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Sonication – An advance tool to improve the functional properties of Horticultural food: A review

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Abstract
Human life has become much busier in these modern days, which resulting in shift their interest towards instant processed foods. As foods are complex materials containing proteins, vitamins, carbohydrates, fats, minerals, water and other organic ingredients with differing compositions, Processing and preservation of food require different applications and precautions. Traditionally, thermal treatments (pasteurization and sterilization) have been used to produce safe food products. However, vitamins, taste, colour, and other sensorial characteristics are lost with thermal treatments. In order to overcome these losses and to produce high quality food products, having natural flavour, taste and free from preservatives, non-thermal food processing methods such as sonication, high pressure processing, pulsed electric fields, cold plasma, ozonisation and oscillating magnetic fields, offer maximum quality and safety to food products have attracted attention of the food industry. Sonication (ultrasound) is such an emerging non-thermal technology which is having a great potential to minimize processing time, cost of processing, maximize quality, ensure the safety of food products and its suitability for various operations and applications in food industry.

Keywords: Sonication, Ultrasound, cavitation, Food and Transducer

Introduction
Foods are complex materials containing proteins, vitamins, carbohydrates, fats, minerals, water and other organic ingredients with differing compositions (Ravikumar *et al.*, 2017) [31]. Processing and preservation of food require different applications and precautions. Traditionally, thermal treatments (pasteurization and sterilization) have been used to produce safe food products such as juice, milk, beer, and wine in which the final product has a shorter storage life (generally under refrigeration). However, vitamins, taste, colour, and other sensorial characteristics are decreased with thermal treatments (Chow *et al.*, 2003) [12].
Moreover increasing consumer demand for high quality food products, having natural flavour, taste and free from preservatives, encouraged the need for the development of non-thermal innovative approaches for food processing (Ulusoy *et al.*, 2007) [38]. Non-thermal food processing methods such as ultrasound processing, high pressure processing, pulsed electric fields, cold plasma, ozonisation and oscillating magnetic fields, offer maximum quality and safety to food products have attracted attention of the food industry (Awad *et al.*, 2012) [5]. In order to meet the consumer demand, new and innovative food processing methods, as well as novel combinations of existing methods, are continually being sought by industry in an effort to produce better quality food, economically. The non-thermal technologies are reported to have potential to be used for food processing as it offers microbial and enzyme inactivation at ambient or lower temperature. Ultrasound is such a non-thermal technology which is having a great potential and its suitability for various operations and applications in food industry (Ulusoy *et al.*, 2007) [38].
Ultrasound is a form of energy generated by sound waves having frequency that is in-audible to human ears. Ultrasound may be defined as a pressure wave that is oscillating between the frequencies 20 kHz and 10 MHz which have a range of ultrasound applications (Butz and Tauscher, 2002) [8]. The technique through which ultrasounds are used in processing or preservation is called Sonication.

A sonicator is a device that generates amplified mechanical vibrations utilizing the high-frequency electrical current produced by a generator. Ultrasound is an acoustic energy but, its effect is a result of physical energy which is generated by the kinetic energy of the molecules in the applied medium. Ultrasound is composed of mechanical sound waves that originate from molecular movements that oscillate in a propagation medium. The waves have a very high frequency, equal to approximately 20 kHz, are divided into two categories i.e., low-intensity and high-intensity waves (Gallo *et al*., 2018) [19]. The presence of ultrasound and its application in nature predates history itself, the use of ultrasound by bats, cetaceans and porpoises (echolocation) to navigate and also to detect the prey or avoid obstacles by producing ultrasound in their vocal chords are such prime applications of ultrasound in nature.

Ultrasound is generally associated with the biomedical field to detect motion, organs, tumours, and pre/post-natal handicaps, and for kidney stone removal, and physiotherapy. Ultrasound has numerous applications in various other fields also. 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 (Povey and Mason, 1998) [29]. By the 1960s the uses of power ultrasound in the processing industries were well accepted and this interest has continued to develop. Now a day's ultrasound is emerging as a promising technology in food processing and preservation owing to its wide range of applications in food industry which are used for highly reliable and effective methods for food processing (Rojas *et al.,* 2017) [34].

