Qualitative analysis of coffee grind profiles from Mahlkonig Guatemala, Bunn G1, Baratza Encore, and Porlex JP-30 grinders.

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Abstract

The relative grind uniformity and morphology of coffee beans ground in four different grinder (Mahlkonig Guatemala, Bunn G1, Baratza Encore, and Porlex JP-30) under SEM imaging has been observed. For certain methods of coffee extraction, a consistent grind size and spherical morphology is vital to extracting a predetermined percentage of solubles deemed ideal for consumption. The grinds observed from the Mahlkonig Guatemala were visually more spherical in shape and had less variation in average size compared to the other three samples. The grinds from the Bunn G1 and Baratza Encore displayed similar properties in size, but the grinds from the G1 seemed more uniform in morphology. The sample from the JP-30, although in the same micron range of the other samples, displayed less desirable defects, manifested in the unevenness in grind consistency and the erratic shapes of the particles.

1 Introduction

The ideal bed of coffee grinds from a technical standpoint is easily understood: the generally accepted ideal solution of coffee consists of a solubles concentration of 1.15-1.3% and a solubles yield (extraction from the coffee beans) of 18-22%. These numbers were found to have the most palatable balance of salts and acids compared to sugars and other heavier organic solutes. From this standard, terminology of under-extraction and over-extraction can be defined. When a coffee solution is under-extracted, the primary solutes in the solution are salts and acids due to their high solubilities in water, resulting in a sour taste. In contrast, when a coffee solution is over-extracted, the amount of sugars and tannin organic molecules (one notable example is caffeine, which is a bitter tasting alkaloid) is disproportionate to the concentration of the acids and salts, which in turn results in an astringent and bitter taste. The goal of coffee extraction is to maintain a balance between these two antitheses of solutes.

Coffee extraction is largely dependent on a multitude of factors, in which many are directly dictated by the preparation of materials and equipment used. One method of coffee extraction, the pour over method, involves pouring near boiling water on top of a bed of coffee grinds in a cone-shaped funnel, letting gravity pull water through the bed and into a carafe below. Factors that affect how much solids are extracted from the beans (total dissolved solids, i.e. TDS) are extensive, but can be broadly reduced to three overarching factors: contact time between the bean and solvent (in this case, water), how aggressive the solvent is, and the interface between the solvent and the beans. Certain extraction methods place more emphasis on one or two of these factors over the others based on the pour-over equipment geometry. For example, the TDS extracted through a Hario V60 Coffee Dripper (a standard piece of equipment used for pour-overs) is greatly affected by the interface between the water and beans. Because the dripper features a quarter-sized hole at the bottom, the rate at which water flows through the grinds (and thus the total contact time with the beans) is largely dependent on the grind size and consistency of the coffee grinds themselves. A larger grind size will allow water to flow through the cone quicker, resulting in under-extraction. Conversely, a smaller grind size will inhibit the flow of water, not only increasing contact time between the water and grinds. Both extremes of the spectrum are usually present in coffee extraction, as the the grind consistency of the beans is never uniform (ideally, there would be a gaussian distribution of grind sizes with a low standard deviation. Realistically, however, the distribution is typically bimodal). As the total surface area of the coffee grinds increases, the more solubles will be extracted from the beans. A smaller total surface area may be advantageous for some brewing methods (for example, full immersion methods require a coarser grind, as the relatively long steeping times would result in over-extraction). However, for V60, a consistent grind size in terms of uniformity and overall surface area is the sole factor in determining the rate of flow within the column, meaning that the grind is especially important in procuring a proper cup.

Different coffee grinders (both for commercial and consumer use) produce a wide range of grind sizes, consistency, and evenness in shape based on the tolerances of the equipment manufacturing and design of the grinder itself. In this lab, coffee grinds from four different grinders ranging from at-home use to commercial grinding were observed under a scanning-electron microscope (SEM) to evaluate the grind relative grind size distribution and morphology.

2 Procedure

Coffee grinds were obtained from four different grinders: Mahlkonig Guatemala, Bunn G1, Baratza Encore, and a Porlex JP-30. The Mahlkonig Guatemala and Bunn G1 are commercial grinders (the main differences being that they both have flat burrs to grind coffee in contrast to the conical designs of the Encore and JP-30 and that they are meant for continuous use with a higher RPM and horsepower motors) while the Baratza Encore and Porlex JP-30 grinders are consumer oriented. It is also worthwhile to note that the JP-30 is a manual hand grinder, while the other three are powered by an electric motor. All of the grinders were dialed in to grind beans to sizes suitable for the Hario V60 to ensure that the general parameters for each sample are consistent. SEM imaging was performed under a 15kV electron beam at magnifications of x30, x80, and x150. Observations of both grind morphology and relative sizes are noted, with any excessively small or large grinds recorded. Issues of confirmation bias and the limit on the scope of the study due to the equipment used is further discussed in detail later in the paper.

