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Review Article

NANO CAVITATION: A NOVEL TECHNOLOGY IN FOOD SCIENCE TO IMPROVE EDIBLE OIL, NANOEMULSION, DAIRY PRODUCTION AND WATER TREATMENT: A REVIEW

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ABSTRACT
Cavitation processing is an emerging technology in food processing. One of the possible new techniques that could meet oil refiners to produce high quality oils with a sustainable and cost efficient process is hydrodynamic cavitation. Nano neutralisation is a novel technology which increases oil yield while substantially reducing the chemicals required to produce refined vegetable oils. Cavitation emulsification provide extended shelf stability, improved smoothness, body and color for a vast array of dairy applications and process mayonnaise emulsions, salad dressings, margarine and butter emulsions, mustards and much more.

Keywords: *Nanocavitation, Food Sience, Dairy, Edible Oil*

INTRODUCTION
When cavitation passes through a liquid, bubble nuclei present in the liquid grow by bubble coalescence and rectified diffusion. When these bubbles reach a critical size range, they collapse under near adiabatic conditions generating extreme conditions within the bubbles and in the surrounding liquid that include intense shear forces, turbulence and microstreaming effects. These cavitation induced physical effects are finding increasing use in food and dairy processing, in applications such as the enhancement of whey ultrafiltration, extraction of functional foods, reduction of product viscosity, homogenization of milk fat globules, crystallization of ice and lactose and the cutting of cheese blocks (www. CTI. com). A range of technical applications of hydrodynamic and ultrasonic cavitation rapidly increases in the world being directly used in medicine, naval applications, pharmaceutics, chemical technologies, cosmetics and cosmetology, etc. In our case we consider a method of generation of controlled hydrodynamic and ultrasound (acoustic) cavitation. It is necessary to note, that the thermodynamic effect of cavitation experimentally received on the trial installation obviously confirms the fact of presence and accompanying complex cavitation effects there are characteristic for ultrasound cavitation. The analysis literary given both scientific and taken from the Internet allows making practically unequivocal conclusion that the thermodynamic effect of hydrodynamic cavitation is the integral part of the interconnected and complex effects of cavitation. These are such effects as sono-luminescence, having dug intermolecular connections in the cavitation's cavities, water ionization, highly effective emulsification and homogeneous phenomenon, de-aeration and change of the structural characteristics of the water, etc. Use of hydrodynamic cavitation as a heat-carrier for water heating is well known (Kanat *et al.,* 2013). The application of ultrasonic cavitation in medicine and biomedicine also has a rather wide range in embryology and experimental morphology (Chuang *et al.*, 2010), therapeutics practice (Riesz *et al.*, 1985) of microbiology and biochemistry (Hernández, 2008; Al-Mahrouki *et al.*, 2012).

Application of Nanocavitation Technology in Edible Oil Processing and Improve it
Hydrodynamic cavitation is used in the chemical industry and for biotechnological applications to improve mass transfer and increase reaction rates of (bio-) chemical reactions. Processing crude oil through a Nano Reactor will make the phospholipids more hydratable so they can be removed without the need of upstream acid treatment of the oil. This will result in a direct cost saving (elimination of the total acid cost and part of the caustic) and also in less oil losses in the soap stock. Other potential applications

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of Nano Reactor Technology in edible oil processing that under studied include Nano Degumming of palm oil and Nano Degumming of soft oils (physical refining). It is expected that Nano Reactor Technology will also be a more cost efficient and environmentally friendly (sustainable) innovation for these standard unit operations of the oil refining process (Wim *et al.*, 2010).

Cavitation Technologies uses a "flow through nano cavitation reactor" (NCR) to modify vegetable oils without chemicals normally needed to process raw vegetable oil into usable edible oil. NCR "promotes the formation, growth and implosive collapse of gas or vapour-filled bubbles in liquids" (APCTT, 2009). As the bubbles implode, the liquid creates progressively greater pressures and temperatures, "generating local jet streams, shock waves, vigorous shearing forces, [and the] emission of ultraviolet and/or visible light that synthesize and modify the mixture at the nanomolecular level" (APCTT, 2009).

