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Role of Nanotechnology in Nutraceuticals

*Rathod Vikas Devidas 1) Mr.L.D.Hingane (M.Pharm PhD Scholar) 2) Mr.Rokade.V.G
Aditya Pharmacy College,Beed Nalwandi Naka Beed, Maharashtra,Pin Code-431122

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ABSTRACT:-The use of nanotechnology in nutraceuticals is rapidly growing due to their ability to improve active ingredient solubility, stability and bioavailability.

Their unique properties are mainly conferred by small sizeand high surface-to-volume ratio. However, these physico-chemical properties are also responsible for potential adverse effects of nanomaterials on human health.

In order to develop new marketable nutraceutical formulations, the evaluation of their efficacy and safety is required.

In this work, we present an in vitro-based approach to simultaneously evaluate efficacy and safety of newformulations in agreement with European Food Safety Authority recommendations and in high-throughput screening fashion.

This approach is time and costs effectiveness, providing a useful support to Companies since it well fits with the safe-by-design concept that is currently under development in Europe.

I. INTRODUCTION:--

❖ **Nutraceuticals:-**

The term nutraceutical was coined in 1989 by **Stephen L.DeFelice**, founder and chairman of the Foundation of Innovative **Medicine (New York)**, combining nutrition and pharmaceutical.

Nutraceuticals are defined as foods, or part of foods, providing medical and health benefits such as the prevention and treatment of diseases .Nutraceuticals range from isolated nutrients and dietary supplements to processed product, such as cereals and beverages.

In the last years, people tried to improve the quality of life modifying their diet and substituting modern medicine with alternative and natural products. Therefore, nutraceutical market and related R&D are rapidly growing.

A major issue in this field is represented by the poor bioavailability of nutraceuticals, which are usually excreted from the body without providing any medicinal benefit.

To increase absorption, bioavailability and controlled release of nutrients and health supplements, nanotechnology can be used.

Nanotechnology is defined as the design, synthesis, and application of materials whose size and shape have been engineered at the nanoscale, when unique chemical, physical, electrical and mechanical properties emerge.

The unique properties of nanomaterials (NM) are due to their small size, usually ranging approximately from 1 to 100 nm (although a general agreement on the definition of nanomaterials is still lacking), the high surface area to volume ratio, and the high reactivity with the subsequent higher uptake and interaction with biological barriers.

❖ **Nanotechnology:-**

The branch of nanotechnology of technology that deals with dimensions and tolerances of less than 100 nanometers, especially the manipulation of individual atoms and molecules.

Nanotechnology is technology to manipulate and control a substance at the nanometer (nm) level (1nm=one billionth of a meter.

The nanometer level is the level of atoms and molecules, and create new materials and devices with fascinating functions making the best use of the special properties of nano-sized substances.

For example, today people need de-vices able to store information at high densities and high speeds, using little energy. One way of realizing this is to make each component very small.

However, as there are limits to miniaturizing components with existing technology, we need technology that uses a different(nanotechnology) approach to process components and systems with nanometer-level precision.

Also, when the size of the matter is at the level of several molecules or atoms, certain properties (the quantum effect or the surface effect)are clarified,which are not particularly noticeable when a substance is a large mass.

Types Of Nanotechnology In Nutraceuticals :-
There are mainly four types nanotechnology in nutraceuticals.
1) Nanoliposomes
2) Nanoemulsions
3) Nanoparticles
4) Nanofibres

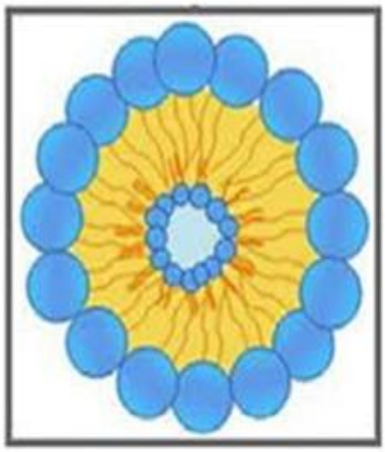
1) Nanoliposomes
Food nanotechnology involves the utilization of nanocarrier systems to stabilize the bioactive materials against a range of environmental and chemical changes as well as to improve their bioavailability.

Nanoliposome technology presents exciting opportunities for food technologists in areas such as encapsulation and controlled release of food materials, as well as the enhanced bioavailability, stability, and shelf-life of sensitive ingredients.

Liposomes and nanoliposomes have been used in the food industry to deliver flavors and nutrients and, more recently, have been investigated for their abilityto incorporate antimicrobials that could aid in the protection of food products against microbial contamination.

