Bruker minispec Droplet Size Analyzer: bringing fast and reliable analyses to food manufacturing quality control

THE DROPLET SIZE in emulsions plays a major role in developing and producing foods such as mayonnaise and margarine because of its influence on key product characteristics, including stability and rheology. This Application Note describes how the Bruker minispec Droplet Size Analyzer 2.0 uses time-domain nuclear magnetic resonance (TD-NMR) to help food scientists understand the size distributions to improve quality control processes and support new product development.

Introduction

Emulsions are dispersions of droplets of one liquid phase (the disperse phase) and in another liquid phase (the continuous phase), which are not miscible or soluble, usually produced with an emulsifier to hold the droplet distribution and prevent separation of both phases into separate layers. They can be found in a variety of foods, including oil-in-water emulsions such as mayonnaise and milk and water-in-oil emulsions such as margarine and butter.

A fundamental characteristic of any emulsion is the droplet size because this affects many of its properties. Droplet size plays a crucial role in emulsion stability, which in turn impacts product shelf-life. Stability is improved by smaller droplet sizes, which results in a reduced tendency for the droplets to coalesce or to separate gravitationally, giving the product a longer shelf-life.

Droplet size is also important in emulsion rheology – with smaller droplet sizes giving higher viscosity – to determine the consistency and spreadability of the final product. Other properties of emulsions that are influenced by droplet size include mouthfeel, the ability to release flavours, overall appearance and colour, and the ability to sustain bacterial activity. The droplet size distribution characteristics must be regularly checked during production quality control to ensure that the end product presents the desired characteristics.

Understanding the droplet size distribution in a food product is essential not only to support quality control but also to accelerate the development of new formulations with targeted properties.

Methods for analysing emulsion droplet size

Three methods are widely used to investigate droplet size distributions in emulsions: dynamic light scattering, optical microscopy, and TD-NMR.

Dynamic light scattering and microscopy typically require sample dilution, which, besides being labour-intensive, presents a significant risk of disrupting the existing droplets, leading to unrepresentative results.

In addition, dynamic light scattering does not discriminate between single and clustered droplets and any solid particles or air bubbles present in the sample affect the results. For opaque samples, it can only provide information about the emulsion fraction near the surface, potentially making the results less representative. Optical microscopy remains an inherently destructive technique, and even constraining the sample between a microscope slide and the cover slip can physically damage the specimen.

TD-NMR provides improved precision to overcome these limitations (**Figure 1**). A key advantage of TD-NMR is that sample preparation is reduced to a minimum, without requiring any sample alteration or dilution. Furthermore, the entire sample is considered in the analysis, irrespective of colour or morphology, and without the interference of any non-magnetic particles or air bubbles. TD-NMR also measures droplet size rather than cluster size, meaning that droplet aggregation does not skew the final distribution. The technique is also non-destructive, allowing a sample to be analysed multiple times.

TD-NMR with the Bruker minispec Droplet Size Analyzer 2.0

Bruker's minispec Droplet Size Analyzer 2.0 performs rapid and reliable TD-NMR analysis of food samples. Measurements can be carried out quickly, typically in 4–15 minutes, and TD-NMR has the lowest cost of ownership per measurement of all existing methods.[1]

