lumero

New data insights in the subvisible world of coffee

New capability to measure the size of nanoparticles in complex mixtures

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Introduction

What do you usually do when you want to measure the size of nanoparticles in complex or multi-component mixtures?

One common scientific approach is to deconstruct a sample using a centrifuge to create a particle size gradient, and measure aliquots using Dynamic Light Scattering (DLS). To extract the smaller particles, the supernatant is taken and diluted - often by thousands or even millions of times - until the sample becomes optically transparent. Several millilitres are then placed in a cuvette for measurement with DLS. After waiting several minutes for the sample to equilibrate, measurements can begin.

At such high dilutions, the concentration of any large, numerically rare, particles have often been reduced to the extent that none are present in the measurement region; at best, they may appear sporadically, introducing uncertainty about the true particle content. Additional concerns arise regarding the impact of dilution on the particles themselves (e.g. due to dissolution or disassembly processes). Doubts arising around appropriate values for viscosity and refractive index can lead to further uncertainty, especially if these parameters are estimated rather than measured.

Moreover, measurements may miss crucial information if minima in the DLS form factor coincide with the particle size distribution [1]. There may also be concerns about particles absorbing light, which reduces scattering signal intensity. Collectively, these complexities introduce uncertainty and ongoing debate. How much time does this cost and how many questions remain unresolved?

The Lumero® simplifies particle size analysis, addressing these challenges directly. We demonstrate this using a familiar real-world example: coffee.

Two billion cups of coffee are brewed worldwide every day, making it the seventh most commonly traded commodity. From farmer to barista, approximately 150 people contribute to producing a single cup. However, the final stage is critical for capturing full flavour [2]. Much of our enjoyment arises from volatile organic compounds and bioactive substances (e.g. caffeine), so chemistry is crucial. However, it is well established that physical form, including size distribution, can make a large difference to sensory properties of food and drink [3]. Many coffee drinkers are aware that grind size influences extraction, but few consider the size of the particles which make it into the final cup - exceptions include Turkish and Greek coffee, which are intentionally prepared in a manner which allows particles through the filter to produce a distinctive texture.

Experiment 1: Freshly Ground versus Instant

Almost every coffee drinker can readily identify the difference between freshly ground and instant coffee. But is there a physical distinction between freshly prepared coffee from a coffee shop and instant coffee?

We investigated this using Lumero®. The volume-weighted particle size distribution shown in Figure 1 reveals that Nescafé Original decaffeinated coffee has an average particle radius of 669 nm and a polydispersity index (PDI) of 0.18. In contrast, an espresso obtained from Dolly's Café at the Roslin Innovation Centre has a significantly smaller average particle radius of 480 nm — approximately 30% lower — and a much broader polydispersity index of 0.34.

It is not surprising that the instant coffee exhibits a narrower size distribution, given that it is manufactured under highly controlled, consistent industrial processes. In comparison, the preparation of espresso involves greater variability and less processing after grinding, leading to a broader range of particle sizes.

The smaller particle radius measured for the espresso is critical to the overall sensory experience of a well-served coffee. Previous studies have demonstrated that coffee particles smaller than 800 nm in diameter (equivalently, a radius of 400 nm) enhance the surface tension at the water-air interface, thereby stabilising foam formation [4]. Furthermore, smaller coffee nanoparticles have been associated with improved aroma, taste, and overall sensory appeal [5].

