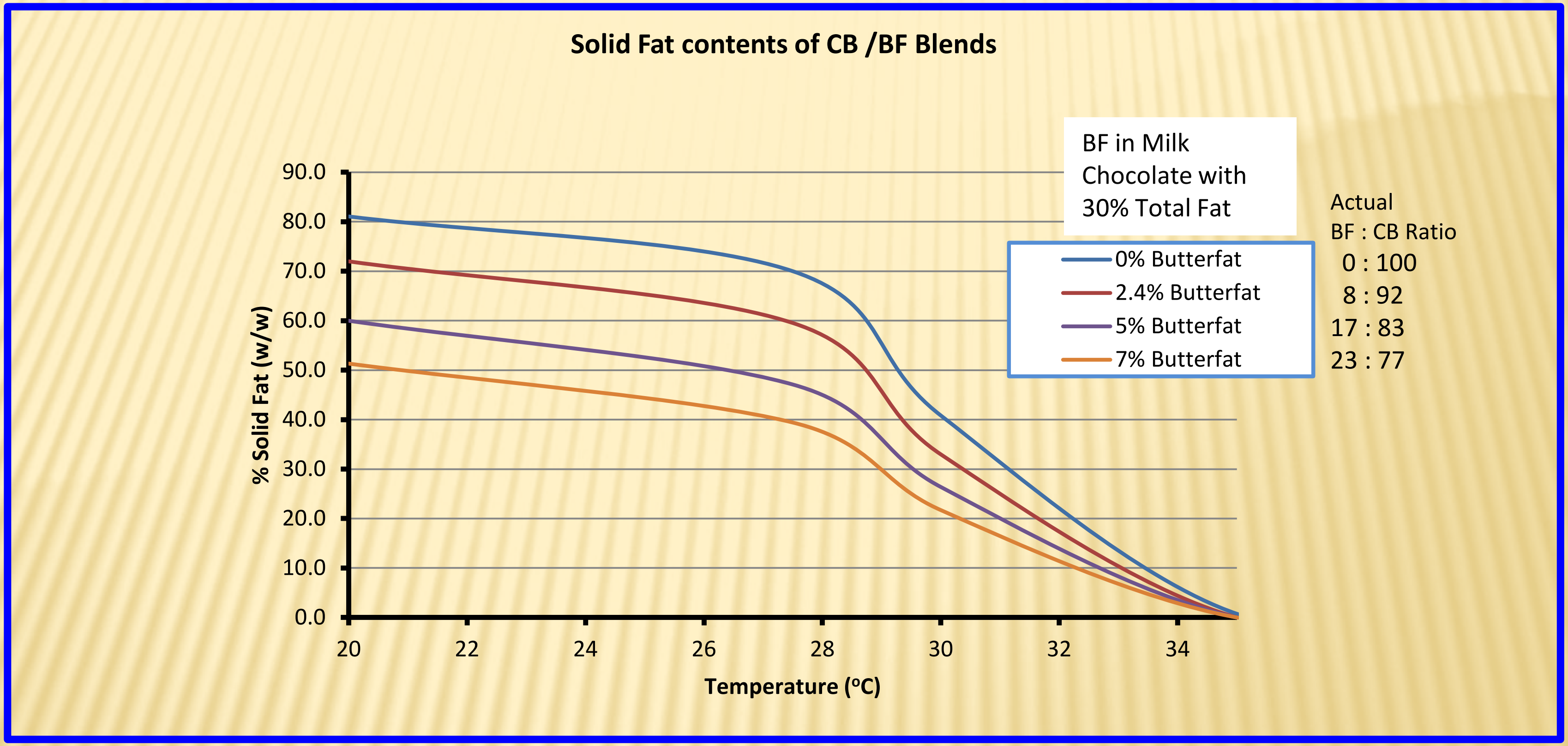


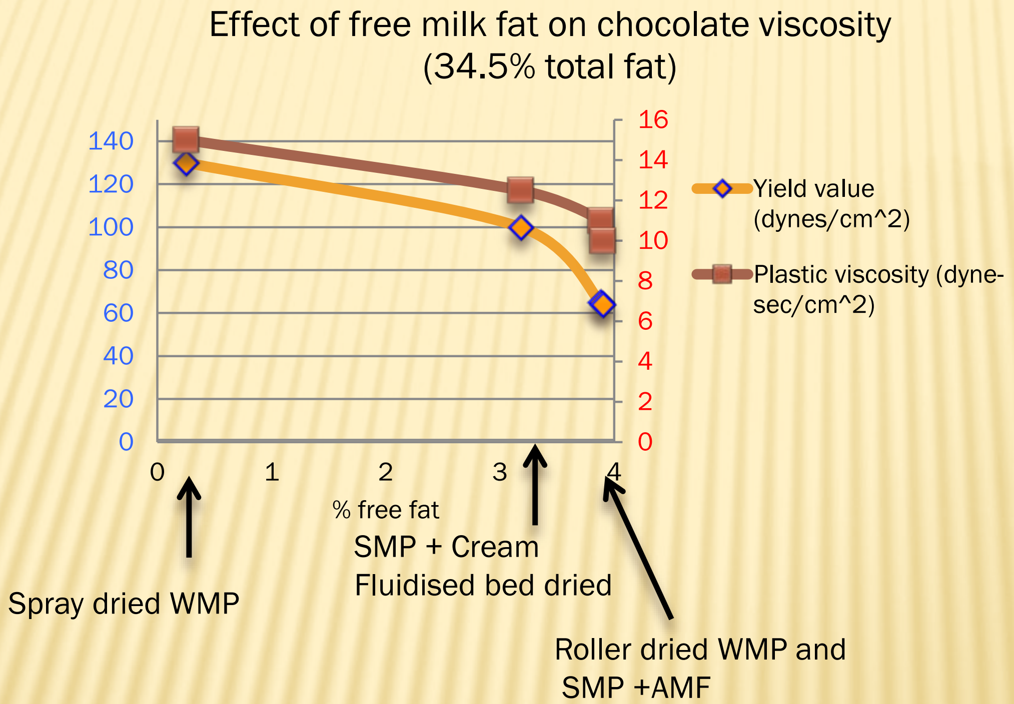
Yet Milk Chocolate at room temperature is considered to be a solid material!

SO WHAT IS HAPPENING?

- On a microscopic scale, chocolate is not a homogenenous material
- Some of the liquid fat in chocolate is structurally bound up with the other ingredients, preventing it from from influencing the overall melting of the product.
- This can be demonstrated by comparing viscosities of milk chocolates made from different processed full cream milk powders with those made from skimmed milk powder and milk fat

EFFECT OF FREE FAT

- Low free fat results in higher viscosity



Effects of Milk Powders in Milk Chocolate (2004), B. Liang and R. W. Hartel. J. Dairy Sci. 87:20–31

WHAT IS HEAT RESISTANT CHOCOLATE?

- Ideally, chocolate that has the same texture and sensory characteristics as regular chocolate, when consumed at temperatures above the normal melting point.
- Also, the chocolate should not deform and melt at these elevated temperatures.
- Optimally, the chocolate should still melt below body temperature to simulate the normal eating sensation of chocolate.

IS THERE A STANDARD DEFINITION FOR HEAT RESISTANT CHOCOLATE?

- There are many patents on the subject, scientific papers, conference presentations and mentions in books about chocolate.
- BUT……..There seems to be no standard definition!
- "Melts at elevated temperature" seems a common claim.
- A good question to ask is "What temperature does my product need to withstand melting and deformation?" (140°F / 60°C may not be such a good idea!)

HOW CAN WE PRODUCE A HEAT RESISTANT CHOCOLATE?

1. We can increase the melting point of the fat phase to reduce the amount of liquid fat in the structure.
2. We can alter the structure to “bind” more of the liquid fat so that it doesn’t influence the integrity of the structure.
3. Insulate the chocolate to prevent it from melting at the surface and retaining it’s shape.

ALTERING THE FAT PHASE MELTING PROFILE

- In most regions, chocolates are extremely tightly regulated in terms of composition.
- Most of the attempts to add harder fats into chocolate have been thwarted by the rigid SOI of chocolate.
- A good idea if you don’t want to call your product “chocolate”!
- Where possible and acceptable a CBI (Cocoa Butter Improver) may be an option.

