An overview of nanotechnology applications in food industry.

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DOI: 10.29322/IJSRP.8.7.2018.p7954
http://dx.doi.org/10.29322/IJSRP.8.7.2018.p7954

***Abstract* -** Advancements of the science has prominently affected the food sector and food consumption patterns in the last few decades. Nanotechnology is one of the major areas that contributed to this improvement as it is an essentially modern scientific field that is constantly evolving as a broad area of research, with respect food processing, preservation, packaging and development of functional foods. Food manufacturers, agricultural producers, and consumers could gain a more competitive position through nanotechnology. Furthermore, the delivery of bioactive compounds for nutritional as well as development of functional food are possible through this technology. It will also replace many fields with tremendous application potential in the area of dairy and food sectors.

Keywords: Nanotechnology, Nano Food, Food Processing, Nano Applications

I. INTRODUCTION

Nanotechnology is understanding the behavior of the matter in dimensions around 1-100 nm [1]. Nanomaterials exhibit unique properties than macro level molecules due to their very nature. It was first integrated and applied in food industry by United States and then followed by Japan and China. Nano food market is rising steadily despite of the criticism it receives and it is expected to grow by 20.4 billion US dollars in 2020 [2]. By 2020 Asian countries will be the biggest market for nanofood with the leading allocation to China. Even though most of the Nano-based food are nutraceuticals and functional foods, product categories will expand in future.

Nano technology is also more focused on developing a better nutrition delivery system which have better competitive edge than most of the available delivery systems such as delivering the ingredients accurately to the targeted site [3]. Most of the world's leading food companies have invested in nanofood technology because of the sustainable and promising results it has been able to provide. Nestlé, Unilever, Hershey, and Kraft are among these multinational companies [4] [5] [6] [7]. Woodrow Wilson International Centre has identified more than 800 products that are targeted towards consumers which indicates the extent and future demand in the nanofood industry.

Sri Lanka also has established nanotechnology academy (SLINTEC Academy) as a private research institute [8]. As for many developing countries including Sri Lanka in South Asia, nanotechnology food market and nanotechnology is at very limitedly applied but growing. Among the nanofood that so far has been developed there is a canola active oil (Israel), which have potentiality to inhibit the cholesterol transportation into the vascular system and increase the bioavailability of vitamins, minerals, and phytochemicals that are insoluble in water or fats.

China has also developed a nanotechnology-based tea which intensifies the additional health benefits. Some food developers in US have developed a chocolate shake that has reduced the use of excessive sugar and with enhanced flavors. South Korea has taken the leading steps of developing antibacterial wheat flour with the use of Nano silver [9] [10]. Nanofood industry is in a constant verge of developing additives for food processing, preservation flavor and color Improvement, safety and packaging. Also, it is applied in matrix design, nanomaterials formation, sensing, processing technology, delivery systems and hygienic aspects.

II. NATURAL NANO FOOD

Nutrients and the structures of food carry more important aspects in creating nanofood. Even in milk most of the nutrients such as protein molecules that fold in to large structures, Fat globules, polysaccharides, disaccharides as lactose, inorganic minerals and vitamins are considered Nano sized molecules [11]. Also, naturally occurring nanostructures improve the functional behaviour of food [12].

Studies have reported that the casein micelles, structural component of milk, can be used to load and deliver nutraceuticals such as Vitamin D2 with lesser photochemical degradation. β-lactoglobulin of milk offers various functional properties of thickening, emulsification, gelation or foaming [13]. Denatured β-lactoglobulin of milk protein at nanoscale process enhanced gelation properties [14]. β-lactoglobulin forms complexes with pectin and convey omega 3 poly unsaturated fatty acids [15]. Not only β-lactoglobulin, other milk whey protein such as α-lactalbumin is also used to develop nanotubes from hydrolyzation by a method known as bottom up process [16].

