COFFEE GROUNDS – USING PARTICLE SIZE AND IMAGE ANALYSIS FOR QUALITY CONTROL

Context

It is estimated that almost 2.5 billion cups of coffee are consumed around the world each day. Coffee consumption is a global phenomenon encompassing many different countries and cultures. While the humble coffee bean is the common denominator, the way it is roasted, ground and brewed varies enormously from culture to culture. From Italian Espresso to Turkish Cezve to Irish Coffee and the more common filter coffees, coffee types and preparation can often reflect a distinctive local culture**.**

One fundamental parameter that contributes to the varying types of coffee is the particle size distribution of coffee grounds. While the origin of the bean and the roasting process contribute to the taste on the palate, particle size or "grind size" is critical to the brewing process. For example, espressos require fine grinds, drip coffee requires medium-sized grinds, and cold brew coffee requires coarse grinds

"Using the same type of coffee, you can prepare different coffee specialties – merely by grinding coffee beans more coarsely or finely. For this reason, choosing the right grinding degree is quite important for maximizing the taste experience. Especially when it comes to cold brew coffee specialties and cold drip grind size." [**1**]

Laser Diffraction is a commonly accepted technique for measuring particle size distribution of coffee grounds.

"Grind particle size is undoubtedly one of the most critical factors in a good grinder. The distribution of particle sizes and (to some extent) shapes may be determined by measuring the scattering of a beam of coherent light as it passes through the sample. This measurement is done in an instrument known as a laser diffraction particle size analyzer. Beam scattering measurements may be done wet (with the sample particles suspended in water) or dry (in air)." [**2**]

Combining Laser Diffraction and Image Analysis

The specific particle size distribution of coffee grounds for espresso, drip coffee, and cold brew will vary depending on bulk coffee producers or even individual craft or home brewers. In this application note, we will focus on how combining laser diffraction and imaging in dry measurements allows a quick assessment of the coffee grinds and one can adjust the grinding process accordingly. The Microtrac SYNC laser diffraction used in this study is equipped with built-in dynamic imaging analysis capability, where laser diffraction and optical imaging data of coffee grounds are obtained in one measurement cell and analyzed in a single software platform. Figure 1 below shows the schematic platform of the SYNC's combined laser diffraction and dynamic image analysis for dry measurements.

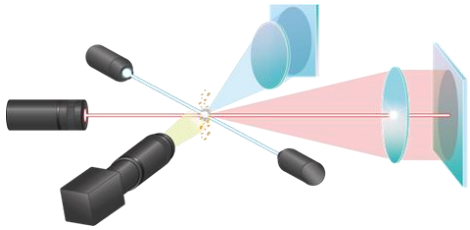

Figure 1. Combined laser diffraction and dynamic image analysis for dry measurements

Espresso, Drip, and Cold Brew Grounds

Coffee grounds for commercially available espresso, drip, and cold brew coffees were used in this study. The bulk samples were reduced to representative aliquots using a Retsch PT100 rotating sample divider. For dry measurements, proper dispersion of the sample is critical. Compressed air is used to condition the sample to ensure that all agglomerates are properly dispersed and that no excess fines are produced by higher pressures. By measuring at different air pressures (pressure titration) the correct conditions were determined to ensure reproducible results for each coffee grade.

Two SYNC configurations were used, each having a different objective zoom for the dynamic image analysis. The high-range camera is effective from 50-4000um, appropriate for drip and cold brew coffee. The low-range camera is effective from 4.6-2000um, suitable for the espresso grind. Approximately 10mls (Three-quarter tablespoon) of aliquots of each sample were used, and three measurements were carried out for each grind size. Figure 2 below shows the average particle size distribution for each ground type.

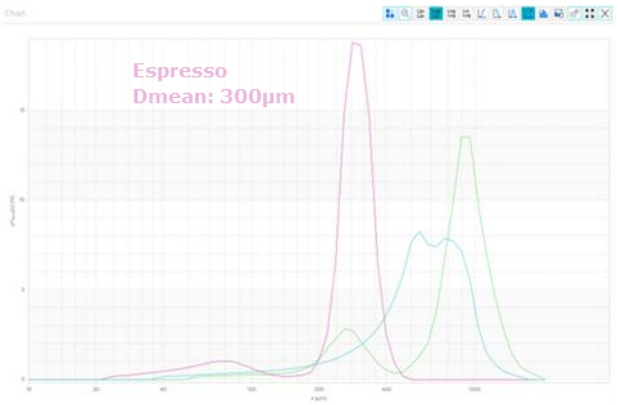

Figure 2. Particle size distributions for each type of ground coffee (volume-weighted, p3x (%)

The comparison plot shows the distinctly different particle size distributions for each type of coffee. The green curve represents the coarsest grind, the filter-packaged cold brew. The blue curve represents the drip coffee, with a medium grind profile. The finely ground espresso is represented by the purple curve. This single comparison plot is a perfect visualization of different coffee specialties.

