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Research Article

Review: Nanotechnologies in Food Texture and Flavor

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ABSTRACT:
In this review, our aim is to examine the different uses of Nanotechnologies in the improvement of Food Texture and Flavor by compiling the results from previous studies. Texture which is one of the major attributes of food that determine consumer acceptance is one of those crucial things to take into consideration in the Food Industry. With the help of emerging technologies like Nanotechnology, Food scientists have been able to improve the Texture of food by employing techniques like Nanoemulsions, Nanoencapsulation, Nanoparticles to mention but a few as further discussed in this review. Flavour acts as a delivery system of chemicals that enhance the consumer’s perception of taste, smell and other organoleptic properties in a product. Chemical and mechanical techniques of flavour nanoencapsulation such as, coacervation, molecular inclusion, spray drying and extrusion along with their general application in the food industry in the form of cyclodextrins and silica nanoparticles have been discussed in this review paper. Some of the most common current application of nanotechnology in the food flavouring industry comprises of fish oil nanoencapsulation, salt nanoparticles, flavour encapsulation and modified food starch.

Keywords: *Nanotechnology, nanofood, texture, flavor, nanoencapsulation, silica nanoparticles.*

1. INTRODUCTION

Nanotechnology has been provisionally defined as relating to materials, systems, and processes which operate at a scale of 100 nanometers (nm) or less. The us national nanotechnology initiative has defined nanotechnology as “the understanding and control of matter at dimensions of roughly 1–100 nm, where unique phenomena enable novel applications; encompassing nanoscale science, engineering and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at nanoscale”[1]

Nanotechnology is a technology that has the potential to revolutionize the food industry in the coming future. The foods which have been cultivated, produced, processed, or packaged using nanotechnology techniques or tools or to which manufactured nanomaterials, which are any material that is intentionally produced at nanoscale to have specific properties or specific compositions, have been added are termed as nanofoods [2] Actually, nanofood has been part of food processing for ages because most of the food structures exist naturally at the nanoscale. [3]

To mention but a few, the applications of nanotechnologies for the food and allied sector fall into the following main categories:

• where food ingredients have been processed or formulated to form nanostructures.

•where nano-encapsulated additives have been used.

•where engineered nanomaterials (enms)/manufactured nanomaterials defined as "any material that is intentionally produced in the nanoscale to have specific properties or a specific composition" have been incorporated to develop improved, active,or intelligent materials for food packaging or in food contact materials (fcms) or surfaces.

• where nanotechnology-based devices and materials have been used, e.g., for nanofiltration (nf) and water treatment

• where nano(bio)sensors have been used for food safety and traceability and contaminant detection

• where applications of ends have been suggested for pesticides, veterinary drugs, and other agrochemicals to improve food production systems [4] [5]

In applying nanotechnology in the food industry,various nanomaterials and structures are utilized which include: nanosystems, nanoparticles, nanofibres, nanoclays, nanotubes, nanofibres, nanoclays, nanotubes, nanocapsules and nanosensors.

The application of nanotechnology to the food industry may allow the modification of many macroscale characteristics of food, such as texture, taste, flavor and other sensory attributes, coloring strength, processability, and stability during shelf life,leading to a great number of new products and in this review, we shall focus mainly on those nanotechnologies that havebeen applied to texture and flavor of food.

2. TEXTURE

In the 1960s and 1970s, texture was brought into mainstream of food science by several studies showing texture to be a prominent food characteristic determining food acceptability[6] [7]. Food texture is defined as those properties of a food that are sensed by touch in the mouth and with the hands. We use many words to describe food texture—foods can be soft or hard, mushy or crunchy, or smooth or lumpy. Texture has also seen a rise in attention from the food industry, which has begun to realize the importance of positive texture in the launch of a viable product [8]. Texture has been shown to be more important than flavor in the rejection of foods [7]. However, flavor has remained the dominant food attribute for a multitude of reasons. Mainly, flavor is highly correlated with overall liking of a food product and flavor benefits from high consumer awareness [9]

Some of the Nanotechnologies that have been utilized to improve Texture of Food are discussed below;

