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Ultrasonic processing and its use in food industry: A review

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Abstract
Ultrasound are sound waves having frequency beyond the audible range of human capacity (~20 kHz). It has a variety of applications with many advantages as compared to conventional methodologies used in food industries. Ultrasound is similar to 'normal' (audible) sound based on physical properties. Ultrasound is one of the emerging technologies that were developed to minimize processing, maximize quality and ensure the safety of food products. It is one of the new technologies which increases and ensures quality and reduces the time of processing and cost of the food products. So ultrasound is used in food technology for processing, preservation and extraction steps. It makes use of physical and chemical phenomena which marks the difference with conventional techniques. It offers great advantage in various fields like productivity, yield, better quality, less time and being environmental friendly.

Keywords: Ultrasound, frequency, processing and preservation

Introduction

Ultrasound has been emerged as a revolutionary technology in the field of food industry. Its use is continuously increasing in various steps of processing of food products. Ultrasonic is a fast growing area of research, which has been found to be used increasingly in the food industry for analysis as well as modification of various food products. The use of ultrasound in food industry involves various novel ideas and methods which are interesting as compared to conventional methods or techniques. This introduces us to the food processing methods which are alternatives to conventional ones. The use of ultrasound is an active subject within the food industry for both of the research and development [1]. When the ultrasound propagates through a material it induces compressions and decompressions (rarefactions) in the particles of the medium, due to which high amount of energy is produced [2]. Sound is a mechanical wave that travels in a straight line and also it requires a medium through which it travels. Ultrasound is a wave with a frequently exceeding the upper limit of human hearing which is greater than 20,000 Hz (Hertz). In ultrasound, the sound ranges can be broadly divided into two different categories. The one is low energy, high frequency diagnostic ultrasound in the MHz range and another one is high energy, low frequency, power ultrasound in the kHz range. So it is possible that ultrasound can be used for processing. The basic principle behind working of ultrasound is that it utilizes interaction between high-frequency sound waves and matter to obtain information about the composition, structure and dimensions of materials through which it propagates. Ultrasound has mainly two distinct categories of frequency ranges. They are high frequency, low energy diagnostic ultrasound in MHz range and low frequency high energy power ultrasound. Low energy (low intensity, low power) ultrasound has frequencies greater than 100 KHz with intensities down $1W.cm^2$. These can be used as monitoring of food products while processing and storage with high quality and safety. It is used for evaluation of the composition of meat products, poultry and fish of raw and fermented stages. It is also used for the quality check or control of fruits, vegetables, cheese, oil, bread, cereals etc. High energy (high intensity, high power) ultrasound has frequencies between 20 and 500 kHz with intensities more than $1W.cm^2$. These are disruptive in nature and have effect on mechanical, physical or biochemical properties of foods. This is used for controlling microstructures and modification, emulsification, defoaming of food products. It also has role in freezing, thawing, microbial inactivation, drying etc. Ultrasound is sound waves which have frequency beyond the hearing capacity of human ears (~20 kHz). Ultrasound is one of the emerging technologies that was developed to reduce the cost and time of processing. It ensures the quality and safety of food products [3].

Few animals use ultrasound for navigation (dolphins) or hunting (bats) tracking the back-scattering sound waves. Ultrasound techniques are emerging technology for modifying food products which are relatively cheap, energy saving and simple. Low power (high frequency) ultrasound mainly monitors the physicochemical properties and composition of the components of food and products during various steps of processing and storage which helps to control the properties and quality improvement.

