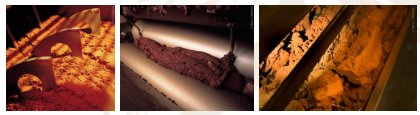
Production of chocolate

Mixing, refining and conching

04/09/2013

Ir. Claudia Delbaere



Outline

- Chocolate composition
- Mixing
- Refining
- Conching
- Tempering, moulding, cooling

Chocolate composition

Ingredients?

Chocolate composition

Fat

- Cocoa butter

- Only cocoa butter?
  - 2000 EU legislation: 5% other fats
    → Palm oil, illipe butter, kokum butter, sal fat, shea butter and/or mango kernel fat
  - Belgian chocolates: 100% CB!!

Chocolate composition

Solid particles

- Cocoa mass or cocoa powder
  - Cocoa solids
  - Cocoa butter



	Cocoa mass	Cocoa powder	Fat reduced cocoa powder
Fat content	50-55%	20-24%	10-12%

Chocolate composition

Solid particles

- Sugar


- Milk ingredients: whole milk powder or skim milk powder + milk fat (AMF, butter oil)
  - Milk solids
  - Milk fat


	Whole milk powder	Skim milk powder
Fat content	± 26%	≤ 1%

Chocolate composition

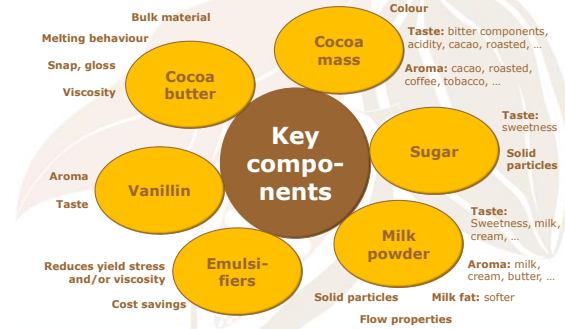
Emulsifiers

- Soy lecithin
- PGPR

Flavours

- Vanillin

Chocolate composition



Chocolate composition

Ingredients	Dark chocolate	Milk chocolate	White chocolate
Cocoa butter	+	+	+
Cocoa mass	+	+	-
Sugar	+	+	+
Milk ingredients	-	+	+
Soy lecithin	+	+	+
Vanillin	+	+	+

Recipe ~ final use (Beckett, 2009)
- Chocolate tablets/bars
- Chocolate confectionery
- Ice cream
- Bakery and biscuit products
- Sugar-free chocolate
- Compound or confectionery coatings
- ...

Chocolate composition

- Examples of chocolate recipes

Mass (%)	Dark chocolate	Milk chocolate	White chocolate
Cocoa butter	12.0	19.0	23.0
Cocoa mass	40.0	12.0	0.0
Sugar	47.5	48.5	46.5
Milk powder	0.0	20.0	30.0
Soy lecithin	0.5	0.5	0.5
Fat content			

Calculation fat content:
- Cocoa mass: 55% fat
- Milk powder: 26% fat (whole milk powder)

Timms (2003)

Chocolate composition

- Examples of chocolate recipes

Mass (%)	Dark chocolate	Milk chocolate	White chocolate
Cocoa butter	12.0	19.0	23.0
Cocoa mass	40.0	12.0	0.0
Sugar	47.5	48.5	46.5
Milk powder	0.0	20.0	30.0
Soy lecithin	0.5	0.5	0.5
Fat content	34.0	30.8	30.8

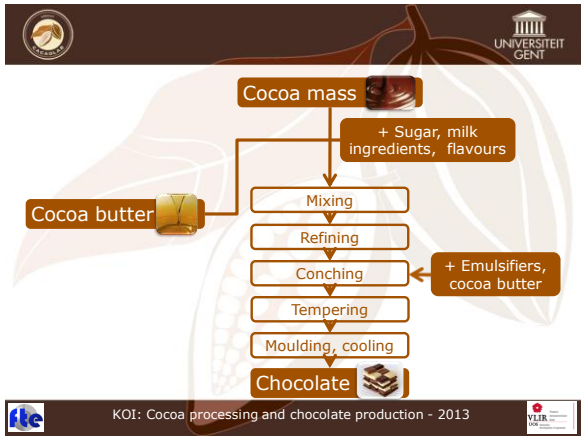
Timms (2003)