According to Momin et.al (2010), processes such as milk homogenization creates favourable environment for the synthesis of Nano scale products. Milk fat globule membrane is utilized in creating nanoliposomes which have possible applications in cheese industry as a carrier. In Nano technological storm, casein micelles, fat globules, whey proteins are very useful in Dairy industry to formulate micro sized and Nano sized structures to achieve desirable Dairy products.

III. APPLICATION METHODS

In general, nanotechnology can be applied by two main different methodologies. Those are "bottom up" method and "top down." method [17]. In top down method, mechanical processes are utilized in converting larger material in to nano size materials. Mechanical processes such as grinding, milling and advance processes of removing molecules from the surfaces are used in top down method to reduce the particle size and increase the surface area [18]. As an instance, a sphere can be used as a contact surface to produce fullerene from a thin flake of graphene. Another example for top down application in Food industry is dry-milling technology. This milling process can convert flour into fine size particles with high water- binding capacity.

However, bottom-up approach of nanotechnology was derived from the basic concept of biology like self-assembly and self-organization. By gradual aggregation of atom by atom or molecules by molecules leads to engineering of substances with Nano level properties. The bottom-up technique includes chemical synthesis, self-assembly and positional assembly [19] [20] [21] [22] [23].

Nanoparticles of a wide range of materials ranging from organic and biological compounds to inorganic oxides, metals, and semiconductors can be processed using chemical self-assembly techniques [24]. These techniques exploit selective attachment of molecules to specific surfaces, biomolecular recognition and self-ordering principles (e.g. the preferential docking of DNA strands with complementary base pairs) as well as well-developed chemistry for attaching molecules onto clusters and substrates (e.g. thiol (-SH) end groups) and other techniques like reverse micelle, sonochemical, and photochemical synthesis to release 1-D, 2-D and 3-D self-assembled nanostructures without an obvious driving force present [25].

Other than that, creating Nano particles such as proteins on templates is also a prominent example of bottom up approach application in food industry. Even though the application of such methods is currently limited in food industry, there are several processes that utilize the bottom up approach methods to produce nanoparticles from atoms are chemical processes based on transformations in solution e.g. sol-gel processing, chemical vapour deposition (CVD), plasma or flame spraying synthesis, laser pyrolysis, atomic or molecular condensation.

IV. NANODISPERSIONS AND NANOENCAPSULATION

Nanoparticles are very useful as delivery vehicle of Functional ingredients (for example, drugs, vitamins, antimicrobials, antioxidants, flavorings, colorants, and preservatives etc.) and their required concentration at desired site can be achieved through nanotechnology. These ingredients, which are rarely utilized directly in their pure form; they are often incorporated into some form of delivery system.

Besides being compatible with food product attributes such as taste, texture, and shelf life, other functions of a delivery system include protecting an ingredient from chemical or biological degradation, such as oxidation, and controlling the functional ingredient's rate of release under specific environmental conditions. Nano dispersion and nano encapsulation are ideal delivery system because they include Association colloids, Bio polymeric nanoparticles, Nano emulsion [26,27].

V. ASSOCIATION COLLOID

A colloid is a stable system of a substance containing small particles dispersed throughout. It is either a binary or multicomponent system whose structure and properties are between those of liquid solutions and sols. These systems are categorized as microheterogeneous systems in which the particles of the colloidal dispersed phase (micelles) are formed by the agglomeration of molecules or ions of the substance dissolved in the dispersion medium. The micelles, or associates, are in thermodynamic equilibrium with the surrounding solution; therefore, a change in the external conditions, the composition of the dissolving medium, or the concentration of the dissolved (dispersed) substance causes redistribution of the substance between the micelles and the solution. Surfactant micelles, vesicles, bilayers, invert micelles, and liquid crystals are a few cases of association colloids which have been utilized to embody and convey polar, nonpolar, and amphiphilic functional ingredients [28,29].

