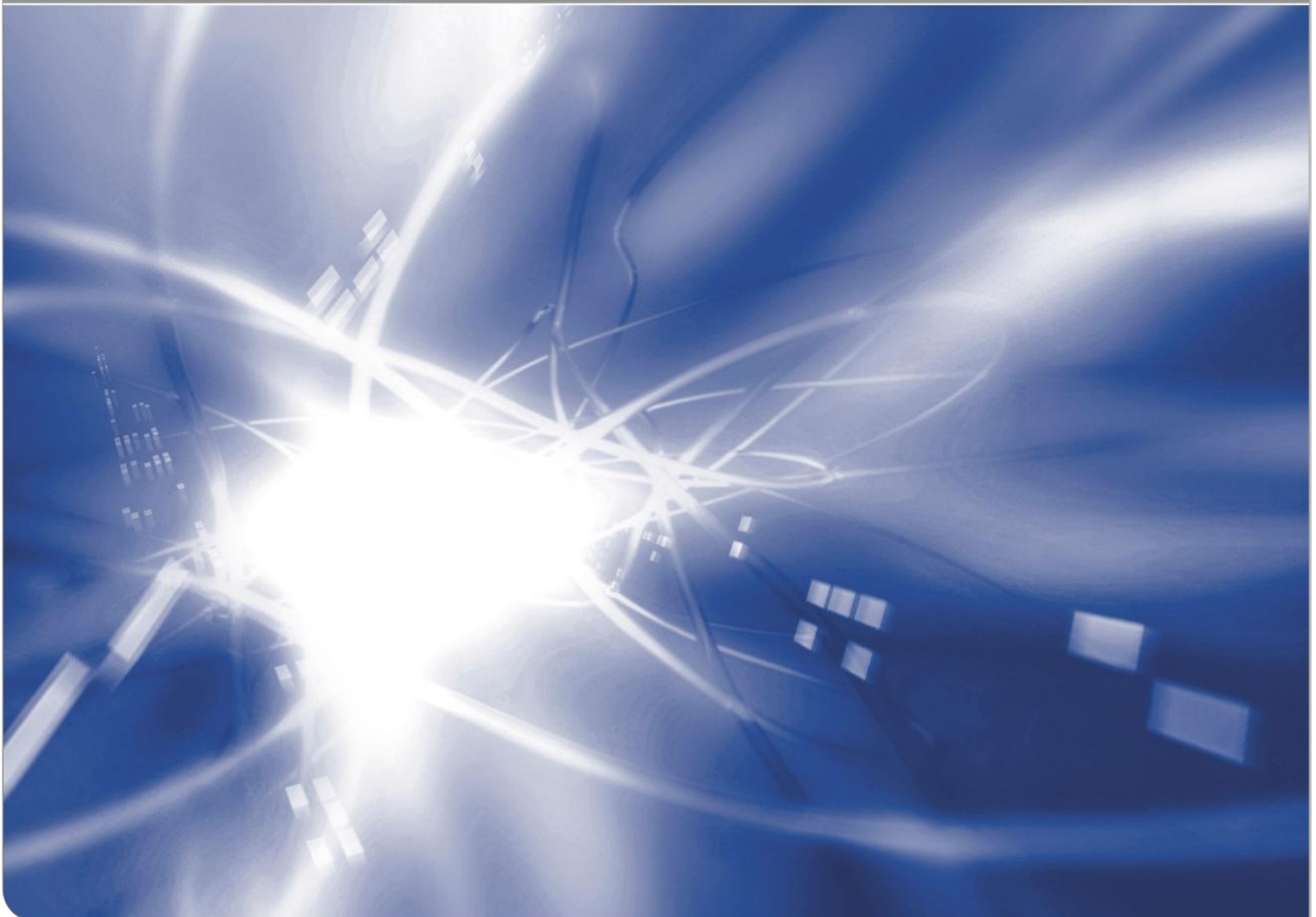


Using the ShearJet® HL60 V2 high-pressure homogenizer for the emulsification and dispersion of food matrices

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Use of high-pressure homogenizers in food applications