USING COCOA BUTTER IMPROVER'S (CBI)

- This group consists of Shea, Illipe (source of SOS) , Palm Fractions and/or ESOS (Enzymatic equivalent for SOS),
- CBI's are non-hydrogenated vegetable fat's and are zero trans as well.
- They can be used in dark or milk chocolate in variable proportion, without any influence on the physical properties of the fat blend when based on an average cocoa butter, and can be used by the chocolate producers with no change of production method.

Using Cocoa Butter Improver (CBI)

Normally when used in chocolate with soft cocoa butter, a CBI can serve as a stabilizing fat, bringing the final blend closer to the normal physical state. In heat resistant chocolate a CBI can increase solids and melt point to increase the resistance to softening in warm climates.

By altering the ratio or fractions used for the CBI blends, it is possible to produce CBI's that can alter the physical properties in chocolate in a specific direction, for instance by making the chocolate harder at higher temperatures.

BENEFITS OF CBI’S

Stabilizing Milk Chocolate

One of the most important applications of CBI’s is to eliminate the undesired influence of milk fat on the melting properties of milk chocolate. Especially when products are stored and consumed in hot climates.

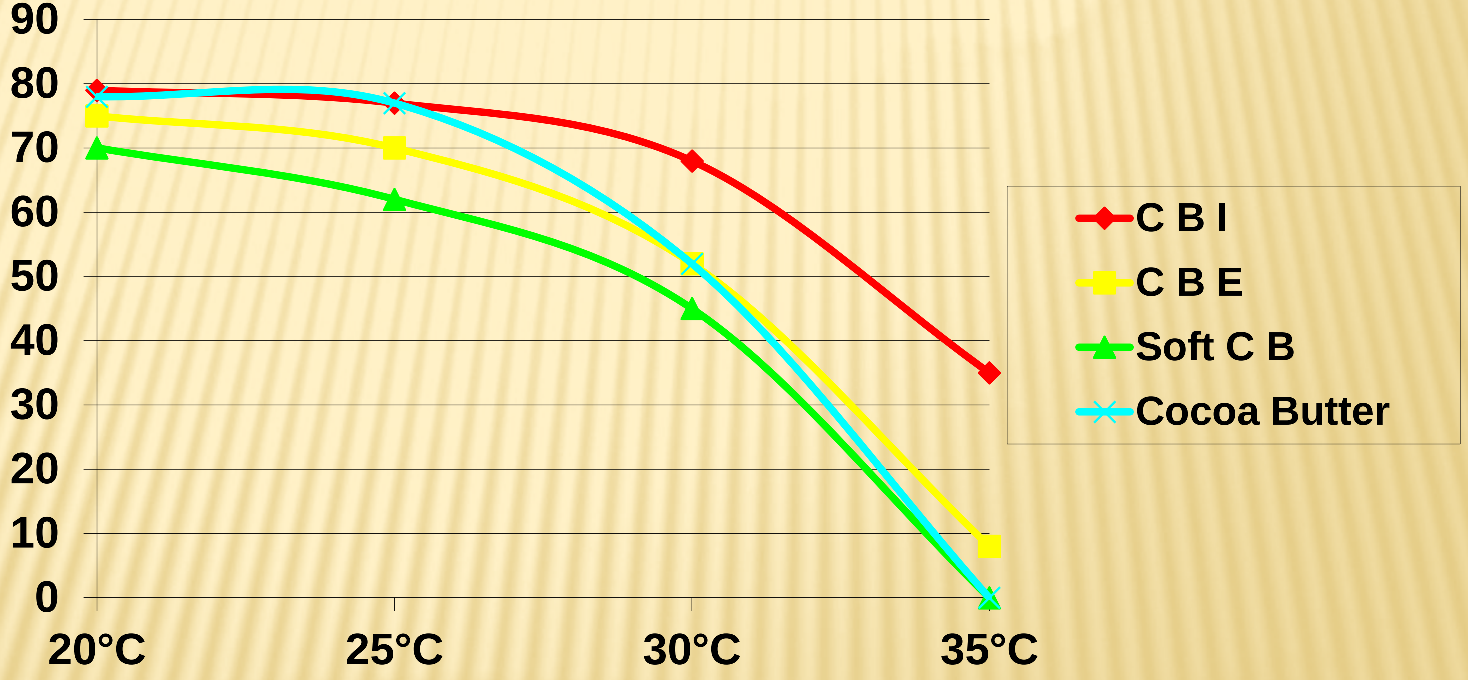
Hardening Dark Chocolate

CBI’s are also used to harden dark chocolate for hot climates, extending its shelf-life and improving its handling and eating qualities.