History of Ultrasound

Pierre curie and Jacques curie discovered the ultrasound waves in 1880 while their study on piezoelectric effect. In 1894, Thorny croft and Barnaby observed that vibrations were produced in the missile. During World War I France and Britain launched programs for submarine detection using underwater ultrasonic transducers consisting of a quartz plate. Before World War II, applications of ultrasound were being developed for a range of technologies, including surface cleaning procedures. In the 1960s, ultrasound technology was well established and used for cleaning in steel and plastic industries. Fromlate 1960s ultrasound is being used to characterize the foods such as meat, fats and oils, milk, bread, fruit, and sauces based on particle size, distribution and composition and also for improving the functional properties of food (Ravikumar *et al*., 2017) [31].

Principles and mechanism of generation of ultrasound

Principle

When sound waves propagated through any product, there will be a production of high amount of energy due to compression and rarefaction of the medium particles. Thus, cavitation is the formation, growth and collapse of bubbles that generate a localized mechanical and chemical energy. When ultrasound waves passes through a liquid medium, formation of gas bubbles inside a liquid due to cavitation occurs. It is the interaction among sound waves, liquid and dissolved gas. It results in pressure change around the dissolved gas nuclei and lead to oscillations. Further, the dissolved gas and solvent vapour spread in and around the oscillating bubbles. Then the bubbles will get expanded in successive cycles to an unstable size and burst. Bursting of bubbles release very high pressure and heat around the collapsing bubbles which break the compounds in the liquid. It cause particle dispersion and cell disruption and provide localized sterilization or pasteurization effect depending on the intensity of applied sound (Ravikumar *et al*., 2017) [31].

Ultrasound when propagated through a biological structure induces compressions and rarefactions of the particles and a high amount of energy is imparted. At sufficiently high power, the rarefaction exceeds the attractive forces between molecules in a liquid phase, which subsequently leads to the formation of cavitation bubbles (Rastogi, 2011) [30].

Solid, semisolid and liquid food preservation by ultrasound waves

When ultrasound is applied in a solid–fluid system, it produces a series of effects that can affect both internal and external resistance to mass transfer between solid and fluid. In solid foods, when ultrasound is allowed to pass through them, product drying at higher rate at lower solution temperature occurs. It also protect product from case hardening, non-enzymatic browning, poor appearance and preservation of natural flavour, colour and heat sensitive nutritive components. It is due to increased cell wall permeability owing to the formation of microscopic channels which facilitates the transport of water out and solute in. Thus, the micro jets hitting the solid food surface may produce an injection of fluid inside the solid and affect the mass transfer between the solid and the fluid (Mason, 2003) [26].

In the solid, ultrasonic waves produce a series of rapid compressions and expansions of the material that can be compared to a sponge squeezed and released repeatedly. This effect, known as the "sponge effect," helps the liquid to flow out of the samples. On the other hand, the compressions and expansions of the material can create micro channels which are suitable for fluid movement (Ravikumar*et al*., 2017) [31]. The effects described, can affect both internal and external resistances to mass or heat transport and are the reason why high-intensity ultrasounds are applied to improve some transport operations. In heat transfer processes, high-intensity ultrasound can be used to improve the convective heat transfer coefficient in a similar way to mechanical agitation (Carcel *et al*., 2007) [9].

Ultrasound is an oscillation wave ranging from 20 KHz to 500 MHz, it can be further divided based on usage and power into two High power (frequency 20kHz to 100kHz) and Low power (frequency >100kHz). Low-intensity ultrasound is mainly used for non-destructive techniques of analysis of fruits and vegetables and their products which provide information about physicochemical properties, such as composition, structure, physical state and flow rate. While high intensity ultrasound is mainly used to alter, either physically or chemically, the properties of foods, for example to generate emulsions, disrupt cells, promote chemical reactions, inhibit enzymes, tenderize meat and modify crystallization processes (Gallo *et al*., 2018) [18].

Table 1: Effects of ultrasound on food

Mechanical Effects	**References**
Crystallization of fats, sugars	Luque de Castro *et al*., 2007 [24]; Cook and Hartel, 2010 [13]
Degassing and destruction of foams	Dedhia *et al*., 2004 [16]
Extraction of aromas	Chemat *et al*., 2017 [10]
Filtration and drying	Tao and Sun, 2015 [37]
Freezing	Kiani *et al*., 2011 [23]
Mixing and homogenization	Mason *et al*., 2005 [25]
Precipitation of airborne powders	Riera *et al*., 2006 [14]
Meat tenderization	Jayasooriya *et al*., 2004 [22]; Alarcon-Rojo *et al*., 2015 [3]
Chemical and Biochemical Effects	References
Bactericidal action	Yu *et al*., 2012 [40]
Wastewater treatment	Oturan *et al*., 2014 [27]
Modification of the growth of living cells	Guo *et al*., 2015 [20]
Alteration of enzymatic activity	Huang *et al*., 2017 [21]
Sterilization of equipment	Chemat *et al*., 2017; [10]

Mechanism of Ultrasound Generation: (Gallo *et al*., 2018) [19]

Any device capable of generating and/or detecting ultrasonic waves is called an ultrasonic transducer. Figure 1 represents the experimental setup required for application of ultrasound.