Chocolate composition

- Examples of chocolate recipes

Mass (%)	Dark chocolate	Milk chocolate	White chocolate
Cocoa butter	9.5	24.50	29.50
Cocoa mass	45.00	10.00	0.00
Sugar	45.00	45.00	45.00
Milk powder	0.00	20.00	25.00
Soy lecithin	0.49	0.49	0.49
Flavour	0.01	0.01	0.01

Source: Belcolade



Mixing of the ingredients

Mixing

- Agglomeration of ingredients in a thick paste
- **Batch mixer**
  - Mixing time: 12-15 minutes
    ! Mix for at least 10 minutes, so that the flavours are absorbed by the sugar crystals
  - Mixing temperature: 40-50°C
    Extra heating by means of a jacketed vessel or a heatgun (labscale)
- **Continuous mixer**
  - Usually used by large chocolate manufacturers
  - Automated kneaders

Mixing

Batch mixers

Planetary mixers

Stephan mixer

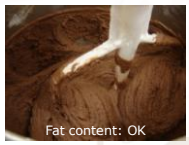
Industrial mixer

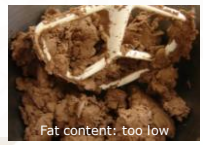
Mixing

- All ingredients containing solid particles:
  - Sugar (+ vanillin)
  - Cocoa liquor/mass or cocoa powder
  - Milk powder
- Fat ingredients:
  - Cocoa butter
  - Milk fat

!!! Only part of the fat should be added

Typical fat percentages for mixing and refining: 24-27% fat (Beckett, 2009)


Fat content: OK


Fat content: too low

Mixing

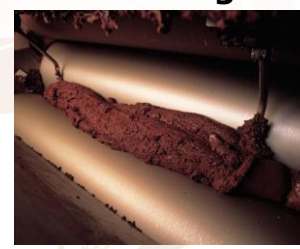
- **Exercise**
  - 5 kg of dark chocolate (after conching)
  - Final recipe:

Mass (%)	Dark chocolate
Cocoa butter	9.5
Cocoa mass	45.0
Sugar	45.0
Soy lecithin	0.5
Fat content	32.0

  - Fat percentage cocoa mass: 50%
  - Fat percentage during mixing and refining: 26%
  - How much cocoa butter, cocoa mass and sugar should be mixed to obtain the desired fat content for the refining process?
  - Answer: 2250 g cocoa mass, 2250 g sugar, 60.8 g cocoa butter

Mixing

Refining



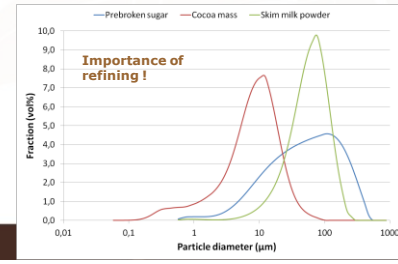
Refining

- A simple but important operation which produces a smooth texture by reducing the size of the particles
- The particle size of the dispersed solid particles must be sufficiently small → chocolate does not feel gritty when eaten
- Maximum particle diameter < 30µm
  - Continental European chocolate: 15-22 µm
  - North American chocolate: 20-30 µm
- Specifications for fineness: product specific
  - Dark chocolate generally finer than milk chocolate
  - Chocolate for cookie drops coarser than solid eating chocolate

Beckett (2009)

Refining

- Cocoa liquor used as an ingredient should be properly milled
- Primary purpose of chocolate refining: grinding
  - Sugar particles
  - Solid milk particles (in case of milk chocolate)