Increasing Bloom Stability

The greatest single advantage of Cocoa Butter Improvers is their ability to inhibit fat bloom, especially in dark chocolate which are most vulnerable to it.

SOLID FAT CONTENT OF CBI & COCOA BUTTER



BENEFITS OF CBI'S

- Similar to cocoa butter in texture, flavor and release.
- Infinite tolerance to cocoa butter.
- Lower than cocoa butter prices.
- Potential to improve shelf life.

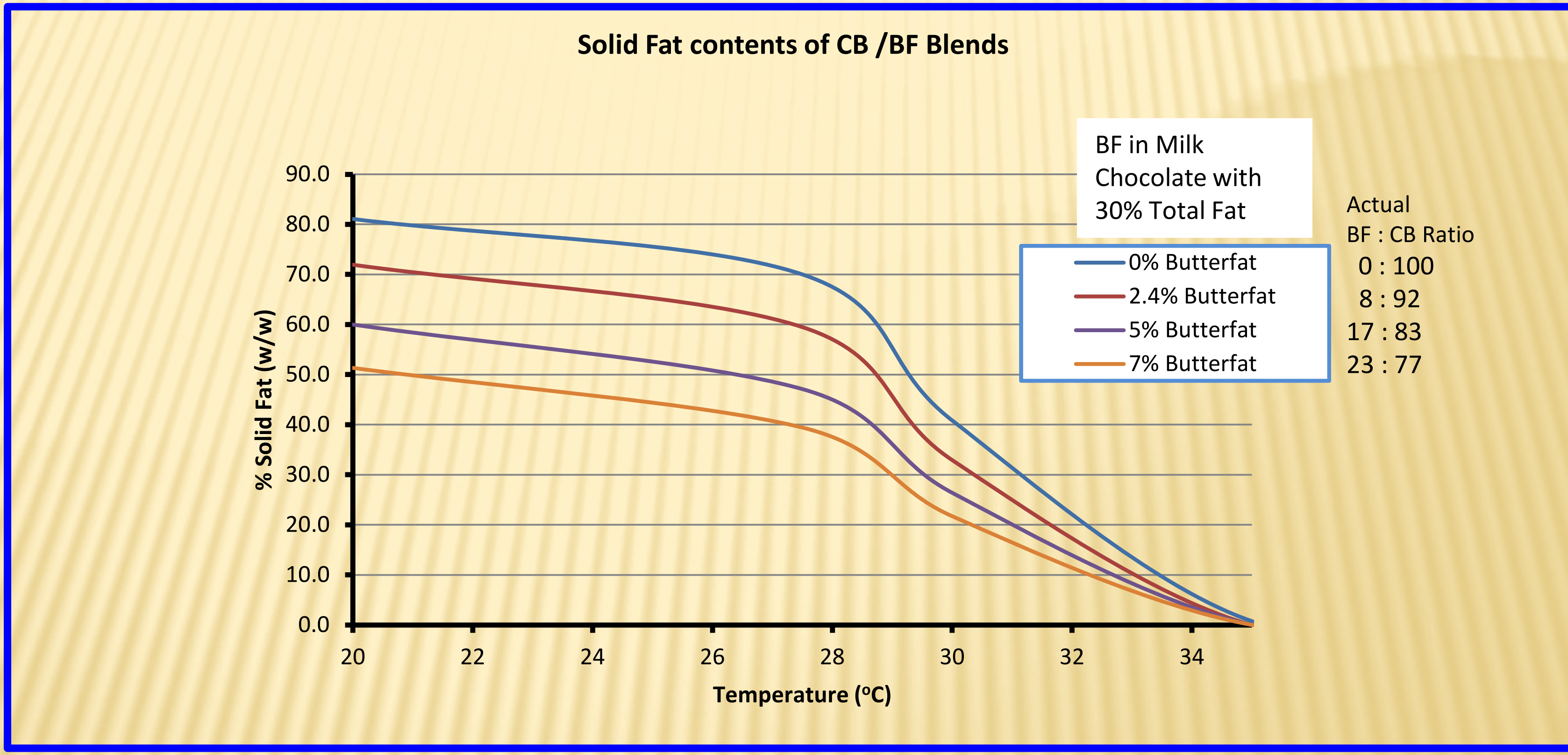
DRAWBACKS OF CBI'S

- Must be tempered just like cocoa butter.
- May not meet standards of identity for chocolate in your market.
- Higher solids, while may improve the stability of a chocolate, it may add a waxy sensation depending on the level used. We will come back to this later.

