Bettersize
BETTER PARTICLE SIZE SOLUTIONS

APPLICATION NOTE

Investigating the relationship between coffee extraction and ground coffee size

Shelly Zhang
Application Research Laboratory, Bettersize Instruments Ltd.

Introduction

Coffee is one of the most popular drinks sold worldwide and is brewed from processed and roasted coffee beans grown on a coffee plant. Coffee plants thrive in tropical areas near the equator called the bean belt. The production and consumption of coffee has been continuously increasing every year for the past decade. As of March 2021, the International Coffee Organization (ICO) estimates the global coffee bean production and consumption in coffee year 2020/21 will be 171.89 million and 164.5 million 60-kg bags of beans, respectively[1]. Assuming full consumption at an ICO-predicted unit price of 120.36 US cents/lb, the annual income from coffee beans will be 26.19 billion US dollars in coffee year 2020/21.[1] Coffee has an enormous and highly profitable market, leading to a rising emphasis on the qualities of coffee beans, ground coffee, and brewed coffee.

Raw coffee beans are first selected, processed, and roasted before they are ground and brewed. The bean roasting process is a series of controlled chemical reactions that bring out the effective substances of interest in raw coffee beans that provide the taste in coffee. These effective substances which contribute to the unique aroma and flavor in coffee are extracted by hot water during brewing. Extraction is a sophisticated process that involves many principles such as fluid dynamics, transport phenomena, and thermodynamics.

The effectiveness of coffee extraction during the brewing process depends on the particle size of the ground coffee, water-coffee ratio, water temperature, brewing time, and brewing method. Specifically, the size of ground coffee determines the length of extraction time, level of extraction, and the final characteristics of the brewed coffee. The Bettersize Laboratory conducted an experiment to investigate how particle size and size distribution of ground coffee affect the effectiveness of coffee extraction using laser diffraction instrument.

Measuring particle size distribution of ground coffee

Commercial roasted Arabica coffee beans harvested from Yunnan, China, were purchased as sample material in this experiment. The coffee from this region is within the bean belt like all others but is different from other coffees in the world in that it has a medium body, chocolate tones and is exceptionally smooth. The beans were ground and sieved into four categories: coarse, medium, fine, and extra fine using a coffee grinder and mesh sieves, as shown in Figure 1.

The instrument used to investigate the relative coffee particle sizes was the Bettersizer 2600 with the dry dispersion unit. The Bettersizer 2600 is a laser particle size analyzer that uses the unique Fourier and inverse Fourier optical systems, to provide accurate measurement results for particles with sizes ranging from 0.02 to 2600 microns (μm). The Bettersizer 2600 can produce results from both the dry and wet dispersion unit. However since flavor compounds would be extracted from ground coffee upon contact with water and potentially altering the particle sizes[2], the dry dispersion unit was used in order to ensure accurate results. All measurement were repeated for at least three times to minimize effects of random errors. Particle size distributions of the four grinds obtained from the Bettersizer 2600 are displayed in Figure 2 below.

Figure 1. Four grinds of ground coffees

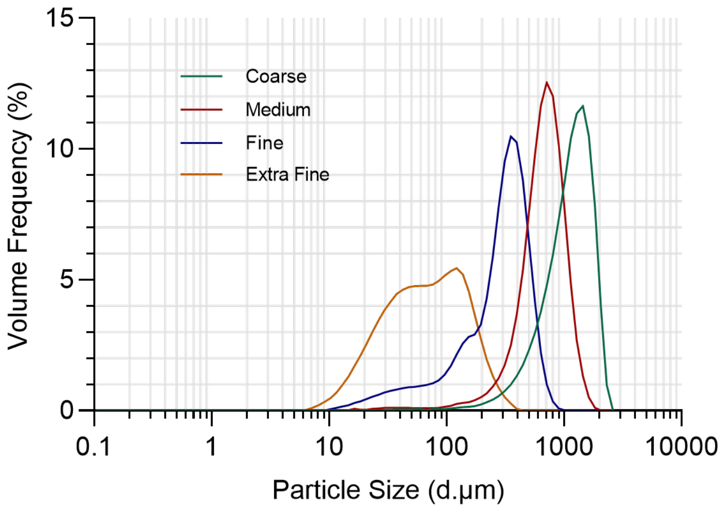

Figure 2. Particle size distributions of four types of ground coffee, obtained by the Bettersizer 2600

Figure 2 shows how the modes of four grinds of coffees locate further towards the fines when grinding level increases. It is obvious that the average particle sizes of ground coffee decreases from coarse grinds to finer grinds. The size distributions were relatively narrow except for the extra fine grind, which suggests that the presence of agglomerated coffee particles in the extra fine ground coffee. Finer particles have a larger surface-to-volume ratio, and hence higher surface energies which tend to agglomerate the finer particles into larger particles.[2] Figure 3 displays the D50s of the coarse, medium, fine and extra fine grinds in microns (μm) which were 1093, 623, 290, and 61, respectively. The results demonstrate the capability of the Bettersizer 2600 in accurately distinguishing and monitoring the particle sizes of ground coffees at different grinding levels.