Most vegetable oils need to be refined to render them more suitable for their final use, be it human consumption or industrial use. The main components to be removed are the free fatty acids (FFAs) and phospholipids. They are usually removed by applying a caustic soda and acid treatment in neutralization and degumming, respectively. Apart from these main unwanted oily substances, other minor components are also removed in refining. Over the last decades, some important improvements have been introduced in oil treatment processes. Improved mixing of chemicals in caustic soda and acid treatment using ultra high shear mixers, and the introduction of enzymes (phospholipases) to specifically attack the gums, have substantially improved the efficiency of these wet oil treatment processes (OFI, 2012).

Which physical and chemical actions actually take place in the nano reactor is not yet fully understood, but its effect is amazing. Crude vegetable oil is pumped through a series of scientifically designed geometries. At each stage, there is a dramatic pressure drop. The water molecules in the oil vaporize and recompress to a liquid at each stage, creating shock waves that break the phospholipid micelles to their molecular level and, hence, make the non-hydratable phospholipids more hydratable. In addition to that, the nano reactor thoroughly mixes the acid and caustic soda solutions that have been added to the crude vegetable oil to a level that even the best high shear mixer cannot achieve. A nano reactor can be installed in any existing neutralisation process with relative ease and at minimal cost (OFI, 2012).

Cavitation Technology for Emulsions Processing

Emulsions find a wide range of application in industry and daily life. In the pharmaceutical industry lipophilic active ingredients are often formulated in the disperse phase of oil-in-water emulsions. Milk, butter and margarine are examples of emulsions in daily life. To facilitate the selection of an emulsification system, the influence of the most important parameters of the emulsion formulation on the resulting mean droplet diameter in the most prevalent continuous emulsification system (www.cti.com).

Ultrasonication is a well-known method to produce nano-emulsions and nanoparticles. According to Anton *et al.*, (2008), the cavitation phenomena is responsible for the formation of nano-emulsions using ultrasonication. The high energy required to produce a nano-emulsion can be described by the Laplace pressure (p), which is the difference in pressure between inside and outside the droplets (Tadros *et al.*, 2004).

$$p = \gamma \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Where, R1 and R2 are the principal radii of curvature of a drop, thus for a spherical drop, R1 = R2 = R, therefore, this equation can be described as follows:

$$p = \frac{2\gamma}{R}$$

Ultrasound delivers high energy and is an alternative method of producing an emulsion. In ultrasound emulsification, the energy input is provided through sonotrodes (sonicator probe) containing a piezoelectric quartz crystal that can expand and contract in response to alternating electrical voltage. Ultrasonic emulsification is believed to occur through two mechanisms. First, the application of an acoustic field produces interfacial waves that become unstable, eventually resulting in the eruption of the oil phase into the water medium in the form of droplets (Li and Fogler[a], 1978). Second, the application of low-frequency ultrasound causes acoustic cavitation, that is, the formation and subsequent collapse of microbubbles by the pressure fluctuations of a simple sound wave. Each bubble collapse event causes extreme levels of highly localized turbulence. The turbulent micro implosions act as a very effective method of breaking up primary droplets of dispersed oil into droplets of submicron size (Li and Fogler[b], 1978).

Cavitation can be utilized for the control of solidification in liquids. The liquid to be solidified is subjected to cavitation in order to control the steps of nucleation and/or crystal growth of the solidification process. Accelerating the polymorphic transformation of edible fat compositions. Such compositions when under cooled by at least 4° C are exposed to cavitation for a time and at a frequency sufficient to induce nucleation of stable polymorph crystals without exceeding the melting point of those crystals. Typical fats to be treated by this method are butter fat and the fats used in ice cream, chocolate, margarine and yogurt. Processes for the preparation of edible emulsion spreads which may be either water continuous or fat continuous. The most common spreads such as margarine have a continuous fat phase and a dispersed aqueous phase. Such spreads are traditionally prepared by passing a mixture of the aqueous phase and the oil phase through a series of one or more scraped surface heat exchangers and pin stirrers. The oil phase of those mixtures is eventually crystallized by cooling under such shear that a W/ emulsion is obtained in which a lattice of fine fat crystals provides the desired consistency and stabilizes the dispersed aqueous phase. Alternatively, the process of spread preparation may start with a continuous aqueous phase emulsion and includes a cavitation step in order to impart fat continuity to the emulsion spread.