WHAT ELSE CAN HELP HARDENING UP THE FAT PHASE?

- Minimise milk fat in formulation.
- Use harder cocoa butters (Malaysian vs Brazilian, for example)

MINIMISE THE MILK FAT IN YOUR FORMULATION



HARDNESS OF DIFFERENT COCOA BUTTERS

Cocoa butter SFI		Country of Origin		
Temp ^{o}C	Temp ^{o}F	Brazil	Ghana	Malaysia
20	68	66.3	76.2	81.2
25	77	60.1	70.4	76.2
30	86	36.9	45.1	54,8
32.5	90	6.6	13.3	19.7
35	95	2	0	0

- From Industrial Chocolate ed. Beckett 4th edition, p420

FURTHER IDEAS ON ALTERING THE FAT PHASE MELTING PROFILE

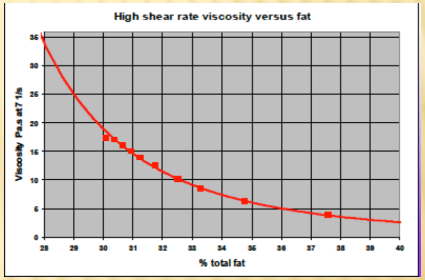
- Interesterification of cocoa butter has been proposed but this is a difficult process to control, with questionable legality.
- Addition of Mahua and Kokum (hard) fats as part of the Non - Cocoa, Vegetable Fat component in countries, where it is allowed.
- Reduce the overall chocolate fat content.
- Are fractionated cocoa butters possible, or legally allowed?
- The use of high melting emulsifiers to add a secondary structure to the fat phase. Problems with typical legal usage limits of 1% max.

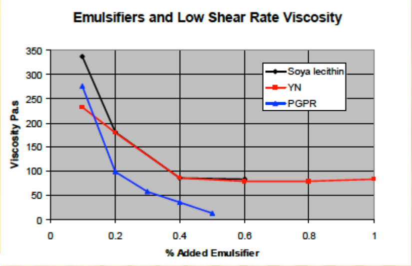
HOW WILL HARDENING THE FAT AFFECT THE MANUFACTURING PROCESS OF THE CHOCOLATE?

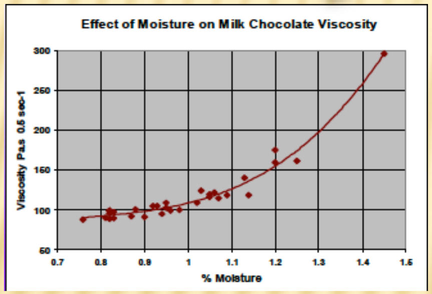
- The most common way of tempering uses the process of melting all the polymorphic fat crystals; cooling the chocolate with stirring to create many form of crystals (nucleation); reheating the bulk to melt out the unstable crystals; followed by cooling again to solidify the remaining stable crystals (growth).
- If we have now increased the melting point of the fat, the tempering temperatures will need to be adjusted upwards. (Melting, Nucleation and Reheat temps)
- The cooling tunnel temperatures will also need to be raised accordingly.

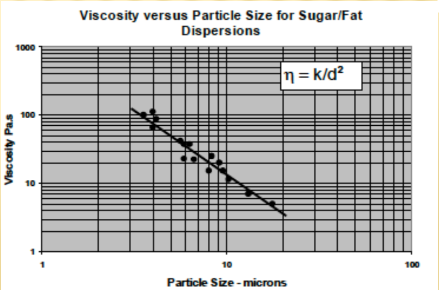
REDUCING THE DEFORMATION OF CHOCOLATE AT ELEVATED TEMPERATURES

- Increase the viscosity by reducing
  - Fat content
  - Emulsifier content
  - Particle Size
- And increasing moisture content









- Note: All these solutions are counter-intuitive to conventional chocolate making

ALTERING THE FAT BINDING STRUCTURE OF THE CHOCOLATE

- This has been done, most successfully by adding water, or hydrophilic (water-liking) molecules.
- Water can be added directly, or via high moisture ingredients, into the chocolate.
- Use high fat bound ingredients such as crumb or full fat milk powder.

