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APPLICATIONS OF ULTRASOUND IN FOOD PROCESSING

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Abstract

Nowadays, researchers are interested in minimal food processing techniques because of the increasing fresh or fresh-like food preferences of the consumers. 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. Its powerful effect, drawn the interest of the scientists to investigate on its applications in many areas. In food science, ultrasound has a wide range of applications. Microbial inactivation, drying, filtration, extraction, homogenization, cutting, emulsifying, cleaning, degassing and inactivation of enzymes are some of the examples of efficient ultrasound applications. The two important well-known benefits of using ultrasound are the reduction of the process duration and process cost. In this review, some ultrasound applications will be discussed in food science and technology.

Key words: Ultrasound, food processing, minimally food processing, sonication, cavitation

INTRODUCTION

Instead of traditional food spoilage control processes, the growing demand to prolong the shelf-life of fresh-like foods with mild preservation techniques such as refrigeration, mild heating, modified atmosphere packaging, irradiation, high pressure, pulsed electric fields, pulsed white light, ultrasound, ultraviolet radiation and the use of natural antimicrobial systems are preferred (Zeuthen, et al., 2002). Environmentally friendly, green novel technologies are nowadays interest of industry due to the expections of consumers. The trend of production of prolonged shelf-life foods which are fresh like is nowadays preference of consumers. Traditional thermal processing reduces product quality and freshness. For prolonged shelf-life, efficient inactivation of microorganisms and enzymes is generally the first aim of effective preservation. Minimal processing of foods with non-thermal methods is growing by the consumers demand (Ohlsson and Bengtsson, 2002). For microbial inactivation or reduction, ultrasound is offered in processes in combination with other techniques, such as refrigeration, heat, modified atmosphere packaging and chemical substances. The usage of ultrasound in process has some well-known advantages such as productivity, yield and selectivity, better processing time, enhanced quality, reduced physical and chemical hazards and is environmentally friendly (Chemat, et al., 2011). Cavitation which is formed via ultrasound is important in food processing applications. Fast movement of liquid molecules forms a whirlpool that ends with a low pressure bubble. Due to the fast movement of the molecules in sonicated liquids, thousands of such bubbles are formed. These bubbles, cavitation and enhanced mass transfer affect the targets which are generated by sonication (Chemat, et al., 2011).

The common range of human hearing is 20 Hz to 20 kHz, approximately. 12 Hz is the lowest sound to hear in laboratory conditions (Rossing, 2007). 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 (Brondum, et al., 1998; Butz and Tauscher, 2002). Application with 20 - 100 kHz called as ‘‘power ultrasound’’ which has power for cavitation formation (Denbow, 2001).

Ultrasound, used in processing is above the range of human hearing frequencies. The device that produce ultrasound is called as transducer, converts AC into ultrasound, as well as the reverse, sound into AC.

Ultrasound applications are based on three different methods:

- Direct application to the product.
- Coupling with the device.
- Submergence in an ultrasonic bath (Chemat, et al., 2011).

Microbial inactivation, drying, filtration, cutting, cleaning, emulsification, homogenization, extraction, crystallization, low temperature pasteurization, degassing, defoaming, activation and inactivation of enzymes, particle size reduction, viscosity alteration, germination of seeds, evaporation, oxidation are some of the examples of efficient applications of ultrasound (Shoh, 1975). Another growing demand for food processing with ultrasound is to provide a non-contact measurement in flow systems for hygienic processing. Flow meters were the examples of early applications of ultrasound as non-contact measurement process control system. It was attractive but some data reading errors due to non-Newtonian flow profiles, containing large particulates in flow medium, was the reason for the need of special design of the ultrasonic flow meters in different mediums (Denbow, 2001). The non-contact measurement systems may be fixed in pipes or to a point, checks the flow in-line in food processing, but costs of these systems make it undesirable for food industry. These systems provide intensive hygienic processing conditions. The worldwide cost reduction of

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these techniques may maintain a better worldwide hygienic food processing. The aim of this paper is to summarize some literature published on the application of ultrasound in food processing.

SOME APPLICATIONS OF ULTRASOUND IN FOOD INDUSTRY

Microbial inactivation, foaming/defoaming, degassing/deaeration, cooking, freezing and crystallization, meat tenderization, drying, brining, pickling and marinating, filtration, extraction, homogenization/emulsifying, cleaning, enzyme inactivation and cutting processes, assisted with ultrasound are some of the most studied and applied processes in food industry.

