HORIBA Scientific

Application Note

Particle Size and Shape Analysis of Coffee

AN186

Few products are so involved in particle sizing from start to finish as coffee. From the classification of the raw, green coffee bean to the relationship between brew quality and the size of ground coffee beans, the quality of the final coffee drink is directly related to particle size and sometimes shape and density as well. The CAMSIZER dynamic image analyzer and LA-960 laser diffraction analyzer offer undeniable advantages in measurement accuracy, quality, and speed over historic sieving techniques.

Introduction

Little time will be spent in this article talking about the history of coffee or those techniques which historically have been used to gauge quality. Suffice it to say that coffee is one of the world's most traded and most valuable commodities and is of specific economic importance to developing countries (1). It also enjoys special status as one of the most universally popular beverages transcending ethnicity and class distinctions. A good cup of coffee is an integral part of everyday life for many people. Coffee growers, suppliers, manufacturers, distributors, etc. know the importance of providing a high quality product and the price premium it can support. So what constitutes "quality" for a cup of coffee?

Quality is Flavor and Flavor is Size

The flavor profile of a cup of coffee is the most important indicator of quality. That flavor profile is determined by several factors: brewing method, grind (excluding instant coffee), roasting, and the size and density of the original green bean. Coffees grown in higher altitudes take longer to develop and often produce beans of greater size and density which can be linked to more popular flavor profiles. Green beans have been classified according to size for this very reason. Additionally, green beans must be sorted into groups of similar particle size to ensure even roasting - smaller beans will roast differently and have a different taste than larger beans given the same time and temperature.

Historically the classification and grading of green bean size is done via screens (a.k.a. sieves) using a chart similar to Figure 1 (2). Additional defect guidelines are included in the Brazil / New York Method and the Specialty Coffee Association of America Method (3).

Relevant to the discussion here are those defects which can be distinguished from "good" green beans by either size or shape. This subset of defects can be identified and reported by the CAMSIZER dynamic image analyzer. The CAMSIZER uses two digital cameras to capture images so that advanced sizing software may calculate the many sizes (length, width, depth, diagonal, etc.) and the many shape parameters (sphericity, aspect ratio, convexity, symmetry, etc.) of the coffee bean. Provided with the aforementioned guidelines (Brazil, SCAA, or custom) the CAMSIZER can grade coffee based on size and it can report the amount of defects and provide photographic evidence (Figure 2). The classification and grading of the raw, green bean can be made more quickly and objectively with the CAMSIZER.

<table>
<tr><th>1/64 inch</th><th>mm</th><th>Classification</th><th>Central America and Mexico</th><th>Colombia</th><th>Africa and India</th></tr>
<tr><td>20</td><td>8</td><td rowspan="3">Very Large</td><td rowspan="6">Superior</td><td rowspan="3">Supremo</td><td rowspan="3">AA</td></tr>
<tr><td>19.5</td><td>7.75</td></tr>
<tr><td>19</td><td>7.5</td></tr>
<tr><td>18.5</td><td>7.25</td><td rowspan="3">Large</td><td rowspan="3"></td><td rowspan="3">A</td></tr>
<tr><td>18</td><td>7</td></tr>
<tr><td>17</td><td>6.75</td></tr>
<tr><td>16</td><td>6.5</td><td rowspan="2">Medium</td><td rowspan="2">Segundas</td><td rowspan="2">Excelso</td><td rowspan="2">B</td></tr>
<tr><td>15</td><td>6</td></tr>
<tr><td>14</td><td>5.5</td><td>Small</td><td>Terceras</td><td></td><td>C</td></tr>
<tr><td>13</td><td>5.25</td><td rowspan="6">Shells</td><td>Caracol</td><td rowspan="6"></td><td rowspan="6">PB</td></tr>
<tr><td>12</td><td>5</td></tr>
<tr><td>11</td><td>4.5</td><td rowspan="2">Caracolli</td></tr>
<tr><td>10</td><td>4</td></tr>
<tr><td>9</td><td>3.5</td><td rowspan="2">Caracolillo</td></tr>
<tr><td>8</td><td>3</td></tr>
</table>

Figure 1: Typical grading chart assigns green beans into different categories based upon size.