WATER IN CHOCOLATE!

- As we all know, adding water to chocolate is normally a very bad idea.
- As any chocolate manufacturer who has encountered unwanted water leaks into chocolate process lines, will have seen very rapidly that chocolate transforms irreversibly from a liquid into “concrete”.
- But this is what we might need to do deliberately, to make heat resistant chocolate.

THAT'S THE THEORY…

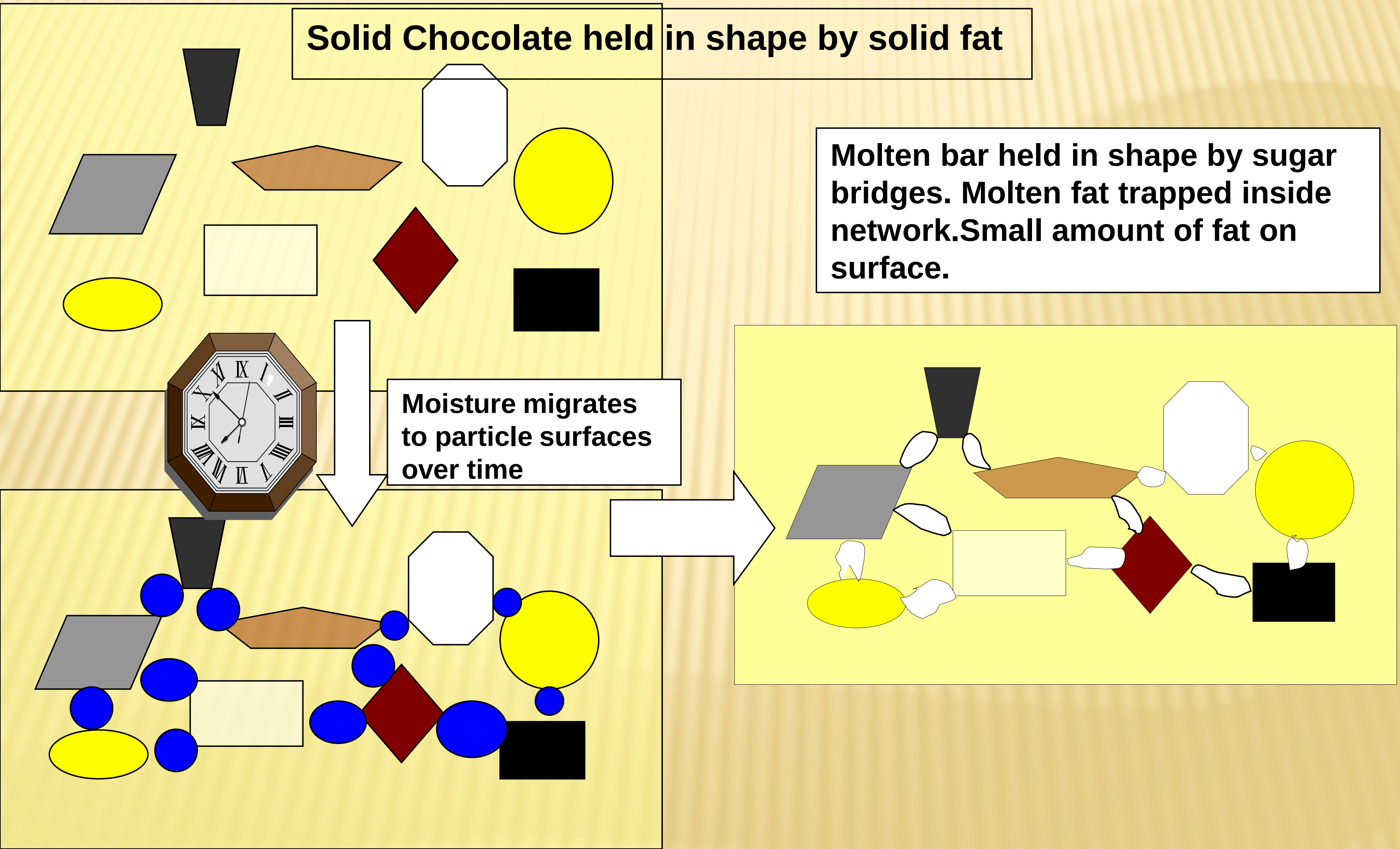
So How Can This Work in Practice

- We can now discuss the mechanism for how this works and ways to achieve this.

HOW TO INTRODUCE WATER INTO THE STRUCTURE IN A CONTROLLED WAY

- Water direct.
- Ingredients containing directly accessible moisture
  - Corn syrup
- Ingredients that contain indirectly accessible moisture
  - Dextrose monohydrate
  - Amorphous sugar (cotton candy)
- Processes that microscopically redistribute the moisture containing ingredients in the chocolate. This allows diffusion of the water throughout the structure to form a sugar based 'ekoskelton' that holds it's shape once the fat has melted and binds the liquid fat..
  - (This happens naturally over time in the product aging process)

AGED SAMPLE


Solid Chocolate held in shape by solid fat
Molten bar held in shape by sugar bridges. Molten fat trapped inside network.Small amount of fat on surface.
Moisture migrates to particle surfaces over time

ARE WE CONSTRAINED TO JUST ADDING WATER?

- Addition of food grade hydrophilic materials, preferably alcohols have been used to produce HRCs
  - Ethanol
  - Glycerol
  - Sugar alcohols (polyols)
- These materials should be added in a form that ensures the best distribution in the chocolate.
- When polyols are used as sugar replacements in sugar free chocolates, it is well known that they can cause practical increased viscosity issues.
- There is evidence that glycerol increases the viscosity of the fat phase in chocolate, making it less likely to 'weep' at elevated temperatures

HOW MUCH WATER IS NEEDED TO GIVE HEAT RESISTANCE?

- It depends….
- Literature values seem to favor around 2- 10% Water, although these higher values seem to be recommended in patent examples. Practically, 2-4% might be nearer the workable range.