High-pressure homogenization is one of the most versatile and widely used processes in the food industry. It enables the fine dispersion and/or disruption of liquids and (soft) solids within a continuous liquid phase under high pressure. Typical food products processed in high-pressure homogenizers on an industrial scale include milk and plant-based milk alternatives, fruit juices, and beverage emulsions. In the case of fruit juices, homogenization is applied to break down pulp fibers and finely disperse them within the surrounding aqueous medium. Beverage emulsions, on the other hand, undergo emulsification, where a hydrophobic oil phase is dispersed into much smaller droplets stabilized within an aqueous phase. Such products are often heated prior to homogenization—as in the case of milk—resulting in a process known as melt emulsification, in which the dispersed oil phase is liquefied before homogenization to facilitate its fine dispersion. When such processes are studied under laboratory conditions—for example, to investigate ingredient functionality or formulation effects—lab-scale homogenizers can be limited by the sample quantities required. This is where the ShearJet® HL60 V2 high-pressure homogenizer offers distinct advantages. Its small dead volume, low required sample volume, defined number of homogenization strokes, and Luer lock connectors enable efficient processing of very small sample amounts. This makes it particularly suitable for studying process–formulation interactions on a laboratory scale. The present application note demonstrates the use of the ShearJet® HL60 V2 high-pressure homogenizer for the emulsification and dispersion of representative food matrices, illustrating the use cases described above.

Production of aroma oil emulsions and transferability to other high-pressure homogenizers

Background

Gum Arabic (GA) is a tree exudate extracted from acacia trees. It is used in processed form as a hydrocolloid or additive (E414) due to its outstanding techno-functional properties. It has been demonstrated that, among other properties, GA from Acacia Senegal exhibits a high emulsifying capacity, while at the same time maintaining a very low viscosity in aqueous solution. This combination makes GA especially suitable for stabilizing concentrated aroma oil emulsions, which represent the first step in the production of soft drinks. In such concentrated beverage emulsions, the aroma oil droplets need to be stabilized against coalescence through the adsorption of GA at the oil-water interface while ensuring that the emulsion droplet size does not exceed 1 μm . However, as a plant-based raw material, the quality of GA can vary significantly in terms of its functional properties, depending on its geographical origin and growing conditions. In order to evaluate the quality of different GA batches small emulsion samples can be prepared using the different GA samples for stabilization. In the present study, the objective was to reduce the required GA sample quantity. To achieve this, the emulsification performance of different homogenizers was compared to verify whether the devices could be used interchangeably for such evaluations.

Experimental

Aroma oil-in-water emulsions were prepared by dispersing weighted orange oil in a Gum Arabic solution. To regulate the density of orange oil and water, glycerol ester was dissolved in the orange oil. The emulsion premixes were then dispersed at a speed of 10 000 rpm for two minutes, using a Ultraturrax T-25 digital high-speed mixer (IKA Werke GmbH und Co. KG, Staufen, Germany). Fine emulsions were produced by homogenizing the coarse emulsions with various high-pressure homogenizers at comparable pressure (800 bar or 12 kPsi, respectively) for two passages. The investigated high-pressure homogenizers comprised a) Microfluidizer M-110 EH, Microfluidics, Newton, Massachusetts, USA; b) HPH 2000/4-SH5, IKA® Werke GmbH und Co. KG, Staufen, Germany; c) ShearJet® HL60 V2 high-pressure homogenizer, Dyhydromatics LLC, Maynard, Massachusetts, USA. Each emulsion was prepared in triplicate. The droplet size distribution of the prepared emulsions was determined by static laser light scattering using a HORIBA LA-950 Particle Analyzer (Retsch Technology, Haan, Germany). The droplet size determination followed the Mie theory. All measurements were conducted in triplicate at room temperature. ¹

Results

Figure 1 shows the cumulative volume distribution Q_3 plotted against droplet size of the emulsions produced at comparable pressure. All three curves show a narrow, monomodal droplet size distribution with droplet sizes well below $1\ \mu\text{m}$. The droplet size distributions for the three high-pressure homogenizers overlap.

