The Complexity of Controlling the Particle Size in Chocolate
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1. Can you speak more about bi-modal versus mono-modal distributions? When is bi-modal preferred?
   The bi-modal is preferred since you have different sizes of particles that together create a better packing then only one size of particles.

2. If aerating chocolate, what’s the ideal particle size?
   There is no real ideal particle size for aeration of chocolate. Most different particle sizes can be aerated.

3. Are there places one can send (a few) samples to have particle size distributions measured by a laser diffraction particle analyzer (e.g. for research purposes)?
   I guess there are recognized external labs that do offer this service. You will have to ask more particularly to the lab you use if they can perform this analysis.

4. If we used three different mills to make a custom tri-modal distribution, could we save even more fat?
   To obtain an ideal filling of the volume with solids, coarser particles should be seven times bigger than the fines and a mixing ratio of 37% fines and 63% coarse particles will result in lowest viscosity. Theoretically, a trimodal distribution, with the right proportion of the different sizes, would help (cfr paper of Farris (1968)).

5. What is the difference between Swiss and Belgian chocolate and what is your preference?
   My preference is clearly subjective and is for sure Belgian chocolate. Main difference is in caramel taste of the milk chocolate. Whereas Swiss is pure milk flavor, the Belgian milk chocolate has a typical dry caramel flavor. This has mostly to do with how conching is done.

6. In your rheology, 32% small particles + 68% coarse particles, what distinguishes the two?
   Defining coarse vs. fine, for example:
   At 30 µm:
   <99% = coarse
   >99% = fine?
   Fines are seven times smaller than large particles.

7. Why does a mono-model distribution require more fat than a bi-modal distribution?
   For a monomodal distribution, a typical maximum packing is $\Phi_m = 0.64$. In this case 64% of the total volume is occupied with solids. The inter-particle space must then be filled with fat. To include more particles into the system without increasing the viscosity they must fit in between...
the larger particles, thus be appropriately smaller. In the ideal case, $\Phi_m$ can become as high as 0.85 (Farris, 1968).

8. How does the chocolate liquor particle size impact the 5-roll refined bi-modal particle size? What is the best chocolate liquor particle size for refining?
Ideally, your liquor is not too coarse – since all is refined on five-roll refiner, the particle size of your starting liquor does not really influence your bi-modal particle size. The coarser it is, the more time needed to refine further on five-roll.

9. When measuring with a micrometer, how critical is the temperature and viscosity for accurate measurement?
As explained there is quite some error on measurement with a micrometer. The least number of variables the better. So always keeping the micrometer vertical and having chocolate at around 40°C- 104°F does help. Viscosity will differ from chocolate to chocolate. For preparation of refiner flakes, normally a dilution with 50% fat or lecithin (warm at 40°C) is used to measure fineness.

10. What is the proportion of particles below 5 µm in commercially available cocoa liquor? These very small particles are responsible for “bad” melting proportion of chocolate.
Proportion in general is very small of these very small particles. It should not matter really since they are refined anyhow. Also, I am not sure this is really causing bad melting. Normally, finer particles are attributed to smoother mouth feel.

11. What is the best method for refining proteins in chocolate and compound? What is the maximum amount of protein you can refine by each processing method?
From experience, going higher than 25% proteins starts to cause issues, since proteins are quite hard to refine. You can refine proteins with ball mill, dry grind or five-roll refiner. Ideally, you can add part of the proteins after refining if they are already on “end” fineness.

12. What laser diffraction number matches up with the micrometer value? Do you use a d-valve or multiple d-valves to characterize chocolate?
For example:

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\begin{align*}
  d_{10} &= 10 \\
  d_{50} &= 20 \\
  d_{90} &= 30 \\
  d_{84} &= 25
\end{align*}
\]

There is no correlation between micrometer and laser diffraction. Most used is $d_{85}$, so 85% of particles are smaller than X microns. In Europe, we use the percent of particles larger than 30 microns. So, a fine chocolate has a maximum of 3% of the particles larger than 30 microns.

13. What are the impacts of particle shape and morphology?
Another aspect of the solid particles is the shape of the particles. Round particles minimize the inter-particle contact and thus, help to reduce yield value and/or viscosity of chocolate. In recent
work (Rummel, 2015), the impact of round spheres versus irregular-shaped flakes has been evaluated. For the same material at comparable particle size distributions, lower viscosities were obtained for the spherical particles. Effects on the yield value were reported in the work of Ziegler and Mongia (Ziegler, 1998). In their application, 50% of irregularly-shaped, refined sugar was replaced with spray-dried inulin. The resulting spherical particles had a lower density, which results in a larger occupation of space for equal weight and thus an increased Casson viscosity. On the other hand, lower yield values were obtained. The hypothesis is that the results can be explained by the smooth and spherical particle shape.

14. Is there a universally-accepted dilutant for particle size measurement?
   No, but mostly oil (warm 40°C) or lecithin are used to dilute refiner flakes for fineness measurement. My preference goes to liquid oils as for example sunflower oil. With the Malvern laser diffraction equipment, we have very good experience with Akomed as a diluting agent.