It mainly consists of three parts

1. **Power generator:** It is a device used to electricity generation and supply to the transducer.
2. **Transducer:** It is a device used to convert electric energy to ultrasound or mechanical energy (Ultrasound waves).
3. **Coupler:** The working end of the system that helps transfer the ultrasonic vibrations to the substance being treated (usually liquid) (Altaf *et al*., 2018) [4].

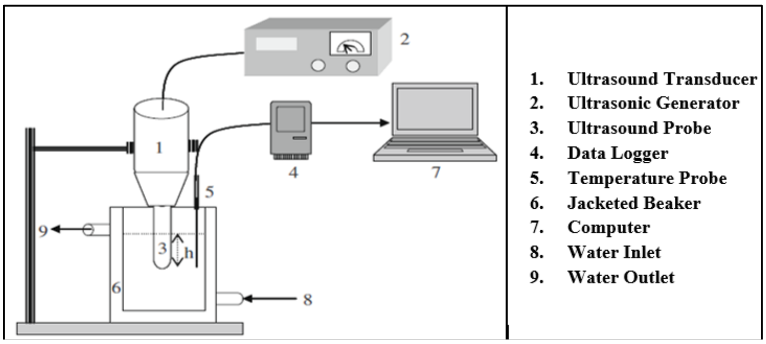

Fig 1: Experimental setup of Ultrasound

Basically there are two types of ultrasound transducers (Altaf *et al*., 2018) [4].

1. Magnetostrictive transducer
2. Piezoelectric transducer

1. Magnetostrictive transducer

This a transducer which work on the principle of magnetostriction effect. Magnetostriction effect works on the principle that certain ferromagnetic substances change their size or dimensions when they are in the presence of a magnetic field. This device consists of a core made up of ferromagnetic materials such as cobalt, nickel, etc which are arranged in the form of layers and into a core. This core in bound to a canister on both the ends and it is surrounded by a copper coil which is connected to electric supply. When electricity is passed through the copper coil a magnetic field is produced around the coil this in turn leads to change in dimensions of the ferromagnetic core. This change in dimensions is proportional to the magnetic field and this change in dimensions cause the production of ultrasound. Its maximum operating frequency is restricted to 100 kHz (Altaf *et al*., 2018) [4].

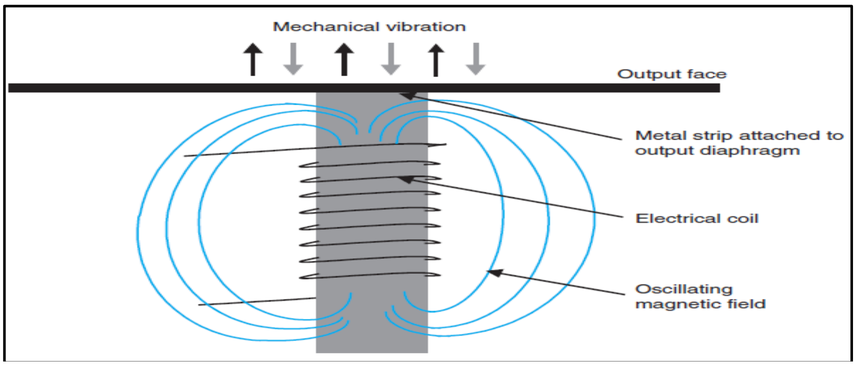

Fig 2: Magnetostrictive transducr

2. Piezoelectric effect

Piezo means pressure Piezoelectricity—using crystals to convert mechanical energy into electricity or vice-versa. Piezoelectricity (also called the piezoelectric effect) is the appearance of an electrical potential (a voltage, in other words) across the sides of a crystal when you subject it to mechanical stress (by squeezing it). It is a phenomenon of certain materials of generation of mechanical vibrations when a charge is applied across the crystal (Inverse piezoelectric effect). The mechanical vibrations are directly proportional to applied charge. It can be operated over the whole ultrasonic range. They are highly efficient over 95 per cent electrically efficient (Altaf *et al*., 2018) [4].