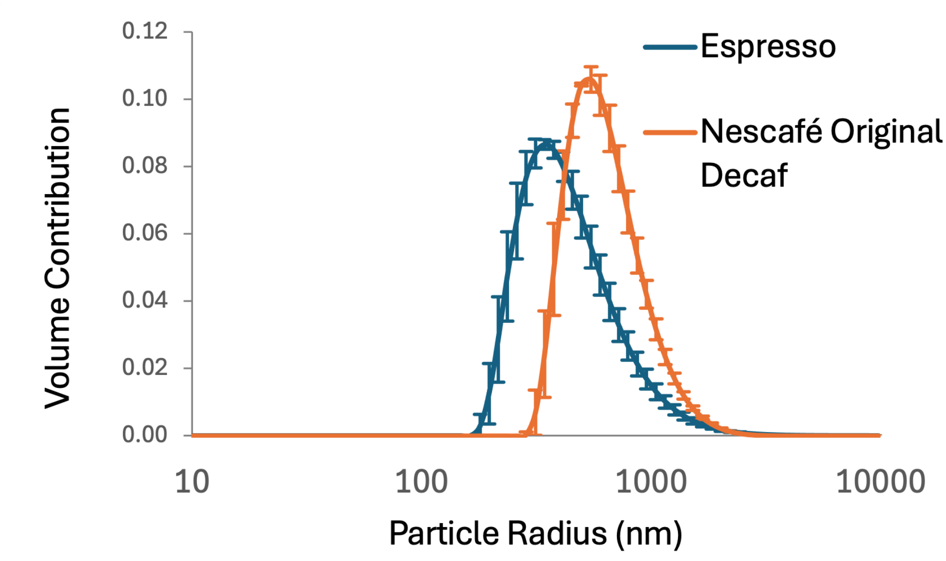

Fig 1. A single peak is observed for each of Nescafé Original (decaffeinated) instant coffee and espresso from Dolly's Café, showing mean particle radii of 669 nm and 480 nm, respectively.

Experiment 2: Comparison of Flat White and Espresso

A flat white was purchased at the same time as the espresso from Dolly's Café. The same machine and preparation process were used to grind the coffee, after which semi-skimmed milk was steamed and poured over the espresso to create the flat white.

Similar to the espresso, the flat white exhibits a "coffee granule" peak with an average particle radius of 417 nm and a polydispersity index (PDI) of 0.21. This peak is slightly smaller than that observed for the espresso, potentially due to the presence of small homogenised fat droplets, which shift the distribution towards smaller particle sizes.

A second, much smaller peak is observed with a mean radius of 82 nm, indicating the presence of casein micelles within the flat white. These are known to typically fall within the range of 25-100 nm [6], and are expected to dominate the particulate content of semi-skimmed milk.

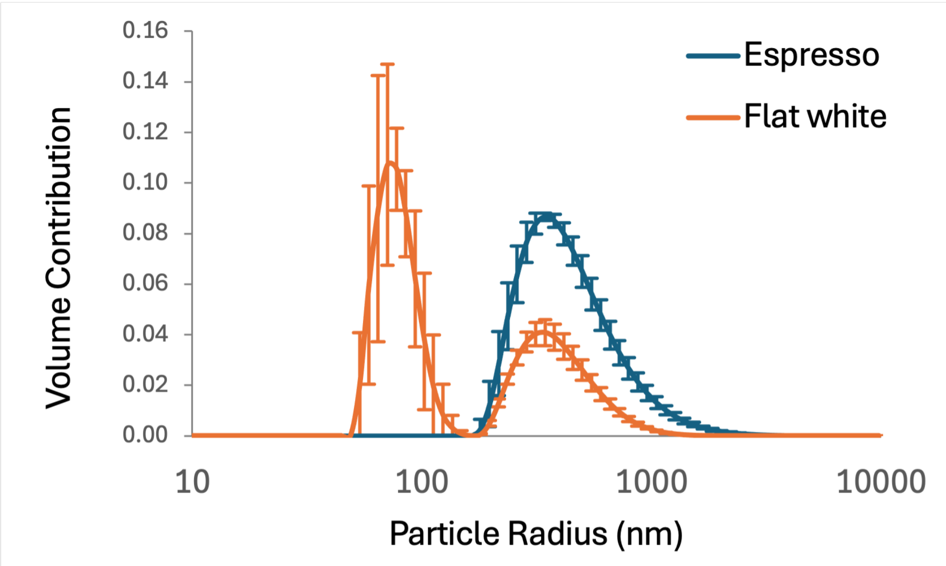

Fig 2. A flat white prepared by adding semi-skimmed milk to espresso shows a second peak with a mean radius of 82 nm, revealing the presence of casein micelles alongside the coffee particles (around 400 nm radius).

Experiment 3: Flat White Comparisons

Not all flat whites are the same. A flat white made with semi-skimmed milk is compared with a "skinny" flat white purchased from Costa Coffee, which is prepared using skimmed milk. In the UK, semi-skimmed milk typically contains up to 1.8% fat, whereas skimmed milk contains less than 0.1% fat.

The peak associated with the coffee particles in the skinny flat white has an average radius of 402 nm and a polydispersity index (PDI) of 0.27, which is generally consistent with the peak of the coffee granules measured for the flat white Dolly's Cafe (average radius 417 nm, PDI 0.21). This suggests that the coffee component remains similar between the two preparations despite being from different vendors.