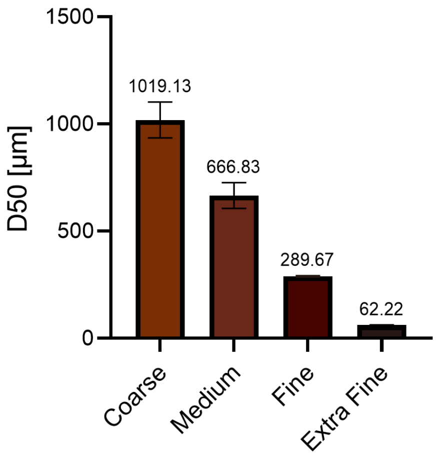

Figure 3. Average D50s of four types of ground coffees, with error bars displayed

Examining extraction level of brewed coffee

All four types of ground coffee were brewed to investigate how did the particle sizes affect the extraction. To ensure that the only variable affecting extraction level is the particle size of ground coffee, other brewing conditions such as the brewing method, the mass of ground coffee, the volume of water used, and the water temperature were all controlled to be identical. The Hario V60 pot was used as the pour-over brewing method in this experiment. The upper part of a Hario V60 pot was a conical cup containing ground coffee and filter paper. Hot water flowed through the cup and dripped to the pot under gravity. For this specific type of coffee beans, it was recommended that for every 8 g of ground coffee, 140 mL of water should be used to make a perfect brew. A balance was set up to ensure this preferred water-ground coffee ratio. The hot water temperature was maintained at 90°C using an electric water boiler with built-in temperature control and digital temperature display.

After obtaining different brewed coffees, they were poured into transparent glass cups to observe their colors, as shown in Figure 4 above. The coarse grind produced brewed coffee with the lightest brown color, where the coffee in the glass cup was still relatively clear, and the bottom of the cup was visible. As the grinds were getting finer / the particle sizes of ground coffees decreased, the colors of brewed coffees were gradually getting darker and darker. Eventually, the color of brewed coffee reached the darkest brown in the extra fine grind, where the liquid was no longer transparent, and the bottom of the cup could be barely seen.

The extraction levels of four types of brewed coffees were examined by measuring and comparing the brewed masses and the total dissolved solids (TDS) concentrations. TDS is a measure of how many solid contents are present in the liquid medium in units of parts per million (ppm), where 1 ppm suggests 1 mg of dissolved solids per kilogram of liquid. In this case, a higher TDS number indicates a greater amount of soluble contents from the coffee beans are present in the brewed coffee.

Table 1 summarizes that given the same amount of water was used for brewing, the masses of brewed coffees decreased when ground coffee sizes decreased. Also, the TDS values increased as grinds moved from the coarse end to the fine end, and the TDS concentrations were inversely proportional to the brewed masses. It was observed from Figure 5 that after brewing, the left-over coffee grounds of coarse and medium coffee grinds were still distinguishably separated from each other, whereas the fine and extra-fine particles were agglomerated and tended to move to the bottom part of the filter paper, forming paste-like mixtures.

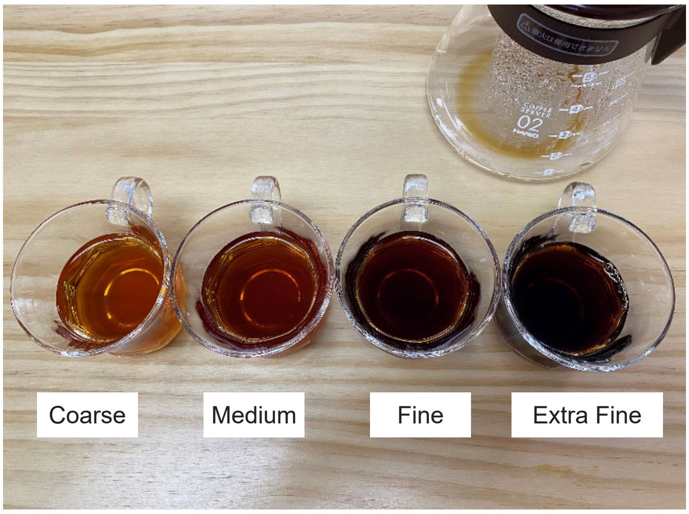

Figure 4. Brewed coffees of four grinds in glass cups

Table 1. Brewed mass and TDS results of four types of ground coffee

Grinds	Brewed mass [g]	TDS [ppm]
Coarse	128.01	541
Medium	124.03	757
Fine	118.27	1050
Extra Fine	119.65	1166

