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To Study High Pressure Homogenizer

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Abstract:

Homogenization is a process of achieving homogeneity throughout a product by particle size modification. It is characterized into three major categories:-ultrasonic pressure homogenization, pressure homogenization mechanical homogenizer. Applications of homogenization are diverse in food industry, chemical industry, pharmaceutical and chemicalindustry. Most important use of homogenization process in food industry is in milk homogenization. Selection criteria of homogenizers depend on particular application. In today's environment, homogenizers are used to produce more consistent emulsions in a high efficiency process. A wide variety of homogenizers have been developed to run at different pressures and capacities depending on the product mixture. In addition to product improvements, today's homogenizers also feature reduced noise and vibration and reduced maintenance. (1, 2, 11)

Dissolution testing is widely used as an analytical technique for evaluating the drug release characteristics and consistency of a pharmaceutical product. A dissolution method for any particular product, including apparatuses, speeds, and media, is developed based on the characteristics of the product. However, dissolution results from the same product using thesame method can still be affected by test variables. Thus, minimizing the variance due to the system used and the operator performing the work to obtain results that distinguish changes between different dosage forms or the same dosage form from different lots is necessary.

Introduction:

The homogenization of foods involves the dispersion of the structural elements (particles, molecules, globules, droplets, aggregates, granules, etc.) within a surrounding continuous material[3]. Such dispersion of the individual elements is achieved by forcing a pump able food to flow through a minute orifice, where the kinetic energy of the fluid is dissipated into energy absorbed,redistributed, and lost in the form of heat. The fluid experiences significant mechanical effects (shear, turbulence, and cavitation) that results in the dispersion of the individual structural elements[4]. Throughout the years, the homogenization of foods has evolved from a manufacturing step carried out in dairy plants to an established and essential unit operation, adopted in many fields. As a unit operation, homogenization performs multiple functions such asreduction of particle size, dissolution, mixing, dispersion, encapsulation, emulsification, and structuring[5]. Currently, there are two major categories of homogenization technologies, commonly referred to as standard homogenization and high-pressure homogenization (HPH), with

operating pressure levels up to 50 MPa and 300 MPa, respectively. Over the past few years, research on the use of HPH has resulted in significant advancement in different aspects of the technology including, inactivation of enzymes, pasteurization, sterilization, extraction, cell disruption, stabilization of bioactive compounds, micro-encapsulation, and others[5]. The applications of high-pressurehomogenization have led to a huge growth in the number of publications in peer-reviewed journals and conference proceedings. This chapter aims at providing a succinct overview of the historical progress of the technology, a review on the physics behind homogenization, an overview of the fundamentalsof operating principles and configurations of different valves, and a summary ofrecent advances[6].

Homogenizer Theories and Principles:[7]

Several theories have developed over the years regarding the process of homogenization using high pressure. The two most prominent surviving theories are the globule disruption by turbulence and cavitation theories. These two remaining theories offer good examples of the influence of various forces on the homogenization process. The theory of globule disruption by turbulence or micro whirls is built on the idea that a liquid jet forms at the outlet of a gap, with small eddies forming as the jet breaks up. As pressure increases, the velocity of the jets increases, producing smaller eddies with more energy. When a droplet in an eddy hits a droplet of its same size, it deforms and breaks up. The idea of this theory is that homogenization varies with the amount of homogenizing pressure. With cavitation theory, pressure changes during homogenization cause bubbles (cavities) in a liquid. As the bubbles grow, they implode or cavitate and release energy. The collapsing and imploding bubbles generate kinetic energy that surrounds particles in a liquid, creating high-speed jets that break up the particles. Bubbles collapsing on the surface of particles send energy directly to the particles and break them apart. The process of collapsing and imploding bubbles creates turbulence in a liquid that results in cavitation. Homogenizers are used to mix emulsions and suspensions. An emulsion is a mixture of two or more liquids that are normally immiscible due to their liquid-to-liquid phase separation. This liquid to liquid phase separation is brought by several physical mechanisms, such as surface tension, polarity or repulsion, and viscosity. Homogenized emulsions are sometimes called colloids, a term used to cover a broader mixture classification.