In this paper, the main physicochemical properties of liposomes and nanoliposomes are described and some of the industrially applicable methods for their manufacture are reviewed.

A summary of the application of nanoliposomes as carrier vehicles of nutrients, nutraceuticals, enzymes, food additives, and food antimicrobials is also presented.


Nanoliposome

Applications of Nanoliposomes
Although nanotechnology applications for the food sector are quite recent, there have been significant developments in this area. The main applications, so far, have been aimed at altering the texture of food components, encapsulating food components or additives, developing new tastes and sensations, controlling the release of flavors, and increasing the bioavailability of nutritional components.

The majority of encapsulation techniques currently employed in the food industry are based on biopolymer matrices composed of sugars, starches, gums, proteins, synthetics, dextrins, and alginates.

However, liposomes have recently begun to gain in importance due to their aforementioned unique advantages Based on the results of liposomal studies in the pharmaceutical and medical research and applications (e.g., drug delivery, cancer treatments, gene therapy, etc.), food scientists have begun to utilize liposomes for the controlled delivery of functional components, such as peptides, enzymes, vitamins, and flavors in various food applications.

In the following sections, some applications of the lipid vesicles pertinent to the food industry are exemplified.

Nanotechnology is an interdisciplinary area of research and development that involves the manufacture, processing, and application of substances or devices that have one or moredimensions in the nanometer range.

Nanotechnology is an advancedbranch of

science that has already started to impact a number of other fields, includingmedicine, cosmetics, agriculture, and food. In addition, nanotechnology in the food area isbeing used as a means to understand how physicochemical characteristics of nanometricmaterials can change the structure, texture, and quality of foodstuffs.

2) Nanoemulsion

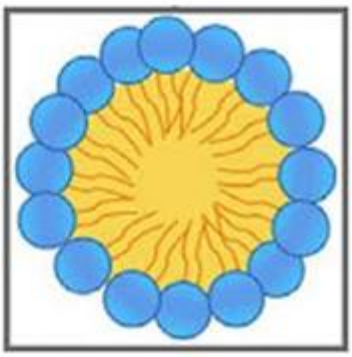
Nanoemulsions have small droplet size and are kinetically stable colloidal systems. They have enhanced functional properties in comparison to conventional emulsions.

The composition and structure of the nanoemulsions can be controlled for the encapsulation and effective delivery of bioactive lipophilic compounds.

Nanoemulsions have potential application in the food industry for the delivery of nutraceuticals, coloring and flavoring agents, and antimicrobials.

The nanoemulsion formulations of active ingredients can be used for developing biodegradable coating and packaging films to enhance the quality, functional properties, nutritional value, and shelf life of foods.

This review focuses on preparation of food grade nanoemulsions using high-energy methods and low-energy approaches and their characterization for physical properties, stability, and microstructure.



Nanoemulsion

The application of nanoemulsion formulations for sustainable food processing and improving the delivery of functional compounds, such as colorants, flavoring agents, nutraceuticals, and preservatives or antimicrobial agents in foods has been discussed.

Applications Of Nanoemulsion

The current use of nanoemulsions in food products is rather limited, but these colloidal systems hold considerable potential for application in several areas, mainly related to the development of novel functionalities.

In particular, the delivery of functional compounds, such as bioactive molecules, micronutrients, colorants, flavorings, or antimicrobial agents, into food and beverage products that naturally do not contain them is highly desired to increase product value by enhancing health benefits, nutritive profile, appearance, aroma, or shelf life.

Oil-in-water (O/W) nanoemulsions are simple but effective delivery systems, which can be formulated using natural or naturally derived ingredients and produced using high-throughput operating procedures that are easily scalable.

The composition and structure of these nanoemulsions can be carefully controlled to provide the required in-product protection and thedesired in-body behavior.

In addition, the ability of nanoemulsions to form gels can be exploited in functional food design, where nanoemulsion gels become a constitutive part of the food.

Nanoemulsions are being increasingly utilized as drug delivery systems for the effective administration of pharmaceuticals because of their potential advantages over other approaches.

Nanoemulsions can be used to design delivery systems that have increased drug loading, enhanced drug solubility, increased bioavailability, controlled drug release, and enhanced protection against chemical or enzymatic degradation.

Moreover, nanoemulsions have better stability to flocculation, sedimentation, and creaming than conventional emulsions. Their small droplet dimensions and large droplet surface area positively influence drug transport and delivery, along with allowing targeting to specific sites.