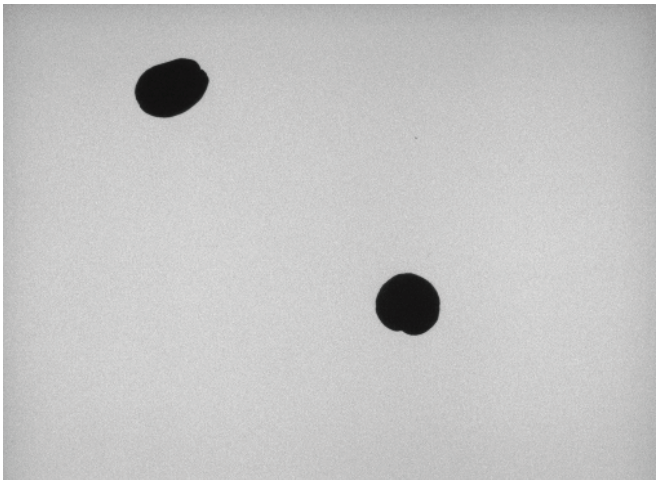

Figure 2: A captured image from the CAMSIZER showing two green beans (of thousands) measured and classified based on size and shape.

Now that the green beans have been separated and re-grouped they are ready for roasting. Coffee will never have a better possible flavor than what is obtained by roasting. Every subsequent step to prepare and then brew the drink will either maintain or lessen the flavor and thus quality. Naturally the goal is to maintain quality as much as possible and here again size plays an important role along with shape and density. Coffee is typically consumed in one of two ways: either the bean is ground to a specific grain size and brewed with hot water, or the bean is ground, brewed, and then dried to produce instant coffee. Each method proves a good match for some state of the art particle size analysis.

Coffee Grinds and Particle Size

The traditional method of brewing coffee involves grinding the roasted beans and then passing hot water over the granules to extract flavor, caffeine, and various other compounds. Several different techniques are popular for brewing the ground coffee particles including the French press, automatic drip machine, and espresso maker. Each technique works best with a different size of coffee grounds: coarse sizes for the French press, medium sizes for the drip maker, and finer sizes for espresso. The size of coffee grounds is determined by the time spent in the grinder.

Smaller particles expose a greater surface area per unit volume than larger particles and thus extract a greater amount of flavor per unit time. Too fine a grind may produce too strong a flavor and clog any filter. Too coarse a grind may produce too weak a flavor. Understanding the relationship between the desired flavor and the size necessary to obtain it is a key factor in quality assurance. The particle size specification that develops from this understanding will typically emphasize control over fine particles, coarse particles, and a size distribution of specific width (i.e. range of sizes).

Ground coffees sold to the consumer typically exhibit a grand size range between tens of microns and a few millimeters. The LA-960 laser diffraction analyzer is ideal for the size measurement of ground coffee because of its industry-leading dynamic range and state of the art PowderJet Dry Feeder accessory (Figure 3). Capable of measuring the grounds in the “as-is” dry form, the LA-960 sidesteps any problematic interactions with a liquid measurement medium.

Figure 3: The HORIBA LA-960 Particle Size Analyzer with PowderJet Dry Feeder accessory.

The PowderJet uses finely controlled compressed air to de-agglomerate (separate) clumped coffee grounds and then measure the particle size distribution (Figure 4) using the laser diffraction technique. Unmatched repeatability, reproducibility, and objectivity are the calling cards of PowderJet dry measurement. Not even the highest quality sieves and best practices can match laser diffraction for precision, speed, and return on investment. Several different ground coffee products were measured on the LA-960 PowderJet and are displayed in Figure 5. Note the overlay of multiple measurements for each product and the high precision those overlays represent. Note also those products with coarsest particles greater than 2000 microns.

The LA-960 can measure dry particles up to 3000 microns (3 millimeters) - a capability not available in other analyzers - ensuring the accurate representation of those largest particles which determine water flow during the brewing process. Measurement length is on the order of seconds as opposed to the minutes that a sieve run requires. The time savings becomes significant when compounded by dozens of measurement each day. Laser diffraction is replacing traditional sieves as the preferred sizing technique of ground coffee for everyone from the smallest specialty to the largest multinational companies.