Advantages of Homogenizer:-

1. Increase of the total surface of the fat globule, which prevents ordelays creaming of the fat and increases light reflection.
2. Enhancement of taste and texture Disadvantages of homogenizer
3. Increase in digestibility.
4. The color becomes whiter.
5. The tendency to foam increases somewhat.
6. A smoother texture appears

Disadvantages of Homogenizer:-

1) Increased area for attack of microbial lipase, resulting in lipolytic changes
2) Increased sensitivity to light influences, leading to taste defects suchas rancid, soupy or oxidized.
3) Increased area for microbial contamination.
4) Reduced thermal stability of the protein (homogenization must bedone after the UHT treatment for UHT milk)

Types of Homogenizer :-

1. Ultrasonic Homogenizing / Sonication

One widely used method to disrupt cells is the ultrasonic disruption. These devices work by generating intense sonic pressure waves in a liquid media. The pressure waves cause streaming in the liquid and, under the right conditions, rapid formation of micro-bubbles which grow and coalesce until they reach their resonant size, vibrate violently, and eventually collapse. This phenomenon is called cavitation. The implosion of the vapor phase bubbles generates a shock wave with sufficient energy to break covalent bonds. Shear from the imploding cavitation bubbles as well as from eddying induced by the vibrating sonic transducer disrupt cells.[10,11]

There are several external variables which must be optimized to achieve efficient cell disruption. These variables are as follows:

- Tip amplitude and intensity
- Temperature
- Cell concentration
- Pressure
- Vessel capacity and shape

Modem ultrasonic processors use piezoelectric generators made of lead zirconate titanate crystals. The vibrations are transmitted down a titanium metal horn or probe tuned to make the processor unit resonate at 15-25 kHz. The rated power of ultrasonic processors varies from 10 to 375 Watts. Low power output does not necessarily mean that the cell disintegrator is less powerful because lower power transducers are generally matched to probes having smaller tips. It is the power density at the tip that counts. Higher output power is required to maintain the desired amplitude and intensity under conditions of increased load such as high viscosity or pressure. The larger the horn, the more power is required to drive it and the larger the volume of sample that can be processed. On the other hand, larger ultrasonic disintegrators generate considerable heat during operation and will necessitate aggressive external cooling of the sample. Typical maximum tip amplitudes are 30-250 run and resultant output intensities are in the range of 200-2000 W/square cm.[10,11]

The temperature of the sample suspension should be as low as possible. In addition to addressing the usual concerns about temperature lability of proteins, low media temperatures promote high-intensity shock front propagation. So ideally, the temperature of the ultrasonicated fluid should be kept just above its freezing point. The ultrasonic disintegrator generates considerable heat during processing and this complicates matters. Disruption can also be enhanced by increased hydrostatic pressure (typically 15-60 psi) and increased viscosity, providing the ultrasonic processor has sufficient power to overcome the increased load demand and the associated sample heating problems can be solved. For microorganisms the addition of glass beads in the 0.05 to 0.5mm size range enhances cell disruption by focusing energy released by the bubble implosions and by physical crushing. Beads are almost essential for disruption of spores and yeast. A good ratio is one volume of beads to two volumes of liquid. Tough tissues such as skin and muscle should be macerated first in a blender or the like and confined to a small vessel during ultrasonic treatment. The tip should not be placed so shallowly in the vessel as to allow foaming. Antifoaming agents or other materials which lower surface tension should be avoided. Finally, one must keep in mind that free radicals are formed in ultrasonic processes and that they are capable of reading with biological material such as proteins, polysaccharides, or nucleic acids. Damage by oxidative free radicals can be minimized by including

scavengers like cysteine, dithiothreitol, or other SH compounds in the media or by saturating the sample with a protective atmosphere of helium or hydrogen gas.

For practical reasons, the tip diameter of ultrasonic horns cannot exceed about 3 inches. This sets a limit on the scale-up of these devices. While standard sized ultrasonic disrupters have been adapted to continuous operation by placing the probe tip in a chamber through which a stream of cells flow, cooling and free radical release present problems[12].

