Food Science and Nanotechnology

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Abstract

Nanotechnology deals with devices typically less than 100 nanometers of computer storage, semiconductors, biotechnology, manufacturing and energy. In future, amazing nanotech products are expected, including extraordinarily tiny computers, advanced system for drugs delivery, nano food materials, micro food emulsions, nano food fibers etc. Liposomes are another type of nanostructure being used to add functionality to food.

KEYWORDS: Nanotechnology, nanomaterial, nanostructure, microemulsion, liposomes

Introduction:-

Nanotechnology is defined as fabrication of devices with atomic or molecular scale precision. Devices with minimum feature size less than 100 nm. are considered to be products of nanotechnology. A nano meter is one billionth of a meter and is the unit of length that is generally most appropriate for describing the size of single molecules. Fabrication of nanomachines, nanoelectronics and other nanodevices will undoubtedly solve an enormous amount of the problems faced by mankind today. Mirrors that don't fog, and fat soluble vitamins in aqueous beverages are some of the first manifestation of nanotechnology.

Application of Nanotechnology in Foods:-

Complex set of engineering and scientific challenges in the food and bio processing industry for manufacturing high quality and safe food through efficient and sustainable means can be solved through nanotechnology. Bacteria identification and food quality monitoring using bio sensors, intelligent active and smart food packaging system.

Nano capsulation of bioactive food compounds are few examples of emerging applications of nanotechnology food industry. Nanotechnology can be applied in the production, processing, safety and packaging of food.

A Nanocomposites coating process could improve food packaging by placing anti-microbial agents directly on the surface of the coated film. Nanocomposites could increase or decrease gas permeability of different fillers as is needed for different products. They can also improve the mechanical and heat resistance properties and lower the oxygen transmission rate. Research is being performed to apply nanotechnology to the detection of chemical and biological substances for sensanges in foods.

Nano foods:-

New foods are among the nanotechnology – created consumes products coming into the market at the rate of 3 to 4 per week, according to the project on emerging nanotechnologies (PEN) based on an inventory. It has drawn up β of 60g known or claimed nano products. PEN's a list are three foods – a brand of canola cooking oil, a tea called Nano tea and a chocolate diet shake called nanoceuticals.

Slim Shake Chocolate:-

Company information posted on PEN's website, the canola oil by shemen industries of Israel contains an addictive called "nanodrops" designed to carry vitamins, minerals and phytochemicals through the digestive system and urea.The shake U.S manufacturer RBC life sciences Inc uses cocoa infused "nanoclusters "to enhance the taste and health benefits of cocoa without the need for extra sugar.

Discussion:-

Use of nanomaterials to improve food quality and food safety: nutrient encapsulation and food packaging

Weiss began by mentioning that he would be addressing one of the "more controversial" aspects of nanotechnology: using nanostructures as food ingredients (i.e.as opposed to using nanotechnology to engineer novel types of sensors and other non-food but food-related products). He said he would, however, briefly address the use of nanostructures in food packaging, noting that in fact one of the earliest applications of nanostructures in the food industry was the use of single-layer, clay-polymer composites in packaging, where single layers of clay are folded into a polymer system to create a new structure. These so-called exfoliated structures, or nanocomposites, prevent the passage of oxygen and water and have proven very stable to degradation. The U.S. Army, for example, is using this type of application to develop new packaging materials for ready-to-eat meals. Today, scientists like Julian McClements of the University of Massachusetts, Amherst, are taking this layering concept one step further and creating multi-layer food (not food packaging) droplets (i.e. microemulsions) and other food objects, where each layer is sequentially deposited onto the object, each layer giving that material a unique functionality . So, for example, one could build a food material with antioxidant functionality in one layer, antimicrobial functionality in another layer, and the reduced passage of oxygen or water in yet another layer. Since the layers are nanometer thin, they would be invisible to the naked eye.

Julian McClements of the University of Massachusetts, Amherst, has been developing a method of adding multiple nanoscopic layers of functionalities to food objects.. Starting materials can include droplets (microemulsions), particulates, biopolymers .

Types of Nanomaterials and Nanostructures

There are several different types of functional nanostructures that can be used as building blocks to create novel structures and introduce new functionalities into foods, including: microemulsions, liposomes, nano-emulsions, particles, fibers, and monolayers. Weiss described several of these structures, their actual and potential uses in the food industry, and research that he and his colleagues have been conducting with some of these various types of nano-sized materials.