The preparations of the sample consisted of applying a layer of carbon tape onto the sample holder and then sprinkling the sample onto the specimen holder. The sample was then pressed onto the specimen holder with a spatula to ensure that none of the grinds would be removed from the vacuum pump in the SEM chamber. The use of a thin layer of gold from a sputter coater was initially suggested to improve the conductivity of the sample. However, initial images showed that because the Hitachi TM-3000 is an environmental SEM, charging of the sample was not an issue.

3 Data and Analysis

3.1 x30 Magnification

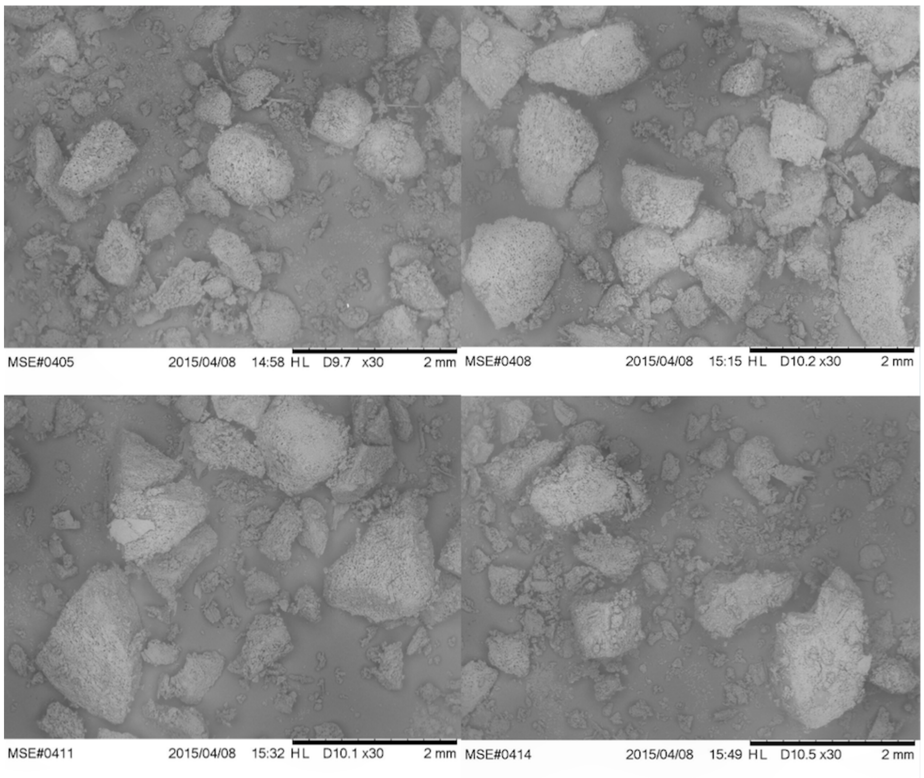

Figure 1: The sample viewed at x30 magnification. Upper left (UL): Mahlkonig Guatemala, upper right (UR): Bunn G1, lower left (LL): Encore, lower right (LR): JP-30.

The comparisons of the grinds from the different grinders are shown above. The data (at least quantitatively) suggests that the Mahlkonig Guatemala produced grinds with the most spherical shape; it can be seen from the x30 magnification that the average coffee grind is more spherical than that from other grinders. Based on the images, it can also be inferred that the particle distribution of the grinds from the Guatemala is more uniform than that of the others.

