APPLICATION NOTE

Particle Measurement of Coffee Powder with Dynamic Image Analysis

Instrument: CAMSIZER X2

Quality Requirement for Coffee Powder

Coffee beans are one of the most important commodities, with an estimated 1.4 billion cups of coffee consumed worldwide every day. The taste of coffee is determined by the roasting of the beans, the size distribution of the powder, and the type and quality of preparation. Different preparation methods in the brewing and filtering process (e.g. espresso machine, filter coffee or AeroPress) require different grinds of coffee powder for an aromatic result. When roasted coffee beans are ground into powder, the determination of the particle size distribution plays a decisive role, as it has a significant influence on the brewing and filtering properties and thus on the taste and salubriousness of the beverage.

When preparing coffee, it is important to achieve optimum extraction of the ingredients that are dissolved from the ground coffee by the hot water or steam. The finer the coffee powder, the more ingredients can be extracted in a shorter period of time. If the grind is not optimally matched to the duration and temperature of the brewing process, there is a risk that the coffee will be over- or under-extracted. An under-extracted coffee (= too coarse grind) has little aroma and watery tase. An over-extracted coffee (= too fine grinding) tastes bitter due to too many dissolved components (e.g. tannic acids).

By reliably determining the particle size, a reproducible grind can be achieved for the respective preparation process, resulting in a great-tasting coffee with balanced aromas.

Due to its high oil content, broad particle size distribution and very irregular particle shape, coffee powder exhibits difficult bulk material behavior, i.e. the particles have a strong tendency to agglomerate and the powder is difficult to pour or convey. This must be adequately addressed in the mechanical and optical measurement methods.

Traditionally, the particle size distribution of coffee powder was determined by analytical sieving. However, the laser diffraction method has become increasingly established as the standard method. Both methods have certain limitations in terms of information content, accuracy and sensitivity. Coffee powder, especially when used in capsules or pods, is highly optimized for the respective preparation process and must comply with very tight quality specifications. These can often only be checked with imaging methods, which provide very high-resolution size distributions with simultaneously high sample throughput.

Fig 1: *The CAMSIZER X2 dynamic image analyzer is perfectly suited for the determination of size and shape of coffee powder.*

How does Particle Characterization of Coffee Powder with Dynamic Image Analysis

In particle measurement with dynamic image analysis according to ISO 13322-2, a particle stream is generated and passed by a camera system. The images of the particles are recorded in motion as shadow projections and evaluated by a PC. Dynamic image analysis works for dry powders and for suspensions. For coffee powder, dry measurement is the better option. The procedure of such a measurement with the CAMSIZER X2 image analysis system is shown in Fig. 2. The CAMSIZER X2 has two cameras with different magnifications, allowing small and large particles to be analyzed simultaneously without prior adjustment of the measuring range, e.g. by selecting suitable lenses. This is a great advantage for the analysis of coffee powder, which usually has a very wide size distribution from the lower micrometer range up to 2 millimeters. During the measurement, the CAMSIZER X2 acquires and evaluates up to 310 images per second, which leads to very stable and reproducible results due to the large number of detected particles. The usual duration of a measurement is 2-5 minutes.

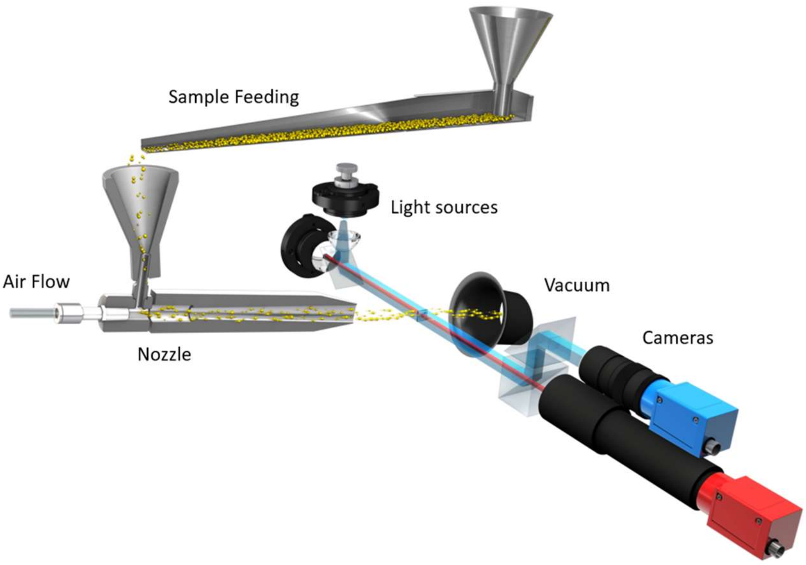


Fig. 2: *Measuring principle of the CAMSIZER X2 for dry measurement of coffee powder. The sample is conveyed into the instrument via a vibrating chute, where it is captured by an air stream. The particles are detected in motion by two cameras with different imaging scales as shadow projections and are evaluated.*

The advantage of the two-camera principle is illustrated in Fig. 3. The diagram shows a size distribution of coffee powder measured with both cameras, together with the result of the same sample only with basic camera and only with zoom camera. The Zoom camera captures the fine fraction, but only a few large particles due to the small image area, which can be seen from the pronounced steps on the coarse side of the distribution. The Basic camera cannot correctly capture the fine fraction due to the poorer resolution. The two cameras therefore complement each other perfectly and are thus superior to any image analysis system with only one camera.