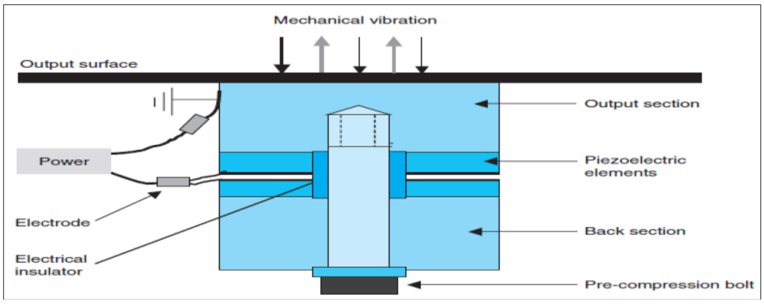

Fig 3: Piezoelectric transducer

Modes of ultra-sonication

Ultrasound can be used for food preservation in combination with other treatments to increase the efficiency of the technique**.**

1. Ultra sonication (US)
2. Thermo sonication (TS)
3. Man sonication (MS)
4. Manothermosonication (MTS)

1. Ultra sonication

It is the application of ultrasound at low temperature. Therefore, it can be used for the temperature sensitive products where there is a concern about the loss of nutrients like vitamin-C, denaturation of protein, non-enzymatic browning etc. However, it needs long period of exposure to kill/ inactivate stable enzymes and/or microorganisms which may cause high energy requirement. During ultrasound application there may be rise in temperature depending on the ultrasonic power and time of application and needs control to optimize the process (Ravi kumar *et al*., 2017) [31]

2. Thermosonication

It is a combination of ultrasound and heat. Here the product is subjected to ultrasound combined with moderate heat. As a result of additional heat, the ultrasound produces a high amount of cavitation which in turn gives a greater effect on inactivation of microorganisms than heat alone. Therefore, the combination of low frequency ultrasound with mild heat will help in reducing the time of processing by 55% and temperature of processing by 16% by reducing product sensory quality (Abdullah and Chin, 2014) [1].

3. Mansonication

It is a combined method in which ultrasound and pressure are applied ultrasound with moderate pressures at low temperatures. Its inactivation efficiency is higher than ultrasound alone at the same temperature (Dolatowski, 2007).

4. Manothermosonication

It is a combined method of heat, ultrasound and pressure. Here, the applied temperature and pressure will maximise the cavitation and give greater efficiency for inactivation of enzymes and microorganisms. MTS treatments inactivate several enzymes at lower temperatures and/or in a shorter time than thermal treatments at the same temperatures. Microorganisms that have high thermo tolerance can be inactivated by MTS. Thermo-resistant enzymes, such as lipoxygenase, peroxidase and polyphenoloxidase are reported to be inactivated by MTS (Ercan and Soysal, 2013) [17].

Applications of Ultrasound

1. Inactivation of microorganisms
2. Inactivation of enzymes
3. Freezing
4. Extraction and degassing
5. Mixing and emulsification
6. Rheological and texture
7. Fermentation
8. Filtration
9. Drying
10. Foam formation and destruction

1. Inactivation of Microorganisms (Birmpa *et al*., 2013) [7]

When applied with sufficiently high intensity US Frequencies above 18 kHz are lethal to microorganisms. The antimicrobial action of ultrasound is mainly because of the following actions:

- **Cavitation**: Cell wall structures are disrupted thinning of cells Cell wall is broken and releasing the cytoplasm content Pore formation, cell membrane disruption, and cell breakage.
- **Free radical production**: DNA injures which produce breakages and fragmentation.
- **Micro streaming:** As US passes through the medium they vibrate and produce currents in the adjacent fluid which exerts a twisting motion on around the bubbles, these small bubbles travel through the sonic field and create micro currents.

Gram- negative bacteria are more readily susceptible to ultra-sound inactivation than the gram-positive ones. Although treatment with ultrasound can by itself cause a reduction in microorganism counts, it cannot be efficiently used in industrial applications because of its poor sterilization effect. It requires long treatment times and/or high acoustic energy, damaging fresh tissues and making them more susceptible to infestation and attacks by microorganisms.