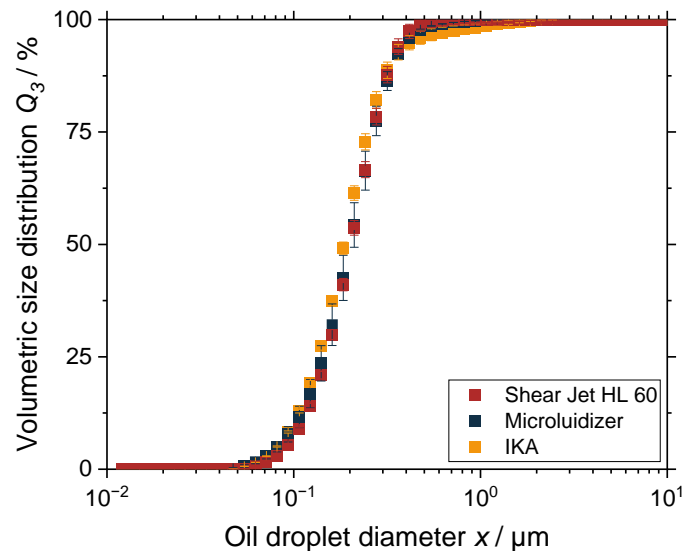


Figure 1: Plot of cumulative volume distribution Q_3 versus droplet size for one gum arabic sample. The emulsions were prepared with a 10 wt% Gum Arabic solution and 10 wt% weighted orange oil at 800 bar.

Conclusion

The ShearJet® HL60 V2 high-pressure homogenizer from Dyhydromatics was successfully used to produce aroma oil-in-water emulsions. The resulting droplet sizes show that the device is suitable to produce aroma oil emulsions with droplet sizes relevant for industrial applications. Furthermore, the droplet size distribution showed that the ShearJet® HL60 V2 high-pressure homogenizer can be used interchangeably with the other two high-pressure homogenizers.

Production of emulsions with increased disperse phase content

Background

The creaminess of emulsion-based food products is closely related to both the amount of dispersed oil and the size of the oil droplets^{2,3}. Higher dispersed-phase contents and smaller droplet sizes generally enhance the perceived creaminess. However, these same characteristics also lead to an increase in the viscosity of the emulsion.

When emulsions contain more than 50 % dispersed phase and droplet sizes below $1\ \mu\text{m}$, their viscosity can become so high that processing with high-pressure homogenizers becomes

challenging ⁴. In addition, such systems are more prone to droplet coalescence, making stabilization difficult.

Experimental

To prepare a high viscous model food emulsion, a pre-emulsion was produced first. To do this, tap water was mixed with 5 wt% Tween 20 (Carl Roth GmbH + Co. KG, Karlsruhe, Germany), a fast adsorbing emulsifier. Then, 60 wt% canola oil (Bröckelmann + Co - Olmühle GmbH + Co, Hamm, Deutschland) were added and the liquids were pre-emulsified with a Ultraturrax T-25 digital high-speed mixer (IKA Werke GmbH und Co. KG, Staufen, Germany) at 5200 rpm for 5 minutes. Fine emulsification was then carried out with a ShearJet® HL60 V2 high-pressure homogenizer (Dyhydromatics LLC, Maynard, Massachusetts, USA) at a pressure of 345 bar in a single pass.

Results

As can be seen in Figure 2, the procedure described above resulted in a monomodal droplet size distribution with droplet sizes below 10 μm . The average Sauter diameter was 2.1 μm . The resulting emulsion appeared stable without any indication of creaming or overprocessing. Processing was smooth without any clogging effects or inhomogenous pumping despite the resulting high viscosity that was comparable to mayonnaise.

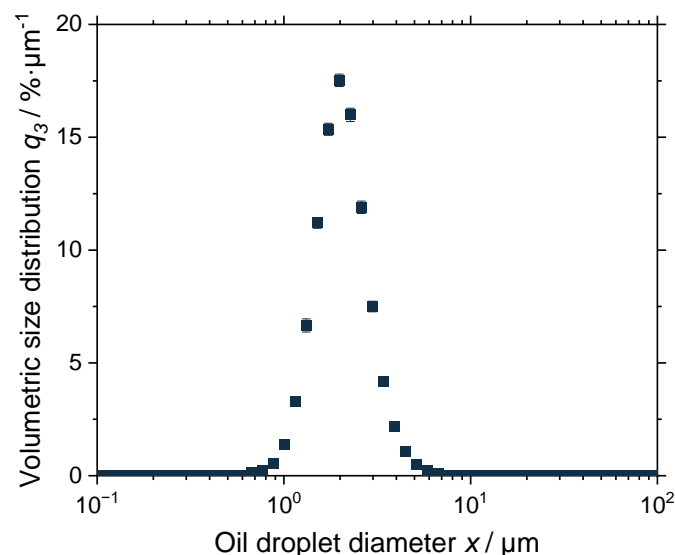


Figure 2: Plot of volume density distribution versus droplet size of the emulsion produced immediately after fine emulsification.