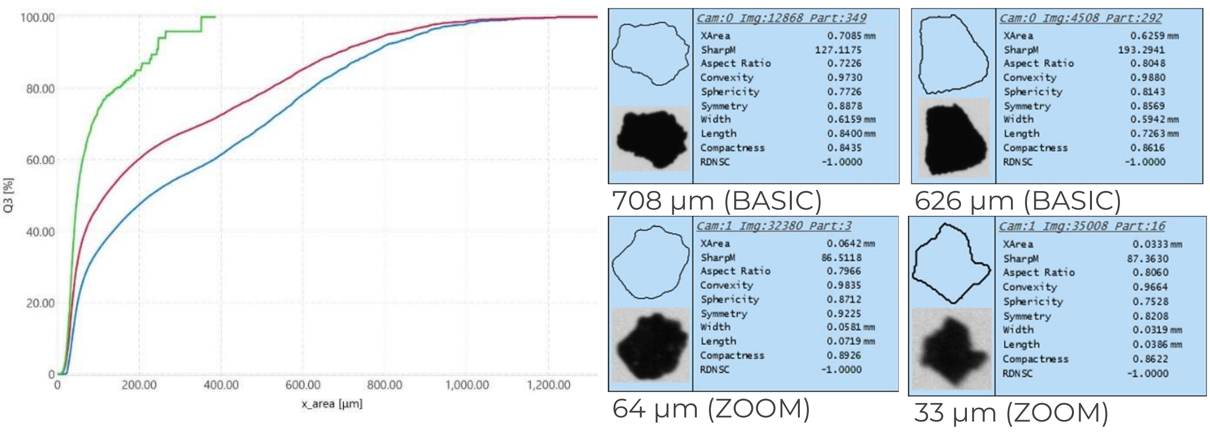


Fig. 3: *Coffee powder sample measured with ZOOM camera only (green}: coarse particles are lost. Coffee powder sample measured with BASIC camera only (blue): fine particles are lost. Measurement with BOTH cameras (red): correct result! The images show particles measured by BASIC and ZOOM camera.*

Example Measurements of Coffee Powder

Coffee powder typically has a broad particle size distribution with a pronounced fine and coarse part. The fine fraction is less than 200 µm, the coarse fraction can reach up to 2 mm. Thanks to the patented two-camera system and the resulting very wide dynamic measuring range, the CAMSIZER X2 can determine both with high resolution and good statistical reliability in the case of coffee powder. This is shown in Figure 4 using the example of coffee powder with different grinds. During the measurement, the particles were dispersed with compressed air in the X-Jet sample feed module (Fig. 2) at 80 kPa. For the vibratory feeding of the coffee powder on a dosing chute, Microtrac developed devices that allow problem-free feeding for measurement even with very poorly flowing coffee powders.

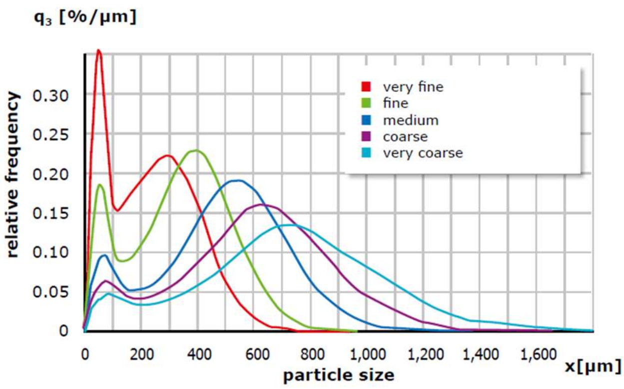
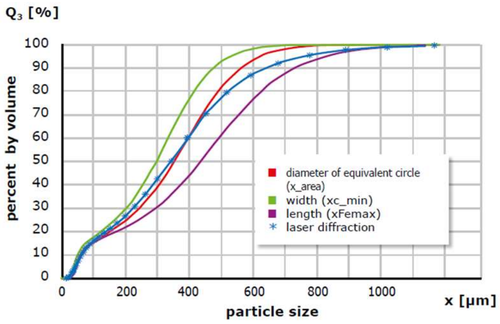


Fig. 4: *Measurement of five different grinds of coffee powder. Characteristic is the always present fine fraction < 200 µm and the wide size distribution up to almost 2 mm. Brewed coffee generally requires a coarser grind than espresso.*