Alternatively, cavitation further provides a process for preparing a W/O emulsion spread comprising the steps of; A. preparing an O/W emulsion having a continuous aqueous phase containing dispersed fully liquefied fat, cooling the emulsion to cause partial crystallisation of the fat, so obtaining a dispersion of partially crystallized fat in a continuous aqueous phase, B. inverting the O/W emulsion into a fat continuous emulsion in the usual way, C. working and cooling the fat continuous emulsion to cause further partial crystallization of the fat until a desired consistency and texture is obtained, For present spread manufacturing processes the cavitation is most beneficial for the preparation of emulsion spreads which are fat continuous. Proper fat crystallisation plays, however, also a role in the preparation of spreads in which fat is the dispersed phase. A since long acknowledged benefit of cavitation is its potential influence on the habitus of the crystallized fat. The formation of one fat polymorph may be promoted over another one. Since some polymorphs possess preferred properties, cavitation provides a tool for improving the properties of the resulting fat and indirectly for improving the properties of food products containing those triglyceride fats. Another benefit of cavitation in production of margarine, is a pretreatment of oil or fat trough cavitation prior to hydrogenation process. Pretreated oil will react much quicker with introduced nickel or other catalyst used in the process (www.CTI.com). Jafari *et al.*, (2006) stated that the powerful shock waves produced by cavitation radiate throughout the solution, breaking the dispersed liquid into very small drops.

Canselier *et al.*, (2002) assert that a two-step mechanism has been discussed for ultrasound emulsification: a first step, in which a combination of interfacial waves and instability leads to the eruption of dispersed phase droplets into the continuous phase; and a second step that consists of reducing size of droplets through cavitation near the interface. The disruption and mixing of shock waves and cavitation explain the very small droplet size obtained.

Work by Henglein and Gutierrez (1993) indicated that at low sonication amplitudes, the effect of the cavitation threshold was dominant and both the chemical yield and sonoluminescence arising from an acoustic field decreased with increasing pressure. Conversely, at higher amplitudes, the bubble collapse effects dominated and yields increased with increasing pressure. Similarly, Sauter *et al.*, (2008) found that low overpressures improve deagglomeration of nanoparticles, whereas higher overpressures had a negative effect.

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Cavitation Technology for Dairy Industry

Milk is an emulsion that is homogenized to reduce the average particle size, which improves its consistency and extends shelf life. The homogenization process is expensive and by utilizing cavitation it can improve quality process, can improve quality of the milk and consistency and reduce operating costs. Milk is a very complex food containing over 100,000 different molecular species. The main components of interest are protein and fat globules. Protein typical size is in the range of 100 nm. They are white, tasteless and odorless and are used to make food, paint, and adhesives. In contrast, the fat globules in raw unhomogenized milk are between 110 µm, while in homogenized milk the size range is 0.22 µm. Milk is oil in water emulsion, with the fat globules dispersed in a continuous phase of skim milk. Cavitation is a mechanical process used to reduce the size of the fat globules in the milk. The net result of this process is a decreased creaming rate according to Stokes' Law, reduced clustering during creaming, and better density matching with the continuous phase. The cavitation process reduces the globule size by passing milk under high pressure through a Nano Reactor. The cavitation/homogenization phenomenon is completed before the fluid leaves the reactor area. The main goal of cavitation/homogenization is to break up the large fat globules and create a stable emulsion that has an increased shelf life, a better taste, and improved mouth feel. In addition to all of the benefits of the cavitation technology, cavitated milk showed better characteristics, such as whiter color, better texture (hardness) (www.CTI.com). Prevention from physical instability of chocolate milk is an important challenge in food science, particularly dairy industries. According to the findings, the increase of power intensity and exposure time led to a significant increase on the degree of homogenization and subsequently a paramount decrease in the size of cocoa particles. Cavitation can be is used for making milk more stable against creaming and for giving the product a richer mouth feel due to a slight increase in viscosity (www.CTI.com). Colour measurements also showed higher values for cavitated samples where with the increase of power intensity and exposure time led to a significant increase on value. Overall acceptance of treated samples had no significant difference against control. Based on the findings it seems that cavitation is an effective processing method for reducing the particle size of cocoa and increasing of chocolate milk stability. In addition, it showed some effects on the degradation of Kcarrageenan network and at higher temperatures these effects were more pronounced. The cocoa particle diameters of chocolate milk which sonicated at 65ºC were smaller than the other temperatures whereas the milk phase volume of one treated at 45ºC was less than the other temperatures. Kcarrageenan at the highest applied concentration (0.02%) effectively prevented from phase separation and sedimentation after 30 days (www.CTI.com).