At the contrary high power (low frequency) ultrasound includes physical, mechanical and biochemical changes through various processes like cavitation which are used in various operations such as extraction, drying, freezing, emulsification and also inactivates the pathogenic bacteria on the surfaces of food products. It is also used for the quality control of fresh vegetables and fruits in both pre- and postharvest, cheese during processing, commercial cooking oils, bread and cereal products, bulk and emulsified fat based food products, food gels, aerated and frozen foods. Other applications include the detection of honey adulteration and assessment of the aggregation state, size and type of protein [4]. High power ultrasound with frequency higher than 20 kHz has mechanical, chemical and/or biochemical effects, which are used to modify the physicochemical properties and enhance the quality of various food systems during processing [2]. Conventional food processing methods use may involve losses of some compounds, low production efficiency, time- and energy-consuming procedures (prolonged heating and stirring, use of large volumes of water etc.). These shortcomings have 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 [5], supercritical fluid extraction and processing [6], extrusion [7], microwave processing [8], controlled pressure drop process [9], pulse electromagnetic field [10], high pressure [11] and subcritical water extraction [12]. Alternatives to conventional processing, preservation and extraction procedures may increase production efficiency and contribute to environmental preservation by reducing the use of water and solvents, elimination of wastewater, fossil energy and generation of hazardous substances.

Ultrasound has significant effect in the food industry in case of rate of various processes. By this technique food processes can be finished in very less time of seconds or minutes with good reproducibility. It reduces the processing cost and simplify the work giving high purity to the final product as compared to conventional processes. Ultrasound in food technology is used for various processes like processing preservation and extraction. It uses different physical or chemical phenomena which are fundamentally different as compared to conventional methods. It has advantages in terms of productivity, yield, quality and also is environmentally friendly [13]. Ultrasound is used for positive effects in food processing such as improvement in mass transfer, food preservation, assistance of thermal treatments and manipulation of texture and food analysis [14]. Ultrasound has its various effects on different systems. On solids it effects through vibrational energy for cutting and melting, in liquids it effects by the production of intense cavitation and in gases it affects by by producing high-intensity acoustic fields. Power ultrasound has history in processing back in 1927, when a paper was published entitled ’The chemical effects of high frequency sound waves. I. A preliminary survey’. This paper explained about the development of power ultrasound described its uses in various areas and its applications including surface cleaning and emulsification [15].

Power ultrasound generation and equipment

It is electricity driven ultrasonic system, which is most commonly used in the food processing industry. It has basic components: power generator, the transducers (converting the electrical power to mechanical vibrations). Two major types of ultrasound transducers are magnetostrictive trasducers and piezoelectric transducers. The main form of ultrasound is diagnostic ultrasound which is mainly used as an analytical technique. It is mainly used for quality assurance, process control and non-destructive inspection. It is applied to determine food concentration, viscosity and composition etc. It is used to measure flow rate, flow level in food packaging.

Magnetostrictive transducer

It provides a large driving force because the system is of an extremely robust construction. However, about 40 per cent of the electrical energy will be lost as heat and thus external cooling is required. Its maximum operating frequency is restricted to 100kHz.

Piezoelectric transducer

It has higher electro mechanical conversion and over 95 per cent electrically efficient. Also it can be operated over the whole ultrasonic range.

Ultrasound phenomena or methods in food preservation

Ultrasound is involved in process development. Unlike other non-thermal processes it can be easily tested in lab or bench-top scale which generates reproducible results for scale-up.

The effects, however, are not severe enough for a sufficient destruction of micro-organisms when using ultrasound alone. This can be achieved by combining ultrasound with heat or pressure or both.

Applications using combination with other preservation methods are:

- **Ultrasonication (US):** It is the application of ultrasound at low temperature and require high energy. It is mainly used for heat sensible products. This method requires long treatment time to inactivate stable enzymes.
- **Manosonication (MS):** It is combined method in which ultrasound and pressure are applied together. Moderate pressures at low temperatures are combined in this. Upon combination inactivation efficiency is higher than ultrasound alone.
- **Thermosonication (TS):** This method is the combination of ultrasound and heat. It produces a greater effect on inactivation of microorganisms than heat alone.
- **Manothermosonication (MTS):** It is combined method of heat, ultrasound and pressure. This method inactivates several enzymes at lower temperatures in a shorter time than thermal treatments. Microorganisms that have high thermotolerancecan be inactivated by manothermosonication.

