

Hyperspectral Imaging: "Night Vision" that unlocks emulsion stability monitoring in complex systems.

Simon Müller^{1,2}, Josep Busom Descarrega¹, Ciara Byrne¹, Peter Fisher², Tim J Wooster¹

¹Nestlé Research, Institute of Food Sciences, Lausanne, Switzerland

²ETH Zürich, Department of Health Science and Technology, Laboratory of Food Process Engineering, Zurich, Switzerland

timothyjames.wooster@rdls.nestle.com

The advance of AI and digital technologies promises a new evolution to unlock understanding in complex colloid systems. Whilst there has been much focus on AI algorithms, there are impressive developments in new sensing technologies. Hyperspectral imaging with its near infrared wavelengths overcomes multiple scattering enabling detailed study of complex colloidal systems. Maintaining the stability of emulsion based products - such as coffee creamers and nutritional beverages - is critical for consumer trust and global distribution. Yet, conventional light-scattering methods fail to detect early-stage defects in concentrated systems. This work introduces hyperspectral imaging (400–1700 nm) as a transformative, non-destructive tool for real-time stability monitoring. By capturing spectral fingerprints across visible and short-wave infrared regions, we quantified fat volume fractions (1–62.5%) and tracked structural changes during creaming and acid-induced aggregation. Key wavelengths (975 nm and 1525 nm) emerged as high-sensitivity markers for dilute and concentrated regimes, enabling precise detection where traditional methods plateau. Using these new spectral finger prints we were able to study the destabilisation dynamics of concentrated emulsions and show that they diverge from Stokes' predictions at high packing densities, revealing complex dynamics beyond viscosity effects. In dilute emulsions, aggregation altered reflectance signatures, offering a novel pathway for kinetic monitoring. These findings position hyperspectral imaging as a next-generation quality control technology—combining chemical insight with spatial resolution to predict defects before they become visible. This approach opens new horizons for studying the dynamics of concentrated colloidal systems and especially when combined with automation and AI spectral analysis.

Keywords:

Hyperspectral imaging, multispectral imaging, emulsion stability, creaming kinetics, near infrared spectroscopy.

Acknowledgements:

This work was funded by Nestlé SPN who is a manufacturer of packaged foods products where the contents of this research can be used.