Microbial Inactivation

The effectiveness of thermal processing depends on temperature and time. By the way, the magnitude of treatment, time and process temperature are also proportional to the amount of nutrient loss, development of undesirable flavours and deterioration of functional properties of food products. Some of the common nonthermal alternatives to conventional thermal processing of foods are pulse-electric field inactivation, microfiltration, pulse-light inactivation, high pressure and ultrasonication (Piyasena, et al., 2003).

Alliger (1975) shown that ultrasound caused a thinning of cell walls attributed to the freeing of the cytoplasmic membrane from the cell wall. During the 1980s research continued to look at the effect of ultrasound in combination with other treatments such as heat, (Ordonez, et al., 1984; Garcia, et al., 1989; Wrigley and Llorca, 1992) and chemicals (Lillard, 1993).

There are some studies on cell destruction effect of ultrasound. Heat, pH, chlorination, presurising are the effective combinations for ultrasound that increase the lethality of the tested microorganisms (Lillard, 1993; Rahman, 1999). Sala et al., (1995) described the triple application of heat and ultrasound treatment under pressure. Heat and sonication togeather is known to increase the lethal effect on microorganisms but surprisingly, the lethal effect of the triple treatment was reported to be tenfold when compared to non-pressure thermosonication. Table 1 represents the effects of ultrasound in combination with heat and pressure (Chemat, et al., 2011; Kentish and Feng, 2014).

The bactericidal effect of ultrasound is attributed to intracellular cavitation and demage of cell walls due to the mechanical effect of cavitation (Hughes and Nyborg, 1962). Ultrasound increases the sensitivity of the cell against heat. Structure of proteins and enzymes changes and becomes more suspective for denaturation (Sala et al., 1995).

Lillard (1993) reported, 2.5 to 4-log reduction of Salmonella in chlorinated water immersed Poultry skin when ultrasound is applied additionally.

Table 1: Effects of ultrasound in combination with heat and pressure (Chemat, et al., 2011)

Inactivation by/of	Vegetative cells	Spores	Enzymes
Ultrasound alone	+	-	-
US and heat	+	+	-
US and heat and pressure	+	+	+

Foaming/Defoaming

When the sonication horn is fixed at the air-fluid interface, foam formation becomes possible. By this method, aerated gelatin and β-lactoglobulin gels were obtained (Zuniga et al., 2011). The placement of the horn at a liquid-liquid interface lets the formation of microspheres of both phases (Suslick et al., 1994). Vilkhu et al., (2008) reported thesame method also for encapsulating volatile aromas and flavors. The use of a powerful ultrasonic transducer, directly fixed above a foaming solution, is effective in destroying the foam (Riera et al., 2006). It may be due to a partial vacuum on the foam bubble surface (Kentish and Feng, 2014).

Degassing/Deaeration

Removal of the air in the solution is possible by ultrasound treatment. Reduction of pressure and boiling are common degassing methods. The agglomeration of the bubbles in the sonicated medium makes easier the rise up of the bigger bubbles through the surface (Laborde, et al., 1998; Tervo, et al., 2006). Degassing with ultrasound is applied on carbonated drinks, beer (defobbing) and wine (Boistier-Marquis, et al., 1999; Matsuura, et al., 1994). The effectiveness of degassing is reduced by the increase of the viscosity of the applied liquid medium (Chemat, et al., 2011).

GIAP Journals

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Cooking

Sonication in cooking led to a homogeneous cooking of the food due to improved heat transfer in the medium (Hausgerate, 1978). Also, reduction of energy consumption is an outcome for ultrasound assisted cooking application. Pohlman, et al., (1997) and McClements (1995) reported the assist of ultrasound in cooking provides a better quality in coocked meats.

Freezing and Crystallization

A nucleus is the point where crystallization starts. The cavitation bubbles acts as the nuclei as a start point of crystals. Ultrasound maintains more rapid cooling as its ability to increase the heat transfer (Li and Sun, 2002). By the help of nuclei formation and rapid cooling ability of ultrasound, the desired types of smaller crystals, not to damage cells, form.

Meat Tenderization

Ultrasound is generally applied succesfully in sanitary application to increase the effect of sanitary agents. The sanitary purpose of application has also a side affect on tenderization. Ultrasonic tenderization applied on poultry meat, veal and beef (Pohlman, et al., 1997) and (Pagan, et al., 1999). Tenderization is produced by the releases the myofibrillar proteins via ultrasound applicaition. By the tenderization with ultrasound, the properties such as water binding capacity, tenderness and cohesiveness, are improved (McClements, 1995).