2.1 Nanoencapsulation

Nanoencapsulation is the incorporation of ingredients in small vesicles or walled material with nano (or submicron) sizes. Nanoencapsulation which is now the extension of microencapsulation is usually in the form of micelles, liposomes, or biopolymer-based carrier systems has been used to develop delivery systems for additives and supplements for use in food and beverage products. These nanomaterials offer several advantages such as preserving the ingredients and additives during processing and storage, masking unpleasant tastes and flavors, controlling the release of additives, better dispersion of water-insoluble food ingredients and additives, and improved uptake of the encapsulated nutrients and supplements [5], [10],[11]. The protection of bioactive compounds, such as vitamins, antioxidants, proteins, and lipids as well as carbohydrates is also achieved by using Nanoencapsulation and this alone has opened up a vast area of application in food products that incorporate nanosized vitamins, nutraceuticals, antimicrobials, antioxidants, functional ingredients,etc. It can reduce the amount of active ingredients needed in formulation and so the cost. After food packaging, nanoencapsulation is currently the largest area of nanotechnology application in the food industry, and numbers of products based on nanocarrier technology are already available on the market.

2.2 Nanoemulsion

When one of two immiscible liquid phases is dispersed as droplets, the resulting mixture is referred to as an emulsion. Nanoemulsions consist of oil droplets in the nano-ranged size, between 10 and 100 nm dispersed within an aqueous continuous phase, with each oil droplet surrounded by surfactant molecules [12] [13] Usually, nanoemulsions are highly stable to gravitational separation because the relatively small particle size means that Brownian motion effects dominate gravitational forces [14]. They also have good stability against droplet aggregation because the range of attractive forces acting between the droplets decreases with decreasing particle size, while the range of steric repulsion is less dependent on particle size [14]. Nanoemulsion-based delivery systems can also improve the bioavailability of the encapsulated components due the small particle size and high surface-to-volume ratio [12].

Nanoemulsion was first prepared in 1940. This type of emulsion is thermodynamically unstable because of the large positive interfacial tension between the oil and water phases. Very little scattering of the visible light takes place due to the smaller droplet size of nanoemulsions as compared to the wavelength of visible light. Therefore, nanoemulsions appear transparent in the visible light spectrum. They have much better kinetic stability to gravitational separation and aggregation than other emulsions. The optical transparency, kinetic stability of nanoemulsions are dependent on the thermodynamic conditions such as compositions, temperature, and pressure as well as on the preparation methods. Therefore, it is possible to prepare nanoemulsions with reproducible properties and definite droplet sizes by utilizing different preparation techniques. Because of these advantages nanoemulsions have been achieving great interest for fundamental studies and applications in different fields such as of healthcare, cosmetics, food, agrochemicals, pharmaceuticals, and biotechnology. Production of Nanoemulsion can be classified into two methods which are high-energy and low-energy methods. As the name suggests, high-energy methods make use of devices that use very high mechanical energy capable of generating intense disruptive forces that break-up the oil and water phases and lead to formation of oil droplets for example, high-pressure valve homogenizers, micro fluidizer and sonication methods, these systems offer more control of the size distribution and composition of the resultant nanoemulsions, but some chemicals can be easily degraded during the production process; further, most production processes are not prepared to be scaled up. On the other side is low-energy emulsification for example phase inversion and solvent demixing methods, require low energy for nanoemulsions production and mainly depend on the intrinsic physicochemical properties of surfactants and the oily phase, and its scale-up is more straightforward. In order to stabilize the nanoemulsions an emulsifier or a combination of emulsifiers is needed. The emulsifier molecules adsorb at the interface between the two phases, lowering the interfacial tension and preventing or slowing down the aggregation of particles of the dispersed phase by increasing repulsion forces between them. The emulsifiers range from proteins to cationic, anionic or nonionic surfactants, and even polysaccharides. Other materials needed for nanoemulsion preparation are solvents such as Sunflower oil, MCTs etc and functional compounds such as bioactive lipids, flavors, antimicrobials, antioxidants, and drugs [10]Analytical Techniques used for nanoemulsion characterization are divided into three categories: separation techniques such as high-pressure liquid chromatography—HPLC and flow field fractionation—FFF, physical techniques such as dynamic light scattering—DLS, zeta potential, differential scanning calorimetry—DSC, Fourier transform infrared—FTIR, nuclear magnetic resonance—NMR and X-ray diffraction—XRD and imaging techniques such as transmission electron microscopy—TEM, scanning electron microscopy—SEM and atomic force microscopy—AFM. Despite some of these techniques being mostly applied to nanoparticles, they can be applied to characterize nanoemulsions as well.

2.3 Nanotechnology application for Food Texture

A report suggested that the number of companies that currently make use of nanotechnology in the food sector may be about 400.

A major focus of current nanotechnology applications in food is the development of nanostructured (or nanotextured) food ingredients and delivery systems for nutrients and supplements. For this, a variety of processes are being utilised, including nano-emulsions, surfactant micelles, emulsion bilayers and reverse micelles [11]

The nanostructured food ingredients are being developed with the claims that they offer improved taste, texture and consistence. For example, low-fat nanostructured mayonnaise, spreads and ice creams claim to be as ‘‘creamy’’ as their full fat alternatives and, hence, offer a healthier option to the consumer.

Nanoemulsion production for encapsulation and delivery of functional compounds is one of the emerging fields of nanotechnology applied to food industry.

Unlike micro- or other conventional emulsions, nanoemulsions can be prepared to be more viscous or gel-like with very low droplet concentrations, which can be easily used to make products with novel texture and with low fats.

Some of the giants of the food industry such as Unilever and Nestlé are also applying nanotechnology to their food products. Unilever has made ice cream healthier without compromising on taste through the application of nanoemulsions. The objective is to produce ice cream with lower fat content, achieving a fat reduction from the actual 16% to 1%. Nestlé has a patent in water-in-oil emulsions (10–500 nm), aiming at achieving quicker and simpler thawing through the addition of polysorbates and other micelle-forming substances; these are claimed to contribute to an uniform thawing of frozen foods in the microwave.

Nanoemulsions in the form of proteins (eg egg, milk and vegetable protein) or carbohydrates (eg starch, pectin, alginate, carrageenan, xanthan, guar gum) help in improving the texture and lead to uniformity of the ice cream. Brominated vegetable oil, ester gum, dammar gum and sucrose-acetate isobutyrate are used as weighting agents to reduce creaming and sedimentation

At nanoscale, nanoparticles serve several purposes in the processing of food. They help in improving the food’s flow property, colour and stability. Silicon dioxide is used as an anti-caking and drying agent. It helps in absorbing the water molecules in food, thus displaying hygroscopic application. Titanium dioxide is used a food whitener for food products such as milk, cheese and other dairy products. Starch as fat replacers to Improve the taste and mouthfeel due to the small particle size.

Nanoencapsulationhas been used to improve the flavor release, retention and to improve the culinary balance. Undesirable taste and odour of some desirable nutrients can be masked throughencapsulation and addition of the nutrient in the food.

3. FLAVOR

Statistical studies have shown that food flavoring industry is immensely technical with their processes, technicality, specialization, innovation and competition under the food and beverage industry.Moreover, it has been estimated that the food industry has significantly undergone an increment in their market value of over US$ 11 billion in the year 2013 and have shown impressive growth in the rate of 3.2% per annum and are thus expected reach a staggering growth to US$ 11 billion in the coming year, specifically in 2018. Due to this, there has been an ever rise in the development of this aspect of food science and the food industry, through increase in production innovation and as an outcome, an increase in investments and the market share of this industry [15].The flavor industry however, is mainly country and region specific, catering mainly to the preferred flavor requirement of the local needs of the given region and the consumer preferences of a specific place.With a large scope in the food industry, flavoring agents have been observed to be highly sensitive to the industrial processes, conditions and manufacturing methods and are therefore termed as chemically volatile compounds. Food flavorings are highly susceptible to increase in temperatures thus very heat and moisture sensitive, very reactive with other components of flavor production and during their incorporation into food products. One of the biggest concerns and problem of the food flavoring industry arise due to the high volatile and chemically reactive nature of food flavoring agents and thus, it is not an uncommon occurring that there is a high loss in food flavor by as high as 60 to 90% during both the processing and storage stage. When looking at the global market distribution of food flavoring, beverages take up the highest percentage composing of 34% of the total global market share followed by dairy, savory or convenience food and confectionary industry taking up 13%, 10% and 9% respectively. Other topics of concern regarding food flavoring in the industry is flavor retention and the current works being done on preserving food flavors so that they are available during ingestion and last for a long period of time and the alteration in manufacturing processes such as storage processes, packaging and material of choice, type and quality of ingredients and how they affect the overall flavor of the food product in terms of reducing the likelihood of decrease in flavor intensity, and avoidance of off-flavor production [16]. Being one of the most important part or constitute of a food product, the flavor in food acts as a delivery system of chemicals that enhance the consumer's perception of taste, smell and other organoleptic properties and therefore ensure in the elevation of consumer's experience [17]Out of all the applications of nanotechnology principles and methodologies, nanoencapsulation takes up a key standing in their applications in the food flavoring industry either through flavor release or flavor retention system in order to ensure adequate balance in consumer perception of a food product [18]

3.1 Nanoencapsulation in flavour

Encapsulation is a technique used to control and stabilize food flavors by covering active food flavoring agents and compounds using encapsulating agents that enables its protection from external environmental hindering conditions such as, evaporation, chemical reactions such as flavor-flavor interactions which subsequently leads to flavor cancellation or production of off flavors, preventions against light to photons such as oxidation, and the overall movement of flavoring compounds off the food matrix they are introduced in [17]. In addition, they also help in maintaining flavor retention, prevention of its loss during production and storage process and ensure a controlled release of food flavor for a long period of time as opposed to a complete concentrated release at once followed by zero flavor there after. The main purpose of nanoencapsulation of food flavoring agents and chemicals are firstly, to protect flavoring compounds from oxidation, moisture uptake, evaporation and from the harsh processing conditions such as, food processing, agitation, freeze-thaw cyclesand storage conditions [19]. Moreover, flavor nanoencapsulation is also responsible in controlling the release of flavor in terms of their impact, time-intensity profile, temperature, shear stress, pH and the degree of flavor or its concentration [19] Lastly, nanoencapsulation of flavor active agents and compounds also ensure the separation of other incompatible flavour agents and prevent them from reactions and hence from producing and adverse chemical constituents that may hinder the overall physical and chemical property of the food product in which it is being used in [19]

Chemical Techniques of Nanoencapsulation

Coacervation

Coacervation is one of the chemical technique of encapsulation which is comprised of the separation of colloid particles from a solution to form a liquid phase known as coacervate which can hold in any form of flavor compounds and other bioactive substances lest it is compatible and insoluble in the coacervation medium [16] This method is comprised of three main steps which are firstly, the formation of oil-in-water emulsion where the active compounds are dissolved and spread into the aqueous phase and the encapsulation polymers are dissolved in organic phase or liquid medium [20].This is followed by the process of deposition of the liquid polymer encapsulant coating on the core material which are the specifically chosen active flavor compounds [20]. Lastly, a stabilization and hardening process is introduced where the coating material or polymer aggregates around the flavor compounds and self-forms nanocapsules that gets accumulated into nanocapsules and are then collected through centrifugation and filtration method, washed using a suitable solvent, undergoes drying and eventually, hardening by thermal desolvation technique [20]. There are two types of coacervation techniques that is, simple and complex coacervation which either uses only one type of polymer encapsulating agent around the active flavor compound or more than one encapsulating polymerfor each of the processed respectively [20]. The encapsulation efficiency of this process can range anywhere between 40 to 90% with soy protein, pectin, gelatin and gum arabic bing the most commonly used encapsulating agent [21] Moreover, the common flavors encapsulated using coacervation techniques are lavender and vanilla oil with the end product being in powdered, paste or in capsule form [21]

Molecular Inclusion

In molecular inclusion, this encapsulation technique is done based on the interaction between chemical compounds where smaller sized active flavor molecules are fit into and surrounded by a larger encapsulating polymer [20]. Cyclodextrins, a naturally occurring cyclical hydrolysed starch derivative, are the most commonly used compounds for nanoencapsulation and are produced through enzymatic process [21] The external part of these compounds are hydrophilic in nature while the internal components are hydrophobic thus the molecules produced are polar in nature, making them highly soluble in liquid complexes [21].The main methods of molecular inclusion are as follows; firstly, cyclodextrins are dissolved in water to form an aqueous solution followed by which the flavoring compounds that are required to be encapsulated are added in to form a crystalline inclusion complex [22]The crystals obtained from this process are then separated from the excess water and other polymer compounds to obtain its pure form and then dried to get the end product of encapsulated flavor [22]. The encapsulation effectivity of this process ranges between 40 to 90%, is highly restricted to flavor compounds with low molecular weight and the common flavors encapsulated commercially are olive, bergamot, onion and black pepper essential oils obtained only in powdered form [21]

Mechanical Techniques of Nanoencapsulation

Spray Drying

Out of all the nanoencapsulation methods, spray drying is the most common one due to its relatively low cost, rapid process,widely available equipments and the efficiency of the process[23]. Moreover, it is also easy to scale up for industrial scale production with 90% of all the commercially available nanoencapsulated products, made from spray drying [23].This technique is comprised of the separation and collection producing wide variety of nanocapsules of high quality which are typically released upon the action by solvents and through the process of diffusion however, the main setback of this process is the difficulty in controlling particle size and inability to resist high temperatures[22]. Moreover, the efficiency range lie from 10 to 90% with this process having the largest choice of encapsulating materials such as modified starch and inulin, encapsulating flavor compounds such as, peach and strawberry flavors, lime, mint, rosemary, and ginger essential oils in powdered form [21]

Extrusion

Lastly, extrusion is a mechanical encapsulation technique which has the main purpose of maintaining the stability of active flavoring compounds and prevent them from getting oxidised when it comes in contact with the physical environment[24]. In this process, a liquid mixture of the encapsulating agent is initially extruded followed by which bioactive agents and active flavoring compounds are added. This leads to the formation of droplets at the discharge point of the nozzle of the equipment due to the action of gravitational, surface tension and frictional forces inside the equipment after which the droplets are immediately solidified into capsules using physical or chemical process to yield a less volatile and more stable flavor nanocapsules [24]. The encapsulation efficiency for extrusion lies within the range of 20 to upto 50% which is comparatively lesser than all the order discussed chemical and mechanical techniques using agent like alginate to encapsulate vanillin into powdered, granulated nanocapsule product [21]

3.2 Flavour nanoparticles

Two of the most commonly used nanoparticles used irrespective of their nanoencapsulated form in the flavoring food industries are, Cyclodextrins and Silica nanoparticles.

Cyclodextrins

Cyclodextrins are a family of compounds made up of sugar molecules bound collectively in a ring also termed as cyclic oligosaccharides with a standard cyclodextrin comprising ofa number of glucose monomers starting from six to eightunits in a hoop, creating a conical shaped structure distinguished as α (alpha)-cyclodextrin, a 6 sugar ring molecule, β (beta)-cyclodextrin which is a 7 sugar ring molecule and γ (gamma)-cyclodextrin, an 8 sugar ring molecule which are all are created from starch via the process of enzymatic conversion [25]. The α- and γ-cyclodextrins are more commonly usedwithin thefoodindustry as α-cyclodextrin is a soluble nutritional fiber and its applicationsconsists of their ability to stabilize unstable or volatile food flavoring compounds and for the reduction of undesirable tastes and odour in the finished food product [26]. On the other hand, β-cyclodextrin complexes with certain carotenoid food colorants wereshownto intensifycolor but alsoincrease water solubility and improvelightstability of the flavoring compounds to reduce their deterioration under various environmental factors that may either cause loss of flavor or the development of undesired off flavor in food [26]. In addition, the typical cyclodextrins are constituted by 6 to 8units, can be structurally observed to have a larger and a smaller opening on its either side of thus exposing it to the substance that is required to be encapsulated into these cyclodextrins capsules[27] Moreover, due to this arrangement the interior of the cyclodextrin structure is not hydrophobic but is considerably less hydrophilic than the aqueous environment or the food suspension they are introduced into and accordingly are thus able to host different hydrophobic molecules due to their structural properties [27]This thus protects the active flavoring agents used from being dissipated and thus lose its potency. In comparison to the internal structural property, the exterior region of cyclodextrin nanocapsulesare sufficiently hydrophilic and thus, increase their water solubility and in turn, increase the solubility of the nanoencapsulated flavors into the food they are mixed or introduced in for flavor enhancement [27]. The formation of the inclusion compounds substantially modifies the physical and chemical properties of the guest molecule such as bioactive flavoring agents and compounds, mostly in terms of water solubility thus, protecting them from external damage but also ensuring that they are homogeneously and efficiently in the product they are being used in.

Silica Nanoparticles

Silica (silicon dioxide [SiO2]), is a non-steel oxide formed through silicon and oxygen that can be divided into two essential types; crystalline and amorphous silica. Crystalline silica may additionally be present in various forms, including quartz, cristobalite and tridymite while amorphous silica can exist as mesoporous and amorphous silica and have been used in flavoring industry for their flavor encapsulation property[28]. Synthetic amorphous silica (silicon dioxide [SiO_2]) has been used for many years in meals packages, together with for clearing of beers and wines, as anti-caking agent to maintain flow properties in powder products and to thicken pastes but are most notable used for their flavor retention property due to their polarity Nanoencapsulation of these Silica particles comes into direct contact of nanomaterials with humans via oral consumption from the end food product it is used in [29] SiO_2 nanomaterials are one of the most used food nanomaterials in the flavoring industry and were studied as providers of fragrances or flavors in several food products [29]. Lipid based nanoencapsulation systems also are in constant testing and are being developed to enhance the overall performance of antioxidants via improving their solubility and bioavailability in the food products containing silica nanoencapsulated food products, and entrap bioactive compounds for efficient absorption [30] But, the protection of nanoencapsulation remains uninvestigated and calls for further risk assessment, in particular for long time exposure and toxicity [30]. The products appear mainly to be powder products like milk powder, instant soups, and specimens. Inspection of the packaging of many distinct manufacturers of such food products brought about the identity of numerous powdered sauce and seasoning mixes, immediate noodles, pancake and cake mixes, coffee creamers and vitamins[28]

3.3 Nanotechnology application for Food Flavor

Nanomaterials are known to permit better encapsulation and release efficiency of the active food components compared to standard encapsulating agents, and the improvement of nano-emulsions, liposomes, micelles, biopolymer complexes and cubosomes have caused improved properties for bioactive compounds safety, controlled delivery systems, food matrix integration, and masking undesired flavors ("Nanotechnology in Food", n.d.). With the ongoing development within the sciences of practical foods and nutraceuticals has truly established a strong correlation between consumption of bioactives and improved human health and overall performance. However, the efficacy and bioavailability of those bioactive ingredients (e.g., omega-3 oils, carotenoid antioxidants, vitamins, and probiotic bacteria) in foods which are frequently used as flavoring agents, remain a challenge due to their instability in food products and gastrointestinal tract, as well as due to their limited bioavailability in our system[31]. In some instances, these bioactive ingredients can also impart an unwanted organoleptic outcomes into the final food product in terms of off taste, unwanted odour which are both an indicator of good food flavor and therefore hinder the acceptability and consumer preference for the final product [31].Molecular gastronomy is a newvicinityin whichchefs collaborate with food scientists to make this kind ofexperiencepossible. Salvona technology has created nanoencapsulated flavors (like gel caps) that adhere to the mouth, prolonging the taste sensation [32]. In addressing those challenges, improvement of effective flavor retention and transport systems are important in order to meet the consumer demands for effective bioactives compounds which such flavoring agents and compounds which has been made particularly possible and effective in terms of current applications in the food industry largely and mainly due to the advancements in nanotechnology and specifically nanoencapsulation techniques.

Some of the most prevalent example of such application that has been in use in the current food industries are, as nanoencapsulation of fish oil, salt nanoparticles, innumerable flavor encapsulation for various kinds of commercial foods products like beverages, as modified food starch that are mainly used as flavor emulsions to add into products in order to maintain food flavors from thickening agents and to protect the overall viscosity of a final product and many more.

