Application of Ultrasound in Food Processing Industries

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Introduction

Ultrasound is one of the non-thermal methods and they are sound waves having frequency beyond the audible range of human capacity (~20 kHz). Ultrasound may be defined as a pressure wave that is oscillating between the frequencies 20 kHz and 10 MHz which are the range of ultrasound applications. Application with 20 - 100 kHz called as ''power ultrasound'' which has power for cavitation formation. The device that produces ultrasound is called as transducer. The use of ultrasound in food processing is not a new idea and it was first used to produce oil and water emulsions in 1927. It can be applied to solid, liquid and gas systems for different purposes. Its instrumentation can be fully automated and make rapid and precise measurements. The principle aim of this technology is to reduce the processing time, save energy and improve the shelf life and quality of food products. The advantages of ultrasound over the heat treatment include: 1. Minimization of flavour loss; 2. Greater homogeneity; 3. Significant energy savings.

Ultrasound generation

Ultrasonic waves are generally produced using a ceramic crystal contained within a transducer that is excited by pulses of electrical energy. This produces high frequency ultrasonic waves, by means of the piezoelectric effect. There are three main types of transducers can accomplish the generation of the ultrasonic waves those are: 1. Magnetostrictive transducers; 2. Liquid-driven transducers; 3. Piezoelectric transducers.

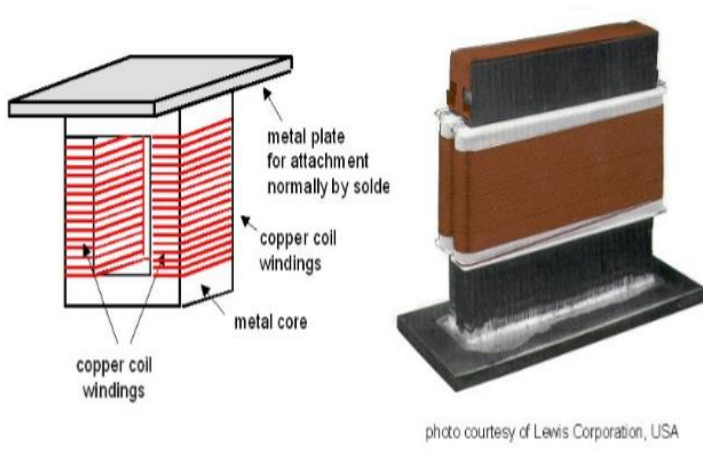

Fig. 1 Magnetostrictive transducers

1. **Magnetostrictive transducers:** The waves are produced by applying electric pulses to a square-shaped nickel core, with coils wrapped around opposing sides (this produces ultrasonic frequencies below 100 kHz and is 60 % electrically efficient) which is shown in the fig. 1. They utilize the magneto strictive property of a material to convert the energy in a magnetic field into mechanical energy.
2. **Liquid-driven transducers:** The transducers generate ultrasound through the interaction of liquid with an oscillating surface, typically in a device designed to produce high-frequency sound waves which is shown in the fig. 2. When a liquid, such as water, is subjected to rapid pressure changes or vibrations, cavitation occurs. Cavitation refers to the formation and collapse of small vapor-filled bubbles within the liquid. As these bubbles collapse, they release energy in the form of high-frequency sound waves, producing ultrasound. Liquid-driven transducers are particularly effective for generating powerful ultrasound due to the density and compressibility properties of liquids, which enhance sound wave propagation (Ensminger and Bond, 2011).

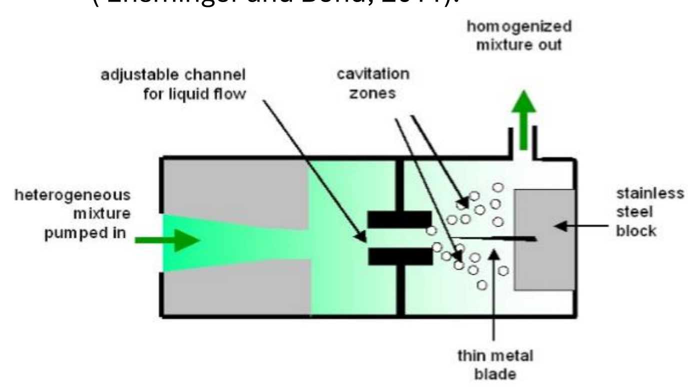

Fig. 2. Liquid driven transduces

3. **Piezoelectric transducers:** The transducers generate ultrasound by utilizing the piezoelectric effect, where certain materials, such as quartz or ceramics, produce electrical charge when mechanically stressed which is shown in the fig. 3. In ultrasound generation, an alternating electrical current is applied to the piezoelectric material, causing it to oscillate at

high frequencies. These mechanical vibrations are transferred to the surrounding medium, creating high-frequency sound waves (ultrasound). Their ability to convert electrical energy into precise, high-frequency acoustic waves makes them highly effective for producing controlled ultrasound (Berlincourt *et al.*, 1964).