Conclusion

The ShearJet® HL60 V2 high-pressure homogenizer from Dyhydromatics is well suited for fine emulsification of emulsions with dispersion phase contents of up to 60 %, and also impresses with its extremely intuitive handling and time-saving cleaning.

Melt emulsification experiments

Background

Milk and dairy products consist of butterfat (triglycerides, according to IUPAC: triacylglycerols, or TAG for short) which is emulsified in a protein-rich continuous phase. In milk production, the butterfat-rich cream is first heated to 50–75 °C to melt the triglyceride mixture and then homogenized. The aim here is to break up the droplets in order to achieve a homogeneous and smaller droplet size distribution than initially present. After high-pressure homogenization, the cream can be diluted with whey to achieve the final desired milk fat content. In the presented study, the aim was to increase the fat content of a given milk. For this, butterfat was added to a commercial milk and homogenized. In this process, the additional butterfat will be stabilized by whey proteins present in the continuous aqueous phase. However, if stabilization of the butterfat does not occur fast enough, e.g. due to slow sample processing, butterfat can cool down leading to recrystallization and lump formation.

Experimental

To produce the melt emulsions, butterfat was heated to 60 °C and dispersed in heated milk using an Ultraturrax T-25 digital high-speed mixer (IKA Werke GmbH und Co. KG, Staufen, Germany) at 15 000 rpm for 1 min. The coarse emulsion was then homogenized with a ShearJet® HL60 V2 high-pressure homogenizer (Dyhydromatics LLC, Maynard, Massachusetts, USA) tempered to 60 °C at 345 bar.

Conclusion

The temperature control of the high-pressure homogenizer was sufficient to prevent crystallization of the butterfat in the pipes and blocking of the high-pressure homogenizer. Due to the potential for connecting a heat exchanger, as well as the short transport distances and low volumes, melt emulsification tests can be carried out with the ShearJet® HL60 V2 high-pressure homogenizer without the need for additional heating coils.

Production of model oat drinks

Background

For the production of plant-based milk alternatives, high-pressure homogenization is a critical processing step for achieving products with a uniform droplet size distribution and enhanced emulsion stability. Among the most popular milk alternatives are oat drinks, which have the advantage of being regionally sourced and free from strong aftertastes. Oat drinks are colloidal systems prone to instability phenomena such as sedimentation, especially due to the presence of insoluble solid components. By reducing the particle size, high-pressure

homogenization can help to improve emulsion stability, shelf life and sensory attributes. The effects of the processing steps heating and high-pressure homogenization on emulsion and foam stability of oat drinks are currently under investigation. For this, lower pressures as typically used industrially in milk homogenization processes are of interest.

Experimental

In a pilot test, oat syrup (provided by an industrial manufacturer) was dispersed in water at pH 7 to create a model oat drink. An emulsion containing 3 wt% sunflower oil was prepared. Homogenization was performed using the ShearJet® HL60 V2 high-pressure homogenizer (Dyhydromatics LLC, Maynard, Massachusetts, USA). The high-pressure homogenizer is typically operated at pressures between 5–30 Kpsi (345–2068 bar). After consultation with the manufacturer, the equipment was also used successfully at a lower pressure of 200 bar. The touchscreen control enabled easy and precise pressure adjustments. Operating below the conventional high-pressure range of the homogenizer did not negatively affect product stability or appearance.

Conclusion

This pilot test demonstrated that the ShearJet® HL60 V2 high-pressure homogenizer from Dyhydromatics is well suited for producing oat-based beverages with a uniform particle size distribution. Its precise pressure control enables operation at lower-than-typical pressures when carefully monitored, thereby extending the demonstrated range of pressure applications for the device.

Preparation of pectin-based microgel particles

Background

From a macroscopic perspective, a gel is a state of matter characterized by a three-dimensional network of structure-forming elements such as polymer chains that encloses solvents ⁵. If such a network structure is formed at the microscopic level, it is referred to as a microgel ⁶. One method for producing a microgel involves breaking down macroscopic gels into particulate structures, whereby the network within the particles is preserved ⁷. The resulting microgel particles (MGP) are dispersed in a solvent and thus form a colloidal dispersion (or suspension) ⁶. MGP are swollen by the solvent and range in size from 10 to 1000 nm ⁶. Due to their deformability, surface activity, reversible swelling capacity, and reactivity to pH and temperature, biopolymer-based MGP are widely used in the stabilization of emulsions and other complex food systems ⁶. One possibility is using pectin-based MGP ^{8–11}.