Repeatability and Reproducibility

Controlling grind size is crucial to delivering the right coffee experience. It ensures uniform extraction rates across batches to maintain the

desired flavor and strength. The consistency of grind directly translates to the consumer perception of a particular brand or brew.

Repeatability

The repeatability of particle size data is assessed by comparison of multiple measurements with the same instrument, operating conditions, and sample preparation. Figure 3 shows the repeatability of particle size measurements for drip brew coffee samples.

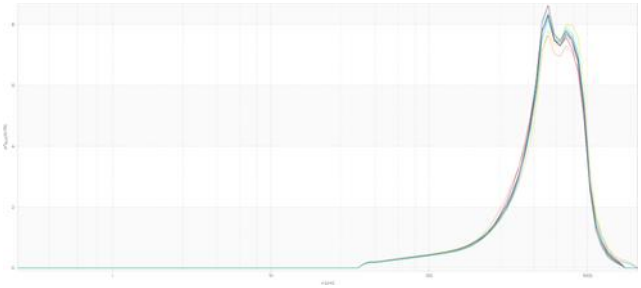

Figure 3. Particle size distributions for all individual measurements of the drip brew (volume-weighted, p3x (%)

The Microtrac DIMENSIONS LS software package easily and intuitively overlays the size charts for quick visual comparisons. The data tolerance feature will immediately flag results as passing or failing against product specifications. Table 1 shows some of the figures extracted from built-in statistical reports. These variations are within the acceptable limit for assessing instrument and method reliability according to good diffraction practices (ISO/DTS 5973).

Summary Figure	Coefficient of Variation (%)
Mean Volume Diameter (M4,3)	1.34%
D10 (Volume Percentile)	2.29%
D50 (Volume Percentile)	1.53%
D90 (Volume Percentile)	1.33%

Table 1. shows the variability of summary data for all individual measurements of drip-brew coffee

Reproducibility

The reproducibility of particle size data is assessed by multiple measurements with different instruments or operators. Figure 4 shows the particle size distributions collected on multiple instruments. Table 2 shows the corresponding statistics. These are within acceptable variations of instruments and methods for reproducibility.

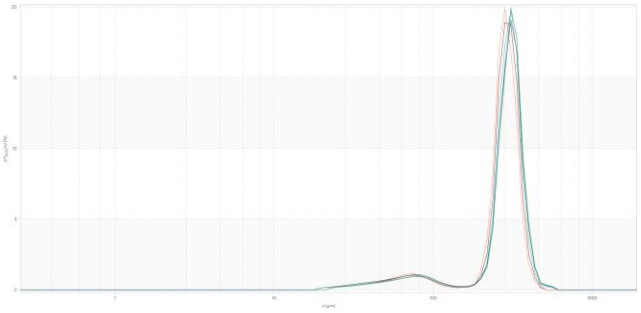

Figure 4. Particle size distributions for all individual measurements of the espresso pod (volume-weighted, p3x (%)

Summary Figures	Coefficient of Variance
Mean Volume Diameter (4,3)	2.77%
D50	2.85%
D90	2.94%

Table 2. shows the variability of summary data for espresso samples.

Integrated Image Analysis

Microtrac's SYNC provides traditional users of laser diffraction with exciting new capabilities to characterize their materials. The fully synchronous laser diffraction and dynamic image analysis make the SYNC unique, with dry imaging capability a class-exclusive feature in particle characterization instruments. The integrated imaging technology captures significantly more information about the size and shape of the materials, along with the quality of the dispersion. Microtrac DIMENSIONS LS Particle Viewer workspace allows users to intuitively search, sort, filter, and scatterplot a range of size and shape parameters.

Particle Viewer

The Particle Viewer workspace is full of powerful features to investigate and solve problems related to particle characterization. The Particle Frame displays the complete images captured by the SYNC during the measurement. The entire catalog of individual images is selectable from the Particle Grid, with full size and shape parameters updated in the Particle Data window. The Particle Grid has simple search or sort functions, where users can create complex and customized filters based on application needs. The Particle Heatmap is a two-dimensional matrix with axes that can be assigned to any size or shape

parameter. Figure 5 is an example of a comprehensive display of the dynamic imaging data of the drip coffee. The Particle Heatmap below shows a scattergram of the aspect ratio of the particles vs size (um). Manufacturers can and depending on the study, particles beyond a user-defined particle size range for drip coffee could indicate the effectiveness of the grinding process (i.e. too many particles outside the specified range for drip coffee grind).

