Production of chocolate
Mixing, refining and conching

04/09/2013
Ir. Claudia Delbaere

Outline

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

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!!

Ingredients?
Solid particles
- Cocoa mass or cocoa powder
  - Cocoa solids
  - Cocoa butter

<table>
<thead>
<tr>
<th></th>
<th>Cocoa mass</th>
<th>Cocoa powder</th>
<th>Fat reduced cocoa powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat content</td>
<td>50-55%</td>
<td>20-24%</td>
<td>10-12%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Whole milk powder</th>
<th>Skim milk powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat content</td>
<td>±26%</td>
<td>≤1%</td>
</tr>
</tbody>
</table>

Emulsifiers
- Soy lecithin
- PGPR

Flavours
- Vanillin

Key components
- Cocoa butter
- Cocoa mass
- Sugar
- Milk powder
- Flavours: vanilla, coffee, tobacco, ...
### Chocolate composition

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Dark chocolate</th>
<th>Milk chocolate</th>
<th>White chocolate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa butter</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cocoa mass</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Sugar</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Milk ingredients</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Soy lecithin</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Vanillin</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

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

### Examples of chocolate recipes

#### Chocolate composition

<table>
<thead>
<tr>
<th>Mass (%)</th>
<th>Dark chocolate</th>
<th>Milk chocolate</th>
<th>White chocolate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa butter</td>
<td>12.0</td>
<td>19.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Cocoa mass</td>
<td>40.0</td>
<td>12.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Sugar</td>
<td>47.5</td>
<td>48.5</td>
<td>46.5</td>
</tr>
<tr>
<td>Milk powder</td>
<td>0.0</td>
<td>20.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Soy lecithin</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Fat content</td>
<td>34.0</td>
<td>30.8</td>
<td>30.8</td>
</tr>
</tbody>
</table>

Timms (2003)

#### Examples of chocolate recipes

<table>
<thead>
<tr>
<th>Mass (%)</th>
<th>Dark chocolate</th>
<th>Milk chocolate</th>
<th>White chocolate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa butter</td>
<td>9.5</td>
<td>24.50</td>
<td>29.50</td>
</tr>
<tr>
<td>Cocoa mass</td>
<td>45.00</td>
<td>19.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Sugar</td>
<td>45.00</td>
<td>45.00</td>
<td>45.00</td>
</tr>
<tr>
<td>Milk powder</td>
<td>0.00</td>
<td>20.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Soy lecithin</td>
<td>0.49</td>
<td>0.49</td>
<td>0.49</td>
</tr>
<tr>
<td>Flavour</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Source: Belcolade

KOI: Cocoa processing and chocolate production - 2013
Mixing of the ingredients

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

- Fat ingredients:
  - Cocoa butter
  - Milk fat

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

Exercise

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

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Mass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa butter</td>
<td>9.5</td>
</tr>
<tr>
<td>Cocoa mass</td>
<td>45.0</td>
</tr>
<tr>
<td>Sugar</td>
<td>45.0</td>
</tr>
<tr>
<td>Soy lecithin</td>
<td>0.5</td>
</tr>
<tr>
<td>Fat content</td>
<td>32.0</td>
</tr>
</tbody>
</table>

- 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
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

Refining

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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

Avoid dry running

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

Refining

Step 2: Fine grinding

- 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

Refining

Five-roll refiner

- Recommendations for roll speed and temperature

<table>
<thead>
<tr>
<th>Roll</th>
<th>RPM</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1^1</td>
<td>&lt; 58</td>
<td>35-40</td>
</tr>
<tr>
<td>R2^T</td>
<td>58</td>
<td>35-40</td>
</tr>
<tr>
<td>R3</td>
<td>155</td>
<td>42-48</td>
</tr>
<tr>
<td>R4</td>
<td>268</td>
<td>50-60</td>
</tr>
<tr>
<td>R5</td>
<td>390</td>
<td>35-40</td>
</tr>
</tbody>
</table>

^1 Fixed roll
^2 Grinding roll at the bottom
^T Grinding roll at the top

After Peter (1994)

Refining

Five-roll refiner

- Fineness of the chocolate can be adjusted by changing

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

Beckett (2008, 2009)
Fat content

- 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.

Colour of refined product

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

Sugar particles

- Crystalline sugar behaves as brittle material under mechanical stress.
- Roll refining of CB+S mixtures: breakage due to chipping and abrasion
- Crystalline vs amorphous sugar: 30-90% of the crystalline sugar becomes amorphous 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

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Deeltjesgrootte (µm)  
0,01 0,1 1 10 100 1000  
Frequentie (vol. %)  
0 1 2 3 4 5 6 7  
1x mengen 1x walsen  
2x mengen 2x walsen
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

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

Three-roll refiner (lab-scale)
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

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

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 reduce processing times

Conching stages

- Feeding
- Dry conching
- Pasty phase
- Liquefaction
- Discharging

- Flower 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 continuous phase
- Flavour development

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

**Moisture reduction**

**Structure development**

**Flavour development**

**Viscosity reduction**

**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

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

**Conching**

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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

Milk chocolate:
- Add a small amount of lecithin (<0.1%) at the beginning of the dry conching

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Structure development – Dark chocolate

Effect of particle size (constant fat content)

Prior to addition of CB/lecithin

Reduction in viscosity

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

![Graph showing viscosity over time with different shear levels](image)

Conching

Beckett (2008)

Flavour development

- Conching is essential for the final flavour development

- Flavour development promoted due to the prolonged mixing at elevated temperatures

- Chocolates show marked decreases in overall 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

Afoakwa (2010)
Flavour development
• Flavour distribution between cocoa solids, sugar particle surfaces and the fat phase before and after 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

EL’olino conche (lab-scale)
• High shearing between tool and conche wall
**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!