2. Pressure Homogenizing:-

High-pressure homogenizers have been used to disrupt microbial cells for many years. With the exception of highly filamentous microorganisms, the method has been found to be generally suitable for a variety of bacteria, yeast, and mycelia.[10,11]

This type of homogenizer works by forcing cell suspensions through a very narrow channel or orifice under pressure. Subsequently, and depending on the type of high-pressure homogenizer, they may or may not impinge at high velocity on a hard-impact ring or against another high-velocity stream of cells coming from the opposite direction. Machines which include the impingement design are more effective than those which do not. Disruption of the cell wall occurs by a combination of the large pressure drop, highly focused turbulent eddies, and strong shearing forces. The rate of cell disruption is proportional to approximately the third power of the turbulent velocity of the product flowing through the homogenizer channel, which in turn is directly proportional to the applied pressure. Thus, the higher is pressure, the higher the efficiency of disruption per pass through the machine. The operating parameters which affect the efficiency of high-pressure homogenizers are as follows:

- Pressure
- Temperature
- Number of passes
- Valve and impingement design
- Flow rate

High-pressure homogenizers have long been the best available means to mechanically disrupt nonfilamentous microorganisms on a large scale. Animal tissue also can be processed but the tissue must be pretreated with a blade blender, rotor-stator homogenizer, or paddle blender. The supremacy of high-pressure homogenizers for disruption of microorganisms is now being challenged by bead mill homogenizers. Still, in terms of throughput, the largest industrial models of high-pressure homogenizers outperform bead mills. The maximum volume of microbial suspension per hour that can be treated by the larger commercial machines is 4,500 liters for high-pressure homogenizers versus about 1,200 liters for bead mills. Even larger capacity high-pressure homogenizers are available but their efficiency in disrupting microbial cells has not been documented. This throughput advantage is diminished somewhat by the fact that most high-pressure homogenizers require several passes of the cell suspension to achieve high levels of cell disruption whereas bead mills frequently need only one.[13]

A familiar commercial high-pressure homogenizer for the laboratory is the French press which uses a motor-driven piston inside a steel cylinder to develop pressures up to 40,000 psi. Pressurized sample suspensions up to 35m1 are bled through a needle valve at a rate of about 1 ml/min. Because the process generates heat, the sample, piston, and cylinder are usually pre-cooled. Typical pressures used to disrupt yeast are 8,000 to 10,000 psi and several passes through the press may be required for high efficiency of disruption. Generally, the higher is the pressure, the fewer the passes. Pressure cells rated at 20,000 psi maximum come in capacities of 3.7 and 35m1 and there is also a 35m1 capacity cell rated at 40,000 psi.

Most high-pressure homogenizers used for homogenization were adapted from commercial equipment designed to produce emulsions and homogenates in the food and pharmaceutical industries. They combine high pressure with an impingement valve. Those with a maximum pressure rating of 10,000 psi rupture about 40% of the cells in a single pass, 60% on the second pass, and 85% after four passes. Capacities of continuous homogenizers vary from 55 to 4,500 liters/hr at 10-17% w/v cell concentrations. With the larger capacity machines, several passes are needed to achieve high yields of disruption. Considerable heat can be generated during operation of these homogenizers and therefore a heat exchanger attached to the outlet port is essential.[13]

3. Mechanical Homogenizers:-

Mechanical homogenizers use mechanical work as the main source of energy for breaking the premix components. They function similarly to a high shear mixer. The premixed fluid or feed can be introduced at atmospheric pressure, low, or medium pressure, much lower than that of a high-pressure homogenizer. Instead of using a valve, rotating parts are used such as cones, blades, and paddles. The rotors are mated with an appropriate stator to create the desirable conditions for homogenization. The homogenization process relies on the mechanical tearing caused by the moving parts. Nevertheless, the previously mentioned physical principles involved in disrupting the particles still apply to mechanical homogenizers.[14,15]

4. Colloid Mill:

A colloid mill is a homogenizer composed of a conical rotor and stator. The rotor and the stator are separated by a small clearance where the premix will flow due to shear and centrifugal forces. As the premix is gravimetrically fed into the rotor-stator assembly by a hopper, it is thrown outward towards the exit slot or holes[14,15]. The high rotating speed (around 3,000 to 15,000 rpm) of the rotor causes a tremendous amount of shearing, which breaks the components of the premix fluid. Moreover, since the fluid is accelerated by the rotor, high fluid velocities can be achieved. With enough velocity, turbulence is also developed. The magnitude of shearing can be adjusted by varying the clearance between the rotor and stator. However, decreasing the clearance will negatively affect the flow rate of the product. This limits the resulting particle size, which is not as fine as particles made by high-pressure and ultrasonic homogenizers. Colloid mills are used for highly viscous products or products with high amounts of suspended solid particles.[14,15]