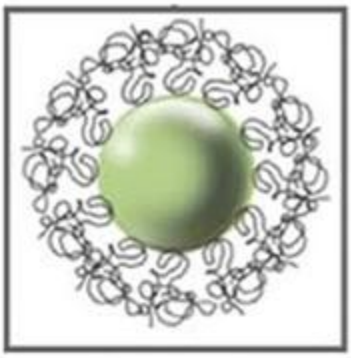
3) Nanoparticles

Nanoparticles (NPs; 1–100 nm in size) have a special place in nanoscience and nanotechnology, not only because of their particular properties resulting from their reduced dimensions, but also because they are promising building blocks for more complex nanostructures.

In addition, a classification of NPs based on their dimensions, morphology and chemical composition is presented. NP uniformity and agglomerations, with a special focus on super

paramagnetic NPs and their nano composites, are discussed.
Nanotechnology is the science that deals with matter at the scale of 1 billionth of a meter (i.e., 10 − 9m = 1 nm), and is also the study of manipulating matter at the atomic and molecular scale.

A nanoparticle is the most fundamental component in the fabrication of a nanostructure, and is far smaller than the world of everyday objects that are described by Newton ' s laws of motion, but bigger than an atom or a simple molecule that are governed by quantum mechanics.



Polymer nanoparticle

The United States instituted the National Nanotechnology Initiative (NNI) back in 2000, which was soon followed (2001) by a plethora of projects in nanotechnology in nearly most of the U.S. Departments and Agencies.

About 20 Research Centers were subsequently funded by the Nationa1 Science Foundation (NSF), an agency responsible solely to the President of the United States and whose mandate is to fund the best of fundamental science and technology projects.

NSF was the lead U.S. agency to carry forward the NNI.

The word "nanotechnology" soon caught the attention of various media (TV networks, the internet, etc.) and the imagination and fascination of the community at large.

In general, the size of a nanoparticle spans the range between 1 and 100nm.Metallic nanoparticles have different physical and chemical properties from bulk metals (e.g., lower melting points, higher specific surface areas, specific optical properties, mechanical strengths, and specific magnetizations), properties that might prove attractive in various industrial applications. However, how a nanoparticle is viewed and is defined depends very much on the specific application.

Applications Of Nanoparticles

Micro- and nanotechnology are tools being used strongly in the area of food technology.

The electrospray technique is booming because of its importance in developing micro- and nanoparticles containing an active ingredient as bioactive compounds, enhancing molecules of flavors, odors, and packaging coatings, and developing polymers that are obtained from food (proteins, carbohydrates), as chitosan, alginate, gelatin, agar, starch, or gluten.

The electrospray technique compared to conventional techniques such as nanoprecipitation, emulsion–diffusion, double-emulsification, and layer by layer provides greater advantages to develop micro- and nanoparticles because it is simple, low cost, uses a low amount of solvents, and products are obtained in one step.

This technique could also be applied in the agri food sector for the preparation of controlled and/or prolonged release systems of fertilizer or agrochemicals, for which more research must be conducted.

Magnetic iron oxide nanoparticles have been used in various fields owing to their unique properties including large specific surface area and simple separation with magnetic fields.

For food related applications, they have been used for enzyme immobilization, protein purification, and food analysis. This review summarizes the basic principles and achievements of magnetic iron oxide nanoparticles in enzyme immobilization, protein purification and food analysis. Their indispensable contribution to food engineering has been also evaluated.

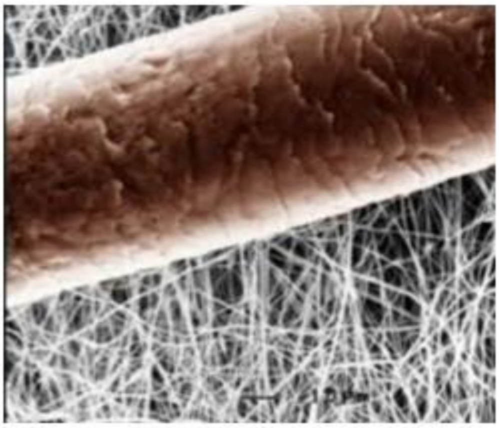
4) Nanofibres

Cellulose is the most abundant and a low-cost biodegradable by-product in the food and agricultural industries.

Electrospun cellulosic nanofibers have remarkable physicochemical properties that make them attractive for many applications in the food sector.

In this review, electro spinning is investigated as an easy method for producing nanofibers from polymers.