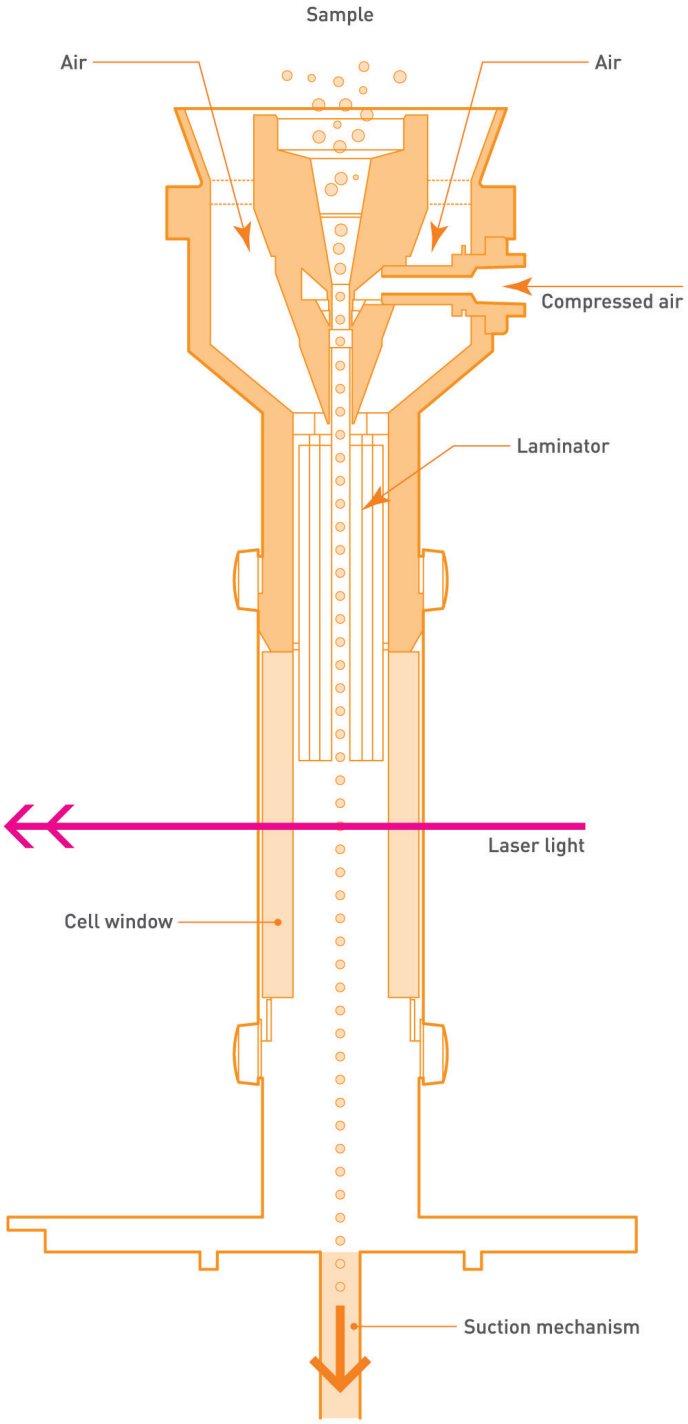

Figure 4: Cross-section of the PowderJet measurement cell. The vertical design eliminates many of the problems found in horizontal designs such as cross-contamination and clean-up.

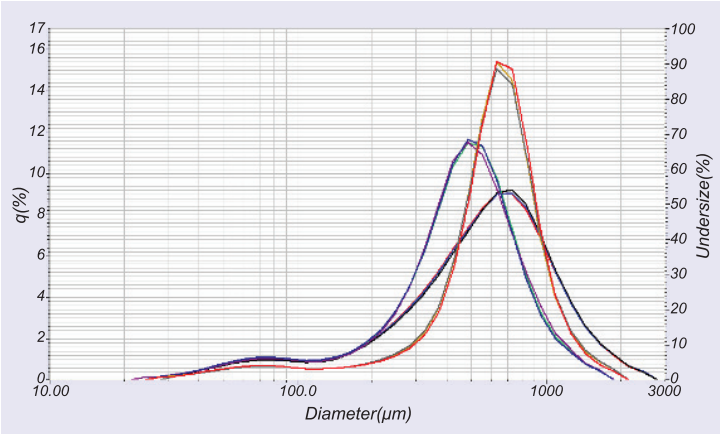

Figure 5: Nine measurements from nine unique samplings of three different ground coffee products. Notice the excellent repeatability and reproducibility as the three measurements for each product overlay very closely. Notice also the product with coarsest particles greater than 2000 microns.