In contrast, the smaller peak associated with casein micelles has an average radius of 56 nm, which is 24 nm smaller than the corresponding peak observed in Dolly's flat white. This difference is likely a result of the more intensive skimming process, which preferentially removes larger particles such as fat droplets and micelle aggregates.

The data also indicates that a significant proportion of the particle volume in the flat whites are composed of casein micelles. Specifically, 82% of the volume-weighted particle size distribution is attributed to the micelle peak in the skinny flat white, compared with only 60% for Dolly's flat white made with semi-skimmed milk. This difference likely arises because the additional fat in the semi-skimmed milk contributes substantially to the larger particle peak in the semi-skimmed flat white. Note that we have not weighted each component by its refractive index so whilst the change is representative of real differences and the systems can be compared, the numbers provided should not be taken as the absolute composition.

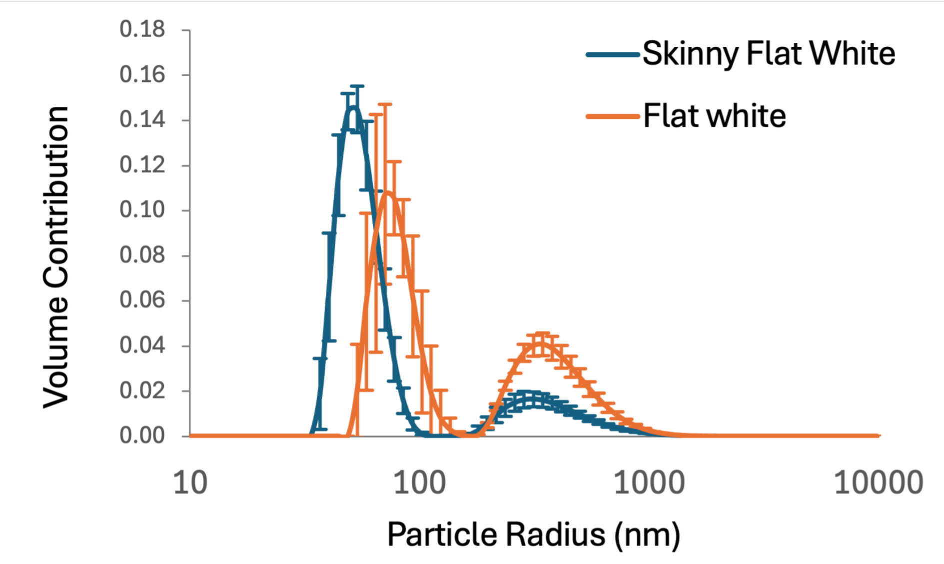

Fig 3. A skinny flat white (made with skimmed milk) bought from Costa Coffee is compared with a flat white (semi-skimmed milk) from Dolly's Café. The smaller peak has an average radius of 56 nm for the skinny flat white, considerably smaller than the radius of 82 nm measured for a standard flat white.

Why Are These Results Important?

Nano-scale detection in complex samples

Lumero® enables the resolution of small structures such as casein micelles, even in the presence of larger, optically complex particles such as coffee granules. The ability to quantify the contributions of distinct particle size populations provides valuable insight into the internal structure and composition of complex, real-world samples.

Broad concentration range

Reliable measurements can be performed across a wide range of sample conditions, from optically clear to highly opaque and even coloured solutions. This removes the need for extensive dilution protocols and allows analysis of samples in states that are closer to their native conditions.

Ease of use

Measurements are straightforward and can be performed by non-experts using portable instrumentation. No specialised sample preparation, protocol development, or optimisation is required, significantly reducing experimental complexity and time.

About Lumero®

The Lumero® particle size analyser utilises Dyneval's proprietary VISTA (Video Intensity Spatio-Temporal Analysis) algorithm to determine particle size distributions through the from fluctuations in light intensity in a microscopy video. The only required input from the user is the viscosity of the medium. This approach enables the measurement of a wide variety of particle types, including transparent, coloured, and opaque systems.

Methods

Coffee obtained from the reported outlets were diluted with water to approximately 10-20% of their original concentration, in order to minimise particle-particle interactions. Average particle radii and standard deviations of the volume-weighted distributions were calculated from a sequence of 3-5 measurements.

For each measurement, $3\,\mu$L of sample was loaded into a sample chamber and maintained at $25\,°$C throughout the analysis.

Want to know more?

Get in touch with our team via contact@dyneval.com to explore how the Lumero® can solve your particle sizing challenges.

For more info visit www.lumerotech.com

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