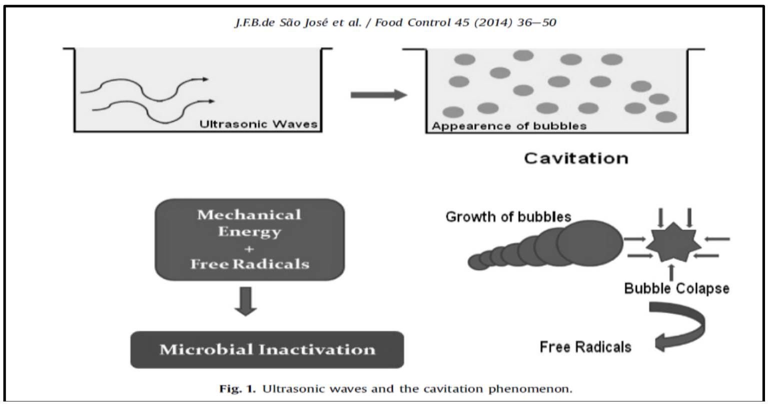

Fig 4: Ultrasonic waves and the cavitation phenomenon

Table 2: Effect of ultrasound on Microorganisms

Organism	US treatment	Crop	Time	CFU treatment	References
E. coli	US 37 kHz	Strawberry	30-45 min/not informed	3.04 log CFU g ^{1}	Birmpa *et al.*, (2013) [7]
S. aureus			30-45 min/not informed	2.41 log CFU g ^{1}	
S. enteritidis			30-45 min/not informed	5.52 log CFU g ^{1}	
L. innocua			10 min/not informed	6.12 log CFU g ^{1}	
E. coli O157:H7	US 40 kHz + Electrolyzed	Chinese Cabbage	3 min/ 23 +/- 2° C	2.60 log CFU g ^{1}	Forghani and Oh (2013) [18]
	water + immediate	Lettuce		2.50 log CFU g ^{1}	
		Sesame leaf		2.33 log CFU g ^{1}	
	water washing	Spinach		2.41 log CFU g ^{1}	
		Chinese Cabbage	3 min/ 23 +/- 2°C	2.80 log CFU g ^{1}	
L.monocytogenes	US 40 kHz + Electrolyzed	Lettuce	3 min/ 23 +/- 2°C	2.60 log CFU g ^{1}	
		Sesame leaf		2.40 log CFU g ^{1}	
		Spinach		2.49 log CFU g ^{1}	

2. Inactivation of Enzymes

Mano-thermo-sonication is responsible for particle size reduction and molecular breakage. Changes in pressures generate stretching and compression in the cells and tissues. But as mentioned before free-radical production is promoted by ultrasound. Such free radicals as H+ and OH− could recombine with amino acid residues of the enzymes. Disruption of tissue is mainly important because it generates better surface contact between the enzymes and free radicals (Cruz *et al*., 2006) [14]. For example, oxidases are usually inactivated by sonication, while catalases are affected at low concentrations. Lower temperatures and/or in a shorter time than thermal treatments (Vercet *et al*., 2001) [39].

Table 3: Effect of ultrasound on inactivation of Enzymes (Baslar *et al.*, 2015)

Juice	Treatment	Temperature (°C)	Enzymes	Inactivation
Apple juice	Ultrasonic probe	40-60	Poly Phenol Oxidase	Max 12.9% decrease for 10 min
Pineapple juice	Ultrasonic probe	54	Poly Phenol Oxidase	Max 20% decrease for 15 min
Orange juice	Ultrasonic probe	<45	Pectin Methyl Esterase	Max 62% decrease for 10 min
Tomato juice	Ultrasonic probe	50-75	Pectin Methyl Esterase	Max 55% decrease for 10 min
Tomato juice	Ultrasonic probe	61	Pectin Methyl Esterase	Max 39% decrease for 10 min
Apple juice	Ultrasonic probe	20-60	Poly Phenol Oxidase	Max 20% decrease for 15 min
Apple juice	Ultrasonic probe	20-60	Poly Phenol Oxidase	Max 37% decrease for 10 min

3. Freezing (Cheng *et al*., 2015) [11]

Power ultrasound, with frequencies in the range of 20–100 kHz, has proved useful in the formation of ice crystals during the freezing of water, since the rate is improved and cell damage reduced. The involved mechanism is acoustic cavitation, in which the acoustically generated bubbles act as nuclei for crystal growth.

Sonication is a highly useful tool in the control of crystallization processes because it enhances the nucleation rate and crystal growth rate, thus generating new and fresh nucleation sites. It also helps in the control of size of crystals.