Instant Coffee is Unsuitable for Sieving

Any person who has attempted to sieve instant coffee has no doubt concluded that there must be a better way. Regardless if it's manufactured by spray-drying or freeze-drying, instant coffee is much too friable to be suitable for sieve analysis. The coffee particles (flakes, granules, powders) all quickly break down to powder, failing to mimic the out-of-the container consumer condition that is the reason for size testing. The CAMSIZER dynamic image analyzer solves this problem by measuring the size, shape, and material density of the instant coffee particles non-destructively. Capable of measuring particle sizes from 30 microns to 30 millimeters, the CAMSIZER easily encompasses the size range of various instant coffee products, be they freeze-dried, spray-dried, agglomerated, non-agglomerated, etc. The size results from several different brands and grades (i.e. Premium, Gourmet, regular) of instant coffee are shown in Figures 6 and 7. The reporting of fines is much more accurate than what will come from sieving because the CAMSIZER measures the unbroken coffee particles. The user can have confidence that whatever fines are measured were a part of the sample and not the measurement process.

Correlation to traditional sieve results is also possible with the CAMSIZER and its ability to "think like a sieve" by measuring the shape of the particles and calculating how that shape would fit through a square mesh opening. Figure 8 shows the results of this elementary fitting applied to an instant coffee product. Besides allowing the CAMSIZER to measure like a sieve, the simultaneous shape measurement can help quantify particle flow characteristics which may be important for process control. A flake-shaped particle and a sphere-shaped particle will obviously transport and pack very differently. The CAMSIZER can measure several shape characteristics during a single analysis including particle sphericity. Figure 9 shows the sphericity (SPHT) distributions of two different instant coffee products: one premium quality (#5) and the other basic (#4). Particles with SPHT value closer to 1.0 are rounder and more regular in shape. As the SPHT value decreases it reflects a particle which is more angular, irregular, and perhaps broken.

The CAMSIZER can also measure the material density of an instant coffee owing to its ability to quantify the total volume of the coffee particles. Combined with the input of the sample's measured weight (or connected directly to the instrument for automatic communication) the CAMSIZER can calculate the material density of a single product as well as small differences between different products. This capability is perhaps most useful for instant coffee manufacturers but can be used for any material including the roasted bean and green bean. The table in Figure 9 shows the differences in material density for three instant coffee products, one roasted bean product, and one green bean product - all measured by the CAMSIZER.

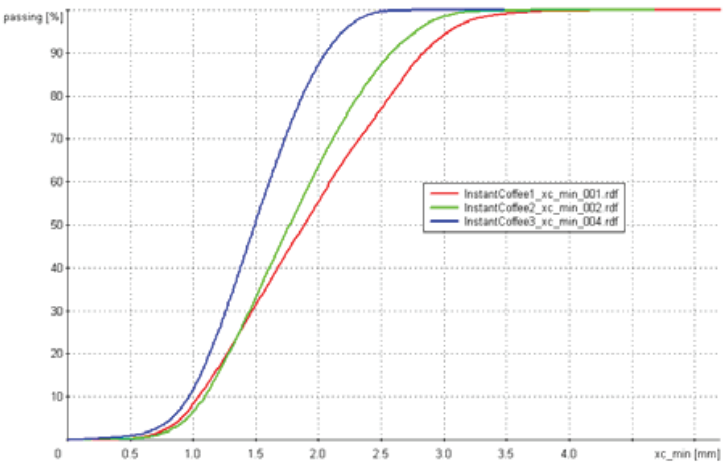

Figure 6: One measurement each of three different instant coffee products (Resolution).