Moreover, the most important applications of cellulosic nanofibers in food science are presented.



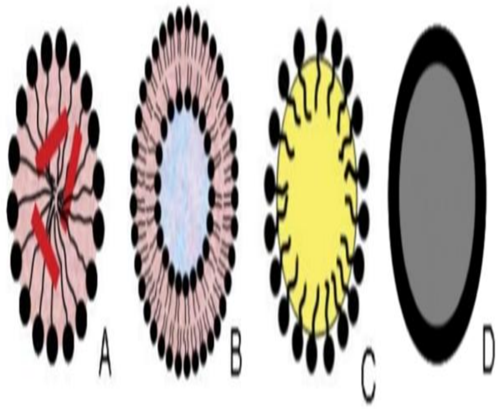
Application Of Nanofibres

- Immobilization of bioactive substances such as enzymes, vitamins, and antimicrobials.
- Nutraceutical delivery systems and controlled release of materials.
- As biosensors
- Filtration, and
- For reinforcing composites and in films. Finally, some potential risks of using electro spinning in food science are reviewed.

Nanoparticulate Delivery System:-

When amphiphilic molecules like surfactants, lipids, and copolymers that have both polar and nonpolar characteristics are dispersed ina polar solvent, hydrophobic interations cause them to spontaneously self assemble into a rich array of thermodynamically stable, lyotropic, liquid crystalline phases with characteristic length scales in the nanometers.

Theseinclude micelles, hexagonal (tubular) structures, lamellarstructures, and cubosomes, which possess a high degree of molecular orientation order despite the fact that they exist in a liquid state.



- **Micelles**

Micelles are submicron spherical particles, typically 5–100 nm in diameter, that are formed spontaneously upon dissolution of surfactants in water at conentrations that exceed a critical level, known as the "critical micelle concentration" (CMC).

This self-assembly process is thermodynamically driven; i.e.interactions of the hydrophobic tail group of surfactants with water are minimized, while interactions of the hydrophilic surfactant head groups with water are maximized. Because of this, micelle integrity under a given set of environmental conditions (pH, temperature, salt concentration) is often maintained for many years.

A remarkable property of micelles is that they have the ability to encapsulate nonpolar molecules such as lipids, flavorants, antimicrobials, antioxidants, and vitamins.

Compounds that ordinarily are not water soluble or are only sparingly soluble can, with the help of micelles, be made water soluble. Micelles containing solubilized materials are referred to as microemulsions or swollen micelles.

While micelles have been used as a delivery system for pharmaceutical compounds for quite a long time, their use as carrier systems for functional food components has only recently attracted increased attention.

Reports of successful application of microemulsions include encapsulation of limonene, lycopene, lutein, and omega-3 fatty acids using a variety of food-grade emulsifiers, although in some cases addition of ethanol as a co-surfactant was required.

Patent applications have been filed for the use of microemulsions to incorporate essential oils in flavored carbonated beverages and toencapsulate alpha-tocopherol toreduce lipid oxidation in fish oil.

❖ Liposome

Liposomes, or lipid vesicles, are formed from polar lipids that are available in abundance in nature, mainly phospholipids from soy and egg.

Like micelles, liposomes can incorporate a wide variety of functional components in their interior. However, in contrast to micelles, they can be used to encapsulate both water-and lipid-soluble compounds.

Liposomes are spherical, polymolecular aggregates with a bilayer shell configuration Depending on the method of preparation, lipid vesicles can be uni- or multi-lamellar, containing one or many bilayer shells, respectively.

Liposomes typically vary in size between 20 nm and a few hundred micrometers. Their core is aqueous in nature, its chemical composition corresponding to that of the aqueous solution in which the vesicles are prepared.

Because of the charge of the polar lipids used in the preparation of liposomes, charged but water-soluble ionic species can be trapped inside the liposomes.

The pH and ionic strength of the liposomal core can thus differ from those of the continuous phase in which the liposomes are later dispersed.

Liposomes have been successfully used to encapsulate proteins and provide a microenvironment in which proteins can continue to function regardless of external environmental conditions.

On the other hand, the interior of the bilayer has properties resembling those of an organic solvent. Consequently, lipid compounds can be encapsulated inside the bilayer, a process known as adsolubilization.reviewed food applications of liposomes.

They cited studies on liposomes to increase shelf life of dairy products by encapsulating lactoferrin, a bacteriostatic glycoprotein as well as nisin Z, an antimicrobial polypeptide.Antimicrobial efficiency of other ingredients in the encapsulated form has also been reported.

