MECHANICAL EFFECTS OF POWER ULTRASOUNDS IN FOOD PROCESSING – A REVIEW

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Abstract: The application of ultrasound in the food industry has been extensively research and developed in different important areas, such as determination of food proprieties, plant, sanitation and food processing. In the food industry, the ultrasound technology has been utilized for inactivation of microorganisms and enzymes, crystallization, drying, degassing, filtration, extraction, sterilization, etc. Food processes performed under the action of ultrasound are believed to be affected in part by cavitation phenomena and mass transfer enhancement. This review present a map of current knowledge on the mechanical effects of ultrasound in food processing technology.
Keywords: Ultrasound technology, mechanical effects, food processing

Introduction

Ultrasound is a relatively new tool in the food industry and provides a significant opportunity to develop high-quality and minimally processed foods. Food products, such as fruit and vegetables, fat and oils, sugar, dairy, meat, coffee and cocoa, meal and flours, are complex mixtures of vitamins, sugars, proteins and lipids, fibres, aromas, pigments, antioxidants, and other organic and mineral compounds.

The applying of conventional food processing methods such as cooking, freezing, drying, filtration, extraction, sterilization, etc., many of these biologically active food compounds can be affected due to the thermally sensitivity or susceptibility to chemical's action. These issues can be accompanied by a low efficiency production and time – and energy consuming procedures. For minimizing of these shortcomings has been led to the use of new sustainable "green and innovative" techniques in processing, pasteurization and extraction, which typically involve less time, water and energy, such as ultrasound assisted processing (Hughes, 1962).

Currently, ultrasound has many industrial applications, which include texture, viscosity and concentration measurement of many solid or fluid foods; composition determination of eggs, meats, fruits and vegetables, dairy and other products; thickness, flow level and temperature measurements for monitoring and control of several processes; and non-destructive inspection of whole fruits and vegetables, egg shells and food packages (Floros, 1994).

Ultrasounds in food processing

In recent years, ultrasounds (US) have been the subject of research in food industry.

In these days, when minimal and green processing is a driver for food preparation, power ultrasound can provide useful possibilities for the food technologist.

Theory

When ultrasonic waves hit the surface of a material, they generate a force. If the force is perpendicular to the surface, it results in a compression wave that moves through the food, whereas if the force is parallel to the surface, it produces a shearing wave. Both types of wave become attenuated as they move through the food. Ultrasound produces very rapid localized changes in pressure and temperature that cause shear disruption, ‘cavitation’ (creation of bubbles in liquid foods), thinning of cell membranes, localized heating and free radical production, which have a lethal effect on micro-organisms. (Fellows, 2000).

There are a large number of potential applications of high intensity ultrasound in food processing of which a number is discussed below.

Filtration

Filtering process using ultrasound can provide a number of advantages, especially for separating solids from liquids, process found in many food industrial branches. Ultrasound provides vibrational energy to keep particles in suspension and moving, leaving channels in the filter open and free for solvent elution. It also causes the filter to vibrate, creating a frictionless surface, allowing the liquid to pass through more readily (TELSONIC, 2007).Ultrasound reduces particle size variation, which also results in increased filtration rates and fine particles (< 10 microns) can agglomerate, which can also increase filtration rates. Ultrasonically assisted filtration has been successfully employed to enhance the filtration of industrial wastewater that is generally considered difficult to process (De-Sarabia, et al., 2000). Ultrasound can also be used for producing juices and fruit extract.

Freezing and crystallization.

Freezing and crystallization are linked in that both processes involve initial nucleation followed by crystallization (Sanz, et al., 1997) One of the basic components of freezing a food system can always be simply pictured as ice crystals distributed across the unfrozen aqueous phase. Sonication is thought to enhance both the nucleation rate and rate of crystal growth in a saturated or supercooled medium by producing a large number of nucleation sites in the medium throughout the ultrasonicexposure (Farid, et al., 2011). The transmitting of the sound waves across the aqueous phase can cause the occurrence of cavitation (Fig. 1), if its amplitude exceeds a certain level (Zheng, 2005) . Traditionally, power ultrasound has been applied to accelerating the ice nucleation of many chemical processes (Fennema, 1973). Under the influence of ultrasound, conventional cooling provides much more rapid and even seeding, which leads to a much shorter dwell time (Acton, 1992). If it is applied to the process of freezing fresh foodstuffs, ultrasound can not only increase the freezing rate, but also improve the quality of the frozen products. Application of power ultrasound can also benefit ice cream manufacture by reducing crystal size, preventing incrustation on freezing surface, etc. (Zheng, et al., 2006) .

Power ultrasound has proven to be extremely useful in crystallization processes. Itserves a number of roles in the initiation of seeding and subsequent crystal formation and growth (Mason, et al., 1996). Also the technology has been applied to the crystallization of materials such as milk fat (Martini, et al., 2008) and triglyceride oils such as a vegetable oil.