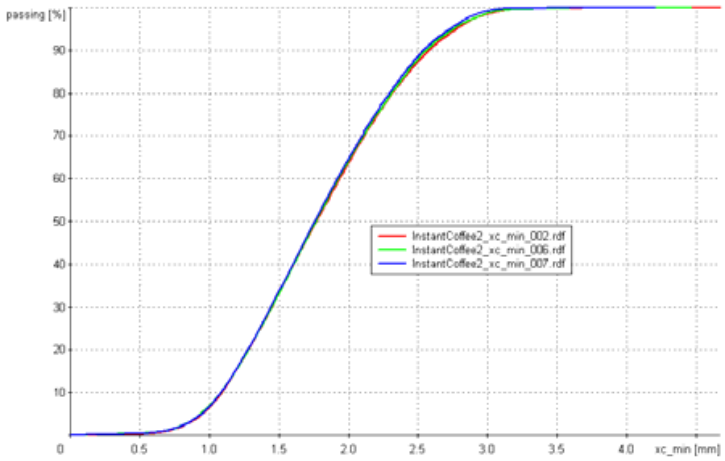

Figure 7: Three different measurements of a single instant coffee product (Precision).

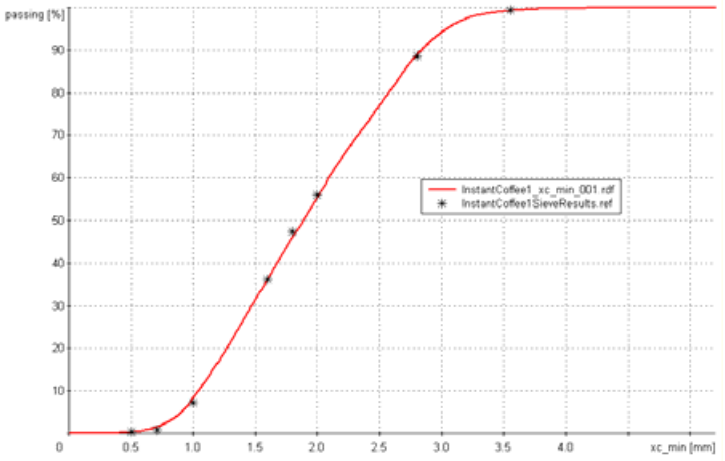

Figure 8: Correlation to historic sieve results (black marks) (Accuracy).

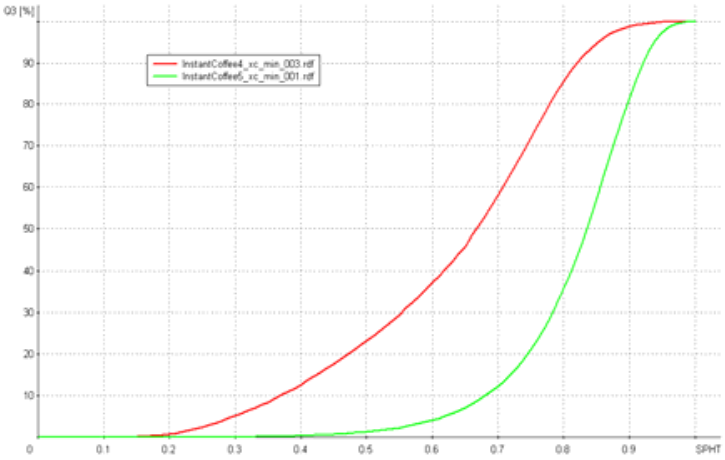

Figure 9: Shape comparison (SPHT) of two different instant coffee products.

Product	Density (g/cm³)
Instant Coffee 1	0.394
Instant Coffee 1	0.397
Instant Coffee 1	0.439
Roasted Bean	0.587
Green Beam	1.30

Figure 10: The densities of five separate coffee samples as measured by the CAMSIZER.

Conclusions

New technologies have matured in the last decade to replace the traditional technique of sieving for coffee particle size measurement. A combination of the CAMSIZER digital imaging technique and the LA-960 laser diffraction particle size analyzer can cover all the size, shape, and density bases from the classification and grading of the raw green bean to the sizing of coffee grounds and instant coffee particles. Utilizing either of these new technologies will lead to significant time and labor savings in addition to a more objective, reliable, and robust measurement. HORIBA Instruments provides state of the art solutions for coffee particle size analysis and the expert training and support necessary to take full advantage of these instruments.

References

(1) Pendergrast, Mark (April 2009). “Coffee second only to oil?”. Entrepreneur.com. http://www.entrepreneur.com/tradejournals/article/198849799_1.html. Retrieved 2009-11-21.

(2) http://www.coffeeresearch.org/coffee/sizingchart.htm

(3) http://www.fao.org/docrep/003/x6939e/X6939e13.htm