Fundamentals of Ultrasound

1. Ultrasonic Disintegration of Cell Structures: It is used for the extraction of intracellular materials, e.g. starch from the cell matrix. Ultrasonic disintegration can easily be tested in any scale. It can be used at lab scale for 1ml to approximately 5L. At bench top scale it can be used at approximately 0.1 to 20L/ minute. Production scale in this case starts at 20 L/minute.

2. Protein and enzyme extraction: Extraction of enzymes and proteins which are stored in cells and sub cellular particles are also processed by ultrasound. It is unique and effective application of high intensity ultrasound. It has potential benefit in the extraction and isolation of novel potentially bioactive components.
3. Extraction of lipids and proteins: Lipids are extracted from plant seeds, such as soybeans (e.g. fluor or defatted soybeans) or other oil seeds. In this case destruction of cell walls facilitates the pressing (cold or hot) and reduces the residual oil or fat in the pressing cake. This technique is applicable to citrus oil from fruits, oil extraction from ground mustard, peanut, herb oil, canola, soy and corn etc.
4. Microbial and enzyme inactivation: It is mainly used in the microbial and enzyme inactivation of fruit juices and sauces. Thermal treatment can cause undesirable alterations of sensory attributes i.e. texture, flavor, color, smell and nutritional qualities like vitamins and proteins. Ultrasound is an efficient non-thermal (minimal) processing alternative.
5. Ultrasonic dispersion and deagglomeration: Ultrasonic cavitation generates high shear that breaks particle agglomerates into single dispersed particles. Ultrasonic laboratory devices are used for volumes from 1.5 ml to approx. 2L. It is involved in the process development and production for batches from 0.5 to approx. 2000L or flow rates from 0.1L to 20m^3 per hour.
6. Synergies of ultrasound with temperature and pressure: Ultrasonication is often more effective when combined with other anti-microbial methods such as thermo-sonication i.e. heat and ultrasound, mano-sonication i.e. pressure and ultrasound and mano-thermo-sonication i.e. pressure, heat and ultrasound.
7. Sonication of bottles and cans for leak detection: Ultrasound is used in bottling and filling machines for the online container leak testing of bottles and cans. The instantaneous release of carbon dioxide is the decisive effect of ultrasonic leakage of containers filled with carbonated beverages.
8. Liberation of phenolic compounds and anthocyanins: It is done from grape and berry matrix, in particular from bilberries and black currants into juice after thawing, mashing and enzyme incubation.
9. Chemical and biochemical effects: ultrasound is used for bactericidal action, effluent treatment, modification of growth of living cells, alteration of enzyme activity and sterilization of equipment.

Use of high intensity ultrasound in food processing

The basics of ultrasound applications are mainly three different methods:

– Direct application with the product.
– Coupling to the device.
– Using ultrasonic bath submergence.

Few application of ultrasound in food processing is as follows:

Drying

Acoustic drying has great potential and have commercial importance. It is used from so long time and has been a topic of interest for many years [16]. Conventional method of dehydrating food products is done by hot air. This method is an economical process but the main problem of this is interior moisture retaining. In this method, the main problem is high temperatures can damage the food, which may affect the colour, taste and nutritional value of the food products [17]. At the contrary ultrasonic osmotic dehydration technology obtain higher water loss and solute gain rates by using lower solution temperatures [18]. So by using this probability of oxidation or degradation is reduced in the foodstuff. The colour, flavor and nutritional value also remain unaffected by using this technology. So by this treatment a reduction in subsequent conventional freeze-drying times and rehydration properties is observed.