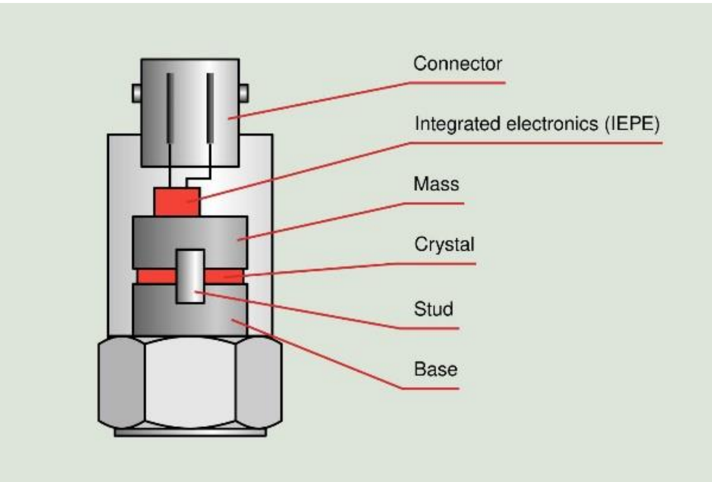

Fig. 3. Piezoelectric transducers

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- **Microbial inactivation**: The mechanism for bacterial inactivation involves the use of cavitation. During cavitation process it changes the pressure and temperature which causes breakdown of cell walls, disruption and thinning of cell membranes and DNA will be damaged. Different kinds of microorganisms have different membrane structure. Gram positive bacteria have a thicker cell wall whereas gram negative bacteria have a thinner cell wall. For example: The inactivation of *Listeria monocytegenes* by high power ultrasonic waves (20 kHz) at ambient temperature and pressure has been found to be low with decimal reduction values in 4.3 min. Due to the combination of sub lethal temperatures and higher pressures of 200kPa, the decimal reduction value will be over 1.5 min to 1.0 min
- **Cutting**: Ultrasonic knife is a blade attached through a shaft to an ultrasonic source. Ultrasound improves the performance of food cutting or slicing. Ultrasound provides the minimization of waste and energy requirement.
- **Effect of ultra sound on juice quality**: Ultrasound is reported to have a minimal effect on the quality of fruit juices, such as orange juice, guava juice, blackberry juice and strawberry juice. Vitamin C retention of orange juice and watercress after ultrasonic treatment is higher when it is compared to thermal processing. It was found that there is no significant effect of ultrasound whereas heat treatment significantly reduces vitamin C content of tomato extract (Unver, 2016).

Advantages of ultrasound

- Minimizing of flavour loss
- Greater homogeneity
- Significant energy savings
- Higher product yields
- Shorter processing times
- Reduced operating and maintenance costs

Disadvantages of ultrasound

- The lack of standardisation in ultrasound operating frequencies and power levels makes comparison between different effects were difficult.
- The effect on colour and antioxidants has been reported in some sonicated samples due to degradation of pigments at high energy levels.
- During emulsification and processing of vegetable oils, a metallic and rancid odour has been detected.

Conclusion

Ultrasonic technologies have the potential to revolutionize the food industry in the near future. They offer several advantages, such as minimizing flavour loss, enhancing product uniformity, conserving energy, increasing productivity, and improving overall quality. Additionally, ultrasonic methods are environmentally friendly and help reduce chemical and physical hazards in food processing. When combined with pressure or temperature, the efficiency of ultrasound increases, but care must be taken to monitor and control any potential nutritional loss. With further research, ultrasound could play a key role in food quality control. Although significant progress has been made in applying ultrasound to food technologies, the field is still in its early stages, and extensive research is needed to develop equipment for large-scale industrial use.

References

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