October / November 2018

VOLUME 7 NUMBER 5

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Precise Perfection

Precision grinding is essential to proper coffee capsule extraction

By Daniel Ephraim

One might assume that the process of placing a pod into a single-serve maker, and brewing that delicious, on-demand espresso, is simple and straightforward; however, by taking a deeper dive into the development of that pod, it is remarkable to understand the high degree of art and science packed into one small product. Let us take a journey into some of this understanding.

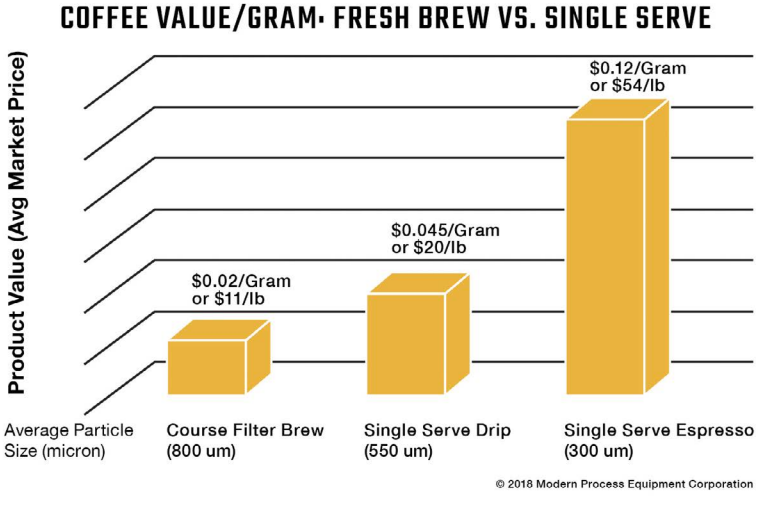
The advancement of the quality single-serve coffee market would be impossible without the development of engineered grinding (particle reduction) equipment to accompany the growth of this market. Some of the revolutionary developments include:

1) The grinding technology required to produce sophisticated grind profiles, and

2) The invention and development of a coffee normalizing system that "compacts" the coffee without loss of integrity.

Additionally, both technologies need to operate in a water-cooled (chilled) and precisely controlled environment to ensure that the coffee exiting the grinding system is as cool, and full of aromatics and volatiles, as the beans that entered the grinding system.

The result: The grinding equipment considerations described above allow for a single-serve product with an almost 600% increase in value (as compared to, say, a fresh brew product). For example, a coarse filter brew grind of, roughly, 800 microns (µm) will have a retail value of $0.02 - $0.03 per gram, while a sophisticated grind in a capsule will sell for approximately 100% more ($0.04 - $0.05 per gram). Similarly, an espresso-style grind will sell for 600% more than the filter brew ground value, or $0.12 per gram (see below).

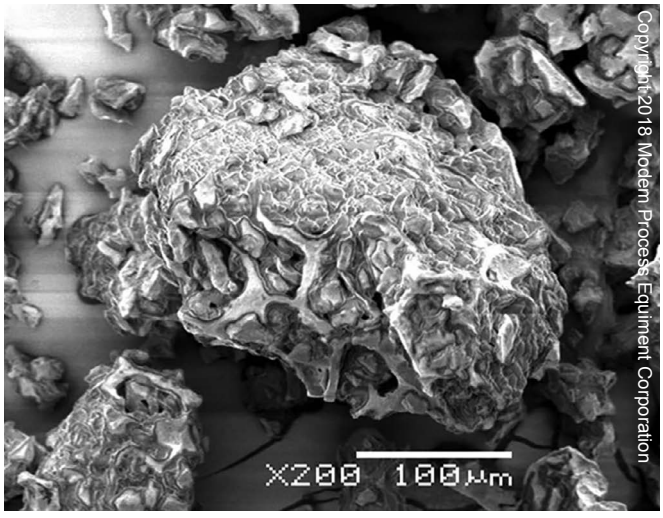


The technologies developed around the single-serve market are the result of challenges inherent in producing an optimal product on a consistent basis. A more in-depth understanding of those requirements allows us to understand the "why" behind the development of these sophisticated technologies, which were explicitly established to correct what would otherwise be barriers to a successful product.

Why is grind important?

The most critical concept in coffee grinding technology in general and with single-serve, in particular, is the managed extraction of the soluble solids from the colloidal structure of the coffee cells within the coffee bean, as shown below. This concept is the "secret sauce" of coffee brewing. If the extraction rate is low, coffee strength is compromised; conversely, if the extraction rate is excessive, there is an extraction of some of the lesser desirable components, which is deleterious to the achievement of the optimal brewed coffee result.

The image below is a much-magnified view of ground coffee particles using an electron microscope. The cellular walls are about 30 microns in diameter, and the colloidal material fills the voids within the ground coffee and cellular structures. Part of this colloidal material is what we want to extract, but with a limit.