Refining

➡ Single stage refining process

- **Separate ingredient milling**: sugar pulverization
  - \+ Better control of the number of fine particles
  - \- Sugar picks up many of the aromas in the mill
- **Refining process**
  - \- Particles are largely fat-free at the end of grinding → fat coating process in the conche takes longer

➡ Two-stage refining process

Step 1: Pre-grinding

- Two-roll pre-refiner: 2 cylinders, placed horizontally, side by side
- Mainly breaking the particles of the granulated sugar → maximum particle size: 100-150 µm
- Aim: producing consistent and uniform feed material for the fine grinding

Beckett (2008, 2009)

Refining

Step 2: Fine grinding

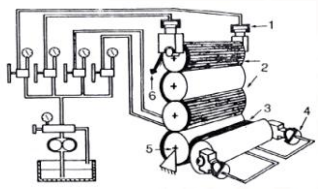
- Five-roll refiner
  - Grinding rolls: vertical arrow of 4 hollow cylinders+ 1 feed roll
    - Length: up to 2,5 m; diameter: up to 400 mm
    - Temperature controlled by internal water flow
    - Held together by hydraulic pressure → uniform straight gap between the rolls
  - A thin film of chocolate is attracted to increasingly faster rolls, travelling up the refiner until removed by a knife blade
  - Maximum particle size: 15-35 µm

Afoakwa (2010)

Refining

Step 2: Fine grinding

- Five-roll refiner



1. Roll stack pressure
2. Chocolate film
3. Chocolate feed
4. Feed roll pressure
5. Fixed roll
6. Chocolate from scraper

Beckett (1999)

! Avoid dry running

Rolls become damaged very quickly if there is no material between them

Refining

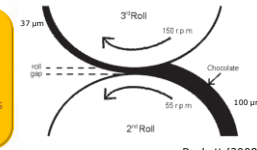
Step 2: Fine grinding

Afoakwa (2010)

- Five-roll refiner
  - Fragmentation of solid particles
    → coating of new surfaces with fat
    → absorb volatile flavour compounds from cocoa components
  - Size reduction = combined result of compression and shear
  - Degree of reduction: generally 5-10

Aim of refining

- Particle size reduction
- Agglomerate breakdown
- Distribution of particles in the continuous phase and coating them with fat



Beckett (2008)

Refining

Five-roll refiner

- Recommendations for roll speed and temperature

Roll	RPM	Temperature (°C) [4]
R1[1]	< 58	35-40
R2[2]	58	35-40
R3	155	42-48
R4	268	50-60
R5[3]	380	35-40

1 Feed roll
2 Grinding roll at the bottom
3 Grinding roll at the top
4 Recommended values for low-fat mixtures, substract 5-10°C for high-fat mixtures

After Peter (1994)

Refining

Five-roll refiner

Beckett (2008, 2009)

- Fineness of the chocolate can be adjusted by changing
  - **Feed roll gap (constant roll speed)**
    - Determines thickness of the initial film
  - **Roll speed (constant gap)**
    - Faster roll speed → greater product throughput → coarser chocolate
    - Ratio of the speeds of the different cylinders is important
  - **Temperature**: significant effect on the rheology of the chocolate film and flow properties of the fat present
    - Higher temperature → less product throughput → finer chocolate
    - High speeds → centrifugal force on the individual particles → are thrown away from the machine, but the film itself if pulling them on
    - Too cold temperature → fat sets + particles become free and are thrown away
  - **Pressure** between the rolls
    - Limited effect, pressure mainly leads to a uniform film along the roller

Refining

Fat content

Beckett (2008, 2009)

- The smaller the required particle size, the more fat is needed to cover the surface of the particles
- Normally advantageous to roll refine the chocolate at the lowest fat content possible:
  Reduce fat at refining by 1% → only 0,5% should be put in the masse at the end of conching to obtain the same viscosity (Kuster, 1991)
- However, tendency to agglomerate increases with smaller particle size and moisture content
  Refining at very low-fat mixture → particle agglomerates might exit the roll refiner

