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Fruit juice sonication: Implications on food safety and physicochemical and nutritional properties

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A B S T R A C T

Over the last years, consumers are increasingly demanding for nutritious, healthy and fresh-like food products, with high organoleptic quality. Nowadays, emerging non-thermal technologies have raised great interest as a viable alternative to the conventional thermal methods, since they have minimal impact on sensorial and nutritional properties of fresh foods. Ultrasound (US) is one of these promising non-conventional processing technologies and it is especially suitable for preservation of fluid foods. US may be used alone or in combination with other preservation techniques, such as mild heat temperatures, high pressures and antimicrobials. Besides, data on inactivation of food microorganisms by US alone are scarce, because the effects of US are usually not severe enough for a sufficient lethal effect. Since many studies on this subject have been published in the last two decades, this review intends to analyze the main effects of US on microbiological, nutritional and physicochemical parameters of fluid foods. While some general trends can be observed, the effects of US are usually highly variable, not only according to treatment duration and intensity, but also according to the food matrix, suggesting that each matrix should be studied and evaluated separately. Generally, the impact of US on food matrices is minimal, unless longer treatment times and higher amplitudes are applied. Other parameters such as the specific resistance of the microbial strain play also a role.

1. Introduction

Consumer's requirements for food are constantly changing. The demand for fresh and natural foods with high nutritional value is increasing. In particular, various food bioactive compounds and their antioxidant activity have attracted high interest (Andlauer & Furst, 2002; Barba, Esteve, & Frigola, 2011; Heckman, Sherry, & de Mejia, 2010).

Fluid food preservation processes should thus be designed to preserve the natural quality of food. Thermal pasteurization or sterilization has the important advantage of ensuring food safety and long preservation due to its destructive effect on enzymes and microorganisms. However, the non-specific effect of heat can affect nutritive and sensorial quality of foods and changes their functional properties (Barba, Esteve, & Frígola, 2012; Ludikhuyze & Hendrickx, 2002).

To avoid the unwanted effects of heat, both food industry and food researchers have explored new alternative methods which can inactivate the activity of the microorganisms present in the food and also certain enzymes of interest, without destroying the nutritional and sensory components that are normally affected during heat treatment. For instance, ultrasound alone and/or combined with other preservation techniques such as antimicrobials and mild temperatures (<50 °C) has been shown to be a promising alternative technology for food processing (Mason, Riera, Vercet, & Lopez-Bueza, 2005). Ultrasound has been shown to be effective against contaminating microorganisms of liquid foods (Cheng, Soh, Liew, & Teh, 2007; Valero et al., 2007) and it can satisfy the requirement of a 5-log reduction of some contaminants pathogens (such as *Escherichia coli* in fruit juices) established by the U.S. Food and Drug Administration (Salleh-Mack & Roberts, 2007).

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Ultrasound can be defined as inaudible sound waves at a frequency above 20 kHz. For food preservation, ultrasound waves of low frequency (18–100 kHz; $\lambda = 145$ mm) and high intensity (10–1000 W/cm^2) are the most effective (Dujmic et al., 2013). The preservative effect of ultrasound is associated with complex phenomena of gas cavitation, which explains the generation and evolution of microbubbles in a liquid medium (Galanakis, 2012). Cavitation takes place in the vicinity regions of a liquid that are subjected to rapidly alternating high-amplitude pressures. During the negative half of the pressure cycle the liquid is subjected to a tensile force, and during the positive half it undergoes compression. The result is the uninterrupted formation of microbubbles, the size of which increases thousands of times (they expand) during the alternation of the pressure cycles.

Microbubbles that reach a critical size implode violently and return to their original size, which causes the release of all the accumulated energy, producing instantaneous local temperature increases which are dissipated without substantially raising the temperature of the liquid treated. However, the energy released and the mechanical shock associated with this phenomenon affect the structure of the cells located in the microenvironment.

Nevertheless, the effect of ultrasound on food spoilage agents is limited and depends on many factors, and therefore its application has been focused towards its simultaneous or alternating combination with other preservation techniques. The application of ultrasound and mild heat treatments (<100 °C, usually between 50 °C and 60 °C) has given rise to the procedure known as thermo-ultrasonication. The combination with increases in pressure (<600 MPa) is known as manosonication, while the use of the three strategies together is called manothermosonication (Knorr, Zenker, Heinz, & Lee, 2004).

The ultrasound equipment used for discontinuous (more common) or continuous process has a treatment chamber containing an ultrasound source capable of generating vibration amplitudes of the order of various tens of micras, together with an impedance adaptation box and an electronic generation unit. This unit consists of two parts: a power amplifier and a system for controlling and monitoring the resonance frequency which keeps the power applied to the transducer steady during the process. Fig. 1 shows some common types of ultrasonic systems employed for fluid food processing.