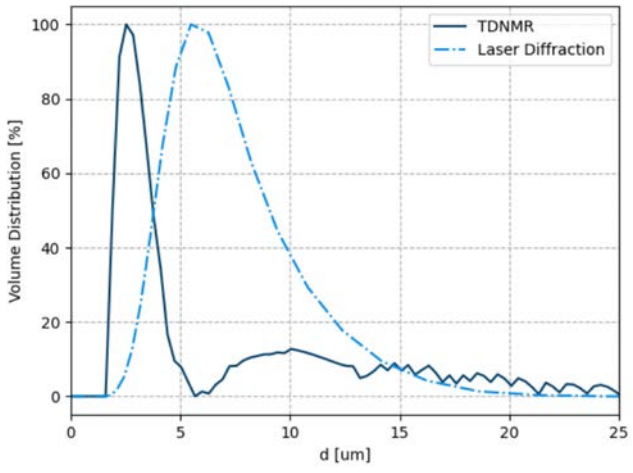

Figure 1: Dataset comparing TD-NMR and laser diffraction results

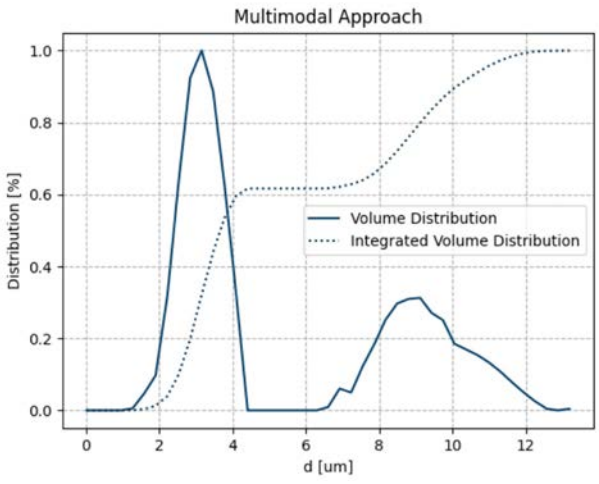

Figure 2: Dataset showing multimodal droplet size distribution

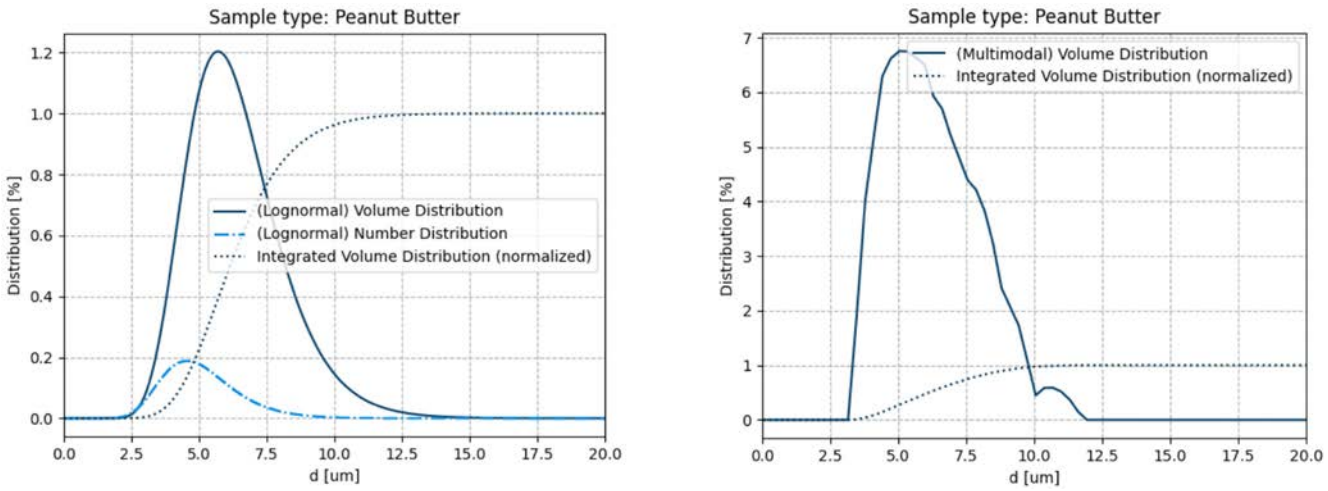

Figure 3: Dataset showing the droplet size as volume and number (only for lognormal fitting) fraction