- This also works for glycerol.
- However, this level will require extremely good dosing control, taking into consideration that maybe a small moisture addition may cause the chocolate to change from a viscous liquid to instant solidification of the liquid chocolate.
- Generally, the higher the viscosity of the moisture source, the better the dispersion of that moisture throughout the chocolate.
- This is where the addition of corn syrup is good as it only contains 20% water. We can now dose up to 10% syrup to get the same effect as 2% water addition. (The 80% corn solids will also have a viscosity increasing effect, but not as much as the moisture component).
- The use of egg whip as the moisture source uses the same principle.

SO THAT'S SIMPLE ISN'T IT?

- NO!
- We have one more very practical problem!
- TIME
- How do we get the water into the chocolate AND still be able to undertake the manufacturing processes such as molding and enrobing before everything sets up solid?
- So we need to find very controlled ways to add the water.

HOW CAN THIS BE DONE?

- Introduce the water into the chocolate as late as possible in the manufacturing process.
- But this will mean adding it to tempered chocolate.
- Tempered chocolate normally is a very unstable system.
- Intense mixing of the water into the chocolate will cause frictional heat that will detemper the chocolate.
- Mild mixing will not distribute the water sufficiently well.
- Continuous dosing of liquid into the tempered chocolate will require very precise control.

HOW CAN THIS BE DONE?

- Find technologies that are not normally used in the food or chocolate industry. I made HRC using a cavity transfer mixer, which is a low shear, intense mixer used in the manufacture of plastics.
- Redistribute the moisture already in the chocolate by re-refining the finished chocolate.
- Disrupt the continuous fat phase by mixing micromilled (P.S.D. typically < 25μm) chocolate ingredients into conched, liquid chocolate to form a pliable dough.
- Use emulsions as a controlled water release systems

