High pressure homogenisation

Identification

Key words	dynamic pressure, homogenisation, pasteurisation, emulsion, non-thermal, milk, yoghurt, ice-cream, cream liqueurs
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Completed by	KU Leuven LFT

How does it work?

Primary objective	Formation and stabilization of fine emulsions.

Working principle

High pressure homogenisation (HPH) is a purely mechanical process, which is evoked by forcing a fluidic product through a narrow gap (the homogenizing nozzle) at high pressure (150-200 MPa, or 350-400 MPa for ultra high pressure homogenization, UHPH) (1,2). The liquid product is subjected to very high shear stress causing the formation of very fine emulsion droplets. Origin of this shear is the sudden restriction of flow under high pressure through a restrictive valve (3). Extreme shear and high energy input have to be applied to reduce droplets from the micro- to the **nano**-scale range. The Laplace pressure which causes the resistance to droplet deformation and breakup needs to overcome. This Laplace pressure increases when the droplet diameter decreases, and is therefore larger for nano- than for ordinary emulsions (4). These nanoemulsions, because of their high surface-to-volume ratio, need high amounts of surfactants (such as proteins) for their stabilization. The interaction of proteins with the newly formed droplets is improved under high pressure homogenization (4).
A high pressure homogenizer consists of a **high pressure pump** and a **homogenizing nozzle**. The pump is used to compress the crude emulsion to the required pressure. During depressurization in the homogenizing nozzle, the drops are disrupted. The nozzle is decisive for the efficiency of disruption for emulsions prepared with high pressure homogenization (1). The homogenizing pressure is typically between 5 and 50 MPa. Using more recently introduced high-pressure homogenizers (e.g. Microfluidizers) it is also possible to produce emulsions at higher pressures (up to approximately 400 MPa) (4). High pressure homogenizers can be classified according to the nozzle type or (roughly) the mechanism that disrupts the droplet (see Figure).

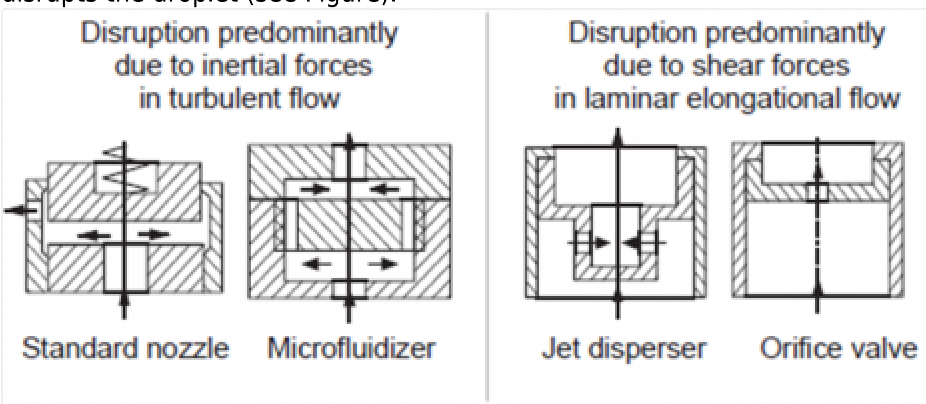

Figure: Homogenizing nozzles classified by mechanism of droplet disruption (from (1))

Images

Additional effects

The high pressures applied cause a temperature increase because of the heat of compression. This temperature increase is enhanced by shear effects and partial conversion of mechanical energy into heat. The result is a total temperature increase of 17-21°C per 100 MPa. This needs to be controlled in case of heat sensitive food compounds (2).
High pressure homogenization also enhances product texture and mouthfeel (3). Using **nanoemulsions** in food products can facilitate the use of less fat without a compromise in creaminess, thus offering the consumer a healthier option (6). Recent research in this field includes the effect of HPH (possibly combined with theat treatment prior to or after homogenisation) on acid gelation properties of recombined whole milk (7), on viscosity and shear stress of fermented dairy beverages (8), microstructure of low-fat yoghurt (9), low-fat emulsion production (10), rheological properties of ice cream mixtures (11) and stabilization of cream liquers (12). These nanoemulsions can also serve as delivery carriers of active compounds (2). In addition, HPH can also be used for **microbial stabilisation**, however, at high pressure levels, e.g. up to 300 MPa.

Important process parameters

the mechanism of droplet disruption depends also on the operating parameters, e.g. flow rate, pressure, number of cycles, temperature, and device parameters e.g. nozzle geometry and impingement design.

Important product parameters	the mechanism of droplet disruption depends on the product parameters, e.g. composition (fat, water, protein...), viscosity (although of less importance compared to rotor-stators-systems), operating parameters (e.g. flow rate) and device parameters (e.g. nozzle geometry) (1).

What can it be used for?

Products	liquid foods (cream liqueurs (12), dairy products (2), (low-fat) mayonnaise, spreads and ice creams structurisation of fruit and vegetable products, ...)
Operations	emulsification, homogenization, pasteurisation
Solutions for short comings	Stabilization of nano-scale emulsions.

What can it NOT be used for?

Products	Solid foods or liquid foods with large particles.
Operations	sterilization
Other limitations	• Scalability of the process • Oil droplets created by jet dispersers display large size distributions, indicating a lack of process control and optimisation (5) • Relatively low efficiency of energy use: in UHPH, depending on the dispersion and emulsion formulation, 41-63% of the energy is lost as heat (4)
Risks or hazards	

Implementation

Maturity	High pressure homogenization is a mature technology in milk homogenization. HP-homogenisers of **piston-gap** can currently deliver pressure up to 150–200 MPa and even more for the latest developments, i.e. up to 300–400 MPa for **ultra-high pressure homogenisation** (UHPH) (4). **Jet dispersers** involve two fluid jets (each from opposite bores) that collide with one another to disrupt particles. Oil emulsification can be performed by direct injection of the oily phase under pressure (up to 350 MPa) into a continuous aqueous phase at low pressure (5). **Microfluidisation** (up to 200 MPa) produces a tighter particle size distribution than that of traditional valve homogenisation (3).
Modularity /Implementation	The scalability of process depends on the formulation of the product (13). Multiple-pass high pressure homogenization can pose a problem with regard to industrial implementation, that can be overcome by applying higher pressures (2).
Consumer aspects	No issues expected.
Legal aspects	No issues expected.
Environmental aspects	Relatively low efficiency of energy use: in UHPH, 41-63% of the energy is lost as heat (4).

Facilities that might be interesting for you

Title	Institute/company
HP homogenizer GEA KU Leuven	KU Leuven LFT
UIP1000hd Ultrasonic Processor - TTZ	TTZ

Further Information

Institutes	KU Leuven LFT, University College Cork - FNS, UMII - IATE, Karlsruhe Institute of Technology
Companies	Stansted Fluid Power, FBF Italia, GEA Niro Soavi
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