The drying which is enhanced sonically can be carried out at lower temperatures due to which probability of oxidation or degradation reduces in the material. This method of drying is useful in case of heat sensitive material [19]. Ultrasonic dehydration involves lower solution temperatures for acquiring higher water loss and solute gain rates [20]. In this case because of application of low temperatures and less time periods for dehydration, the colour, flavor and nutritional value of products remain unaltered. While in conventional methods the high temperatures may cause damage to the product by changing the colour, taste and the nutritional value of products [17]. It has also been used prior to the drying of vegetables like pretreatment. It reduces subsequent conventional and freeze-drying times in rehydration processes.

Filtration

In the food industry, to produce solid-free liquid or to isolate solid from its mother liquor, the separation of solids from liquids is an important step. In this case two specific effects is involved:

- Agglomeration of fine particles in the nodes of the acoustic waves
- Generation of sufficient vibrational energy to keep the particles partly suspended and therefore leave more free ‘channels’ for solvent elution.

Acoustic filtration also called as ultrasonically assisted filtration is successfully used to increase the vacuum filtration of difficult mixtures to separate like coal slurry [21]. But the main problem in filtration is deposition of solid materials on the surface of filtration membrane. Ultrasound is useful in the filtration processes because it can increase the flux by breaking the concentration polarization and cake layer on the surface of membrane without creating an affect on the permeability of membrane. This method is mainly applied to extract the fruit juice and drinks from the pulp. From another studies it is clear that high-power acoustic or ultrasound is used for to remove the cake which is accumulated in the filtration processes [22].

Depolymerization

This is one of the oldest applications of ultrasound which is involved in the degradation of polymers [23]. The depolymerization mainly involves two possible mechanisms:

a) By collapsed cavitation bubble mechanical degradation of the polymer.
b) Chemical degradation

Chemical method involves reaction between the high energy molecules and the polymer. The high energy molecules like hydroxyl radicals are produced from cavitation phenomenon [24].

Ultrasound has important potential for the conversion of raw materials like carbohydrates which are polymeric in nature to useful less weight molecules or its simpler components. In food industry, the area in which the use of ultrasound is active is to depolymerise starch [25]. So due to its progress in sonochemical engineering it may play a big role in the carbohydrate industry.

Defoaming

Foam is a colloidal system and dispersion of gas in liquid. They are thermodynamically unstable and have density approaching that of the gas. The distance between individual bubbles are very small. Foam has applications in a variety of industrial processes eg. cosmetics and food production etc. But the intensive foaming or persistent foams are undesirable in various processes. This is so because it may lead to problems like loss of products, decrease in productivity etc. In history foam has been controlled by the use of mechanical breakers, lowering the temperature and by the addition of chemical antifoams [26]. High intensity ultrasonic waves have a distinctive method of foam breaking because they does not need high air flow, prevent chemical contamination and also it is operated under sterile conditions or in a contained environment. So because of this it is an appropriate choice for implantation in the pharmaceutical and food industries. This defoaming system for ultrasound has been developed on a different and new type of ultrasonic generator. In this on a rotation system a focused airborne emitter is placed which is controlled by electricity. So when the transducer rotates a complex movement is created which covers a large defoaming area with different rotation speeds. Under the acoustic beam most of the bubbles break almost instantaneously.

Demoulding and extrusion

When the industrial cooking of foods is done, it leads to adhesion of the products to the cooking vessel or mould. If this product is removed easily it makes cleaning easy and also container is reusable in less time. But the cooked product is difficult to remove from the mould because of product adhesion to the mould by cooking. To counteract this difficulty the moulds are fabricated with a surface coating of white grease, thin layer of silicone or PTFE (Polytetrafluoroethylene). So to replace them over a span of time is expensive and also not absolutely successful. So in these days this problem is solved by using mechanical methods such as knocking vibration for the removal of adhered products. The alternative solution to the earlier conventional methods is achieved by coupling the mould or vessel to a source of ultrasound to release the food products [27]. So by using this technique the cleaning of residual material from the mould become easy and is done automatically.