Microemulsions

Microemulsions are very, very small particles with diameters typically within the 5–50 nm range. Unlike emulsions, microemulsions are thermodynamically stable. They are transparent solutions, prepared by dispersing a milky solution and then adding some surfactants to the system; as such, they are actually three-component systems. They have a wide range of interesting applications. In non-food industries, they are used for enhanced oil recovery, in lubricants and coatings, and in cosmetics and agrochemicals. In the food industry AQUANOVA (A German supplier of liquid formulas) for example, makes a range of microemulsion products for solubilizing (i.e., increasing the water solubility of important nutrients and vitamins). Microemulsions are also being explored for their potential to improve reaction efficiencies (e.g., interesterification, hydrogenation) and for fortification of foods.

Weiss and his colleagues are studying microemulsions for their potential to encapsulate and deliver antimicrobials. The researchers have shown that encapsulated concentrations of antimicrobials slow or completely stop *E. coli* growth in culture. When non-encapsulated antimicrobials are added, the antimicrobials partition into the aqueous phase only and there is not nearly as much bacterial inhibition. Encapsulated anti-microbials have also shown very high activity against bacterial biofilms, which are otherwise very resistant to disinfectants and difficult to remove from surfaces; unlike most disinfectants, which are typically inactivated in the top layer of a biofilm, because of their polymeric properties the microemulsions are able to penetrate down to the lower layers of the biofilm. Weiss said that when he and his colleagues started studying antimicrobial microemulsions, they built relatively simple systems, where they simply encapsulated an antimicrobial with a simple micelle. Since 2006, he and his team have been engineering more sophisticated antimicrobial carriers, by altering the surface properties of the micelle (i.e., by adding a charge and making an either anionic or cationic binary micelle) and then encapsulating the lipid antimicrobial with that altered, binary micelle. The charge gives the structure an electrostatic property that better targets microbial surfaces. Weiss explained how mixed microemulsions (e.g., mixed cationic/anionic micelles) are more stable than binary micelles in certain environments (e.g., cationic micelles are not very stable in refrigerated environments, but mixed cationic/nonionic micelles are).

The next step with microemulsions is to build even more complex structures, for example by combining charged binary microemulsions with charged food polymers, such as pectins, and creating stable microemulsion-polymer clusters with potentially improved functionalities) Weiss and his colleagues are experimenting with these more complex structures in an effort to make a palatable antimicrobial microemulsion (which would otherwise be too bitter to ingest).

The next step for microemulsion nanotechnology is the creation of composite microemulsion-polymer clusters with novel functionalities, such as antimicrobial potency or palatability.

Liposomes

Liposomes are another type of nanostructure being used to add functionality to food. Liposomes are spherical bilayer membrane structures with aqueous cores, so unlike lipophilic-containing microemulsions, they can be used to contain and deliver hydrophilic, or water-soluble, ingredients. Moreover, their internal pH is adjustable, so they can contain ingredients that otherwise would not be stable under certain circumstances. As with microemulsions, there is a lot of engineering that can be done and different materials that can be used, leading to a range of differently shaped and sized final products. For example, depending on how the phospholipids base materials are put together, one could form either multiple vesicular structures or single onion-shaped vesicles. Also as with microemulsions, Weiss and his colleagues have been experimenting with liposomes as a way to encapsulate antibacterials, in this case nisin, and they have shown that encapsulated microemulsions are better than free nisin at inhibiting growth over a longer period of time, partly as a result of a more controlled and long-term sustained release.

Liposomes are, however, extremely fragile. A liposome is basically just a shell with water inside, and it leaks over time. In fact, this is why industry hasn't really been that interested in liposomes until now. Weiss and his colleagues have shown that it is possible to engineer leak-resistant liposome surfaces by surrounding the liposomes with polymeric layers and forming double-layered, or two-layer, liposomes. Two-layer liposomes are significantly more stable to long-term storage than single-layer liposomes, and they have greater controlled release possibilities.

Next steps for nanoliposomes include forming double-layered liposomes ("secondary liposomes") that are more stable and leak-resistant than single-layer liposomes ("primary liposomes") and that have greater controlled release .