5. Rotor-Stator Homogenizers:

In terms of construction, these homogenizers are the closest to high-shear mixers. Their rotor-stator assembly is sometimes called a mixing head, generator, or probe. The assembly is lowered into a batching tank, vessel, tube, or container where the premix fluid is homogenized.[14,15]Rotor-stator homogenizers work by accelerating the fluid tangentially, but because of fluid inertia, it does not completely flow together with the rotor. Instead, the fluid flows towards the shear gap or the region between the rotor tip and the stator. High-velocity differentials and turbulent fluid flow are inside the shear gap, producing high shear rates. The rotor and stator profile, their separation distance, and other features such as holes and slots control the resulting particle size.[14]Materials enter the rotating fixed rotor system at high speeds in an up-and-down direction to form a spiral shape. The suction created by the rotor and stator forces the sample between them, subjecting it to high shearing forces. Solid samples are incompatible with rotor-stator homogenizers, and multiple samples take time and labor.[15]

6. Bead Mill:

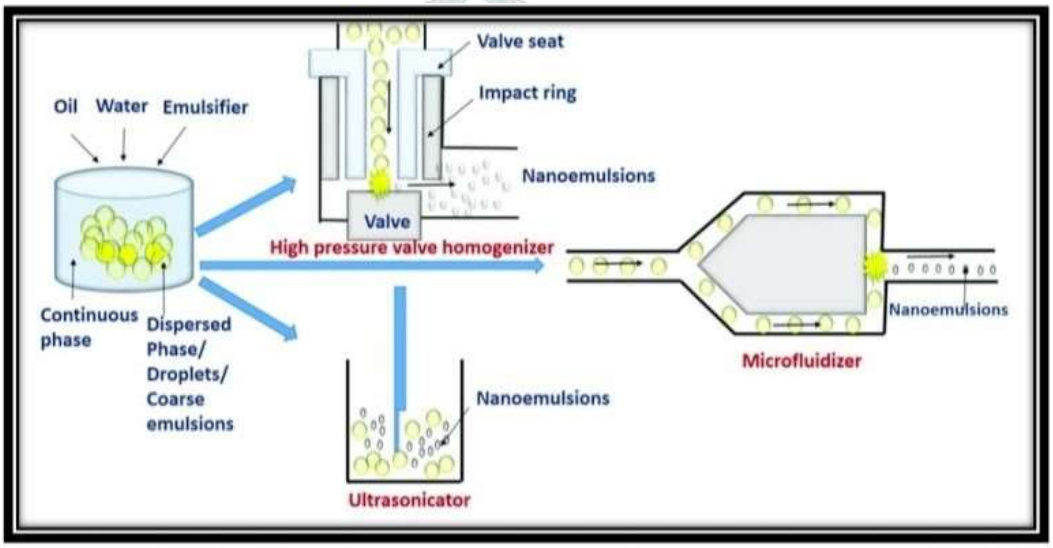
Bead mills (sometimes referred to as ball mills) are homogenizers that employ beads for mechanically grinding and breaking large particles dispersed in the premix fluid. The beads are grinding media that reduce particle size by strong impact and shearing forces.

7. Blade Type Homogenizers:[16]

These homogenizers use blades as their rotor. Unlike the colloid mills and rotor-stator homogenizers, they do not have a shear gap formed with a stator. The shearing effect is developed only by the high-speed rotation of the blade. Their construction and operation closely resemble that of a blender.