Extrusion is also a similar property of ultrasound which is its ability to release material from a surface, by virtue of reducing drag. In this ultrasound is provided by energy input by ultrasonic excitation of the metal tubes, so the food is extruded. The ultrasonic source is attached to tube at right angle for providing radial vibration. So this process improves the fluidity of sticky or highly viscous materials through tube by reducing the drag resistance. It also has property of modification of structures of food products [28].

Degassing/deaeration

A liquid contains gases in the mixed form for example a liquid may contain oxygen, carbon dioxide and nitrogen gas. Degassing in an ultrasonic field is done when acoustic waves cause rapid vibration of gas bubbles and adjacent bubbles move within the liquid and coalesce. Degassing in ultrasonic field becomes highly visible phenomenon when an ultrasonic cleaning bath is used with tap water used regularly inside. It occurs when the acoustic waves bring the rapid vibration of gas bubbles and these bubbles grow to sizes which rise up through the liquid, against gravity, until they reach the surface. During the processing of carbonated drinks, its main role is to remove or displace the air from the liquid surface. So by doing this damages caused by bacteria and oxygen are avoided. Mainly this technique is used to degas carbonated beverages such as beer before bottling [29]. Deaeration process by ultrasound involves coupling a transducer to the bottle's outside which leads to degassing. So by using this the advantages like decrease in the number of broken bottles and wasting of beverages are obtained as compared to conventional method of mechanical agitation [30]. Ultrasonically assisted degassing is useful in case of aqueous systems but is difficult in case of viscous liquids to remove gas for example like melted chocolate.

Defrosting/thawing

Freezing is a technique which is widely used for increasing the shelf life of various food products [31]. But if thawing conditions are optimized it can be successful. Acoustic thawing is a promising technology in the food industry if optimum frequencies and acoustic power are chosen. To thaw frozen food products is a slow process and is also very inconvenient and costly process. Thawing is a slow process so also involves damaging food stuffs by the contamination of microorganisms through chemical and physical changes with time. So it is important to quick thawing at low temperature for the good food quality and to escape excessive dehydration of food. The work on the relaxation mechanism showed that when a frequency in the relaxation frequency range of ice crystals in the food was applied, the more acoustic energy could be absorbed by frozen foods [32]. So it was observed that the thawing process in this relaxation frequency was faster than the process using only conductive heating. So it is believed that acoustic thawing is a good technology in the food industries if the acoustic power and frequencies are optimum. So acoustic thawing has advantages like cutting the time or shortening the thawing time so reducing drip loss the improvement in the product quality [33].

Freezing and crystallization

Ultrasound play a role in the crystal formation too. The ultrasound which ranges from 20 kHz to 100 kHz is very helpful in crystallization process. These two processes are linked because both of these involve initial nucleation followed by crystallization [34]. When ultrasound is exposed to the medium it enhances both the nucleation rate and rate of crystal growth by the production of various number of nucleation sites in the medium. The basics to this is because the cavitation bubbles behaves as nuclei for crystal growth.

Freezing or cooling is a technique of food preservation which is used from a long time ago by preserving food in natural ice or over winter storage. During freezing the water content present in the food material get converted into ice crystals. While in case of conventional freezing the problems like non-uniform crystal development and destruction or texture because of the continuous formation of small ice crystals. These crystals kept growing in size and hence break some of the cell walls which leads to the destruction of cell structure

and drip loss on thawing. So due to problems like non-uniform crystal development, loss in sensory food quality in case of conventional methods new innovative technologies such as air blast, immersion freezing, cryogenic freezing, fluidized-bed freezing, high pressure freezing and their combinations are now the most widely and commonly used method in the food industry [35]. When ultrasound is applied, even conventional cooling provides much more rapid and seeding, due to which dwell time is reduced [36]. 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 ultrasonic exposure. This may be due to cavitation bubbles acting as nuclei for crystal growth and/or by the disruption of seeds or crystals already present within the medium thus increasing the number of nucleation sites.