The roasting of the coffee beans influences their brittleness. Ground coffee from brittle beans often consists of angular, or pointed, grains, which lead to lower packing density in compacted coffee. Both, the particle size distribution, and the particle shape affect the bulk density, the filtering and extraction properties of the powder, and thus also the quality of the prepared coffee. Figures 5a and 5b show that the CAMSIZER X2 can use image analysis to determine both width, length, and circle-equivalent diameter simultaneously and output each as its own distribution curves. Thus, one measurement produces multiple results based on the three different definitions of particle size. The results with respect to these parameters differ significantly, which at the same time describes the irregular grain shape: for spherical particles, the distributions for all three size definitions would be identical. In comparison, the result of laser diffraction, which assumes the particles to be spherical, provides only an average over the width and length of the particles. Thus, the distribution obtained by laser diffraction most closely matches the "circle equivalent diameter" definition of image analysis, but with a bigger span. In the two examples in Fig. 5, the median values (d50) are well comparable, and the same is true for the percentage of fines < 200 µm. Laser diffraction is thus quite capable of characterizing coffee powder reasonably reliably. However, the correct detection of coarse fraction is difficult. As the diffraction angles become smaller with increasing particle size, this is more difficult to measure. Thus, the resolution of the instruments inevitably becomes poorer for large particles. In addition, small amounts of oversize particles may not generate enough signal to be represented in the results. This is particularly clear in the example in Fig. 5b: the image analysis finds particles up to 2 mm long, the laser result does not show any particles > 1200 µm!



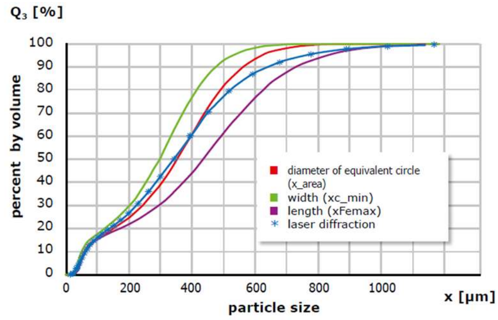


Fig. 5a (left): *Measurement results of a coffee sample, approx. 10 µm - 1000µm. CAMSIZER X2 and laser diffraction.*
Fig. 5b (right): *Measurement results of a coffee sample, approx. 10 µm - 2000 µm. CAMSIZER X2 and laser diffraction.*

The problem with sieve analysis of coffee powder is the cohesiveness of the product. The oil content inevitably leads to clumping, adhesion to the sieve frame and clogging of the sieve meshes. Below 200 µm, air jet sieving should be used in any case. All this represents a high time expenditure to determine a size distribution that ultimately comprises no more than eight data points (= number of sieves used). Comparison with dynamic image analysis shows that the sieve data compare very well with the size definition "particle width" (Fig. 6). This is due to the fact that during the sieving process, the grains align in such a way that they pass through a sieve with their smallest possible projection area. Sieve analysis therefore tends to determine particle width. It further follows from these observations that a comparison between sieve analysis and laser diffraction can hardly be reasonably and reliably achieved for irregularly shaped particles such as coffee powder.

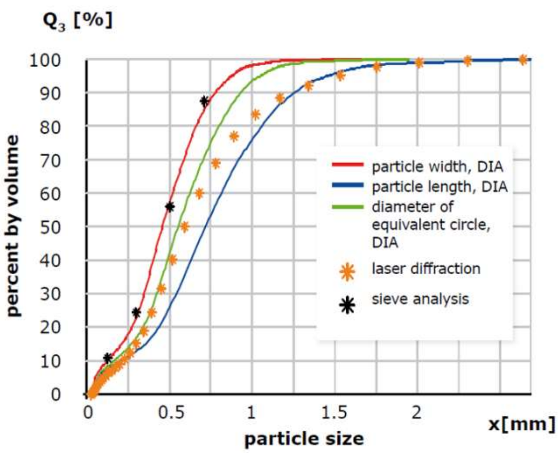


Fig. 6: *Analysis of a sample of coffee powder with laser diffraction (orange), sieve analysis (black) and dynamic image analysis CAMSIZER X2: particle width (red), particle length (blue), circle equivalent diameter (green). Note the large difference between laser diffraction and sieve analysis.*

Summary

When characterizing coffee powder with dynamic image analysis, the advantages of the method come into their own. However, it should be noted that only a two-camera system such as the CAMSIZER X2 provides a measuring range that can capture the broad size distribution of coffee powder in one analysis. The simultaneous use of two cameras (CCD zoom and CCD basic) with different reproduction scales ensures that the fine and coarse fractions are measured correctly. This eliminates the need to preset the measuring range by selecting suitable lenses or objectives, as is necessary with many other image analyzers and sometimes even with laser diffraction instruments. Both cameras contribute to the measurement result, and the size distribution is calculated automatically. In the case of coffee powder, it is important to record the entire distribution as accurately as possible in order to be able to reliably predict the extraction behavior, quantity of dissolved substances and thus ultimately the taste.
For example, CAMSIZER data is used to correctly adjust grinders of fully automatic coffee machines at the factory to achieve the optimum particle size distribution for the brewing process.

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