Liposomal-entrapped phosvitin was used to inhibit lipid oxidation in a variety of dairy products and ground pork. Liposome-encapsulated vitamin C retained 50% activity after 50 days of refrigerated storage, whereas free ascorbic acid lost all activity after 19 days.

❖ Nanoemulsions

Nanoemulsions are simply very fine oil-in-water (o/w) emulsions with mean droplet diameter of 50–200 nm.

An emulsion is defined as a mixture of two completely or partially immiscible liquids, such as oil and water, with one liquid being dispersed in the other in the form of droplets.

Examples of emulsified food products are mayonnaise, milk, sauces, and salad dressings. In contrast to these well-known o/w emulsions, nanoemulsions are small enough not to scatter light in the visible region of the spectra; thus, they appear clear instead of being optically opaque.

Because of their small size, they also do not cream within an appreciable time. Creaming is the process whereby oil droplets move to the top of the emulsion to form a concentrated oil-droplet layer.

This is often followed by a complete breakdown of the emulsion, yielding a clearly visible oil layer on top of the emulsion.

Nanoemulsions and macro-emulsions can be manufactured in a similar fashion using high-pressure homogenizers, or membrane and micro fluidic channels.

It should be noted that the proper choice of surfactants and/or polymers is critical in the production of nanoemulsions. Because of their small size, nanoparticles have excellent penetration properties to ensure rapid delivery of high concentrations of active ingredients to cell membranes. Bioavailability of lipophilic active ingredients can be substantially improved by delivery in nanoemulsions.

For example, nanoemulsions have been used in parenteral nutrition for quite some time. Also because of their small size, they may also exhibit some interesting textural properties that differ from those of an emulsion containing larger droplets.

For example, they may behave like a viscous cream even at low oil-droplet concentrations, a fact that has attracted attention in the development of low-fat products.

❖ Biopolymeric nanoparticles

Consist of a matrix of biopolymers that may be linked through intermolecular attractive forces or through chemical covalent bonds to form solid particles. Nanoparticles may consist of a single biopolymer or may have a core-shell structure.

Because of the versatility in terms of compounds that can be encapsulated and the degree to which these particles can be engineered and surface properties can be tailored, they have rapidly become the most promising nanoscale delivery systems in the pharmaceutical and cosmetics industries.

Polylactic acid, a keycomponent of many biodegradable nanoparticles, was first developed in 1932, but its high cost and susceptibility to hydrolytic breakdown were believed to make it unsuitable for use in biomedical or agricultural applications or sparingly used in research.

However, the use of this polymer as an ideal material for sutures was discovered in the 1970s, and a process was developed in the 1980s to produce the polymer via bacterial fermentation, greatly reducing costs and increasing production rates.

Today, a wide variety of natural and synthetic polymers have been used to encapsulate and deliver compounds. Among these are chitosan, a natural antimicrobial and antioxidative polymer obtained from crustacean shells and the synthetic polymers L-, D-, and D,L-polylactic acid (PLA), polyglycolic acid (PGA), and polycaprolactic acid (PCL).

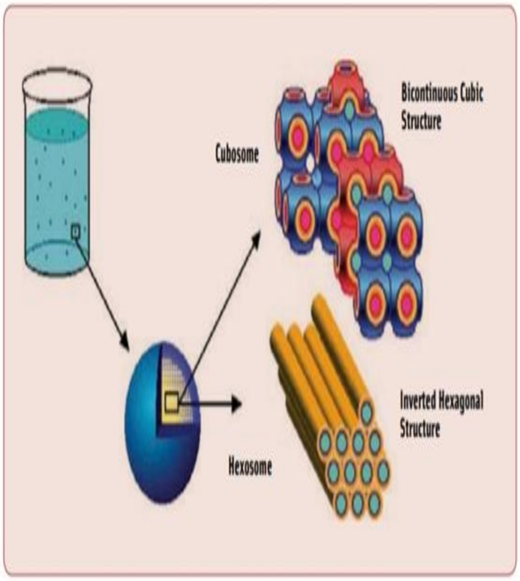
Copolymers created using combinations of the monomers lactide,galactide, and caprolactone are also increasingly used

❖ Cubosomes

Cubosomes are bicontinuous cubic phases which consist of two separate, continuous, but nonintersecting hydrophilic regions divided by a lipid layer that is contorted into a periodic minimal surface with zero average curvature.