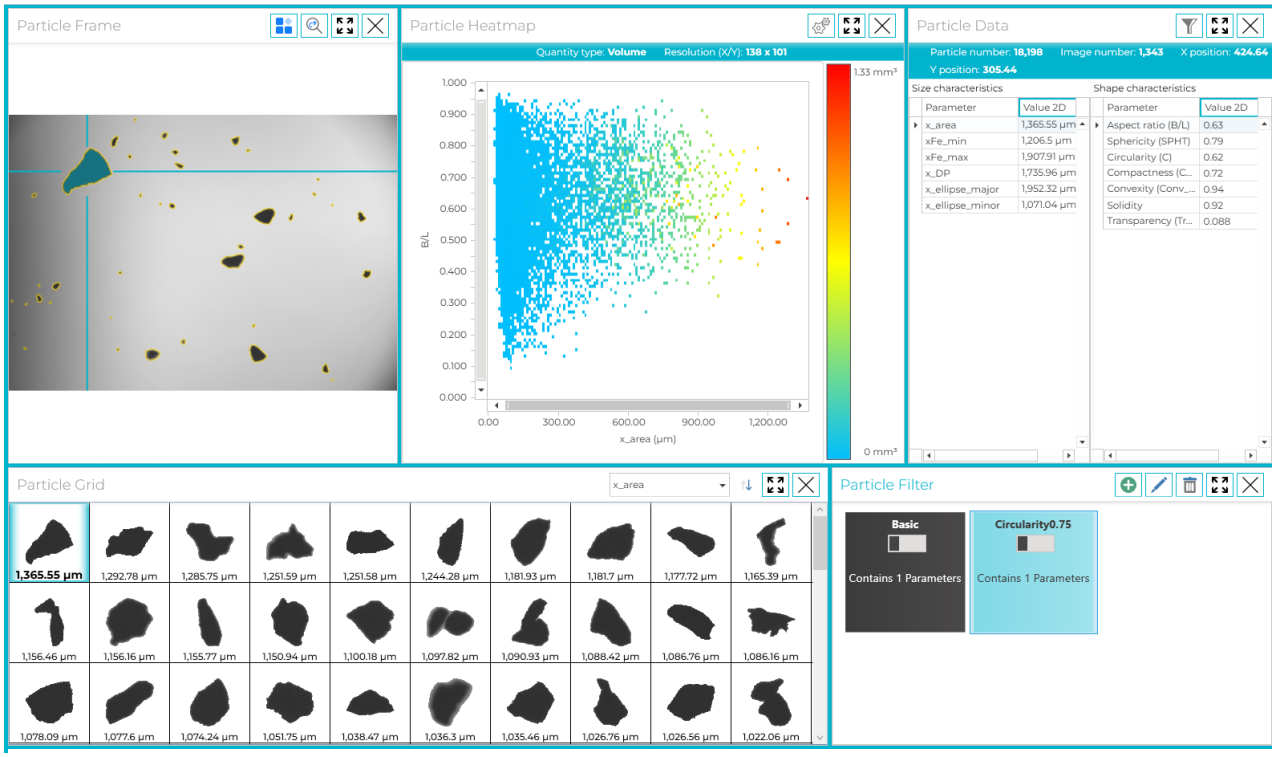

Figure 5. The Particle Grid is shown sorting the images based on a descending area equivalent to diameter (x_area). The same parameter is plotted against the aspect ratio (B/L) to create the volume-based Heatmap for this sample.

Conclusion

The addition of Imaging data to more traditional laser diffraction measurements provides coffee manufacturers with significantly more data about their coffee grinds. Laser diffraction alone provides a volume distribution based on the nearest equivalent sphere of the particles measured. In practice, users look to the repeatability of results to determine the quality of a specific grind. With Image Analysis, a "treasure trove "of extra information becomes available – Morphology, Aspect Ratio, Sphericity, Angularity, Longest Diameter, Shortest Diameter, etc. – all of which deliver a better understanding of not only coffee grind but also the machinery and processes used to produce the grind. With the SYNC system, the ability to make Laser Diffraction AND Image Analysis measurements of the same sample at the same time in the same sample cell is uniquely positioned to deliver maximum information to users. All measurements for this application note were done in fully automatic mode within 5 minutes, making the SYNC a robust solution for testing and quality control of production.

Please visit our SYNC laser diffraction with imaging for more information.

References

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