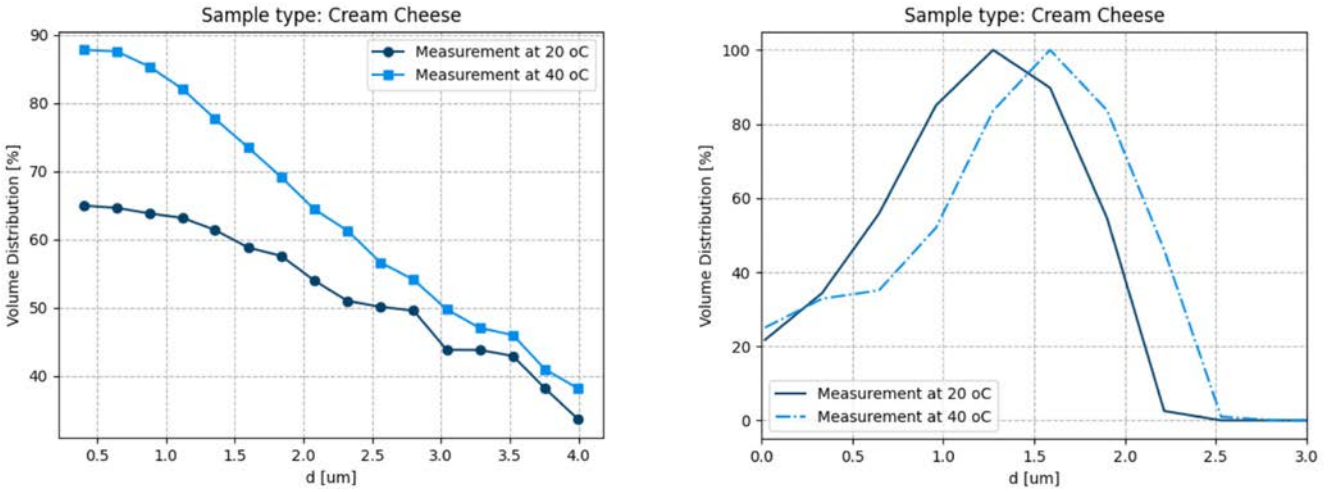

Figure 4: Dataset showing results obtained at different temperatures

TD-NMR provides results with low-field permanent magnets in a compact benchtop instrument. The new Droplet Size Analyzer 2.0 also offers a new user interface, GoScan for minispec, which offers intuitive experiment setup, real-time data acquisition, and improved data analysis. This affords users the option to characterise multimodal droplet size distribution, and further improve the results for unimodal distributions where a lognormal shape is assumed.

TD-NMR applications

A major application of TD-NMR in emulsion-based foods is the determination of droplet size distribution, with typical values of approximately 1–30µm for a water-in-oil emulsion and 0.5–20µm for an oil-in-water emulsion. One advantage of the new GoScan software is that assumptions about the form of the distributions are no longer needed: previous software versions assumed a log-normal distribution, which was not applicable for all emulsions. GoScan allows for multimodal droplet size distribution analysis (**Figure 2**), which can occur due to inconsistencies in processing conditions, for example. The log-normal distribution approach also comes with improvements in GoScan as normalisation by area and the possibility to quantify the number of existing droplets as volume fraction (**Figure 3**).

The Bruker minispec Droplet Size Analyzer 2.0 allows the user to work at different temperatures, from 5°C to 50°C. Depending on the product characteristics (like viscosity and stability), performing the measurement at higher or lower temperature is recommended. For example, viscous samples like cream cheese are recommended to be measured at a higher temperature (**Figure 4**).

Conclusion

TD-NMR using the Bruker minispec Droplet Size Analyzer 2.0 offers food manufacturers a straightforward and accurate way to obtain droplet size distributions within a range of emulsions, providing important information on the likely effects on product stability and rheology.

In research applications, the system provides manufacturers with a tool to identify improved emulsion formulations and help bring new products to market faster. From a quality control perspective, TD-NMR is a rapid and cost-effective way to check that product samples meet required parameters.

Reference

1. Droplet size analysis: Droplet size distribution analyzer [Internet]. [cited 2023 May 16]. Available from: https://www.bruker.com/it/products-and-solutions/mr/nmr-food-solutions/droplet-size-distribution-of-oil-in-water.html.