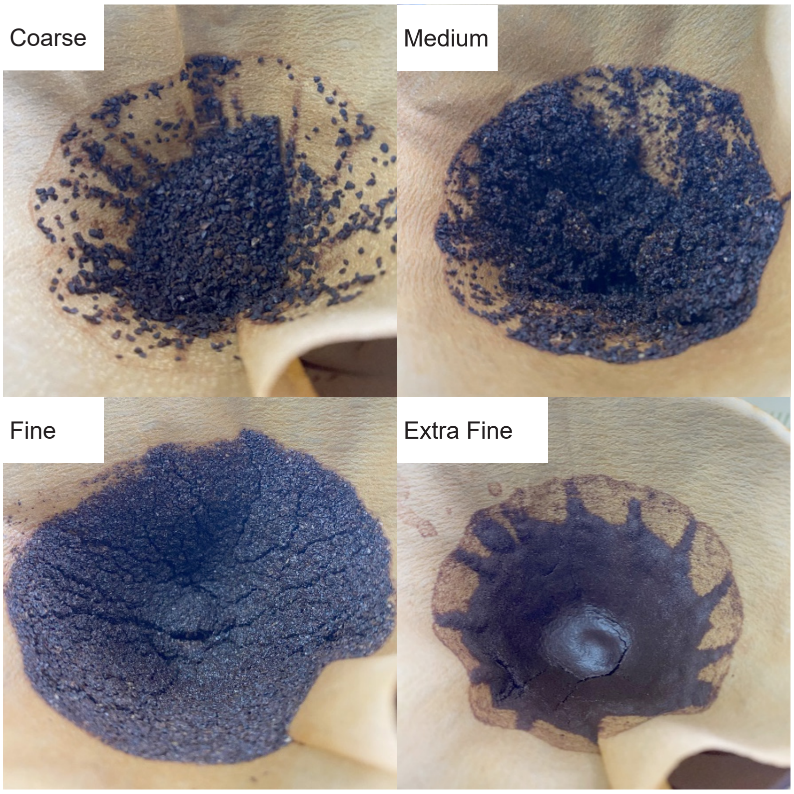

Figure 5. Coffee grounds of four grinds after brewing

The reason accounted for these observations is the particles' surface areas. Finer particles have larger surface areas, which allows them to have larger contact areas with hot water during brewing compared to coarse particles. Larger contact areas lead to a longer time in which hot water flows through the ground coffees, increasing the amount of water that will diffuse into and stay inside the coffee particles. Less water leaves the coffee particles and drips into the pot, resulting in the decrease in masses of brewed coffee for finer grinds. Consequently, greater extraction of effective substances from ground coffee, namely caffeine, are done in finer grinds[2].

Five colleagues in the Bettersize laboratory were asked to participate in a blind taste test of four types of brewed coffee to sensibly investigate coffee's extraction levels. It is worth noticing that a taste test is always subjective and the results only represent personal opinions regarding this specific type of coffee beans brewed by the pour-over method. According to colleagues who participated in the taste test, the coarse and medium grinds coffees were "bland, watery, lack of aroma", while the extra fine grinds coffee was "strongly acidic and bitter". The fine grinds coffee received most compliments because it was "just about right, closest to coffee from a coffee shop". The colors and masses of brewed coffees, along with the results from taste test and TDS measurements, reflected that the extractions of coarse and medium grinds were barely done, but the extra fine grinds were over extracted thus the strongly acidic taste and high TDS values and dark brown color. Given all other brewing conditions identical, particle sizes of ground coffees should be carefully controlled such that coffee with suitable extraction level could be produced.

Conclusions

Particle size and size distributions of ground coffee significantly affect the extraction level and the flavor quality of brewed coffee. In real-life practice, effects brought by particle size of ground coffee may be compensated by other variables such as brewing methods, brewing time, and water temperature. In order to explore the perfect combination between these variables to produce perfectly brewed coffee, monitoring the particle sizes and size distributions in ground coffees is necessary. The Bettersizer 2600 is a sophisticated and reliable instrument that provides particle sizing solutions to the coffee industries, including manufacturing coffee bean grinders, coffee machines, instant coffee, and packaged ground coffee.

References

(1) Coffee Market Report, March 2021. International Coffee Organization March 2021.

(2) Severini, C.; Derossi, A.; Fiore, A. G.; De Pilli, T.; Alessandrino, O.; Del Mastro, A. How the Variance of Some Extraction Variables May Affect the Quality of Espresso Coffees Served in Coffee Shops: Espresso Coffee and Its Quality. J. Sci. Food Agric. 2016, 96 (9), 3023–3031. https://doi.org/10.1002/jsfa.7472.

Bettersize
BETTER PARTICLE SIZE SOLUTIONS

Bettersize Instruments Ltd.

Further information can be found at

https://www.bettersizeinstruments.com

Email: info@bettersize.com

Address: No. 9, Ganquan Road, Lingang Industrial Park, Dandong, Liaoning, China

Postcode: 118009

Tel: +86-415-6163800

Fax: +86-415-6170645

Download Our Application Notes:

Visit Our Bettersizer 2600 Site: