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Review Article

Nanotechnology and Nutraceuticals

Abstract

This paper provides an insight of some of the growing number of nano-applications being researched and commercialized in nutraceuticals. Recently, number of applications in dairy and food processing, preservation, packaging and development of functional foods have become based on nanotechnology. Several critical challenges, including discovering of beneficial compounds, establishing optimal intake levels, developing adequate food delivering matrix and product formulation including the safety of the products need to be addressed. In addition the potential negative effects of nanotechnology-based delivery systems on human health need to be considered.

Introduction

Nanotechnology involves the characterization, fabrication and or manipulation of structures; devices or materials that have at least one dimension (or contain components with at least one dimension) that is approximately 1–100 nm in length [1]. Cell membranes, hormones, DNA etc. are examples of naturally occurring Nano structures, the same as food molecules, proteins, fats, carbohydrates etc. [1]. Helmut Kaiser Consultancy (2009) estimates an increasing growth in the development of food and dairy related Nano products and patent applications [2].

Nanotechnology applications include a range of Nano-scale materials added to foods and Nano-encapsulation techniques as delivery systems for other food components [3]. Nanoparticle-sized ingredients may increase the functionality or bioavailability of ingredients and nutrients, and thereby minimize the concentrations needed in the food product [4]. Food companies are currently producing nanoparticles in emulsions in an attempt to control the material properties of foodstuffs, such as in the manufacture of ice cream to increase texture uniformity [5].

Functional foods and nutraceuticals

Functional foods & nutraceuticals can be categorized as following type:

Nutraceuticals: Nutraceuticals are often defined synonymously with functional foods in the media and literature. In fact, the term nutraceutical, is a portmanteau of the words “nutrition” and “pharmaceutical”, and was coined by Stephen DeFelice, M.D., founder of the Foundation for Innovation in Medicine in Cranford, N.J. It covers a gamut of products that range from isolated nutrients, dietary supplements, fortified foods, functional foods and medical foods. Thus, nutraceuticals are more correctly defined as parts of a food or a whole food that have a medical or health benefit, including the prevention and treatment of disease. Historically, the United States Food Drug and Administration (USFDA) have defined any specific foods used for the prevention or treatment of disease as drugs.

Dietary supplements: Dietary supplements are defined as any product (other than tobacco) that is intended to supplement the

diet and contains one or more of the following: a vitamin, mineral, herb or other botanical; an amino acid or metabolite; an extract; or any combination of the previously mentioned items. According to USFDA regulations, a dietary supplement may be marketed in food form if it is not “represented” as a conventional food and is clearly labelled as a dietary supplement. Specific health or structure/function claims are allowed on dietary supplements provided the USFDA deems adequate scientific substantiation exists for the claim.

Fortified foods: Fortified foods are enriched with vitamins and minerals, usually at a range up to 100 percent of the Dietary Reference Intake (DRI, formally called the Recommended Daily Allowance or RDA) for that nutrient. Often, these foods are mandated by law to be fortified to a level that replaces nutrients lost during processing, as in adding B vitamins to many baked goods. Breakfast cereals is a food category that has been fortified since the 1940s.

Functional foods: Functional foods are any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains. This is a tricky definition because the term “traditional nutrients” refers only to vitamins and minerals. The reason is that these are considered essential to the diet and/or correct a classical nutrient deficiency disease; for instance, vitamin C corrects scurvy. Hence, the vitamin D content in sardines, which alleviates rickets, is not an example of a functional food, while soy, which contains soy protein associated with a reduction in cardiovascular disease, is one because soy protein is not considered to be essential. Other functional foods include red grapes and cranberry juice (for the oligomeric proanthocyanidins, OPCs) and oat bran (for the fiber content), all with health benefits attributed to “non-nutrient” compounds as classified by standard agreement of the term. So-called “super-fortified” foods--those fortified with more than 100 percent of the DRI and/or foods that have added botanicals or other supplements—also fall into the category of functional foods. Two examples of the latter are orange juice with echinacea (*Echinacea angustifolia* or *E. purpurea*) and salad dressing with omega-3 polyunsaturated fatty acids (PUFAs). Functional foods may carry health or structure/function claims provided adequate scientific evidence supports the claim.

Medical foods: Medical foods refer to a food formulated to be consumed or administered internally while under the supervision

of a physician. The food product is intended for the specific dietary management of a disease or condition for which distinctive nutritional requirements are established by medical evaluation. Medical foods may be used to treat diabetes, obesity or heart disease, for example, and may carry specific claims, but in a strict sense are sold through physicians and not through conventional retail outlets.

Application of nano technologie in food

The concept of “nanoceticals” is gaining popularity and commercial dairy/food and food supplements containing nanoparticles are available [6,7].

The examples of food-related Nano products are:

- Carotenoids nanoparticles can be dispersed in water, and can be added to fruit drinks for improved bioavailability;
- Canola oil based Nano sized micellar system is claimed to provide delivery of materials such as vitamins, minerals, or phytochemicals;
- Patented “Nano drop” delivery systems is in the form of encapsulated materials, such as vitamins. It is administered transmucosally, rather than through conventional delivery systems such as pills, liquids, or capsules; and
- Chinese Nano tea (Nano-based mineral supplements) claimed to improve selenium uptake.
- A wide range of nanocetical products containing Nano cages or Nano clusters that act as delivery vehicles, e.g., a chocolate drink claimed to be sufficiently sweet without added sugar or sweeteners;
- Nano silver or Nano gold are available as mineral supplements.
- carriers including lycopene, beta-carotenes and phyosterols claimed to prevent the accumulation of cholesterol
- A synthetic lycopene has been affirmed GRAS (“generally recognized as safe”) under US FDA procedures

Current applications of nanotechnology in foods and food contact materials

Some of the benefits of Nano science have already been seen in the agro food sector, others are still at the research and concept stage. They include the following global applications:

- 1) Sensory improvements (flavor/colour enhancement, texture modification).
- 2) Increased absorption and targeted delivery of nutrients and bioactive compounds.
- 3) Stabilization of active ingredients such as nutraceuticals in food matrices.
- 4) Packaging and product innovation to extend shelf-life.
- 5) Sensors to improve food safety.
- 6) Antimicrobials to kill pathogenic bacteria in food.

Nanotechnology in food and dairy processing

The application of nanotechnology with respect to food and dairy industry will be covered under two major heads viz. food additives (Nano inside) and food and dairy packaging (Nano outside). Food additives (Nano Inside) covers Nano dispersions, Nano capsules and functional ingredients (for example, drugs, vitamins, antimicrobials, antioxidants, flavorings, colorants, and preservatives etc.) and comes in different molecular and physical forms such as polarities (polar, nonpolar, amphiphilic), molecular weights (low to high), and physical states (solid, liquid, gas). These ingredients are rarely utilized directly in their pure form; instead, they are often incorporated into some form of delivery system. Weiss et al. (2006), examined that a delivery system must perform a number of different roles [4]. First, it serves as a vehicle for carrying the functional ingredient to the desired site of action. Second, it may have to protect the functional ingredient from chemical or biological degradation (for example, oxidation) during processing, storage, and utilization; this maintains the functional ingredient in its active state. Third, it may control the release of the functional ingredient, such as the release rate or the specific environmental conditions that trigger release (for example, pH, ionic strength, or temperature). Fourth, the delivery system has to be compatible with the other components in the system, as well as being compatible with the physicochemical and qualitative attributes (appearance, texture, taste, and shelf-life) of the final product.

Nano-processed foods

Nanotechnology is also being applied to processed foods and drinks, and a number of foods containing nanoparticles and Nano capsules are currently available for purchase, though without being required to indicate the presence of these Nano-materials on their packaging. However the rule is different for different regulatory agencies. These Nano-processed foods have entered the food supply largely in the absence of public awareness, Nano-specific labelling requirements, or Nano-specific food safety regulations. Most major food companies, including HJ Heinz, Nestle, Hershey Foods and Unilever, have invested heavily in nanotech research and development in these areas. Kraft’s global ‘Nanotech Research Consortium’ of 15 universities and national research laboratories, for example, reflects a corporate strategy to lead developments for a Nano food future [8].

As Peerak Sanguansri and Mary Ann Augustin describe this shift in scale in food science and technology research; “The next wave of food innovation will...require a shift of focus from macroscopic properties to those on the meso- and Nano-scales, as these subsequently control the hierarchical structures in food and food functionality” [9]. A range of Nano techniques and materials are being developed in an attempt to assert greater control over food character traits, and to enhance processing functionalities, such as flavor, texture, speed of processing, heat tolerance, shelf life, and the bioavailability of nutrients [10]. As with all food processing research and development, one of the aims is to achieve these ends in a cost effective way, and to continue producing cheap convenience foods with consumer appeal. But a major growth area has also been in the development of so-called ‘functional foods’ are nutritionally engineered foods that are marketed with nutrient or health claims [11] and nanotechnology provides a range of approaches to the cost effective production of

foods with modified nutrient profiles and novel traits.

Food 'fortification' through nanotechnology

Nanotech companies are trying to fortify processed dairy and food products with nanoencapsulated nutrients, their appearance and taste boosted by Nano-developed colours, their fat and sugar content removed or disabled by Nano-modification, and 'mouth feel' improved. Food 'fortification' will be used to increase the nutritional claims for example the inclusion of 'medically beneficial' nano-capsules will soon enable chocolate chip cookies or hot chips to be marketed as health promoting or artery cleansing. Nanotechnology will also enable junk foods like ice cream and chocolate to be modified to reduce the amount of fats and sugars that the body can absorb. This is possible by using nanoparticles to prevent the body from digesting or absorbing these components of the food. In this way, the Nano industry could market vitamin and fiber-fortified, fat and sugar-blocked junk food as health promoting and weight reducing [12].

Applications of nanotechnology in food packaging

Silver has a long history of being used as an antimicrobial agent in food and beverage storage applications. Numerous ancient societies stored wine and water in silver vessels. Web searches on the historic uses of silver reveal anecdotal reports of early settlers placing silver dollars or silver spoons at the bottom of milk and water bottles to prolong shelf life, and of seafaring ships or airliners lining their water tanks with silver to keep water potable for long periods of time. Silver was the sterilization agent for water on the Russian MIR space station and on NASA space shuttles, and silver's broad-spectrum antimicrobial activity and relative low cost have made it a candidate as the active disinfecting agent for water in developing countries. In 2009, the FDA modified the food additive regulations to permit the direct addition of silver nitrate as a disinfectant to commercially bottled water at concentrations not to exceed 17 lg/kg.

Measurement of nanoparticles in food and other biological matrices

These techniques may be applied to carry out measurements of nanoparticles in the pure form, the measurement and quantitation of nanoparticles in food, biological tissues and other biological matrices presents considerable challenges, since suitable equipment and measurement strategies are not yet available. Many food products also contain considerable amounts of naturally occurring nanoparticles, such as proteins, silica or traces of titanium dioxide, which makes detection of added nanoparticles difficult, as it rules out techniques such as elemental mapping where there are already significant background levels. Techniques such as elemental mapping can only be applied to nanoparticles such as gold and silver, which are not naturally present in foods or food packaging materials. Measurement of particle mass of nanoparticles in the pristine form (as synthesized), is relatively straightforward, while measurement of the surface area of a given mass of nanoparticles is more difficult, as many of the current techniques do not distinguish fully between porosity and surface area, e.g. nitrogen adsorption. An additional complication is, as already discussed, the very ready aggregation of nanoparticles that occurs in biological media, resulting in larger particles, or even a gradual increase with size as a function of time. Such aggregation makes it

almost impossible to measure either particle number or surface area in biological matrices.

Regulations of nanotechnology and nanoproducts

Many nanotechnology initiatives, commissions, or centers have been launched by governments, academia, private sectors in the United States, Europe, Japan, and some other countries around the globe to ensure rapid development and deployment of nanotechnology, promote economic growth, maintain global competitiveness, and improve the innovative capability [13,14]. Some of them have also participated in proposing regulation to improve the protection of human health and the environment.

These organizations or research centers mainly supported by the government sources play an essential role in performing or supporting nanotechnology researches, including the basic researches on nanotechnology, the applications of nanotechnology, safety assessment of nanomaterial, and the development of regulatory control. They also provide long-term coherence and platforms for interdisciplinary people or experts to promote nanotechnology to the public as well as to give an impetus to the nanotechnology industry.

Regulatory development in nanotechnology among the nanotechnology-based consumer products, companies based in the USA have the most products, followed by companies in Asia, Europe, and elsewhere around the world. In some Asian markets, some products may use the term "nanotechnology" and its "small size" concept to promote their products by claiming that the tiny ingredients could be absorbed easily with novel functions, whereas most of the products failed to prove their claims on size and functions with robust scientific data. In some countries (i.e. the USA), some existing laws such as notably the Toxic Substances Control Act; the Occupational Safety and Health Act; the Food, Drug and Cosmetic Act, and the major environmental laws may at least provide some legal basis for regulating nanotechnology.

Codex Alimentarius Commission, an intergovernmental agency established jointly by FAO and WHO, is promoting coordination of all food standards work undertaken by international governmental and non-governmental organizations. In order to prevent regulatory gap, Codex Alimentarius Commission, participating in the development of international food safety regulation, should take into account the use of nanoparticles and other Nano scale technologies in food and agriculture. Up to now, there is no international regulation of nanotechnology or Nano products. Only a few government agencies or organizations from different countries have established standard and regulation to define and regulate the use of nanotechnology.

A number of expert bodies have already issued opinions on issues related to applications of nanotechnology and its safety, including the European Commission's Scientific Committee on Emerging and Newly Identified Health Risks, the EU Scientific Committee on Consumer Products, the US Food and Drug Administration, the UK Committees on Toxicity, Mutagenicity and Carcinogenicity of Chemicals in Food, Consumer Products and the Environment, the UK Royal Society and Royal Academy of Engineering (Royal Society and Royal Academy of Engineering, the German Federal

Institute for Risk Assessment, the Dutch Institute of Food Safety, Wageningen UR (RIKILT) and National Institute of Public Health and the Environment; Center for substances and integrated risk assessment (RIVM) and the US National Institute of Occupational Health (NIOSH).

Conclusion

Only a small number of Nano products have actually been commercialized, mainly in countries outside the EU, the US being the leader in innovation in this field, followed by Japan and China. A recent report identified a wide range of applications in food and food technology, and suggested that the value of the worldwide nanotechnology food market may total \$20.4 billion (19.4 billion) by 2010 and \$1 trillion (740bn) by 2013. The principal areas in the food sector where nanotechnology has potential for use are in encapsulation and emulsion formation, in food contact materials and sensor development, and some applications of the technology are close to utilization.

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