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Nano-Bubbles (NBs) - Emerging Science in Food Processes

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SUMMARY

Nano size bubbles are applied in the food processing sector due to its unique properties. Properties such as high stability and dissolution rate, large surface-volume ratio and free radicals generation provides various means to alter physical properties and environmental conditions of the aqueous medium, e.g. water, milk, carbonated drink, seasoning solution etc. Several methods such as cavitation, electrolysis and membrane methods are available for generation of tiny size bubbles. In fact, gaseous bubbles (size: 0.1 – 1400 micron) have been applied to produce beverages, baked products, dairy products, chocolate and confectionery products with alteration of methods and products in favour of high desirability.

INTRODUCTION

Nanoscience and nanotechnology are the study and application of extremely small things, ranged in 10^{-9} m in size. It is having a huge benefits in practical applications in many manufacturing sectors, such as food and agriculture. The nano-size particle (1–100 nm) with large surface area has great potential functions in food industries. In food industries, nanoparticles are leading in formation of the food with high quality and good nutritive value. There are several methods used to prepare nano-particles, normally classified as "top-down" and "bottoms-up" processes. Top-down approach begins with pattern generated on a larger scale, then reduced to nano-scale e.g. attrition and milling. While bottom-up approach starts with atoms or molecules and build up nanostructures. Depending on the type of the material and its desirable characteristics and application, one can choose an appropriate method to form a nanoparticles (Khanh *et al*., 2020).

Nano Bubbles (NBs)

Bubble is a small pocket of air/gas inside a solid, a liquid or surrounded by a colloid within a larger fluid environment. Nano-bubbles or fine bubbles are small gaseous entities that are found when solutions are supersaturated with gas. The size of the nano-bubbles is of nano-scale in diameter ranging 0 to 1000 nm. Unique properties of extremely ultrafine bubbles or Nano-bubbles have highlighted huge interest in wide fields of advanced science and technology including medical, agricultural and food sectors (Zhu *et al*., 2016). The prominent features of NBs include high specific surface area per volume ratio and high internal pressure (Figure 1). In addition, the high stagnation of NBs in the liquid phase can increase the dissolution of gas above super-saturation in water. ζ – potential (Zeta potential, ZP) of NBs considered as a physical characteristic at the boundary layer called slipping plane dividing the formed double layer between the counter ions on the bubble interphase and the bulk solution (Fan *et al*., 2010). All the bubbles or particles in suspension system have higher Zeta potential value confer to be stable system. In another prospect, collapse of microscopic bubbles based formation of nano bubbles with high oxidizing power generates shock well and hydroxyl radical (OH^-), which add the advantage to the sanitizing process. The other possible advantages of using NBs include the simple and low-cost materials for their production together with their low environmental impact.

Generation of NBs

Numerous methods like cavitation, electrolysis, applying nano-pore membrane and sono-chemistry using ultrasound have been used to create small bubbles. Simplicity, efficiency together with scalability are important features of NBs generation methods for incorporating NBs generator into industrial processes. Cost of production and environmental impact are important factors in production systems.

Cavitation methods

One of the most common techniques applied to produce gas filled nano bubbles is cavitation. Formation of cavities occurs when the homogenous liquid phase undergoes a phase change due to a sudden reduction of pressure below a certain critical value, lead to the formation of small cavities which is filled with vapour in places where the pressure is relatively low. Two ways to drop the pressure, hydrodynamic and acoustic cavitation which is related to a fluid flow and an acoustic field, respectively.