Experimental

Low methylester sugar beet pectin was provided by Herbstreith & Fox GmbH & Co. KG (Neuenbürg, Germany). According to the manufacturer, the pectin exhibited a degree of esterification of 39 wt%, a degree of acetylation of 5 wt%, and a galacturonic acid content of 65 wt%. To prepare a 2 wt% pectin solution, 98 g of demineralized water was added to 2 g of pectin. The suspension was heated to 70 °C while stirring with an IKA C MAG HS 7 magnetic stirrer (IKA Werke GmbH & CO. KG, Staufen, Germany) until the pectin was completely dissolved, and then cooled to room temperature. A 40 mM CaCl₂ solution was dispersed in a 600 mL beaker using an Ultraturrax T-25 digital high-speed mixer (IKA Werke GmbH und Co. KG, Staufen, Germany) at 13.000 rpm, with the pectin solution added in a volume ratio of 1:1. After complete addition, the suspension was dispersed for another 3 minutes under the same conditions. The resulting 50 wt% MGP suspension was diluted with demineralized water to obtain a 5 wt% MGP suspension. This 5 wt% suspension was subsequently homogenized. One suspension was produced by homogenizing twice at 621 bar using a ShearJet® HL60 V2 high-pressure homogenizer (Dyhydromatics LLC, Maynard, Massachusetts, USA), while another suspension was prepared by homogenizing twice at 600 bar using a Microfluidizer Processor M-110 EH (Microfluidics, Newton, Massachusetts, USA). The particle size distribution of the MGP was determined by static laser diffraction using a HORIBA LA-950 particle analyzer (Retsch Technology, Haan, Germany) equipped with a flow cell. The scattered light was measured by detectors and the particle size distribution was calculated using Mie theory. Measurements were made in water with a refractive index of 1.547 for the MGP. The particle size distribution was determined in triplicate at room temperature.

Results

The particle size of MGP suspensions is crucial, as it directly influences their functional properties. Therefore, it is important to produce MGP suspensions with a uniform particle size. One possible approach to achieve this is the use of a high-pressure homogenizer.

Figure 3 shows the particle size distributions of the MGP suspensions prepared using the ShearJet® HL60 V2 high-pressure homogenizer and the Microfluidizer processor. In both cases, a similar particle size distribution was obtained. Minor deviations between the curves can be attributed to the assumption of spherical particles in the calculation of particle size. Since the production process does not yield perfectly spherical particles, slight differences in the curve profiles are expected.

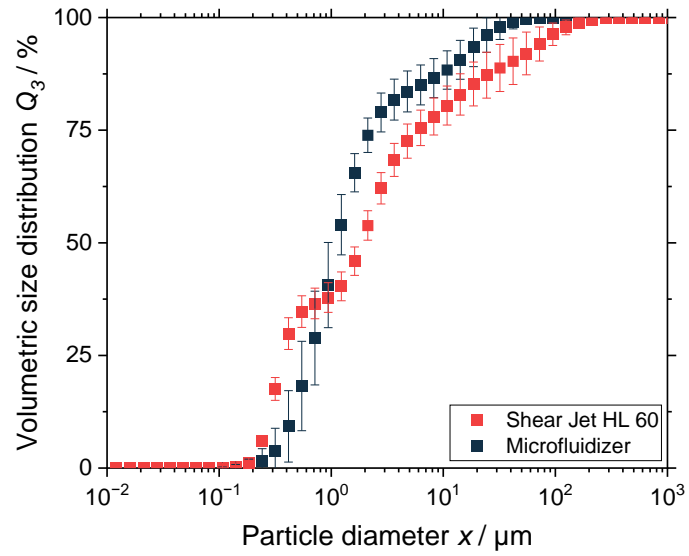


Figure 3: Volumetric size distributions Q_3 of microgel particle suspensions produced using a Microfluidizer and a Shear Jet HL 60

Conclusion

The ShearJet® HL60 V2 high-pressure homogenizer from Dyhydromatics was successfully used to produce MGP suspensions with a uniform particle size. Furthermore, the droplet size distribution showed that this uniformity is transferable between the two different high-pressure homogenizers.

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