8. High Pressure Homogenizers :

. FIG 1. High pressure homogenizer



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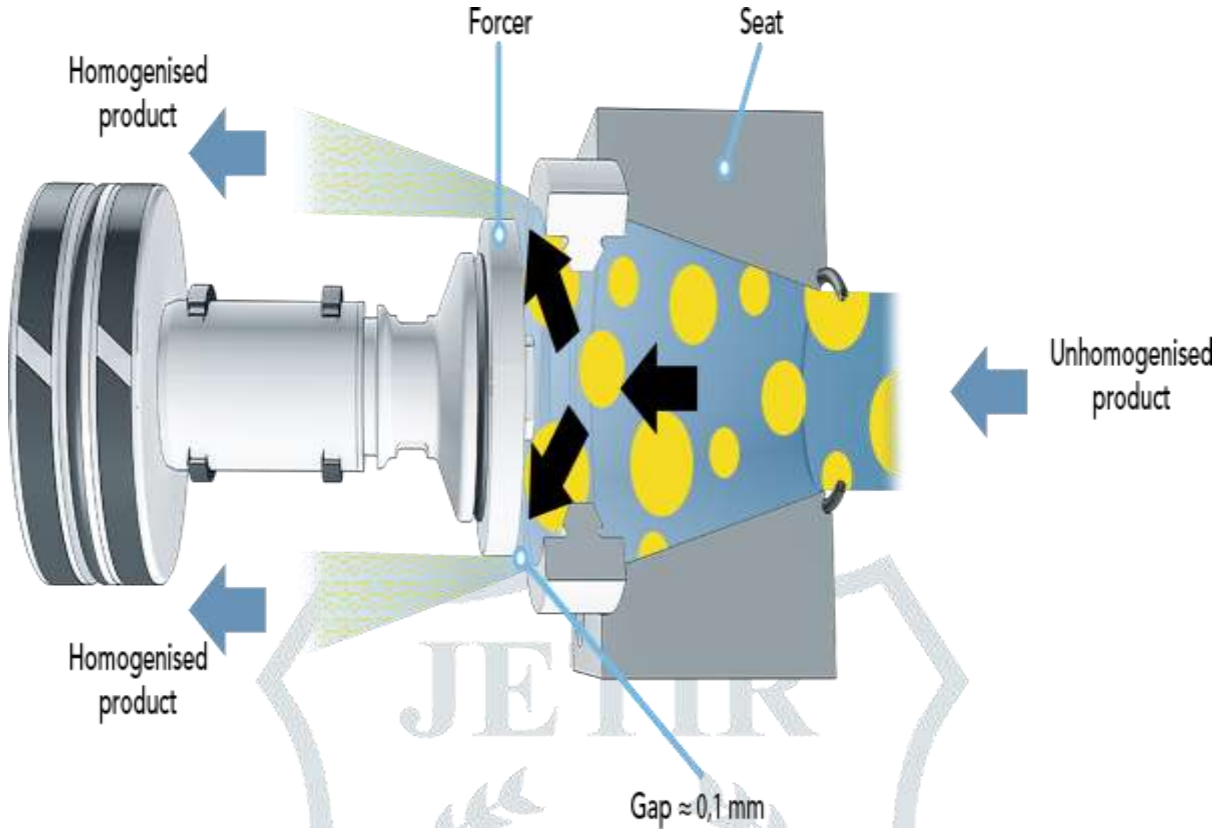

FIG 2 High Pressure Homogenizer

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Homogenization Mechanism:-

a. The non-homogenized product enters the valve seat at high pressure and lowvelocity.

b. As the product enters the close (and adjustable) clearance between the valveand the seat, there is a rapid increase in velocity and decrease in pressure.

c. The intense energy release causes turbulence and localized pressure differences which tear apart the particles.[28,29]

d. The homogenized product impinges on the impact ring and exits at a pressuresufficient for movement to the next step. Homogenizers may be equipped with a single valve assembly (single-stage) or two valves connected in a series (two stage). For most products, a single-stage valve is sufficient. A two-stage assembly, where ~10% of the total pressure is applied to the 2nd stage, controlsback pressure and minimizes clumping. This improves the droplet size reductionand narrows the particle size distribution. Generally, two-stage homogenizationis used for products with a high fat content or products where high homogenization efficiency is required.[30,31]