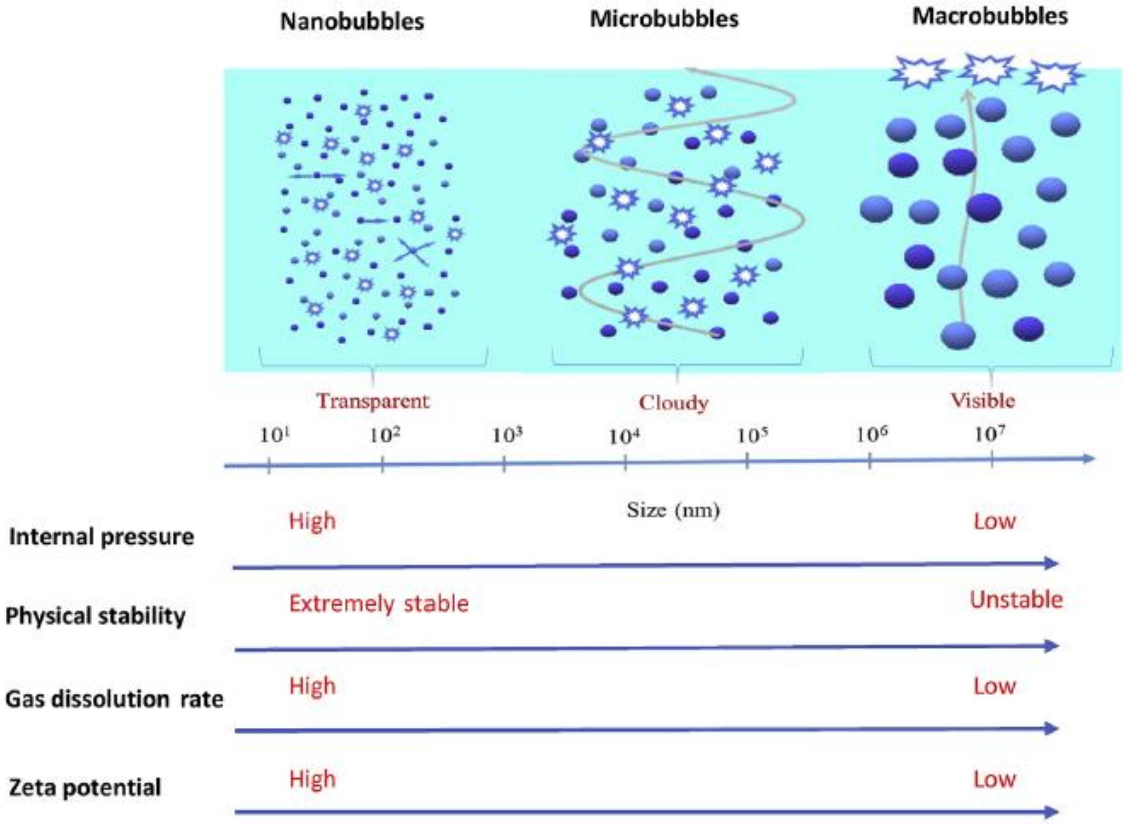

Figure 1. Different parameters of NBs

Hydrodynamic cavitation

An occurrence of vaporization and generation of bubbles is a result of moving fluid subjected to pressure reduction. Bubbles are implode due to increase of local pressure, resulting in hydrodynamic cavities. The size of bubbles generated can be governed by controlling pressure, temperature, etc. applied to the flowing fluid. Hydrodynamic cavitation can be achieved by different system geometries such as venturi, orifice plate, and throttling valve that make change of velocity in the system. NB of air with average diameter from 130 to about 529 nm were able to be generated in water via venturi tube. Agitation and multiphase pumps improve the size of the NBs. Hydrodynamic cavitation has advantages like simple equipment and low maintenance cost is one of the cheapest and most energy efficient modes to produce NBs. Venturi type generator based on hydrodynamic cavitation mechanism has been widely used because of its easiness to scale up, operate and control

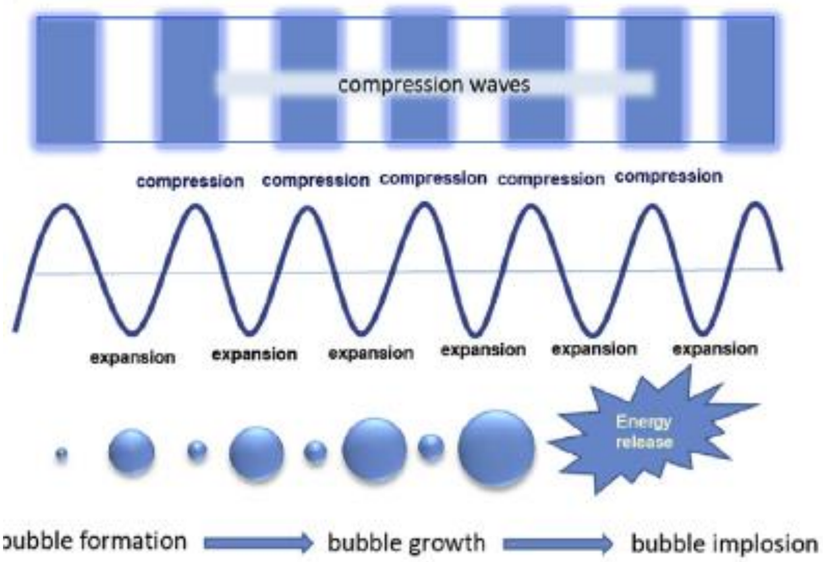

Figure 2. Acoustic cavitation

Acoustic cavitation

Acoustic cavitation can be created by propagating ultrasonic wave through the liquid leading to the pressure variations and the subsequent formation of bubbles. By decreasing the pressure dramatically under the value of saturated vapour pressure, ultrasonic wave can create gas bubbles via local compression-expansion cycles that help to separate dissolved gases (Demangeat, 2015).

Electrolysis method

NBs can be created by means of chemical reactions such as electrolysis (Kikuchi *et al*., 2007). Water is decompose into hydrogen and oxygen gases due to electrolysis, caused by the electric potential. Production of gas occurs at electrodes. If concentration of the produced gas reaches the super-saturation level in the anodic and cathodic streams of the bulk water, NBs can be generated.