3.2 x80 Magnification

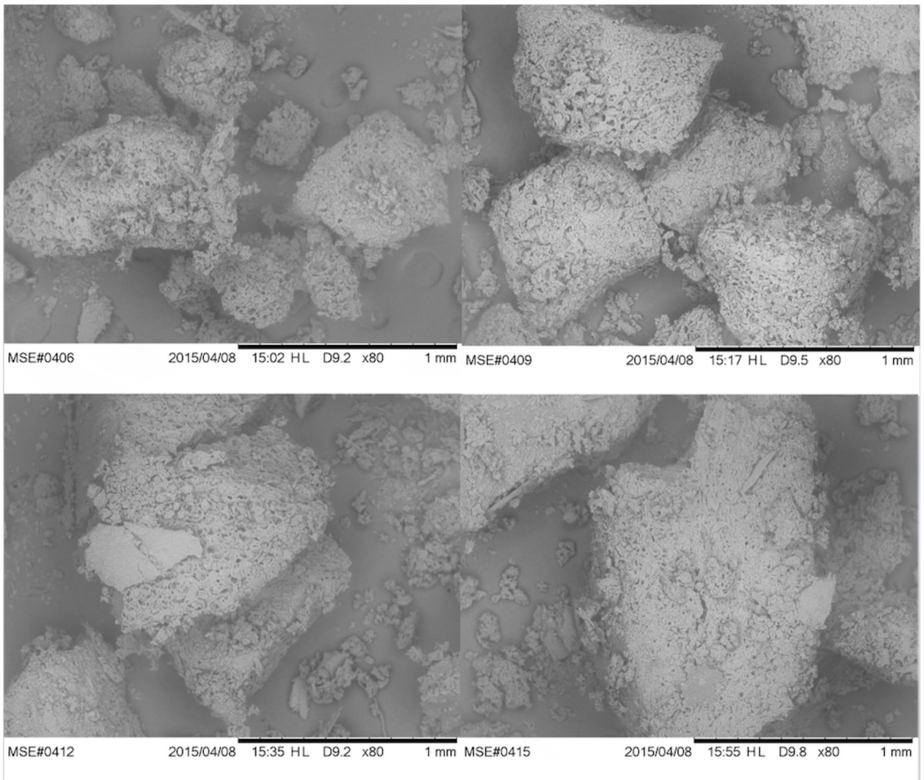

Figure 2: The sample viewed at x30 magnification. Upper left (UL): Mahlkonig Guatemala, upper right (UR): Bunn G1, lower left (LL): Encore, lower right (LR): JP-30.

The grinds of the Encore and JP-30 are noticeably more jagged and uneven in shape. The grinds from the Encore in the x30 image have long and relatively straight edges. The x80 images in Fig. 2 below are magnified on grinds of interest, in particular the defects and non-uniform grinds of each sample. The Guatemala has on average a more spherical shape for the grinds compared to the other samples. The finer grinds from the Guatemala sample, however, show a higher deviation from a spherical shape (though the amount of fines appears to be visibly less than other samples).

The particles shown for the G1 in this magnification are more uniform than those found in the Encore and JP-30, though also feature the longer straight edges of the particle instead of a flush round surface. The particle shown in the bottom right (JP-30) has the most aberrated edge, with a chip on the side of the particle. These particulates were common in the JP-30 sample, suggesting that the burrs on the grinder were unstable when the beans were grinded.

3.3 x150 Magnification

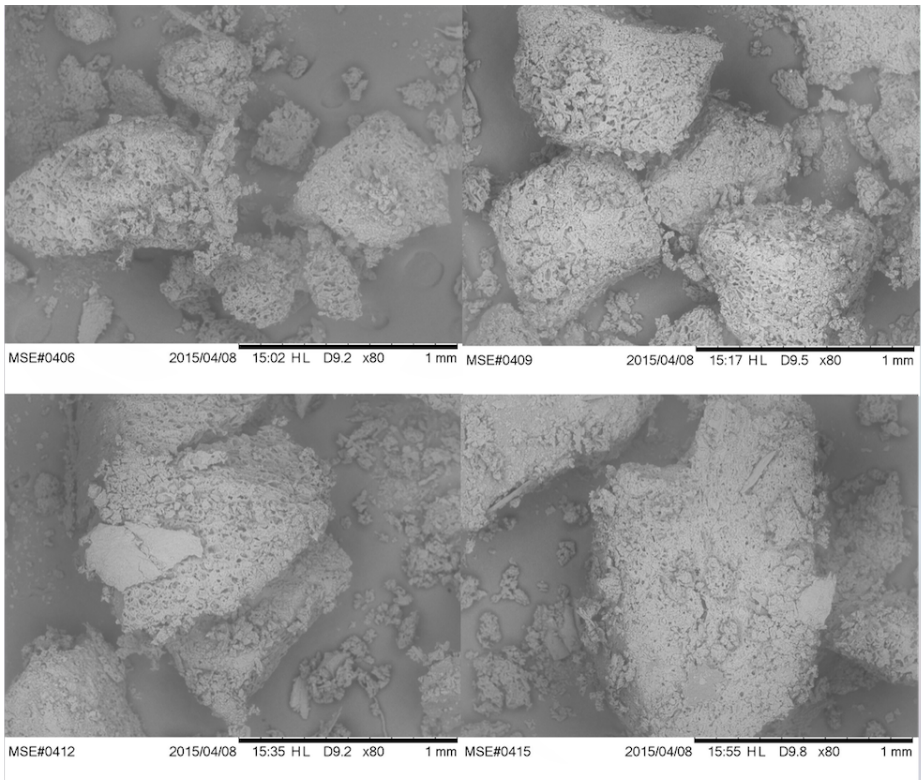

Figure 3: The sample viewed at x150 magnification around areas of interest. UL: Mahlkonig Guatemala, UR: Bunn G1, LL: Encore, LR: JP-30.