The latest hydrodynamic cavitation technology enables efficient processing of yoghurt. The dairy nutrition cross over into the high-growth nutritional beverage market is a further trend that promotes yoghurt products. The evolution of the yoghurt market is further driven by consumer demand for nutritional products that are natural, functional, healthy, tasty and convenient. Combined with a highly competitive market place and environmental pressures, new and innovative processing technologies are needed. Hydrodynamic cavitation technology uses a rotor with precisely machined cavities spinning in a liquid chamber that generates controlled cavitation. The process generates and collapses bubbles due to the decrease and then increase in pressure produced. As the bubbles collapse, a very powerful energy wave (shockwave) is released into the surrounding liquid. This cavitation shockwave creates a very efficient, microscopic mixing effect along with friction that generates controllable, scale-free heating (SPX Corporation, 2015). The microstructural conditioning and functionalization it performs can unlock the natural functional properties from whey proteins that can improve yoghurt viscosity, texture, stability and taste in low or non-fat nutritional products.

The cavitation technology can improve existing processes and end products, as well as facilitate the production of high value yoghurt products with low fat and high nutritional whey proteins. Sweet whey and lactic acid whey acidified with yoghurt cultures, or ideal whey from milk fractionation can be used as the whey source and products can be based on liquid or recombined powder WPC of various grades. Controlled hydrodynamic cavitation offers many benefits and versatility in the growing yoghurt market. The scale free heating it provides is ideal for use with high fouling products and can increase running time

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and reduce required CIP cycles. It provides excellent microscopic mixing and dispersion with efficient hydration and emulsification. Overall this reliable, low maintenance technology offers real potential to further reduce operational costs and provide high-end quality products. Heath denaturation and cavitation force enhance viscosity / texture and taste and stability of the products. Gentle smoothing to eliminate grainy structure and syneresis especially for high protein yoghurts (SPX Corporation, 2015). Fat globules are routinely homogenized (prior to inoculation of milk with yogurt starters) to improve yogurt consistency and to prevent serum separation in the final product. These effects are not only due to fat globule size reduction but also to the effects of pressure on other milk constituents, mainly proteins (www.CTI.com).

Cavitation is also can be used in ice cream making. The Cavitated/homogenized mix gives a creamier product, when the mix is frozen. However, experienced ice cream makers know, that it is beneficial to store homogenized ice cream mix a few hours at low temperature (4°C) before freezing. This aging process permits any added emulsifying agent (glycerol mono and distearates) to partially displace some of the casein submicelles from the fat surfaces. The reason, this is beneficial, is not well understood, and is still a subject of research (www.CTI.com).

Cheese is one of the most demanded products around the world. Each year, the cheese industry reports considerable sale increases. Varieties of this dairy product with the highest demand include cheddar, colby, monterey jack, mozzarella, ricotta. The main processing steps of cheese making include the clotting or curdling of the milk, removal of whey, acid production, salting, shaping and ripening. The essential step during cheese processing is the formation of the curd that occurs by enzymatic and microbial activity. Many environmental conditions such as temperature, enzyme concentration, or microbial load are very important during the process to generate a firm curd in a specific time. One of the desirable aspects in cheese making is to reduce the curdling time and increase the yield, because the final yield of cheese is around 10%. Nano cavitation reactors can be applied in cheese making in order to improve these aspects while at the same time improve the overall of cheese. When cavitation was applied to milk to study the proteolytic activity of the enzymes related to curdling, the main observable effect was that cavitation speeds up the hardening of the curd and the final product showed a better firmness because of the activity on the chymosin, pepsin, and other related enzymes. When cavitation is used to enhance the extraction not only the yield and enzyme activity were increased considerably, but also extraction times were much shorter than without cavitation. The reason for that could be attributed to the distraction of cellular structure because of the action of cavitation, increasing the activity of the substance contained in the cells and the migration of proteins and minerals from cells to the solution. The activity of the chymosin increased with cavitation and the nitrogen content of the extract decreased at the same time. Other uses of hydrodynamic cavitation in the cheese making industry are in the flavor arena (www.CTI.com).

CONCLUSION

Nano neutralisation has been found to substantially reduce chemical consumption. It has been proven to increase oil yield and substantially reduce the chemicals required to produce refined vegetable oil while maintaining and even improving, oil quality. The heart of the technology is the Nanocavitation reactor. A nano reactor is a static device with no moving parts. Cavitation has shown to have a beneficial influence on nucleation and eventually on the strength of the crystal lattice that even at relatively low solid fat levels a spread product with a good consistency, texture and stability is obtained.

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