When temperature or pressure is slightly decreased, crystallization can occur in an uncontrolled manner due to which severe problems occur [37]. So this technique has advantages in food industry because of efficient heat transfer throughout the cooling process.

Brining, pickling and marinating

Pickling and marinating are the techniques which are used with a variety of vegetables and meat products. Most commonly used salt-brining or pickling fermentation has mainly three limitations

(1) For brining, a high quantity of sodium chloride is used which may require the desalting process for the use of food products
(2) The process is difficult to control during fermentation
(3) By soaking methods the products may get soften, bloated or structural damage may occur.

So to eradicate these limitations there is a need for alternative technologies. Ultrasound reduces pickling time of products particularly the foods which have crunchy texture [38]. Also the products contain low sodium content so there is no need for desalting. This process provides a product which is uniformly salted. Brining involves two main mass transfer processes: water migration happens from the meat to the brine and the solute migration happens from the brine to the meat. Ultrasound energy can be used with combination for the methods like brining or marinating raw foodstuffs by submerging it in the brine or marinade [39]. So the salting time is mainly reduces by this technology. It was found that the water and NaCl contents of samples after treatment were higher in sonicated than non-sonicated samples. In the cheese industry, the effect of ultrasound on mass transfer during cheese brining has been investigated.

Cutting

Ultrasonic is used since the early 1950s, it is mainly used for the accurate cutting of brittle materials like ceramics, glass and in aerospace industry for carbon fibre composites. It is used because it has improved food processing by providing a new way to cut or slice. So by using this maintenance costs and product waste is minimized. It involves a knife-type blade which is attached to a shaft linked to an ultrasonic source [40]. The cutting tool can be considered as acoustic horn which is a part of ultrasonic resonating device. These tools can be of different or many shapes. The ultrasonic cutting depend on the condition and type of food e.g. thawed or frozen [41]. The most widely used application of ultrasound is the cutting of fragile food products. It also play a great role in improvement of hygiene because due to vibration the product adherence on the blade is prevented and so there is less development of microorganisms on the surface. This is because of the property of ultrasound in the 'auto or self-cleaning' of blade. So there is also less wastage of food products as compared to conventionl method. Hence the foodstuffs retain a better standardized weight.

Cooking

In conventional cooking method either by frying or boiling the exterior of the food may be overcooked as compared to the interior. This may reduce the quality of the product. Ultrasound has the ability to provide improved heat transfer characteristics so there is no problem such like the conventional method. So this technology have been utilized in the cooking [42]. So cooking by ultrasound leads to greater cooking speed. It also provide an energy efficient and rapid method which also improves the textural attributes of food. The post-cooking moisture content is also preserved by using this. The use of high-intensity ultrasound thus has the potential to increase the water-binding properties of meat [43]. So ultrasound is useful in cooking of moist meats and hence is useful in the food industries for food processing. A patent describes a cooking vessel in which ultrasound is applied to a hot oil to provide better and more even overall frying and it is claimed to reduce energy consumption.

Meat tenderization

The traditional method of meat tenderization is mechanical pounding. But this method makes poor quality of meat. Power ultrasound is one of the method which is very useful in this technique. Ultrasound act by using two methods:

1. By the breakage of integrity of muscular cells or
2. By increasing the rate of enzymatic reactions by using biochemical effect [30].

Ultrasonic tenderization can be achieved with poultry meat, veal and beef. So ultrasound is used for producing processed meats. Meat products are present in the recombined form such as beef rolls. These meat pieces are held together by a protein gel which is formed by the myofibrillar proteins released during processing [43]. Tumbling the meat pieces by sonication or adding salt help in tenderization of meat. So the samples which are treated with these are superior in quality. So ultrasound help in improving physical properties of meat products which includes tenderness, water-binding capacity and cohesiveness.