Refining

Colour of refined product

- The smaller the particle size, the lighter the colour is

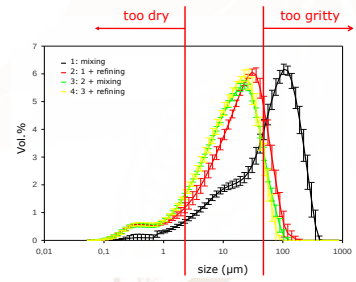
Refining

Sugar particles

- Crystalline sugar behaves as brittle material under mechanical stress
- Roll refining of CB+S mixtures: breakage due to chipping and abrasion
  Beckett (2009)
- Crystalline vs amorphous sugar
  30-90% of the crystalline sugar becomes amourphous during roll refining of chocolate masses and can absorb large quantities of different flavours
  Beckett (1994)
- Importance of particle size of sugar particles!
  - Mainly medium fine sugar (0.6-1.0 mm grain size)
  - Use of icing sugar (0.005-0.1 mm grain size): too dry chocolate

Refining

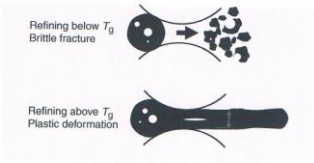
Sugar particles



Refining

Whole milk powder

- Roll refining of CB+WMP mixtures: brittle fracture when ground below the glass transition temperature (T_g)
- Spray-dried WMP: the milk fat is entrapped in a matrix of glassy (amorphous) lactose, which normally behaves as brittle material during roll refining



Effect of glass transition temperature (T_g) upon the refining process

Beckett (2009)

Refining

Whole milk powder

- Fat inclusions + trapped air reduce the hardness of the particles
  → milk powder fractures more easily than crystalline sugar
  → when refined together, milk powder is broken preferentially

- Grinding temperature > T_g due to
  - Increase in roll temperature
  - Decrease in T_g (as moisture content ↑)
    → WMP particles deform plastically
    → Deleterious effect on product viscosity and sensory properties

Beckett (2009)

Refining

Skim milk powder

- Brittle fracture < T_g, but requires greater force to grind
  (no milk fat droplets present)

- Plastic deformation > T_g, but appear to recover their original shape to a greater extent than WMP particles. However, the surface becomes sticky and particles agglomerate → agglomerates larger than the roll gap

Beckett (2009)

Refining

Three-roll refiner (lab-scale)

Refining

Particle size measurement

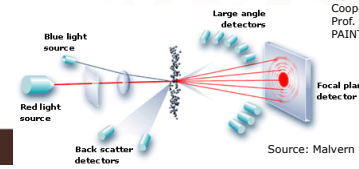
Micrometer

- A simple and rapid method to determine the fineness of ingredients and chocolate products

Laser diffraction

- Determination of particle size distributions
- Particles passing through a laser beam will scatter light at an angle that is directly related to their size
- Particle size distributions are calculated by comparing a sample´s scattering pattern with an appropriate optical model using a mathematical inversion process

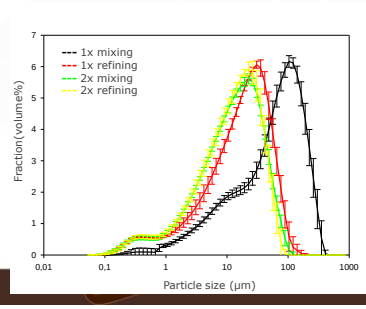
Malvern Mastersizer Cooperation: Prof. Paul Van der Meeren, PAINT, UGent



Source: Malvern

Particle size measurement

Laser diffraction: particle size distribution (PSD)
→ volume distribution



Conching

Conching

- Essential process in the chocolate manufacturing
- Name derived from the Latin word 'shell'
  (traditional conche resembled the shape of a shell)
- Contributes to the development of viscosity, final texture and flavour
- Combination of mixing and shearing
- Carried out by agitating the chocolate at more than 50°C for many hours

Afoakwa (2010)