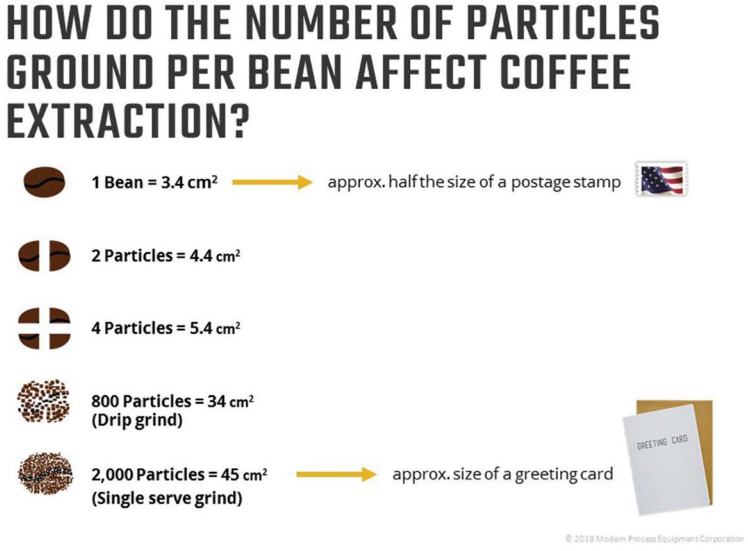


Magnified view of coffee bean

The physics behind grinding coffee and soluble solids extraction:

The extraction of soluble solids from the ground coffee particles is a function of the exposed surface area of the ground coffee to the extraction media, in this case, water (hot or cold). As the area exposed to water increases through grinding, the greater the extraction due to the area exposed to the water.

The table below demonstrates this relationship.



Extraction has its limits

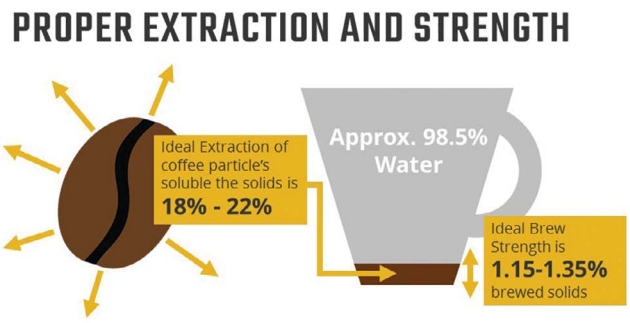
So far, this concept seems straightforward: Increase the surface area of the coffee exposed to the water = increased extraction; however, there is a problem. Every brewing methodology has its target for how much area should be exposed, and it is critical that there is not an over-extraction of soluble solids from the coffee, which would be just as detrimental as an under-extraction of the soluble solids.

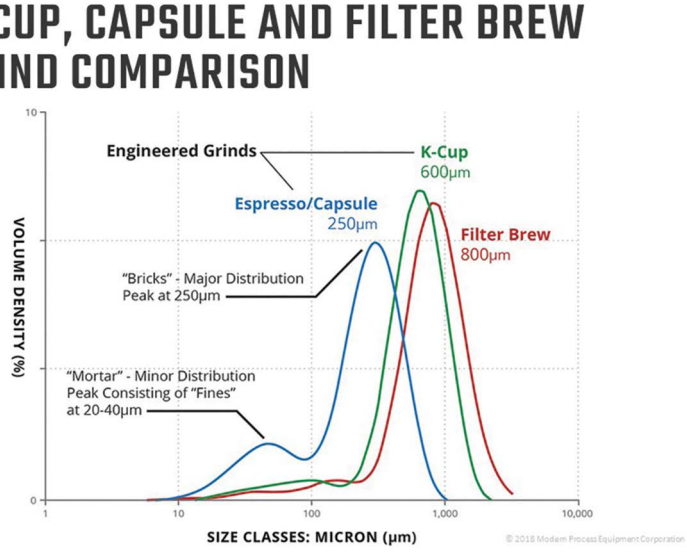
The graphic (at right) depicts the concept.

This empirical illustration illustrates that there is a lower and upper limit to the desired extraction, with too little extraction resulting in a weak, underdeveloped brew and too much extraction resulting in a bitter, off-tasting result.

The next goal is to optimize the mean, or average particle size of the ground coffee precisely to the desired exposed surface area, given the brewing methodology. Also, to make things more difficult, it is critical to optimize the mean particle size for the brewing method, as well as optimize the percentage of particles in the desired particle distribution range(s).