EMULSIONS

- Protect the water using emulsions
  - Use water-in-oil emulsions to deliver water microscopically throughout the chocolate and allow diffusion to do the rest.
  - These emulsions can be prepared using an offline homogeniser and then dosed into the chocolate.
  - Oil has to be compatible with cocoa butter and legally acceptable in the SOI for chocolate. Cocoa butter is the best.
  - Emulsifier has to also be acceptable to SOI so look at lecithin, PGPR etc.
  - Dosing of emulsion becomes easier.
    - 2% water = 5% of a 40% water in oil emulsion

ADDING MOISTURE-CONTAINING SOLIDS

- The solid material will need to undergo significant size reduction to ensure its sensory acceptability in the finished chocolate.
- Normally this material will have to be added into the paster, prior to refining.
- May need to reduce processing temperatures to prevent the moisture availability too early on in the chocolate making process. (This is generally done for the manufacture of sugar-free chocolates).
- High temperatures might cause grittiness in the chocolate due to particle re-aggregation.
- The solids could be refined separately off line and then added at the end of the conching process.

YET ANOTHER ISSUE

- Adding water to chocolate, either directly or indirectly, will increase the possibility of sugar bloom at the surface of the product.
- Also the flavour mechanism for the delivery of chocolate taste is dominated by the fat phase. Increasing the amount of hydrophilic phase may well change the partition coefficient of the flavor components and their delivery in the HRC. (Think of the difference between the flavors of chocolate milk and milk chocolate!)
- There is scant sensory data in the literature comparing HRC and conventional chocolate.

SENSORY FACTORS

- Ideally, HRC should mimic the positive attributes that make chocolate so desirable to consumers!
- The ‘internal skeletal matrix’ of the HRC can be made to dissolve slowly in the mouth creating the effect of fat melting in normal chocolate.
- Don’t forget that HRC may well taste waxy and unpalatable at “normal” temperatures. Test it at the temperatures that it is designed for!

PACKAGING

- There does not appear to be much data in the literature covering insulated packaging for chocolate products.
- If this is to be a commercial possibility, it is likely to have implications on cost and availability.
- Likely to involve novel materials
- These are examples of chocolate products from warm climates that are packaged in tubes and are meant to eaten molten.
- If the rules don't fit…
  change the rules

USING THE EXTERIOR OF THE PRODUCT ITSELF AS A HEAT RESISTANT PACKAGING

- Formation of heat resistant shells with normal chocolate product inside

- This has the advantage of minimizing any sensory textural differences between the HRC and regular chocolate.

THE ISSUES OF STANDARDS OF IDENTITY

- As has been mentioned, some solutions that have been discussed, most likely fall foul of the SOI's for chocolate in various regions
- The big question that has to be resolved with your Marketing dept. is
  - "Does this matter?"

AM I ALLOWED TO DO THIS?

- Many of the processes that have been described in this presentation are covered by patents in particular regions of the world
- It is not the remit of the PMCA or this presentation to advise in these legal matters.
- A basic patent review is included in the webinar handout available after the Q&A session.

FURTHER READING

- A very comprehensive literature review on this subject by Stortz and Marangoni may be found in Trends in Food Science & Technology Vol 22 (2011) 201-214
- Much of the data for this presentation has been obtained from the Background Art of various Patents and Patent Applications published on the subject of Heat Resistant Chocolate.

PROS AND CONS

Heat Resistant Chocolate Process	Advantages	Disadvantages
Change Fat Composition and melting point	Use existing technologies /equipment but at elevated temperatures	May compromise SOI May taste waxy
Disrupt chocolate structure	Can conform to SOI	May require different processing technologies Difficult to implement May suffer from other issues such as sugar bloom
Insulation	Possible to use regular product	Probably expensive Novel technologies and novel material sciences
All individual processes	Potential to expand chocolate markets	Maybe covered by IP

SUMMARY

- We hope to have conveyed that this is a very interesting and complicated topic. There are many factors to be considered and many practical manufacturing problems to be solved.
- It is quite likely that some of the manufacturing processes will have to be quite different from conventional chocolate making technologies, in order to process products with very different physical properties.
- Other food manufacturing processes such as Extrusion or Rotary Molding might be the preferred method of forming HRCs, rather than molding and enrobing

CONCLUSION

- There is, however, a great benefit to being able to understand the fundamental science behind the challenges, in order to best provide innovative commercially viable solutions to making Heat Resistant Chocolates.
- Thank you for your interest.