4. Extraction and Degassing (Pico. 2013) [28]

When these bubbles collapse onto the surface of a solid material, the high pressure and temperature released generate microjets directed towards the solid surface. These microjets are responsible for the degreasing effect of ultrasound on metallic surfaces, which is widely used for cleaning materials. Another application of microjets in food industry is the extraction of vegetal compounds, because this allows improved solvent penetration into the plant body and can also break down cell walls.

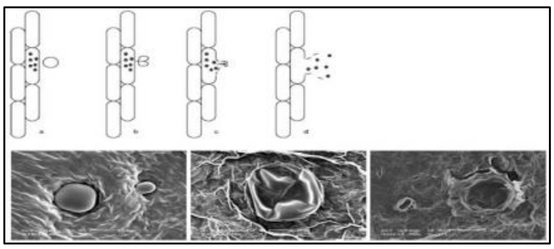

Fig 5: Generation of bubbles (a), then, during a compression cycle, this bubble collapses (b) and a microjet directed toward the plant matrix is created (b and c). (Pico. 2013) [28]

5. Mixing and Emusification (Mason *et al*., 2005) [25]

When cavitation bubbles collapse and produce shockwaves, powerful forces are generated that cut the process material into microscopic sizes. This increases the surface contact area between the liquids, gases and/or solids being mixed and maximizes the efficiency of the procedure for processes such as hydration, emulsification and gas/liquid mixing. Cavitation can produce superior results when mixing liquids with gases, solids, or other liquids.

6. Rheological properties of food (Rojas *et al*., 2017) [34]

Rheological properties in juices are related to structure, particle size, and composition. The food product consistency can be changed permanently or temporarily, either increasing or decreasing the consistency, depending on the ultrasound energy for microscopic particles various factors like Brownian moment play a big role whereas for larger particles non-hydrodynamic properties like shape, size, and distribution play a major role. Ultrasound processing that cause the increase/ decrease in juice consistency or serum viscosity and alsoindicated better sensorial preference.

Table 4. Structural Effects of Ultra and Processing That Influence the Renological Responses of Juice (Rojas *et al*., 2017) [34]

Structural Effect	Rhenological Response
Increase in the interaction forces among small particulars with continuous phase	Increase juice consistency
Release of intracellular compounds in the juice	Increase juice consistency
Decrease in polysaccharide size	Decrease juice consistency

7. Fermentation (Rojas *et al*., 2017) [34]

Ultrasound aids enhances the rate of fermentation. Mechanism is ultrasound drives off CO_2 (produced during the fermentation) which normally inhibits the fermentation. Increase in the fermentation rate of sake, beer and wine, when a relatively low intensity ultrasound was applied during the fermentation.

8. Filtration (Acoustic Filtration) (Mason *et al*., 2005) [25]

It Increases the flux by breaking the concentration polarization and cake layer at the membrane surface without affecting the intrinsic permeability of membrane. It has been successfully employed to enhance the filtration of industrial juices. Optimized ultrasound intensity is very important to prevent the damage of filters. Conventional belt vacuum filtration achieves a reduction in moisture content from an initial value of 85% to 50%, whereas electroacoustic technology achieved 38% (Apple juice).

9. Drying

The use of ultrasound along with drying is very beneficial. It can be dried more rapidly and at a lower temperature so it can be used for heat sensitive foods. It improves heat and mass transfer phenomena in drying processes. It aids in dehydration by cavitation and compressions & rarefactions. Ultrasound generates high forces and turbulence and it maintains the moisture inside the capillaries of the material thus making the moisture removal easier. Ultrasonic process is economically viable being 11% less expensive than the air-drying process to dry papaya (Awad *et al*., 2012) [5].

Table 5: Different food materials and their assisted drying procedure

Material	Assisted drying procedure	Reference
Apple cubes	Hypertonic solution of sucrose in solid-liquid system	Sima *et al.,* 1998 [36]
Curd onions	Saturated NaCl brine in solid-liquid system	Sanchez *et al.,* 1999 [35]
Carrots	Direct contact in solid-gas system	Gallego *et al.,* 1999
Apples and carrots	Air born radiation and direct contact in solid-gas system	Riera *et al.,* 1999b [32]
Lemon slices	Saturated NaCl brine in solid-liquid	Carcel *et al.,* 2002 [9]
Potatoes	Ultrasonic vibrations in direct contact in solid-gas system	De la Fuente *et al.,* 2003 [15]

10. Antifoam (Mason *et al*., 2005) [25]

Control of excess foam produced during the filling operation of bottles and cans on high-speed canning lines before capping. Partial vacuum on the foam bubble surface produced by high acoustic pressure. Cavitation and resonance of the foam bubbles which create interstitial friction causing bubble coalescence. Atomization from the liquid film surface and acoustic streaming.