The grinds viewed at x150 magnification shows similar results of the x80 magnification, zooming in on the uneven portions of the samples. The particles from the Encore and Porlex shown, the edges of the particles are abrupt with a small radius of curvature; this suggests that the grinder applied uneven pressure on the bean when grinding. Other particles in the also Guatemala and G1 grinds display this feature (not pictured in the x150 magnification), but are less severe than those observed in the Encore and JP-30. It is worthwhile to note that although the edges on the upper right particle were similarly abrupt to those in the lower right and lower left images, the deviation in that particles radius was visually smaller.

4 Error Analysis

In analyzing error, it is important to consider the limitations of the instruments used and the qualitative nature of SEM imaging. The grinds are large enough (from around 100μm to upwards of 2000μm in diameter) in comparison to the magnification capabilities of the SEM that viewing a broad range of particles is difficult. This creates the problem that whatever portion of the sample viewed must be selected with forethought in that it must represent an average distribution of grind sizes in the sample. This raises issues with confirmation bias, as the grinds selected to be observed may be influenced by the expectations of the SEM operator. This problem was mitigated by surveying the total landscape of the sample and allowing multiple people to select the best represented section.

The sample preparation of the grinds may have also affected the distribution of the grinds in the image. When preparing the sample, the finer particles in the sample adhere to the carbon tape easier because the smaller particles have a larger surface area available for adhesion. Coating the carbon tape with this layer of fine particles makes sticking the larger particles in the sample more difficult, as not only is there less surface area on the particle to adhere to the carbon tape, the majority of the tape is stuck with the smaller fines. In future studies, a more mechanically stable method of adhering the samples to the specimen holder is recommended.

Another inherent limitation that arises from SEM imaging is that the instrument in this application can only be a qualitative analysis of the sample; energy-dispersive spectrometry (EDS) is not useful in this study because of the high concentration of organic compounds in the grinds. A more qualitative study of the grind consistency of the samples is best found by measuring the differential volume of the sample particulates. At best, the results presented can serve as a precursor observation to be confirmed by further research through differential volume analysis. Given the potentially significant results for this experiment, it is suggested that these measurements be taken for future study.

Lastly, the age of the coffee beans were grinded may have affected the grind size and consistency in all of the samples. After the initial roasting of a coffee bean, expelling much of its water content, the bean continuously absorbs more moisture as it is stored in an ambient environment. When a completely dry bean is roasted, geometric defects in the bean play a higher factor in how a bean will fail (or break into smaller pieces in this application) than the geometry at which the bean contacts the grinder. An older bean with a higher moisture could result in more moisture, reducing the chance of a bean cracking at an arbitrary plane from a microfracture and instead being ground more evenly.

5 Conclusion

Coffee grind samples from four coffee grinders (two commercial, two consumer) were analyzed under SEM to quantitatively evaluate their grind uniformity, evenness in shape, and morphology. It was found that out of the four samples, the grinds from the Mahlkonig Guatemala grinder featured the most uniformity in grind sizes and smallest deviation of radius in morphology. The sample from the Bunn G1 and Baratza Encore featured similar results in consistency and morphology, while the grinds in sample from the Porlex JP-30 were noticeably more erratic in size and oddly-shaped. It is suggested that the designs of the Guatemala, G1 and Encore grinders are more stable when grinding beans compared to the JP-30, which correlated with the visual data gathered in this study.

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References

[1] *Elements of Xray Diffraction*, B. D. Cullity and S. R. Stock, 3rd Edition, Prentice Hall: Upper Saddle River, NJ (2001).

[2] *Surface Area and Time*, Matthew Perger, The Barista Hustle, Melbourne, Australia (2015). `http://baristahustle.com/surface-area-and-time/`

[3] *The Most Important Thing About Brewing Coffee*, Matthew Perger, The Barista Hustle, Melbourne, Australia (2015). `http://baristahustle.com/the-most-important-thing-about-brewing-coffee/`

[4] *The EK43 Part Two*, Matthew Perger, Matt Perger, Melbourne, Australia (2014). `http://mattperger.com/The-EK43-Part-Two/.VPUSHZU5CM8/.VPVXg1PF9DU/.VS2zHxPF9XA#.VS74chPF9XA`

[5] *SCAA Brew Chart*, SCAA (2009). `http://www.mountaincity.com/images/SCAA_brew_chart.jpg`