The continuous and periodic structure results in a very high viscosity of the bulk cubic phase. However, cubosomes prepared in dispersion maintain a nanometer structure identical to that of the bulk cubic phase but yield a much lower, water-like viscosity.

Its tortuosity can be useful for slowing diffusion in controlled-transport applications. Its isotropic optical property permits uses in many different products.



Compared to liposomes, cubosomes have much higherbilayer area-to-particle volume ratios.The cubosome structure can be changed by modifying the environmental conditions, such as pH, ionic strength, or temperature, thus achieving controlled release of the carried compound.

Cubosomes may be used in controlled release of solubilized bioactives in food matrices as a result of their nanoporous structure(approximately 5–10 nm); their ability to solubilize hydrophobic, hydrophilic, and amphiphilic molecules; and their biodegradability and digestibility by simple enzyme action. The cubic phase is strongly bioadhesive, so it may find applications in flavor release via its mucosal deposition and delivery of effective compounds. The rate of release appears tunable through system optimization or ideal formulation of products for specific purposes.

Production and Applications:-

- A fairly large number of manufacturing methods are available to produce solid nanoparticles, including nanoprecipitation, solvent evaporation, and spontaneous emulsification followed by solvent diffusion.
- Several new methods have been developed that use milder chemicals and those that can be easily removed from the final product by such methods as “salting-out” and electrospraying.
- Biological methods of producing nanoparticles and nanostructures have also been explored in recent years.
- One example is using plant viruses as

templates to synthesize nanomaterials with predesigned surface functionality for target recognition, controlled gates for substance uptake and release, and imbedded metals and dyes for facilitated imaging.

- The development of "coated and conducting" DNA molecules has enabled medical researchers to produce a new generation of nanoparticles that combine targeting of cancer cells, controlled release of anticancer drugs, and localized generation of heat inside the cell, thereby dramatically boosting the performance of anticancer drugs.
- Other applications include the ability to rapidly detect the presence of single molecules (proteins or DNA fragments), eliminating the need for amplification or enrichment.
- The sensitivity of some of these new techniques is 1,000 times that of conventional polymerase chain reaction (PCR).
- Nanotechnology provides tools and means to precisely graft biological and chemical ligands onto the surface of nanoparticles.
- The surface modification allows nanoparticles to recognize target cells. With a site-specific controlled-release mechanism built in, the nanoparticles can deliver the functional compounds to the target site to increase their effectiveness and efficiency.
- This capability may allow for better bioavailability and absorption in the gastrointestinal tract.
- On the other hand, specific molecular recognition, site targeting, and adhesion action may be used to bind undesirable compounds encountered in the food consumption chain and remove harmful matters from the digestive system of humans and animals.
- One relevant research discovery is that polystyrene nanoparticles with specifically functionalized adhesion mechanism can bind the nanostructured K88 fimbrial adhesin of Escherichia coli cells in poultry guts and agglomerate them to remove the pathogens prior to slaughtering of birds.
- This technology improves food safety by reducing the pathogenic load.The safety of using such nanoparticles has been preliminarily demonstrated through an array of in-vitro and in-vivo biosafety tests.
- This is an important step to assure a responsible and safe deployment of this new nanotechnology.
- For the recognition and binding of specific molecules and cellular structures, molecular imprinting techniques are another set of tools in which a variety of polymers are created that can form complementary nanoscale binding pockets for the intended targets.
- Development of new and creative approaches to identify nanoscale binding domains with complementary ligands for selective recognition in food systems will help to accelerate the development of intelligent biomolecule–modulated protein and bioactive-compound delivery systems.Targeted delivery systems have greater benefits and fewer adverse effects.
- For example, one can imagine that targeted delivery of a salty taste will require much less salt in the bulk of foods to achieve the desirable salty sensation.

Limiting factors on the nanoencapsulation process

Delivery systems should be designed to protect nutraceuticals during processing, storage and transport from adverse factors such as undesirable interactions with other food ingredients, pH, light, temperature or oxygen. The following describes some of the principal factors that can affect the nanoencapsulation:-

- **Emulsions and solvents effect**

If techniques need the preparation of emulsions and the use of solvents, it has been observed that the amount of solvents as well as the method used for their evaporation influence the final characteristics of the capsules obtained. When the selected methodcontains the parameters of emulsion-solvent and evaporation/extraction. The stability ofthe water-in-oil emulsion is a critical factor for a good internalization of the active principle. When the first emulsion is unstable, the efficiency of the microencapsulation is low because the aqueous phase tends to emerge with the continuous phase of another capsule.