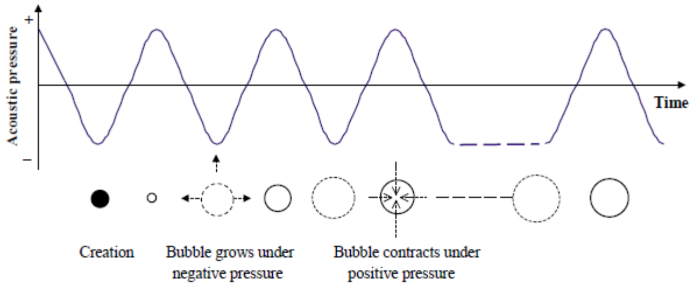

Fig. 1. Motions of bubbles during cavitation (Zheng, 2005)

Defoaming and degassing

Degassing and defoaming of liquids is an interesting application of ultrasonic devices. In this case, the ultrasound removes small suspended gas-bubbles from the liquid and reduces the level of dissolved gas below the natural equilibrium level (Figure 2). The degassing and defoaming of liquids are required for many purposes, such as:

- Sample preparation before particle size measurement to avoid measurement errors;
- Oil degassing before pumping to reduce pump wear due to cavitation;
- Degassing of liquid foods, e.g. juice, sauce or wine, to reduce microbial growth and increase shelf life (Hielscher, 2004).

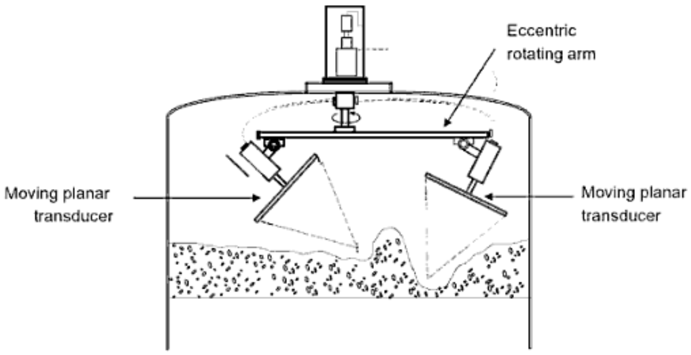

Fig. 2. Ultrasonic defoaming in a fermenter vessel (Hielscher, 2004)

Drying

Another example of ultrasound application of potentially great commercial importance is acoustic drying. Ultrasonically enhanced drying can be carried out at lower temperatures than the conventional methodology which reduces the probability of oxidation or degradation in the material (Dolatowski, et al., 2007). In some foods (for example gelatin, yeast and orange powder), the rates of drying are increased by two to three times. This is thought to be due to both to the creation of microscopic channels in solid foods by the oscillating compression waves, and by changing the pressure gradient at the air/liquid interface, which increases the rate of evaporation. Acoustic drying has the potential to be an important operation because heat sensitive foods can be dried more rapidly and at a lower temperature than in conventional hot air driers (Fellows, 2000).

Cooking

In a conventional cooking method, when foods are exposed to elevated temperatures either in an oven or being fried or boiled, they are gradually cooked from the surface to the interior. Ultrasound has the ability to provide improved heat transfer characteristics, which is a key requirement to avoid such problems, and these have been utilized in cooking (Andrew, 2004).

In addition to using ultrasound in isolation to cook food, ultrasound-assisted water bath cooking is also likely to prove effective, due to the higher increased heat transfer coefficient produced by ultrasound (Torley, 2007) and agitation of the liquid by ultrasound mixing helping to ensure an even temperature through-out the cooking medium (Pohlman, 1997).

Emulsification

If a bubble collapses near the phase boundary of two immiscible liquids, the resultant shock wave can provide a very efficient mixing of the layers (Figure 3). Stable emulsions generated with ultrasound have been used in the textile, cosmetic, pharmaceutical and food industries (Mason, et al., 1996). In the food industry, ultrasonic emulsification is attracting interest for products such as fruit juices, mayonnaise and tomato ketchup (Povey, et al., 1998), in the homogenization of milk (Wu, et al., 2000) and in aroma encapsulation (N. Mongenot, et al., 2000). It is comparable to microfluidization in terms of generating sub-micron dispersions (S.M. Jafari, et al., 2007), but there are indications that the emulsification of edible oils might lead to some deterioration in quality (Chemat, et al., 2004).

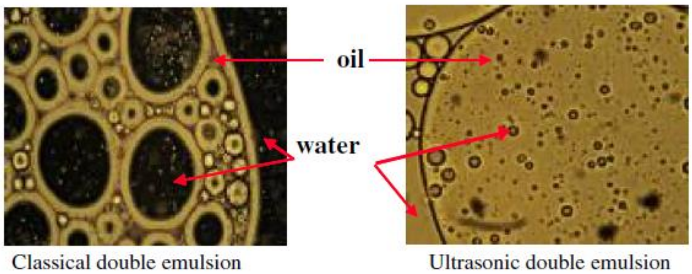

Fig. 3. Phase dispersion of two immiscible solvent and drop size distribution by Power Ultrasound and Mechanical Agitation (Chemat, et al., 2004)

Cutting

In recent years, the ultrasound assisted cutting and slicing technology, has been introduced into the food industry in such diverse applications as the cutting of frozen fish, cheese, ice cream bars and bakery products (Ahmed, 2006). Ultrasonic cutting uses a knife-type blade attached through a shaft to an ultrasonic source (Rawson, 1988)

Cutting with the superimposition of ultrasonic vibration is a direct competitor of technologies such as high-velocity water jet cutting and conventional techniques such as using saws or knives. The low energy requirements for ultrasonic cutting have been presented (Schneider, 2008).

Conclusions

The use of ultrasound in processing creates novel and interesting methodologies, which are often complementary to classical techniques. It has proven particularly useful in filtration, freezing, crystallization, de-foaming, drying, cooking, emulsification and cutting, providing reduced processing times and increased efficiency. There is wide scope for further research on the use of ultrasound in food processing both from an industrial and academic viewpoint.

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