Sterilization/pasteurization

Conventional thermal pasteurization and sterilization are the widely used techniques till date for inactivating microorganisms and enzymes in the food products. But these methods take great time for the processing and may lead to loss of nutrients, development of undesirable flavor and deteriorating the quality of food products. By the use of ultrasound such processes can be improved on the basis of the effects of cavitation. At a great high acoustic power inputs, it break cells but at lower intensity a cell can be inactivated [44].

The ultrasound is effective in the dairy industry for the processes like pasteurization. It is found effective for killing the micro-organisms like *E.coli*, *Pseudomonas* etc. and it does not have detrimental effect on the total protein or casein content of milk [45]. The microbes are killed mainly by thinning of cell membranes and by the production of free radicals.

Ultrasound is also effective to inactivate the enzyme which are responsible for deteriorating the fruit and vegetable juice. These enzymes are mainly pectinmethylesterase, polyphenoloxidases and peroxides etc. [46]. The use of ultrasound in pasteurization continues to be of great interest to the dairy industry. It has proved effective for the destruction of E. coli, Pseudomonas fluorescens and Listeria monocytogenes with no detrimental effect on the total protein or casein content of pasteurized milk. The mechanism of microbial killing is mainly due to the thinning of cell membranes, localized heating and production of free radicals. Investigation on ultrasound effectiveness have also shown the inactivation of enzymes such as pectinmethylesterase, polyphenoloxidases and peroxidases responsible for deterioration of fruit and vegetable juice and various enzymes pertinent to milk quality. So various treatments like thermosonication (TS) and manothermosonication (MTS) inactivate various enzymes. Ultrasound with combination to heat has potential to accelerate the rate of sterilization by taking less time and also reducing damage as well as intensity of thermal treatments.

Emulsification/homogenization

It is a technique of delivering the hydrophobic bioactive compounds into different food products. Acoustic emulsifications have different improvement over the conventional methods. The emulsion produced from this technique has sub-micron distribution. These emulsions are more stable as compared to conventional ones. In this case there is no need of adding surfactants. This method utilize less energy than the older conventional methods. Ultrasonic emulsification is developing area for in-time treatment [47]. It is used in food industry for various products like fruit juices, mayonnaise and tomato ketchup etc. It is also comparable like microfluidity for generating sub-micron dispersions [48].

Ultrasound in food preservation

Ultrasound processing is one of these new methods. While its application in food processing is relatively recent, it has been proved that high-intensity ultrasonic waves can rupture cells and denature enzymes, and that even low-intensity ultrasound is able to modify the metabolism of cells. In combination with heat, ultrasonication can accelerate the rate of sterilization of foods, thus lessening both the duration and intensity of thermal treatment and the resultant damage. The advantages of ultrasound over heat sterilization include: the minimizing of flavour loss, greater homogeneity; and significant energy savings.

Applications

Applications of ultrasound in food preservation can be divided into two main categories depending upon its area of utilization:

a) Directly related to food

Microorganism inactivation

It has been shown that microorganisms do not all react in the same way to ultrasound treatment.

Factors affecting the effectiveness of microbial inactivation are:

- Amplitude of ultrasound waves.
- Exposure or contact time.
- Volume of food processed.
- Composition of food.
- Treatment temperature

Spore inactivation

Microbial spores are resistant to extreme conditions such as high temperatures and osmotic pressures, high and low pHs, and mechanical shocks. Those bacterial spores that survive heat treatment may severely restrict the shelf-life of thermally processed foods because of spoilage and poisoning.

Enzyme inactivation

To prevent denaturation, an enzyme has to keep its native conformation. Hydrophobic interactions, hydrogen bonding, vander Waals interactions, ion paring, electrostatic forces and steric constraints stabilize the three-dimensional molecular structure of globular proteins.

b) Indirectly related to food

One of the major long-established industrial applications of power ultrasound is in surface cleaning and it has proved to be an extremely efficient technology. Ultrasound is particularly useful in surface decontamination where the inrush of fluid that accompanies cavitational collapse near a surface is non-symmetric.