- **pH effect**

It has been observed that the pH also has an effect on the encapsulation capacity and the final size of the capsules obtained. Studies show that during coacervation process, the sizes of the particles can change if the value of pH changes, since the density is modified of the gel charge (positive, neutral or negative) which gives rise to molecules contracted or expanded as a function of intra molecular repulsion forces.

Also using the technique of ionic gelation,

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the pH possibly influenced the solubility of the protein, which allowed a better interaction with the polymer, obtaining a higher content of encapsulated hydrolyzate.

- **Polymer: concentration and characteristics**

Natural starch does not have emulsifying property, and it is mostly hydrophilic, which confines its application for the encapsulation of hydrophobic bioactive compounds. Therefore, modified starches (cross-linked, oxidized, acetylated, hydroxypropylated) are produced by altering the chemical structures through chemical, biochemical, physical and/or enzymatic methods in order to improve functionality and extend commercial applicability.

- **Temperature effect**

An example, the temperature effect on the gelling solution can be controlled to promote heat-set or cold-set gelation of certain biopolymers. This approach can be used to form gelatin hydrogel beads by injecting a hot-gelatin solution into a cold environment.

At high temperatures, the gelatin molecules have a random coil conformation, but upon cooling below a critical temperature they form helical regions that act as cross-links between different molecules through hydrogen bonding. Conversely, globular proteins (such as those from whey, egg, or soy) can be made to gel by heating them above their thermal denaturation temperature to cause them to unfold and associate through hydrophobic attraction and disulfide bond formation.

Significance Of Nanotechnology In Food Sector:-

- **Food Processing:-**

Food processing is the conversion of raw ingredients into food and its other forms by making it marketable and with long shelf life. Processing includes toxin removal, prevention from pathogens, preservation, improving the consistency of foods for better marketing and distribution. Processed foods are usually less susceptible to early spoilage than fresh foods and are better suited for long distance transportation from the source to the consumer. All these are made more effective by the incorporation of the nanotechnology nowadays.

Nano capsules delivery systems plays an important role in processing sector and the functional property are maintained by encapsulating simple solutions, colloids, emulsions, biopolymers and others into foods.Nano sized self assembled structural lipids serves as a liquid carrier of healthy components that are insoluble in water and fats called as nanodrops. They are used to inhibit transportation of cholesterol from the digestive system into the bloodstream.

- **Food Packaging**:-

Food packaging for food requires protection, tampering resistance, and special physical, chemical, or biological needs. It also shows the product that is labelled to show any nutrition information on the food being consumed. The packing has a great significance in preserving the food to make it marketable.

Innovations in packaging have lead to quality packing and consumer friendly approach in determining the shelf life, biodegradable packing and many more. Nanotechnology in packaging is categorized based on the purpose of the application.

- **Barrier Protection:-**

The food products are preserved by maintaining it in an inert and low oxygen atmosphere for inhibiting microbial growth and spoilage, thus the material used should be impermeable to gases. Nanocomposites are incorporated in the polymer matrix of the substances due to their large surface area which favors the filler-matrix interactions and its performance. Also the nanoreinforcement's acts as small, barriers for gases by complicating the path of the material, both are known as polymer nanocomposites .Nanoclays are composite materials having complex metallic ores.

They are naturally obtained from volcanic ash as Montmorillonite ,provides barrier to permeation of gases or polymer based clays prepared by nylons, polyolefin, PET, PA, epoxy resin, poly methane are used for polymer matrix in food packaging to get higher quality. But polyamide based nanoclay have been developed largely and commercialized under the trade names Durethan, Imperm, Aegis and noted for their durability and protection.

Various researches have been developing in nanocomposites from cells and carbon nanotubes since packaging plays a backbone for commercialization of products.

- **Antimicrobial Packaging:-**

The barriers include natural Nanoparticle to control microbial growth which leads to pathogens or spoiling. Silver nano particles are

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used in all forms including biotexiles, electrical appliances, refrigerators, kitchenware's. Silver nanoparticles show needed action in bulk form, and its ions have the ability to inhibit wide range of biological processes in bacteria.

Zinc oxide's antibacterial nature increases with decreasing particle size, it can be stimulated by visible light, and they are incorporated in number of polymers including polypropylene. E. coli contamination can be controlled using Titanium dioxide as a coating in packing material.

It is also combined with silver to improve disinfection process. Chiston is a biopolymer derived from chitin recently reported antimicrobial properties additional to material for encapsulation. Antimicrobial packaging would be highly healthy and consumer friendly products.