Membrane method

Another popular method to create NBs is using membrane as the medium for liquid and gas dispersion where the gas phase is pressed through the pores of the applied membrane into a flowing aqueous phase. Size is related to pressure applied.

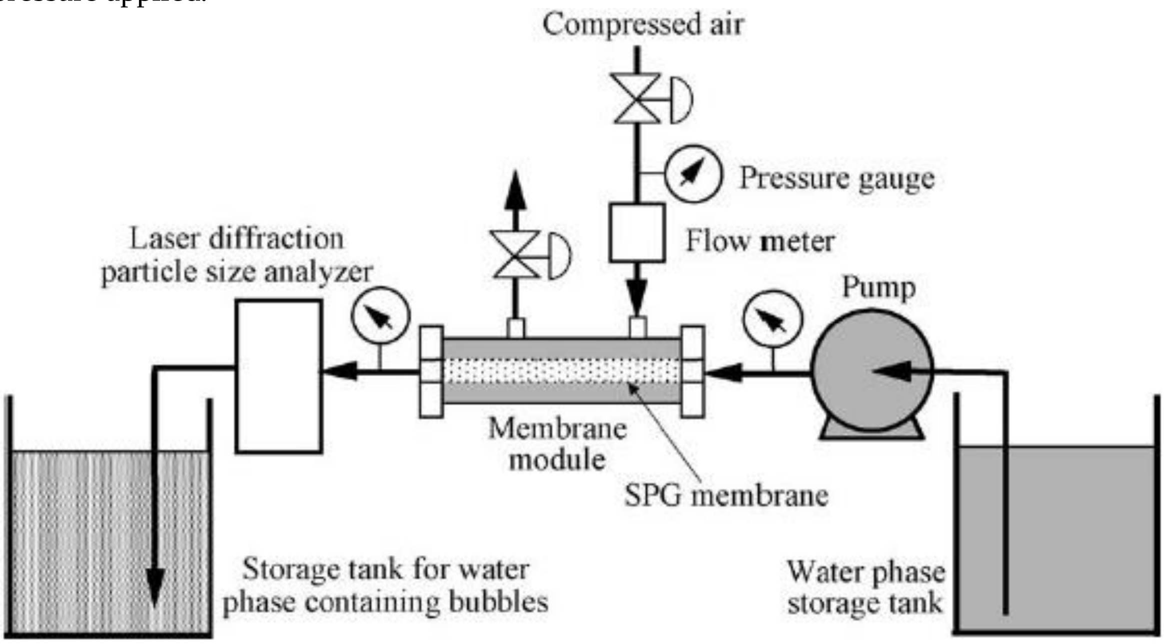

Figure 3. Membrane method for generation of nano-bubbles

Applications in Food

There are wide range of applications for all industries where nano bubbles are incorporated or possible to be incorporated. NBs technology has been explored in many applications including froth flotation, surface cleaning without the support of detergent and mineral or bio-molecular separation. There are also applications of NBs in water treatment and sterilization using O_3 nano-bubbles. With huge potential applications of NBs, it is anticipated that NBs can be the next potential driver to advance processing technologies in food industry. In fact, gaseous nano bubbles have played a vital role in determining stability, microstructure and functionality of beverages (e.g. beer, wine), baked products (e.g. breads, puff pastry, cracker), dairy products (e.g. cheese, ice-cream, whipped cream), confectionery products and chocolate. In these food systems, the bubble size can vary between 0.1 and 1400 μm (Khanh *et al*., 2020). NBs have an application in designing foam products, gel and cream-based foods, carbonated drinks and nutritional supplement carriers, in which extreme stability, uniform dispersion of gas, novel texture and improved functionality can be obtained with the presence of NBs. There is a possibility to reduce the slip in microfluidics as nano bubbles offers reduced flow resistance in processing. The efficiency of liquid food manufacture is limited by the high viscosity of materials, because the higher viscosity equates to more power or operational costs to pump the liquid through the manufacturing equipment. For example, in dairy manufacturing, membrane filtration process is prone to membrane fouling when increasing the protein concentration of milk and the combination of chemical additives to regulate flow or dilution in order to decrease the viscosity of the dairy product, which may cause the adverse effect on other features of the liquid food. By injecting small bubbles having an average diameter in the range of 100–5000 nm into the liquid dairy product before passing through the ultrafiltration processing to concentrate and standardize milk proteins, the benefits of decreasing viscosity of the liquid flux could be realized.

CONCLUSION

With a huge potential applications of nano-bubbles, it is anticipated that NBs can be the next potential driver to advance processing technologies in food industry. It is of an interest to understand feasibility of NBs application in designing foam products, gel and cream-based foods, carbonated drinks and nutritional supplement carriers, in which extreme stability, uniform dispersion of gas, novel texture and improved functionality can be obtained with the presence of NBs. An understanding of fundamental properties of NBs and their potential applications in food products and manufacturing process will also present food industry a new tool to innovate food products as well as open up the possibility of employing NBs in food processing at industrial levels.

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