Ultrasound-assisted extraction

UAE in comparison to non-conventional extraction techniques

Ultrasound-assisted extraction is an emerging potential technology that can accelerate heat and mass transfer and has been successively used in extraction field. Ultrasound waves after interaction with subjected plant material alter its physical and chemical properties and their cavitational effect facilitates the release of extractable compounds and enhances the mass transport by disrupting the plant cell walls. UAE is a clean method that avoids the use of large quantity of solvent along with cutting down in the working time. Ultrasounds are successively employed in plant extraction field. Ultrasound is well known to have a significant effect on the rate of various processes in the chemical and food industry.

Application of UAE in food research

The use of ultrasound can enhance the extraction process by increasing the mass transfer between the solvent and plant material. Ultrasound in the use of plant extraction has benefits in increased mass transfer, better solvent penetration, less dependence on solvent used, extraction at lower temperatures, faster extraction rates and greater yields of product.

Application of UAE in food industry

For the food industry the use of ultrasound assistance is becoming increasingly important. The mains matrix of ultrasound assisted extraction is vegetable (seeds and herbs). Compounds extracted will be use as immediately (liquor) or as food and cosmetic additives (essential oil, molecule with special activity).

Ultrasonic food processing involves a vibrating knife producing a nearly frictionless surface to which food products do not stick nor deform. The surface cleanly cuts or slits products including fillers such as nuts, raisins, dried fruit or chocolate morsels without displacement or plowing.

Advantages of ultrasonic food processing

- Wider cutting temperature range
- Cuts cleanly through various densities and consistencies of products with filler materials
- Cuts edges cleanly without pinching or feathering for higher yield in packaging

- Cutting speeds can be increased substantially
- Cleaner, repeatable and more consistent slits and cuts
- Greatly reduced normal down time for clean up
- Does not smear the cut surface
- Ease of use - uncomplicated and user friendly. As simple as flipping the switch on or off.
- Flexibility in adapting the Ultrasonics cutting equipment to existing conventional slitting and cutting equipment.

Food industries using ultrasonic food processing

- Cheese
- Fish
- Prepared meats
- Vegetable
- Bakery and snack foods
- Candy and confectionery
- Health bars

Ultrasound is a nonthermal processing technique that can be used in a broad range of applications. This technology can increase process efficiency through enhanced yields, increased throughput and reduced processing costs as well as modify biomaterial structure. The range of applications of ultrasonic processing in the food and other industries is expanding rapidly. Innovation-driven research organizations and companies are investing more in the development of novel processes and the improvement of existing processes to increase process efficiencies, product quality or to design products with new functionalities. Most ultrasonic systems require a liquid (often water) to couple and deliver energy.

- Reduced environmental footprints
- Shortened processing times
- Higher product yields
- Reduced processing costs and/or maintenance costs
- Improved or new products with enhanced textures, colours and flavours.

In most cases, ultrasound does not cause detrimental effects on food quality attributes and it enhances retention of fresh flavours and pigments, resulting in products with more appealing flavour, taste, colour and brightness. Ultrasound has also proven to be a powerful tool for targeted,product-specific texture modulation.

Conclusion

Ultrasound has many applications in the food industries. But it can provide more benefit when coupled with other methods of food preservation. While it has considerable advantages over pre-existing technologies. So from the applications and advantages of ultrasound it is evident that ultrasonic processing is one of the new technologies which has huge future in the food industry. By using ultrasound, full reproducible food processes can now be completed in seconds or minutes with high reproducibility, reducing the processing cost, simplifying manipulation and work-up, giving higher purity of the final product, eliminating post-treatment of waste water and consuming only a fraction of the time and energy normally needed for conventional processes. The advantages of using ultrasound for food processing, includes: more effective mixing and micro-mixing, faster energy and mass transfer, reduced thermal and concentration gradients, reduced temperature, selective extraction, reduced equipment size, faster response to process extraction control, faster start-up, increased production, and elimination of process steps.

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