MONITORING COFFEE GRINDING WITH LASER DIFFRACTION PARTICLE SIZE ANALYSIS

The flavor and strength of coffee depends on the coffee beans selected, the roasting process, the brewing method and the fineness of the ground coffee used. In commercial grinding, the process is well developed and monitored by the use of laser diffraction particle size analyzers. The speed, consistency, and ease of use have made it the most popular method for process control.

History of Coffee

Botanical evidence indicates that *Coffea Arabica* originated in central Ethiopia and was brought to Yemen where it was cultivated since the 6th century. Upon introduction of the first coffee houses in Cairo and Mecca, coffee became a passion rather than just a stimulant.

It spread in the 17th century to Europe and soon to plantations in the New World. Today there are coffee plantations in many countries, but all are in the tropics because the trees need hot sun, plenty of rain at certain times of the year, and a hot dry season in which to pick the beans.

Plantations are found in rolling, hilly country, often above 450 meters above sea level. The coffee trees do best in rich, well-drained, volcanic soil. They require careful cultivation and care

Production Process

At first the fruit is deep green, but this slowly ripens to yellow then bright red. Each fruit has a sweet pulp that covers two coffee beans. The fruit is picked when ripe, either individually or a whole tree at a time, but in most cases this is still done by hand. The fruit is winnowed to remove the leaves and other materials, then the beans are removed by one of two methods.

Either the fruit is dried and the bean removed through a crushing procedure or the fruit is soaked to make it soft and easily removed. The beans are then washed, dried, and packed for export. The 'green' beans have little flavor when harvested and must be roasted. Coffee beans from different parts of the world have different flavors depending on the growing conditions.

The roasting process also can affect final flavor. They must be heated to the correct temperature to remove the moisture, without burning the beans. The beans are rotated as they are heated to keep an even temperature over the whole batch.

To make the final coffee drink, the roasted beans must be ground, either at a central factory, in the local shop, or at home, then extracted with hot water. There are a number of ways to make the final coffee drink, depending on the type of bean and desired variety of coffee.

Instant coffee is also available to avoid the brewing process. In the factory, the coffee is ground and brewed, then the water is removed, leaving a pure coffee powder.

Effect of Particle Size on Brewing

Several factors affect the final brew including the bean itself, the roasting process, the brewing method, and the fineness of the grind. Each brewing method will brew better if the beans are ground to the optimal size in the first place.

Brewing Method	Coffee Grind
Percolator	Coarse
French Press	Coarse
Drip coffee makers	Medium
Espresso mocha pots	Fine
Espresso machines	Extra fine
Ibrik	Turkish

The terms can be open to interpretation (just how fine is extra fine?), but the following is a rough guide:

- Coarse - Very distinct particles of coffee. Chunky.
- Medium - Gritty, like coarse sand.
- Fine - Smoother to the touch, a little finer than granular sugar or table salt.
- Extra fine - Finer than sugar, but not quite powdered. Grains will still be discernable.
- Turkish - Powdered, like flour.

Commercial coffee grinders have more precise specifications for each grade of coffee to maintain a consistent product for their customers. Routine tests on the grinding process maintain optimal final product and control any drifts in the grinding process, accounting for variables in the raw coffee beans.

Fig. 1: The HORIBA *Partica* LA-950

Analytical test method

Laser diffraction has proven to the most popular size testing method because of its speed, reproducibility, and ease of use. This must be done with a dry sampling method because coffee will extract in almost any fluid, precluding any type of wet analysis.

Sieve analysis has traditionally been used, but the advantages of laser diffraction allow the instrument to pay for itself in faster response allowing better control of the grinding process, more frequent tests of the grinding allowing more consistent product, and reduced labor costs. The LA-950 data can be reported in standard sieve sizes for easy comparison with historical data.

With a modern laser diffraction instrument, most parameters of the sample analysis are automatically controlled or recalled as part of a standard test method. The sample is loaded into the instrument, the sample information is entered, and the full analysis cycle is completed automatically.

The HORIBA Partica LA-950 shown in Fig. 1 above is a superior choice to systems that have traditionally been used for this application for a number of reasons.