❖ **Biodegradeable:-**

Pollution is the most concerning factor which affects the environmental characteristics. The effect of non-degradable plastics changes the soil nature and accumulation of toxic gases in atmosphere leads to global warming, hence bio degradable plastics came into effect but they lack mechanical strength and permeable to water and gases .These disadvantages are prevailed over by nanotechnology incorporated packaging material made of natural or synthetic nanoparticles having properties like bio-degradable, renewable resources having high mechanical strength. Nanoparticles are obtained as the proteins, carbohydrates, lipids from animal and plant materials, also metal oxides nanoparticles and carbon nanotubes are used.

In addition collagen, zein, cellulose from corn is synthesized into nanofibers it is highly porous in nature .These nano materials are added along with nanoclays and used for comfort packaging. They also have additional novel properties like sensors, antibacterial action and as biocatalysts.

❖ **Smart Packaging:-**

Sensors are devices used to detect the physical quantity of substances and converts into observer readable signals. They are used to regulate the internal environment of the food stuffs and their properties are sensed regularly which is indicated by sensors. A recent report shows that the current smart packaging segment is dominated by oxygen scavengers, moisture absorbers and barrier packing product, accounting for 80% of the market.

Whereas the bakery and meat products having attracted most nano-enabled packaging technology to date. The food environment is continuously sensed for oxygen content, temperature, pathogens and indicators are used for proper alarming. They also show the shelf life of the products with the help of the nanosensors.

Some examples include gold nano particle incorporated enzymes for microbes detection, gas sensing related to condition of food products : nanofibrils of perylene-based fluorophores indicates fish and meat spoilage by detecting gaseous amines. Others include zinc oxide and titanium oxide nanocomposites for the detection of volatile organic compounds.

Nanobarcodes are used for tagging and also for security.Thus the use of smart sensors is beneficial to the consumers in terms of better quality identification and producers for rapid distribution and authentication of the food products.

❖ **Nutritional Supplements:-**

According to a survey, the total market value of nanofood would reach US$5.8 billion (food processing US$1303 million, food ingredients US$1475 million, food safety US$97 million and food packaging US$2.93 billion) in 2012.Thus making heavy profit to economy.

Nanoceuticals, Nutrition-be-nanotech, are commercial names for supplements. Nanosized powders are used for increasing absorption of nutrients, nanocochleates are considered as effective tool for nutrient delivery to cells without affecting color and taste of food products. Vitamin sprays disperse nanodroplets are used for better absorption of nutrients.

Supplementary aspect main involves encapsulation techniques where the needed probiotics, and other products are targeted into the human system with the help of iron and zinc nano structured capsules. Thus, nanotechnology in food supplement is very effective than common supplements because they react more effectively with human cells due to their size.

II. CONCLUSION:-

The use of nanotechnology in food industry and nutraceuticals sector is continuously growing due to the amazing properties conferred to products from these new materials. In nutraceuticals products, nanotechnology are used to improve solubility, stability and bioavailability of active ingredients.For instance, researchers found that dibenzoylmethane nanoemulsions ranging from 50 to 200 nm enhance oral availability threefold over conventional emulsions in the 10-100 μm range. The use of nanotechnology in nutraceuticals raises new questions on their safety, and great efforts are done to balance opportunities and risks. Indeed, oral administration of NM-containing nutraceutical formulations might have an impact on consumer health. EFSA has developeda practical approach for assessing potential risks arising from applications of nanoscience and nanotechnologies in the food and feed chain. This approach foresees the study of physico-chemical transformations occurring during digestive process with the aim to check the conversion of NM into non-nanoform substances. To avoid unwanted adverse effects of NM-based product, biopersistent NM should be evaluate from a toxicological point of view. Appropriate in vitro and in vivo studies on biopersistent NM should be undertaken to identify hazards and obtain dose-response data to characterize the hazard.

In this work, we presented a useful workflow to develop new efficient and safe nutraceutical formulations. This process includes evaluation of: (i) stability and controlled release of active ingredients during digestive process; (ii) mucoadhesion and mucopenetration, transport across in vitro intestinal-like epithelium model and transcytosis via follicle-associated epithelial M cells; (iii) safety. The presented approach is a combination of in vitro model for digestion, mimicking the different biological composition of digestive tracts, and in vitro model for absorbent tissue. This model permits high-throughput screening of new formulations to evaluate their efficacy and safety in agreement with EFSA recommendations. Moreover, it well fits with the safe-by-design concept that is currently under development in Europe.

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