Conclusion

Ultrasound is an emerging technology in food science and technology. It finds a in the areas of food analysis (fruits, vegetables, and dairy products) and detecting contamination by foreign extraneous materials in canned and dairy foods. It is a non-toxic and eco-friendly is an emerging technology as it saves lot of energy. The application of low power (high frequency) ultrasound provides a non-invasive, cheap and simple technique that can be used for estimating the food composition (fish, eggs, dairy, etc.), monitoring physicochemical and structural properties (emulsions, dairy products and juices) and detecting contamination by metals and other foreign materials (canned food, dairy foods, etc.). High power (low frequency) ultrasound, on the other hand, modifies the food properties by inducing mechanical, physical and chemical/ biochemical changes through cavitation, which reduces reaction time and increases reaction yield under mild conditions compared to conventional route.

A lot of research has been conducted on ultrasound technologies in food technology. But still a great deal of future research is necessary in order to produce industrial-automated ultrasound systems. This will help in reduction of labor, cost, energy, and should ensure the maximum production of high value and safe food products.

References

1. Abdullah N, Chin NL. Application of the rmosonication treatment in processing and production of high quality and safe-to-drink fruit juices. Agriculture and Agricultural Science Procedia. 2014; 2:320-327.
2. Alarcon FAN, Rojo S. Ultrasound application as pre-treatment for drying of fruits. 2011; 135-41.
3. Alarcon-Rojas ML, Alberto C, Miano AC, Augusto PED. Ultrasound Processing of Fruit and Vegetable Juices. Ultrasound: Advances in Food Processing and Preservation, 2017, 181-99.