- The automation of the sample feeder, vacuum and dispersion pressure, measure start and measure completion make the sample analysis a one-button operation. This ensures consistency in testing procedures and allows operators of any skill level to easily analyze samples with high data reliability.
- The wide dynamic measurement range from below 1 µm up to 3mm allows for full sample accountability without missing any of the finer parts of the distribution. There is no need to purchase or change optical components to measure the full size range accurately.
- The standard vibratory feeder chute with the sample dam to smooth the sample flow is used to provide a consistent feed rate, improving stability and reproducibility.
- With the PowderJet Dry Feeder shown in Fig. 2 the large dispersion nozzle is needed because of the larger particle sizes, but still provides all the dispersion energy necessary, even for finer coffee grades.
- More economical price than alternate systems of similar specification.
- The sample flows directly from the end of the vibratory feeder, through the dispersion nozzle, and to the measurement zone in a short, straight path and without contact with any parts of the system. There are no angles or transport tubes in the sample stream, therefore no sample will be hung up in the system. This eliminates the need for system cleaning and possible sample cross-contamination

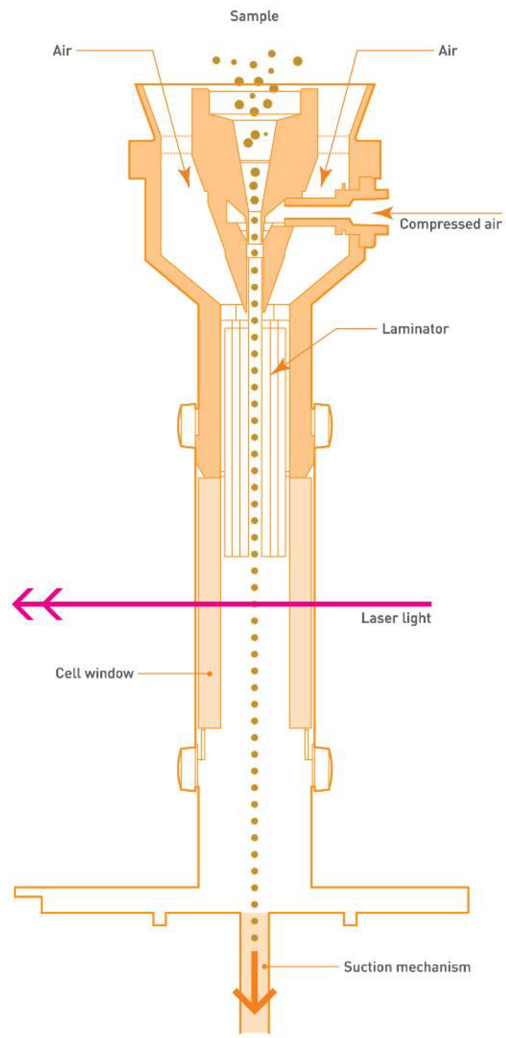


Fig. 2: Dry Cell Diagram

Example data

Four different types of coffee were analyzed using the *Partica* LA-950 system and PowderJet Dry Feeder. The coffee samples ranged from coarse to fine (espresso). The data shown in Fig. 3 includes the frequency distribution for all four types of coffee analyzed during this study. Median sizes ranged from 1250 to 305 µm. Note that all but one of the samples showed a coarse tail over 2000µm.

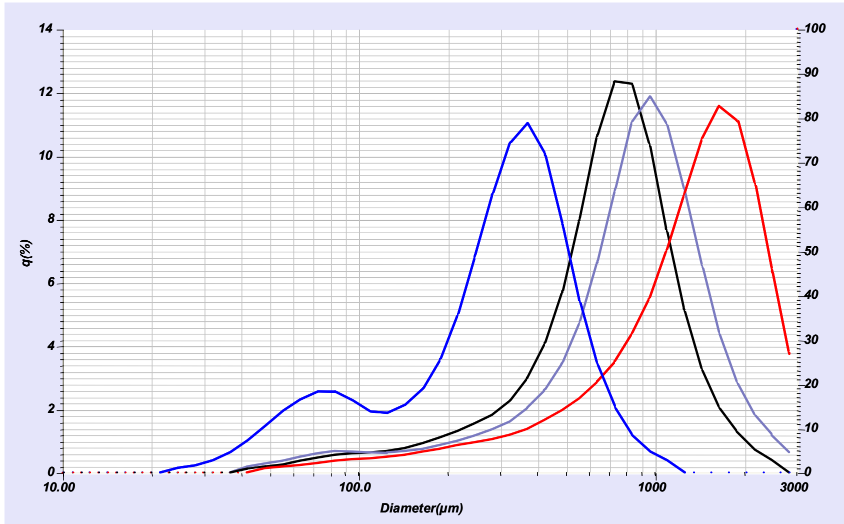
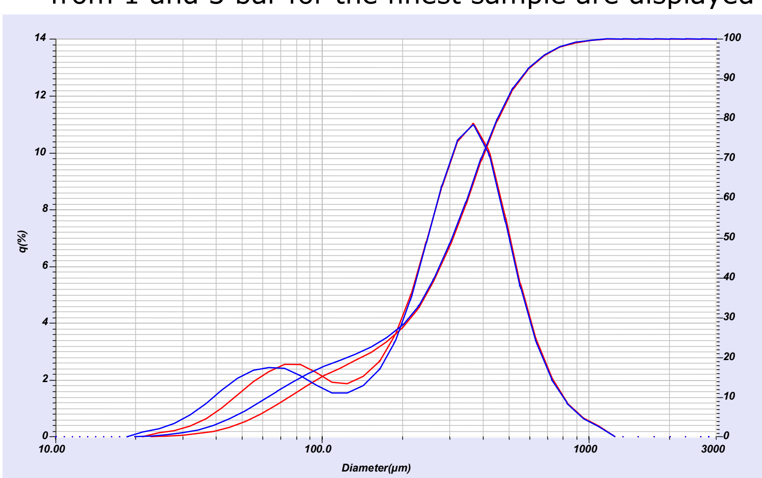