Biopolymeric Nanoparticles

Biopolymer nanoparticles are highly bioactive solid particles with diameters of 100 nm or less. They are already heavily used in the drug delivery industry, where they serve as the basis of modern anticancer drug delivery systems. Weiss and his colleagues have demonstrated that the particles can also serve as carriers of antimicrobial components, with nicin-containing biopolymeric nanoparticles exhibiting much more potent activity against *E. coli* O157:H7 than particles without nicin. The application of biopolymeric nanoparticles in the food industry is precluded however by the fact their manufacture requires the use of organic solvents. While alternative methods of assembly could be pursued, as of yet biopolymeric nanoparticles do not have any direct applications in food systems.

Solid Lipid Nanoparticles (SLNs)

An alternative to the biopolymer nanoparticle approach is the actual construction of solid particles using lipids as the base material. These so-called solid lipid nanoparticles, or SLNs, are basically crystallized emulsions composed of a high-melting point lipid and a bioactive lipophilic component. SLNs are typically about 50–500 nm in diameter and can be either sprayed or applied as powder. Smaller SLNs (i.e., 120–130 nm or less in diameter) have crystal structures that exhibit very different behaviors than those of larger SLNs because of surface-initiated crystallization. Because of these behaviors, smaller SLNs serve as highly effective carrier systems for susceptible bioactive ingredients. Weiss and his colleagues have demonstrated this fact by showing that SLN-encapsulated β-carotene lasts much longer than nonencapsulated β-carotene when stored at 20°C. Interfacial engineering is the key to success. When the interfaces of the SLNs are not engineered properly, the emulsions degrade very rapidly and the β-carotene is lost very quickly over storage time. If, however, the engineering of the SLN interface is done properly (i.e., via surface-initiated crystallization using saturated lecithin as the surfactant), the resultant crystal structure readily entraps the β-carotene and with very little degradation over the time .The next step forward, Weiss said, is the creation of more complex structures. He pointed to the work of David Weitz , Harvard University, who has shown how SLNs can be used to form shells around emulsion droplets, creating what are known as colloidosomes. As with simpler SLNs, colloidosomes can be loaded with bioactive compounds, which are released upon the application of mechanical or thermal stress.

Nanofibers

Finally, Weiss described some of the work he and his colleagues have been doing with nanofibers. He explained how the fibers are produced through a process known as electrospinning, whereby an electric voltage is applied to a polymer solution, resulting in deposits of either microparticles or very ultra fine fibers. The fibers range in size from 30–500 nm in diameter. The advantage to this technique is that a variety of morphologies of particles can be created, with different morphologies having different properties and textural attributes. As they have with other types of nanomaterials, Weiss and his colleagues have demonstrated that nanofiber technology can be used to create potent antimicrobial systems that maintain their antimicrobial capacity for long periods of time. In collaboration with researchers at the University of Tennessee, Weiss and colleagues have also demonstrated how nanofibers serve as ideal materials for catalysis because of their extremely high surface-to-mass ratio and high reaction kinetics. By modulating the surface, some very unusual reactions can be run that would not be possible with larger structures.

Future steps include combining nanofibers with other nano-scale systems, namely microemulsions, and building more complex structures with greater functionalities . Weiss and his colleagues have demonstrated that the technique of co-spinning antimicrobial microemulsions inside the nanofibers can yield another type of highly active antimicrobial nanofiber system.

One of the next steps with nanofiber technology in food is to combine the nanofibers with others type of nanomaterials, in this case microemulsions, to form novel structures with new functionalities.

Conclusion:-

The future of nanoscience concluded by many Scientists. Weiss said that it is difficult to predict the future direction of nanoscience, since many of these structures are being built faster than their new properties (and potential functionalities) can be determined. However, what we have learned so far has allowed us to begin experimenting with architectural design and creating new microscopic structures with this wide range of simple building blocks. The building blocks can be combined in various ways (e.g., microemulsions inside of nanofibers), giving us enormous control over how these systems are assembled.

In contrast to how food structures have traditionally been constructed (i.e., from recipes), nanoscience enables a bottom-up design approach using molecules as the starting material: We then assemble these molecules and engineer their surfaces in ways that lead to new functionalities. We do not fully understand, however, how most of these structures are going to function within the food matrix where they will be applied. Many unanswered questions remain about their lifetime, mobility, and location inside actual food systems. Understanding this complex interaction between the nanostructures and the food products that contain them is critical to discussing safety.

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