Conching

- Typical conching times: 4-24 hours
- Typical conching temperatures: 45-105°C

Milk chocolate
- Crumb milk chocolate: 10-16 hours at 49-52°C
- Milk powder chocolate: 16-24 hours at up to 60°C
- Replacing whole milk powder with skim milk powder + butter fat: temperatures up to 70°C may be used
- Temperatures >70°C lead to changes in cooked flavours

Dark chocolates
- Typically conched at higher temperatures: 70°C or up to 82°C

! Higher temperatures recude processing times

Afoakwa (2010)

Conching

- **Conching stages**

Feeding

Dry conching
- Flake or powder converted into a paste by mechanical (*shear*) or heat energy
- Reduction of moisture content
- Removal of certain undesirable flavour-active volatiles such as acetic acid
- Improvement of interactions between the disperse and continous phase
- Flavour development

Pasty phase

Cocoa butter + lecithin

Liquefaction
- Thick paste converted into a free-flowing liquid
- Intense stirring, shearing → homogenization

Discharging

Conching

- **Conching stages**

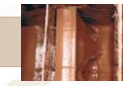
Feeding

Dry conching

Pasty phase

Cocoa butter + lecithin

Liquefaction



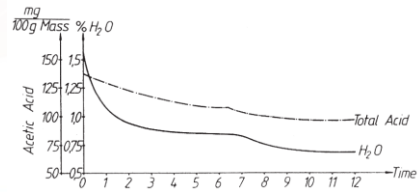
Discharging

Conching

Conching

Chemical changes

- Changes in moisture and acidity during a conche cycle (time in hours)
- Moisture:
  - Detrimental to the chocolate's flow properties
  - When removed: takes some of the undesirable acidic flavours with it
  - Easier to escape when a lot of surfaces are still uncoated with fat



Beckett (2008)

Conching

Structure development

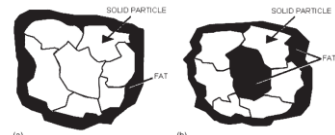
- Conversion of the powdery, crumbly refined product into a flowable suspension of sugar, cocoa and milk powder in a liquid phase of cocoa butter (and other fats as appropriate)
- Initially, many of the particle surfaces are still uncoated with fat
- As the temperature rises, more of the cocoa butter melts and the particles begin to stick together
- Sometimes formation of balls of several centimeters in diameter → run around the conche before joining together to form a thick paste
- Within the paste: still a lot of milk and/or sugar particles that are not coated with fat
- When the paste is thick: shear/smearing action coats particles with any fat that is nearby

Beckett (2008)

Conching

Structure development

- Breaking up agglomerates (groups of particles that are loosely stuck together) (Beckett, 2008)
  - (a)No fat within agglomerate → breakage gives new surfaces that have to be coated with fat → viscosity increases
  - (b)Fat in the middle → breakage releases more fat than necessary to coat the surfaces → viscosity decreases



(a) Agglomerate composed of solid particles. (b) Fat containing agglomerate.

!! Milk chocolate: add a small amount of lecithin (<0,1%) at the beginning of the dry conching

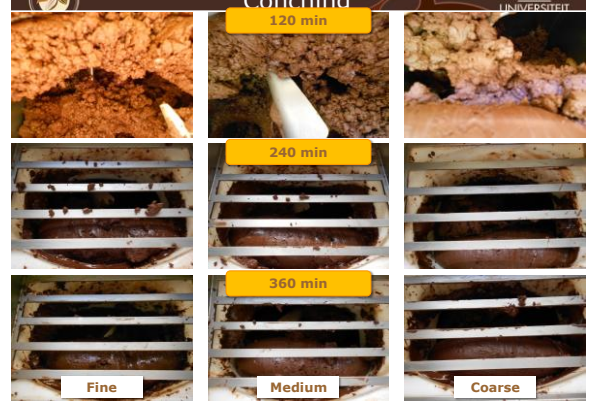
Beckett (2008)

Conching

Structure development – Dark chocolate
Effect of particle size (constant fat content)