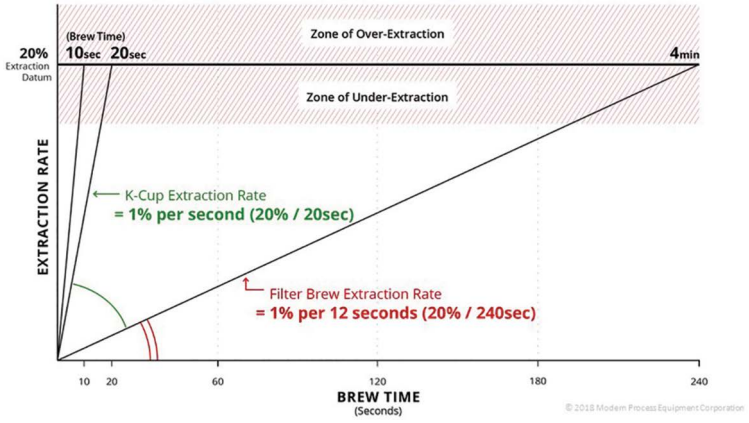
The graph at right shows the difference between a standard filter brew, K-Cup, and espresso grind. It is important to note the "bump" on the espresso grind profile, which is desired for the unique "bricks and mortar" grind profile of an espresso product.





COMPARING BREW METHOD EXTRACTION RATES

PODS vs CAPSULES vs FILTER BREW



DENSIFICATION IS FITTING THE PRECISE AMOUNT OF COFFEE TO THE CAPSULE

WITH THE MPE-PATENTED VORTEX DENSIFIER, THE COFFEE PARTICLES ARE "POLISHED" SO THEY FIT TOGETHER MORE EFFICIENTLY.

The graph above clearly shows the overall challenge(s) of single-serve grinding

Comparing the brew time of a pour over or bottle brewer against that of a capsule, one can see a 90% or greater reduction in the brew time and yet, it is necessary to achieve the same soluble solids (not more, not less) as shown above. All grinding is essential for proper brewing, but the margin of error, and the technical consideration of capsule grinding is critical for not only brew strength but also for time.

Time vs. grind, grind vs. time

After achieving the ideal grind size for a given capsule configuration, there is an added requirement, which is controlling the time of brew through the grind. This may seem confusing alongside the concept of optimizing the grind size to the brewer; however, it may make more sense if broken-out as this:

1) Think about an espresso brewer, and precisely how the particle distribution can affect the time it takes to brew the espresso.

2) Similarly, with capsule grinding, there is a further need to "tweak" the grind so that it brews in the given amount of time (depicted in the graph above).

3) This is especially the case with espresso style capsules; wherein there is a combination of particle sizes, which, on the one hand, provide the ideal extraction and, on the other hand, provide the "mortar" between the other particles.

Densification of ground coffee

Densification can be characterized as the fluffiness (or conversely, the non-fluffiness) of the coffee so that it can fit efficiently into a capsule manufactured at rates of up to 1,600 capsules per minute.

The chart that follows compares two capsules and the amount of coffee packed into each. In each case, the volume is the same, but the quantity of coffee is different. The difference is the density, or "compactness", of the coffee, which is achieved at the grinder, for each ground coffee product, with the Vortex densifier/normalizer.

The first technical achievement in normalization, as represented by the Vortex normalizer, allows more ground coffee to fit into a defined space such as a capsule. Since coffee is an organic product that has different density characteristics depending on its origin and is roasted to various degrees, the density, or fit, of the coffee into the capsule must be a dynamic process to meet the specific density requirement.

The second critical element in normalization is the density control system, which must provide unparalleled consistency in density over time, thereby providing a "set it and forget it" confidence. If the art is contained in the development of the optimal (taste and strength) parameter control adjustment, the science is provided by the ability of that control system to ensure consistency and repeatability over an extended period.

Grinding of coffee for single-serve has several significant considerations:

1) The particle size and distribution must be correct for the specific type of single-serve capsule.

2) The granulometry distribution of the ground coffee must first be optimized to meet the design of the single-serve capsule (mean particle size) as well as minimize the ground coffee particles that fall outside that range.

3) The coffee grinder must be capable of producing a grind that can control the brew time of the capsule through the granulometry design.

4) Control of the density of the coffee is critical so that the optimal amount of coffee will not only fit into the capsule but also do so under high-speed packaging conditions.

5) All of the above must be achieved while the process operates in a water-cooled (temperature-controlled) environment.

Having to control these variables, simultaneously, is virtually impossible manually, and, accordingly, programmable logic controls (PLC) controls with recipe(s) for each parameter selection is a crucial part of a single-serve grinding system.

With this greater knowledge on grinding, it is hoped readers will gain an elevated level of appreciation for what is required to make a daily single-serve cup of coffee.

Daniel Ephraim is president of Chicago-based Modern Process Equipment Corporation. He has been active in the development and design of coffee grinding and other related processing equipment for more than 40 years. He has presented at numerous coffee conferences and symposiums and conducted hundreds of coffee grinding seminars worldwide.