15. What is the cost impact between 17 and 22 µm? Which particle size measurement is more reliable?
   You need 1-2% more fat to achieve the same rheology. Laser diffraction measurement is for sure the most precise method, while a micrometer measures average particle size.

16. What refiner is more energy-efficient with high throughput?
   Dry-grind is actually due to the fact that only part (dry part) is refined and less heat is created, versus ball mill and five-roll refiner. 50% of needed energy of five-roll refiner goes into cooling energy.

17. Does particle size impact reaction rates during processing, for example, Maillard browning?
   When we conch milk chocolate, interactions between reducing sugar and proteins do happen. There, particle surface matters, so I’d believe that with smaller particles and thus more relative surface, a more intense reaction may occur (after all, during conching, shearing is intense and increased viscosity is not limiting particles to interact).

18. Can you use different sizes of balls in a ball mill to simulate size distribution from roll refiner?
   Different sizes of balls in one-ball mill will not work. You can have different ball mills refining different fineness and, by mixing these, mimicking bi-modal particle distribution.

19. Is it true that micrometers are not measuring average size but the size of the biggest, hardest particle?
   Micrometers measure the sort of average, since there will be most resistance where most of the same particles size are, not really the single hardest particle.

20. Can two ball mills produce a bi-modal distribution?
   Yes, they can.

21. What makes Belgium chocolate Belgium chocolate?
The soil, the air, the country... No, really it’s all about heritage and producing great-tasting chocolate. It is fine chocolate (so no large particles >30 microns that you can taste in the mouth) that is nicely conched creating a nice “dry” caramel flavor for the milk chocolate. The ingredients used are also important, and cocoa is based mostly on West African cocoa beans.

22. Can chocolate be refined too fine?
Even though I did answer no during the answering session at PMCA, I would say yes now. Under a certain fineness, consumers don’t taste a difference anymore and going finer will cost more CB and it takes longer to produce without a real added value for the consumer. Once going finer then 17-18 microns, most people will not taste the difference anymore. Too fine chocolate will also compromise its usability for certain applications. It’s about choosing the correct product for the correct application.

23. How important is dilution of a chocolate sample with an oil to measuring particle size?
It is only needed for measuring fineness of refiner flakes. Once your chocolate is liquid after conching, no dilution is needed anymore to measure with a micrometer. For refiner flakes, we use normally 50% liquid oil dilution. If measuring with a laser, the accuracy of this method relies on the detection of single particles – particle separation is crucial. This is usually done by diluting the sample in oil and applying ultrasound.

24. My chocolate supplier tells me the particle size of the chocolate I buy is 26 microns, but when I measure it I get 35 microns. Why?
There is a serious measuring error with the micrometer. Also, temperature and how you hold the micrometer plays a role. Also, three clicks are normally used, but if the supplier turns a bit more you will have another measurement. Normally, a measurement with a micrometer is repeated three times in a row and the average measurement is taken to avoid some variance.

25. For a compound coating, other than a 5-roll refiner, which grinding method produces the “best” particle size? Ball mill, air classifying mill, or some other mill?
I would say ball mill, as you can recirculate until correct fineness is obtained and you have less of the “dry” grind flavor.

26. What is the lowest fat content a ball mill can process?
If you can add some of the dry components as CP after refining, you can get to about 26-27% fat, though the part that goes through ball mill will have higher fat content (close to 31%).

27. Does the 32%/68% rule for bi-modal distribution apply to all chocolate types (dark, milk, white), or are the ratios different?
Yes, it applies to all.

28. Why does bi-modal grind distribution require more fat when there is higher surface area proportion?
The more area surface, the more surface that needs to be covered with fat, though the packing of the particles as already stated plays an important role as well.
29. **What is the best way to measure pre-refiner mass?**
   Measuring the mix before the refiner is difficult, indeed. I am not aware of a standardized measurement technique on this. Basically, the only thing I could imagine is some kind of backwards extrusion or texture analyzer results.

30. **What distinct flavors happen with dry grinding?**
   A dry-grinded chocolate mix is expected to taste high in sweetness, high in bitterness and low in cocoa. Normally on the five-roll I would expect amorphous surfaces due to very local increased temperatures. This step and the associated recrystallization is believed to have a huge impact on taste. A more smooth taste is expected. Basically, the dry conching is a transfer of aroma around the sugar, masking sweetness and increasing other attributes. When using a five-roll with all materials present, this transfer should be supported, whereas for a dry grind the effect should be lower.

31. **What effect does particle size have on taste, apart from mouthfeel?**
   The perception of taste in the mouth is a complex interaction of many parameters. Only attributing effects to particle size does not lead very far, as other effects might overlap the impact of particle size.

32. **I have heard that higher fineness chocolate works better for coverage in hollow moulding – have you found this to be true?**
   Yes and no, it all depends on yield value. For hollow moulding, you want a low-yield value for good coverage. A coarser chocolate will get you quicker with less fat to a lower yield.

33. **How have the high-end Easter rabbit producers gotten around this if product is low fineness?**
   Good shaking and turning and also more fat in the chocolate.

34. **Which particle size reduction system has the smallest footprint in production?**
   Probably the round stone grinder but very low output. I would say ball mill probably has the smallest footprint for still good output.