Prior to addition of CB/lecithin

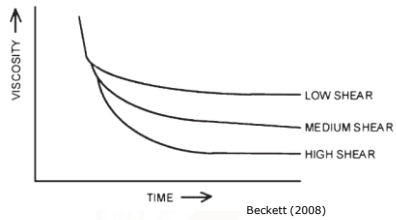
Conching



Conching

Reduction in viscosity

- Change of viscosity with time for conches with different shearing actions



Beckett (2008)

Conching

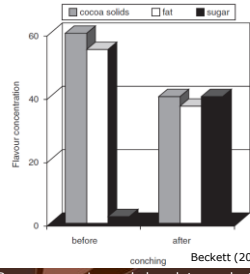
Flavour development Afoakwa (2010)

- Conching is essential for the final flavour development
- Flavour development promoted due to the prolonged mixing at elevated temperatures
- Chocolates show marked decreases in overal off-flavours *(astringent and acidic notes)* after conching
- Residual volatile components are removed:
  - Short-chain volatile fatty acids such as acetic acid (end products of fermentation) → Air spaces surrounding a conche in operation have an odor of acetic acid
  - Volatile phenols, …
- Formation of caramelized flavour due to reaction with lactose and milk proteins (Maillard reaction) → milk chocolate

Conching

Flavour development

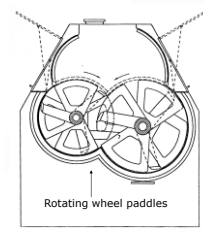
- Flavour distribution between cocoa solids, sugar particle surfaces and the fat phase before and after conching

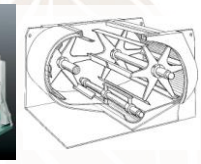


Beckett (2008)

Conching

Industrial conches



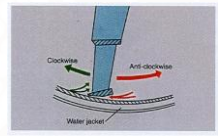


Conching

Industrial conches: example (Frisse conche)

- Typical example of overhead conche used in modern chocolate industry
- Consists of a large tank with 3 powerful intermeshing mixer blades, providing shearing and mixing action

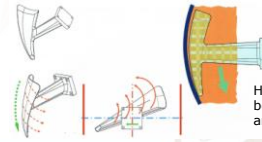
Beckett (2008)



High shearing zones because of overlapping stirrers

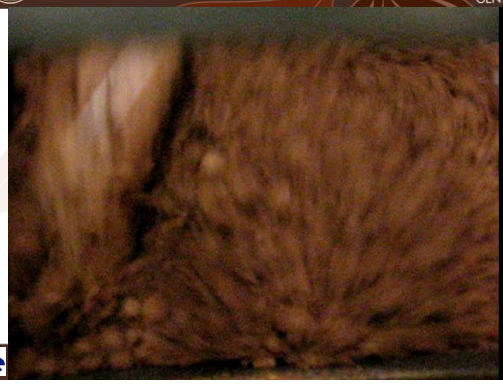
Conching

ELK'olino conche (lab-scale)

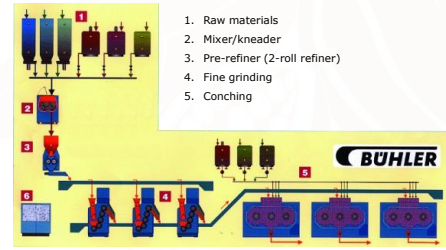


High shearing between tool and conche wall

Conching



Industrial continuous processes



1. Raw materials
2. Mixer/kneader
3. Pre-refiner (2-roll refiner)
4. Fine grinding
5. Conching

Conching

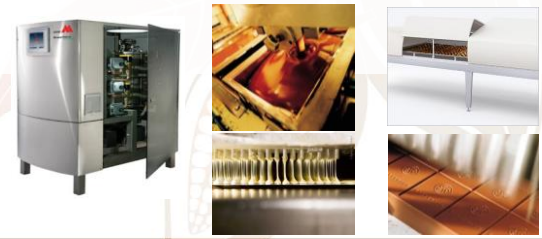
After conching

Storage tanks

Transport in a road tank

Solidification and stored as blocks or drops

Tempering/moulding/cooling



Thanks for your attention!

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