Brining, Pickling and Marinating

Brining, pickling and marinating are used for preservation of foods and also the products are preferred for their desired taste. Salt, commonly around 10 % in brine, is used as a barrier for the growth of bacteria except for Lactic acid bacteria. Sonication increases the transfer of salt and water in tissues so helps to reduce the pickling time and a uniformal salting (Hatloe, J. 1995).

Drying

In literature ultrasound assisted drying is called as acoustic drying and has potentially great commercial importance. Ultrasound creates microscopic channels in the material and these channels allow the easy transportation of the vapour from center to surface. Gallego-Juarez (1998) noted that heat transfer is increased aproximatly between 30-60 % in liquid systems. Sounication treatment permits the application of lower temperatures than conventional methodology in drying process. Heat sensitive foods may be dried with the ultrasound assisted drying applications to avoid alterations of flavour, colour and nutritional values (Mason, et al., 1996; Rahman, 1999). The treatment produced a reduction also in rehydration properties (Chemat, et al., 2011).

Filtration

The membranes used in conventional filtration have a wide range from the simpliest to the osmotic types. The clogging is the main problem in filtration. By the time, the cake formation in front of the surface of the filter resists the transfer of the material through the filter. Ultrasound maintains the suspension of the particules in the system that prevent from the congestion of the channels of the solvent to elute (Grossner, et al., 2005).

Extraction

Ultrasound is mentioned as a green technique for applications in extraction. By the assistance of ultrasound, the amount of solvent used, total extraction time and the energy consumed reduces. The aid of ultrasound in extraction the process may be completed in minutes instead of hours with high reproducibility. It increases the purity of the target substances. Ultrasound is applicable in all matrices. It increases the contact of the solvent molecules with the target material. Ultrasoun may destroy some of the cell walls of the plant tissues and helps simplification. The application of ultrasound increased the yields of flavonols from plant materials (Chemat, et al., 2011). Especially in dried materials, ultrasound assistance improves the extraction quality parameters (Molins, et al., 1997).

Homogenization / Emulsifying

Particul size is one of the main important parameter for the success and stability of both homogenization and emulsifying processes (Chendke and Fogler, 1975). In some cases, existence of micro particules avoids the need of addition of surfactants. Existance of microparticules makes the emulsions more stable. In-line applications are possible in production lines (Behrend and Schubert, 2001). Fruit juices, mayonnaise and tomato ketchup (Povey and Mason, 1998), homogenization of milk (Wu, et al, 2000) and aroma encapsulation (Mongenot, et al, 2000) are some of the applications in industry.

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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 (Schneider, et al., 2008; Schneider, et al., 2009).

Cleaning

The amount of solvent and the time spent for cleaning are the important parameters to focus when cleaning procedure discussed. Ultrasonic energy is now used extensively in critical cleaning applications to both speed and enhance the cleaning effect. Ultrasonic cleaning devices generally operate between 20-50 kHz. Ultrasonic cleaning is the oldest industrial application of power ultrasound (Chemat, et al., 2011). Surface cleaning is applicable to a wide range of disciplines and applications (sensors, filters, substrates, reactors, catalysers and heat exchangers). It is effective on relatively hard materials such as metals, glass, ceramics, and plastics, which reflect rather than absorb sound. Cavitation is responsible for cleaning effect of ultrasound (Shoh, 1975). Maximizing cavitation of the cleaning liquid increases the cleaning effect of ultrasound. Temperature and ultrasonic frequency are the most important parameters for reaching to a maximum cavitation.

ENZYME INACTIVATION

Enzyme inactivation may be a need for prolonged shelf-life of some foods and enzyme inactivation can be easily achieved by heat treatment. In some cases, it may be difficult to inactivate heat resistance enzymes and the magnitude of applied heat may alter some food properties. Inactivation may be more effective if the ultrasound application is combined with another inactivating method. Triple combination of heat, sonication and pressure has a snergystic effect to increase the inactiavation on enzymes, compared with ultrasound alone (Earnshaw, et al, 1995). Pectinmethylesterase from oranges is one of the strong resistant enzyme against heat. However, heat, sonication and pressure all togeather effectively inactivates enyzmes (Vercet, et al, 1994).

CONCLUSION

Ultrasound treatment is a good opportunity to inactivate microorganisms and enzymes when combined with heat and pressure. This triple combination serves a successful inactivation process in lower temperatures which provides a solution for industry to obtain fresh-like foods. The ultrasound establishing cost has been declining and this will make ultrasonic power more competitive with conventional processes. So the opportunity of combination of ultrasound with other types of processes gets easier. Further research is needed to enable the commercial realization of ultrasound in food processing, especially the alternatives of new combinations or applications.

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Green Chemistry & Technology Letters
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