The various parameters of the transducer excitation signal (resonance frequency, voltage, current, phase, power) are captured and stored in a computer for treatment (Adekunte, Tiwari, Cullen, Scannell, & O'Donnell, 2010; Soria & Villamiel, 2010). Current ultrasound technology comes from the exploitation of two properties possessed by certain materials: piezoelectricity and magnetostriction. A piezoelectric ultrasound generator is based on the generation of electric oscillations of a particular frequency which a material with piezoelectric properties transforms into mechanical oscillations (transducer). Another method for producing ultrasound vibrations is by the use of magnetostrictive transducers. The functioning of these devices is based on the mechanical distortions experienced by certain materials when they are subjected to an intense magnetic field (Adekunte et al., 2010; Soria & Villamiel, 2010).

With regard to the use of ultrasound in the food industry, manosonication and manothermosonication are particularly effective for sterilization of jams and liquid egg and, in general, to extend the shelf life of liquid foods. Isolated ultrasonication is effective for the decontamination of raw vegetables and whole eggs submerged in liquid medium. For purposes other than preservation, it has been used successfully to tenderize meat and for the recovery of valuable compounds from different vegetal and algal matters (Barba et al., 2015; Deng et al., in press; Rosello-Soto et al., 2015). Better known and more widely practised is the use of ultrasound in emulsification and homogenisation systems and in the cleaning of certain equipment (Knorr et al., 2004).

In recent years various research groups have studied how ultrasound may affect microbial inactivation (Jose et al., 2014) and physicochemical and nutritional parameters in liquid foods (Tao & Sun, 2015), such as fruit and vegetable juices, milk and other beverages. It has already been shown that its behavior varies depending on the food matrix and therefore it is necessary to evaluate each product before it can be marketed. Some of the most important findings on this subject are described below.

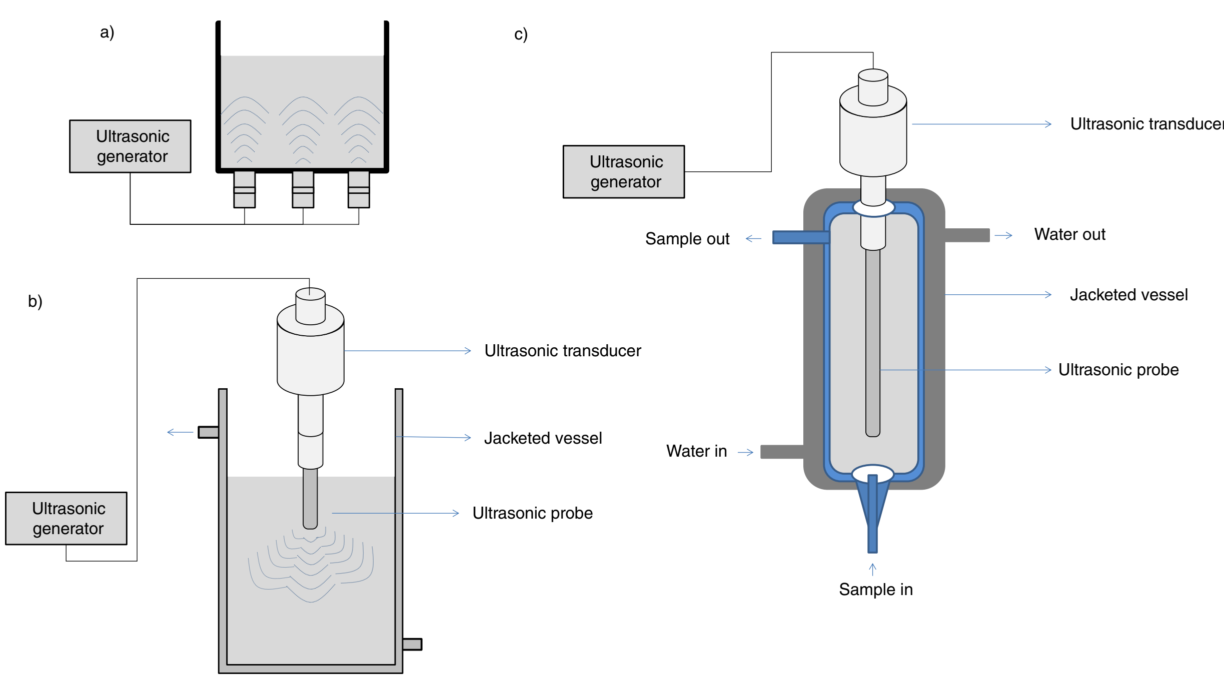

Fig. 1. Various types of ultrasonic systems: a) ultrasonic bath; b) batch type probe system and c) continuous probe system) used for liquid food processing.