4. Altaf U, Rouf A, Kanojia V, Ayaz Q, Zargar I. Ultrasound treatment: A novel processing technique for food preservation. The Pharma Innovation Journal. 2018; 7(2):234-41.
5. Awad TS, Moharram HA, Shaltout OE, Asker D, Youssef MM. Applications of ultrasound in analysis, processing and quality control of food: A review. Food Research International. 2012; 48:410-27.
6. Başlar M, Yildirim HB, Tekin ZH, Ertugay MF. Ultrasonic Applications for Juice Making. Handbook of ultrasonic and soon chemistry, 2016, 1-22.
7. Birmpa BH, Colak H, Hampikyan H. The use of ultrasonic waves in Food Technology. Research Journal of Biological Sciences. 2007; 2(4):491-97.
8. Butz P, Tauscher B. Emerging technologies: Chemical aspects. Food Research International. 2002; 35:279-84.
9. Carcel JA, Garcia-Perez JV, Riera E, Mulet A. Influence of high-intensity ultrasound on drying kinetics of persimmon. Drying Technology. 2007; 25:185-93.
10. Chemat ZJ, Stadnik J, Stasiak D. Applications of ultrasound in food technology. *Acta Scientarium Polonorum* Technology Alimentaria. 2017; 6(3):89-99.
11. Cheng X, Zhang M, Xu B, Adhikari B, Sun J. The principles of ultrasound and its application in freezing related processes of food materials: A review. Ultrasonic Sonochemistry. 2015; 27:576-85.
12. Chow R, Blindt R, Chivers R, Povey M. The sono ncrystallisation of ice in sucrose solutions: primary and secondary nucleation, Ultrasonic. 2003; 41:595-04.
13. Cook JD, Hartel H. Acoustically assisted diffusion through membranes and biomaterials. Food Technology, 2010, 79-84.
14. Cruz TJ, Riera E, Vercet A, Lopez-Buesa P. Application of Ultrasound. Emerging technologies for food processing. 2006; 13:323-51.
15. De La Fuente JFBDS, Andrade NJD, Ramos AM, Vanetti MCD, Stringheta PC, Chaves JBP, et al. Decontamination by ultrasound application in fresh fruits and vegetables. Food Control.2003; 45:36-50.
16. Dedhia JFBDS, Andrade NJD, Ramos AM, Vanetti MCD, Stringheta PC, Chaves JBP. Decontamination by ultrasound application in fresh fruits and vegetables. Food Control. 2004; 45:36-50.
17. Ercan SS, Soysal C. Use of ultrasound in food preservation. Natural Science. 2013; 5:5-13.
18. Forghani BH, Oh H. The use of ultrasonic waves in Food Technology. Research Journal of Biological Sciences. 2013; 2(4):491-97
19. Gallo M, Ferrara L, Naviglio D. Application of Ultrasound in Food Science and Technology: A Perspective Foods. Foods. 2018; 7(10):164.
20. Guo TJ, Riera E, Vercet A, Lopez-Buesa P. Application of Ultrasound. Emerging technologies for food processing. 2005; 13:323-51.
21. Huang JFBDS, Andrade NJD, Ramos AM, Vanetti MCD, Stringheta PC, Chaves JBP et al. Decontamination by ultrasound application in fresh fruits and vegetables. Food Control. 2017; 45:36-50.
22. Jayasooriya BH, Colak H, Hampikyan H. The use of ultrasonic waves in Food Technology. Research Journal of Biological Sciences. 2004; 2(4):491-97.
23. Kiani WS, Bhat R, Rosma A, Cheng LH. Effects of thermo sonication on the fate of Escherichia coli O157:H7 and Salmonella Enteritidis in mango juice. Letters in Applied Microbiology. 2011; 56:251-57.
24. Luque de castro JFBS, Venetti MCCD. Effect of ultrasound and commercial sanitizers in removing natural contaminants and *Salmonella enterica*, *Typhimurium*on cherry tomatoes. Food Control. 2012; 24:95-99.
25. Mason TJ, Riera E, Vercet A, Lopez-Buesa P. Application of Ultrasound. Emerging technologies for food processing. 2005; 13:323-51.
26. Mason TJ. Sonochemistry and sonoprocessing: the link, the trends and (probably) the future. Ultrasonic Sonochemistry. 2003; 10(4-5):175-179.
27. Oturan JFBDS, Andrade NJD, Ramos AM, Vanetti MCD, Stringheta PC, Chaves JBP. Decontamination by ultrasound application in fresh fruits and vegetables. Food Control. 2004; 45:36-50.
28. Pico Y. Ultrasound-assisted extraction for food and environmental samples. Trends in Analytical Chemistry, 2013, 43.
29. Povey MJW, Mason TJ. Ultrasound in Food Processing. *Springer*, Berlin, 1998.
30. Rastogi NK. Opportunities and challenges in application of ultrasound in food processing. Critical Reviews in Food Science and Nutrition. 2011; 51(8):705-22.
31. Ravikumar M, Suthar H, Chirag Desai C, Gowda AJS. Ultrasonication: An Advanced Technology for Food Preservation. International Journal of Pure Application of Biosciences. 2017; 5(6):363-71.
32. Riera JFBDS, Andrade NJD, Ramos AM, Vanetti MCD, Stringheta PC, Chaves JBP, et al. Decontamination by ultrasound application in fresh fruits and vegetables. Food Control. 1999; 45:36-50.
33. Riera VVM, Nguyen TP. Application of ultrasound to pineapple mash treatment in juice processing. International Food Research Journal. 2006; 19(2):547-52.
34. Rojas ML, Alberto C, Miano AC, Augusto PED. Ultrasound Processing of Fruit and Vegetable Juices. Ultrasound: Advances in Food Processing and Preservation, 2017, 181- 99.
35. Sanchez R, Blindt R, Chivers R, Povey M. The sono crystallization of ice in sucrose solutions: primary and secondary nucleation, Ultrasonic. 1999; 41:595-04.
36. Sima JFBDS, Andrade NJD, Ramos AM, Vanetti MCD, Stringheta PC, Chaves JBP. Decontamination by ultrasound application in fresh fruits and vegetables. Food Control. 1998; 45:36-50.
37. Tao JD, SUN H. Acoustically assisted diffusion through membranes and biomaterials. Food Technology, 2015, 79-84.
38. Ulusoy BH, Colak H, Hampikyan H. The use of ultrasonic waves in Food Technology. Research Journal of Biological Sciences. 2007; 2(4):491-97.
39. Vercet TJ, Riera E, Vercet A, Lopez-Buesa P. Application of Ultrasound. Emerging technologies for food processing. 2001; 13:323-51.
40. Yu JG, Oliveira FIP, Gallão MI, Weller CL, Rodrigues S, Fernandes FAN. Ultrasound-Assisted Osmotic Dehydration of Strawberries: Effect of Pretreatment Time and Ultrasonic Frequency. Drying Technology. 2012; 28:294-03.