Fig. 3: Results from all Samples

Sample Conditions

All samples were analyzed at multiple settings on the PowderJet Feeder: 1, 2, and 3 bar. The coarsest sample was also analyzed using a free fall cell designed for granular material not requiring air pressure for proper dispersion. None of the samples displayed significant sensitivity to the air pressure setting, but the results from 1 and 3 bar for the finest sample are displayed in Fig. 4 and Table 1.



	3 bar	1 bar
Mean Size	320.30	312.18
Mode Size	367.61	367.09
D10 (µm)	75.26	62.98
D50 (µm)	309.25	305.16
D90 (µm)	559.22	549.35

Table 1 Summary Results

Fig. 4: Results from measurements at 1 and 3 bar

Note: A pressure titration should be performed on most samples when using the PowderJet Dry Feeder to establish optimum conditions.

Typical measurement system settings include use of the large disperser nozzle, low dispersion pressure or the Vacuum Cell for the largest size grade, target sample feed to achieve 95% laser transmittance (start at highest speed), and the sample metering dam to level and even the sample flow.

Reproducibility
Since these samples are all large granular materials the reproducibility is mostly governed by the sampling errors*. When care is taken to perform proper sampling, the results overlay closely as shown in Fig. 5.

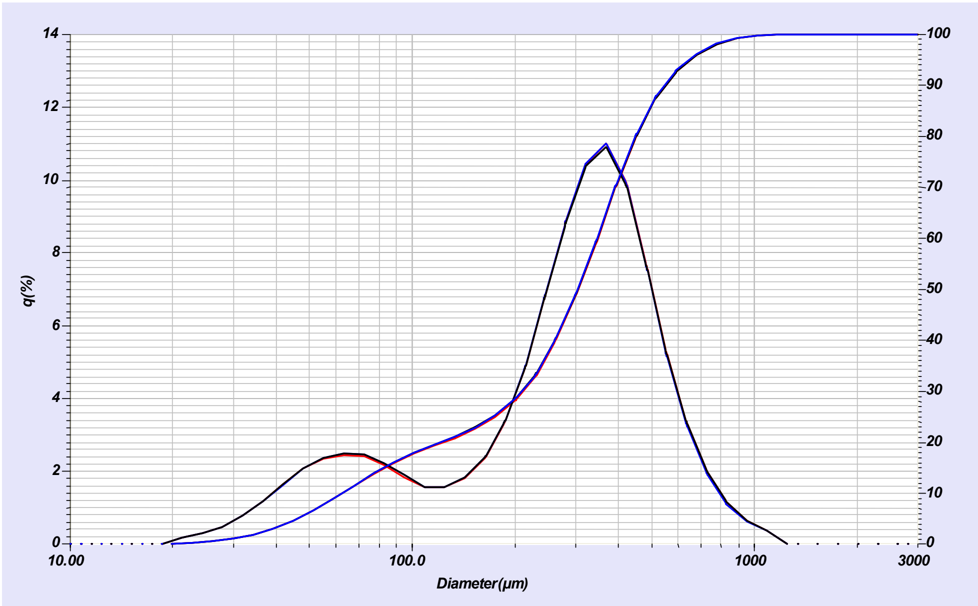


Figure 5: Reproducibility

*For a review of sampling errors associated with particle size analysis please refer to:

Allen, T., Particle Size Measurement, 5th Edition, Volume 1, 1997, Chapman and Hall, ISBN 0 412 72950 4

ISO 14488 Sample preparation — Sampling and sample splitting of particulate materials for the characterization of particulate properties, available at www.ansi.org

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