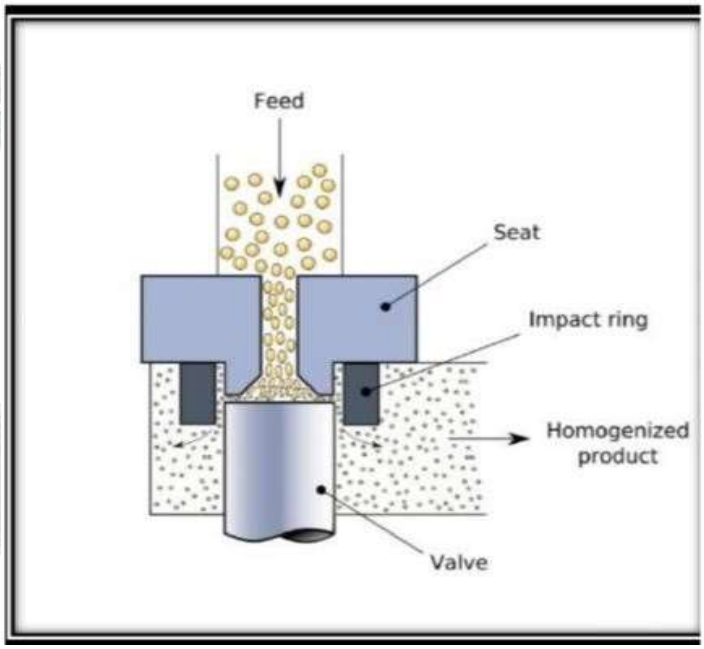

FIG 3. Mechanism of Working of Homogenizer

Applications of High Pressure Homogenizers:-

1) Pressure homogenizers produce the most advanced results in this area of processing equipment and are called upon where stringent requirements must bemet and the most efficient process saves manufacturing time and money.[35]

2) Our high pressure homogenizer applications also include unique applicationchallenges such as pastes requiring fine particles, agglomeration difficulties, hard materials and products requiring a longer shelf life.[37]

3) Our high pressure homogenizers are designed to succeed with these applications. With BEE laboratory systems many process parameters can be modified to further improve results and reduce the number of passes required.This is an in-line mixing technology, so the entire product batch receives the same level of processing. It is also a scalable technology so the results developed in the lab will scale up to manufacturing[38].

4)

How Homogenizers are used:-As discussed, homogenizers are used in a variety of industries for a variety of purposes. Some of the most common onesare:

1. **Food and Beverage: –**

Food and beverage manufacturers rely on homogenizers to improve the stability and appearance of their products. The homogenization process keeps milk from separating into cream and other liquid and viscous substances (like orange juice, milk, mayonnaise, salad dressings and yogurt) from dividing backto their individual parts.[40]

2. Biotech Industry: –

The biotech industry includes those companies that make products out of living organisms[41]. These types of businesses, mostly concentrated in the medical and agricultural fields, work with microorganisms (like bacteria, fungi and viruses), as well as plant and animal tissues, to modify crops and livestock,create and test medicines and engineer biofuels. They use homogenizers to lyse cells, reduce particle size and create micro and nano particles for both research and production objectives. Specially, homogenizers help ensure that biotech processes consistently maintain scalable results while always preserving the integrity of cell content.

3. Pharmaceutical and Chemical Industries:-

Whether they use chemicals to manufacture drugs, plastics or other products, both pharmaceutical and industrial chemical companies need homogenizers tohelp them break apart one substance so that it can be evenly dispersed into another one. Not only does this facilitate easier and more uniform mixing, it creates a final product with “a tighter distribution of smaller particles." This increases the bioavailability and lengthens the shelf life of pharmaceutical products, and it increases conductivity and improves surface cohesion of products used for industrial chemical applications. Indeed, chemical products of all kinds, from life-saving medications to paint, need homogenizers to effectively blend product particles, sustain uniformity and cut down costs.[41]

Conclusion: -

The critical evaluation of the available literature data has showed the great potential of HPH for microbial inactivation and food safety purpose. Since1990 several Authors have been tested its potentialities in vitro and real systems, demonstrating its different ability for pathogenic species inactivation in relation to the strains considered, the food matrix and technological procedures adopted.However, until the introduction of new valve design and ultra-high pressure homogenizers, able to reach pressures of 400 MPa, this technology was implemented in food industry only for fat globule reduction, forjuice treatment and emulsion creation. The introduction of these new variables have opened new field in food sector, also for food decontamination and permitting to replace or minimize the traditional thermal treatments generally applied for the safety purposes. The new main applications regard the treatmentof milk (for consumption or dairy product manufacture), fruit and vegetable juice, vegetable milks, and food component (such as enzymes) obtaining more stable and safer products without detrimental effects on quality properties. In fact, in the most of the cases, the literature data have underlined an improvement of the sensory and nutritional properties and stability of the HPH and UHPH treated products. The replacement of traditional thermal treatment can represent an advantage for the industry since this HPH is a cold technology with a lower impact on the environment, more sustainable, saving energy, time and additional costs. Moreover the literature data have demonstrated that HPH, when applied to the milk for cheese making, can increase the cheese yield, reduce the cheese hydrolytic patterns, reducing the costs for ripening. [36, 38]

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