One most commonly prevalent use of nanotechnology in terms of masking undesired flavor in a food product is through nanoencapsulation of fish oil. Omega-3 fatty acids derived from few kinds of fish have a highly undesirable aroma but are a commonly used nutritional supplement for its wide array of health benefits. However due to their undesired flavor and odour, scientists have developed firm coating comprising of gelatin or gum arabic which are hydrolysed into firm collagen, to encapsulate and trap the flavor and form a film coating that prevents these compounds from reacting to atmospheric oxygen and thus prevents the overall release of small [33] The nanocapsules have no taste and odour upon consumption and when released into the stomach cavity, break open to release active compounds providing health benefits without the consumer having to experience any undesired flavour and odour [33].

Scientists have also found that bycreating nanoparticles that fasten onto flavor receptors inside the tongue, they couldmanipulate how we enjoyeach flavors viaconverting the chemical bonds that preserve molecules and atoms together, tiny building blocks can be assembled in ways that can make salt saltier, chocolatessweeter or in general, increase the flavor concentration or intensity in a food product[32]. The main underlying mechanism is that salt grinded into nanoparticles have greater surface area which as a result, leads to its increased absorption and distribution into the food it is added into which in turn, reduces the amount of salt required in food [34].In addition, the reduced salt consumption can decrease the adverse health effects by minimising flavor alteration in foods that require large amount of salt for preservation [34]

3.4 Current concerns of nanotechnology in food

With studies on the application of nanotechnology in the food industry still being at its early stages, there have been innumerable concerns brought up from regular individuals who are uninformed or with no background knowledge in the field in general, and consumers in terms of their overall safety and any possible acute or chronic adverse health outcome from its consumption. Even for various scientist who do possess adequate knowledge, with the researches and applications being in its developmental stage, we ourselves are also uninformed of the possible long term outcomes from their use and such liberal application in our food products at an intensively high levels. Some studies have shown the effects from the in vivo oral toxicity studies suggest that, after oral exposure, nanosilica turns into bioavailable to some degree and can exert toxicity on the liver and how the silica is absorbed and if these effects are caused by nanosilica debris, dissolved silica or a combination of those two [15].Another study also talks about the increase in ALT and fatty liver patterns can be due to activated macrophages, however can also be caused by another mode of action. Moreover, macrophages can be activated by nanoparticles present in the food systems, but also with the aid of dissolved chemical substances [28]. However, it is of our utmost priority to take every novel innovations regarding nanotechnology with sufficient belief and skepticism and maintain an open mind on to their possible effects both in terms of being beneficial and harmful for humans, other living organisms and the environment.

To combat such cases, we are primarily responsible for providing correct and complete knowledge about the concept, underlying processes and their outcome in terms of application in our everyday life, which is easy to understand by regular individuals irrespective of their literacy level so that the ever rising skepticism over novel scientific discoveries are not always looked at in negative light.

CONCLUSION

Currently, the use of nanotechnologies is no longer limited to the structuring of food constituents at the nanoscale but it is expected to bring a range of benefits to the whole food chain such as development of new tastes and textures to reduced use of fats and enhanced absorption of nutrients. From the previous studies, we can conclude that there is increasing application of Nanosystems such as Nanoemulsions, Nanoencapsulation and the use of nanoparticles like starch,silicon dioxide in food to improve the texture of food by using various techniques. As for the flavour aspect of nanotechnology in food industries, it is widely evident that nanoencapsulation techniques are the most prevalent out of all the methodologies composed of either chemical or mechanical nanoencapsulation technique such as, coacervation and molecular inclusion, and spray drying and extrusion processes for each of the categories classified under nanoencapsulation techniques. Application of nanotechnology has been constantly under studies with their current applications in the food flavoring industries in terms of, flavor enhancement, introduction of new flavor in food and beverages, masking undesired flavors and most importantly, to protect volatile and highly reactive flavor compounds from environmental deterioration and oxidation, thus preserving flavor compounds in food products for long periods of time. Nanotechnology-derived food products are set to grow worldwide and a variety of food ingredients, additives, carriers for nutrients/supplements are already available in some countries. Although the exciting possibilities offered by the nanotechnologies in the food sector have been in principle demonstrated, the acceptance by consumers remains rather low. This reaction could be due to the risk perception related in general to nanotech applications, but as expected, notably surrounding the food field.

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