VI. BIOPOLYMERIC NANOPARTICLES

The risks of chronic toxicity due to the intracellular and tissue overloading of non-degradable polymers were soon considered as a major limitation for human application. Therefore, the medical field is more concerned on developing Biopolymeric nanoparticles. Biopolymeric nanoparticles can produce by using basic components of any food such as proteins or polysaccharides through aggregation or by inducing phase separation in mixed biopolymer systems [30].

First Biopolymeric nano particles designed by using Albumin &non-biodegradable synthetic polymers such as poly acrylamide and polymethyl acrylate [31]. Polylactic acid (PLA), a common biodegradable nanoparticle; which is often used to encapsulate and deliver drugs and micronutrients like iron, vitamin, protein etc. It has confirmed that the PLA need an associative compound such as polyethylene glycol for successful results and the functional ingredients can be encapsulated in nanoparticles and released in response to specific environmental triggers [32]. biopolymer nanoparticles in particular offer several advantages, which include the ease of their preparation from well-understood biodegradable polymers and their high stability in biological fluids and during storage. These nanoparticles have a higher potential in therapeutic and food industry relate applications.

VII. NANO-EMULSIONS

According to Weiss L. (2006), processing techniques and functional foods are used for homogenization. But high-pressure valve homogenizers or micro fluidizers are used to produce nano-emulsions. Nano-emulsion droplet sizes varies in the range of 20–200 nm and show narrow size distributions. As McClements (2004) stated, The functional ingredients can be incorporated at droplet, interfacial region or continuous phase using the nano-emulsions. Nano emulsions enhance solubilization capacity for lightly soluble drugs.

The small droplet size creates unique rheological and textural properties of nano-emulsion. Also, it makes them transparent and pleasant to touch [33]. According to McClements and Dekker [34], nano-structured multiple emulsions can offer multiple encapsulating abilities from a single delivery system due to complex properties. Nano emulsions are not limited to one functional component. They can carry several functional components and they released in response to a specific environmental trigger.

According to Quresh et.al. (2012), It is possible to develop smart delivery systems by engineering the properties of the nanostructured shell around the droplets. It can facilitate the use of less fat without compromise in creaminess for callery concern people. such concept is incorporated in fabrication of ice-cream by Nestle and Unilever [35].

VIII. NANOFIBERS

Nanofibers varies in diameters from 10 to 1000 nm. They are produced by electrical spinning with the use of synthetic polymer. As the fiber from not a food grade biopolymer, it is limitedly used in food industry. Cellulose is the most abundant and low-cost biodegradable by-product in the food and agricultural industries. According to Ravichandran R. (2010), If in future, it will possible to manufacture nanofibers from Food grade biopolymer, then its use may undeniably increase. Nanofibers are used as structural component of green food packaging, platform for bacterial culture and structural matrix for artificial food.

IX. NANOTUBES

Graveland, Bikker and Kruif have reported that certain globular protein from milk like α-lactalbumin can be made to self-assemble to form nanotubes under appropriate condition. Firstly, milk protein α- lactalbumin are partially hydrolyzed then itself assemble to form nanotubes at neutral pH & the presence of appropriate cation. The diameter of nano tube is around 20nm. For fabrication of nanotubes, the required minimum concentration of α-lactalbuminis 20gm/l [36].

The desirable properties of Nanotubes include high ability to withstand pasteurization temperature, important encapsulating agent and mask undesirable flvour and aroma productive substance [38]. Apart from these, being basically milk protein, it is easy to apply in other Dairy products [37]; nontheless its hydrolysis its hydrolysis increase Digestibility and nutritive value [39].

X. NANOCAPSULES

In nature, casein acts as a natural nano capsules for calcium and phosphates. It covers these components and supply to neonates. Apart from these, it has significant nutritive value. Casein micelle has high biological activity, good dispersity, retain their basic structural identity through processing. A novel approach is using casein micelle for capsulation of hydrophobic molecules and for enrichment of high fat or low-fat food products. They have no influence on a sensory attribute of final product. The concept behind the use of Nano capsulation is to increase absorption and control bioavailability of vitamin.

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