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Application of nanotechnology in bioengineering industry and its potential hazards to human health and the environment

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Abstract
Nanotechnology is regarded as one of the most transformative technology of 21st century, which has potential to upgrade scientific innovation while tremendously giving advantage to the society. Bioengineering is the application of the life sciences, physical sciences, mathematics and engineering principles to define and solve problems in biology, medicine, health care and other fields. Bioengineering is a relatively new discipline that combines many aspects of traditional engineering fields such as chemical, electrical and mechanical engineering. Examples of bioengineering includes, artificial hips, knees and other joints ultrasound, MRI and other medical imaging techniques, using engineered organisms for chemical, food and pharmaceutical manufacturing industry. The applications of nanotechnology in bioengineering sector are safety (e.g., detection of pathogens in food), food security (e.g., intelligent, active, and smart packaging systems), food processing (e.g., encapsulation of flavor or odor enhancer; food textural or quality improvement; new gelation or viscofying agents). Nano-enabled materials (NEMs) are manufactured with dimension of less than 100 nm. The use of these nano-enabled materials (NEMs) in food contact substances is considered to improve functionality of food product. Nano-enabled materials (NEMs) are desirable for food packaging application due to increased surface reactivity and dispersibility. However, various studies shows that various nano-particles like nanocellulose, nanosilver etc. migrating out of packaging material at low levels and can cause health risks to consumers. Hence, it is necessary to research in this area to adequately characterize potential human hazards and risk associated with nanotechnology to human exposure, despite is immerse benefits to human health.

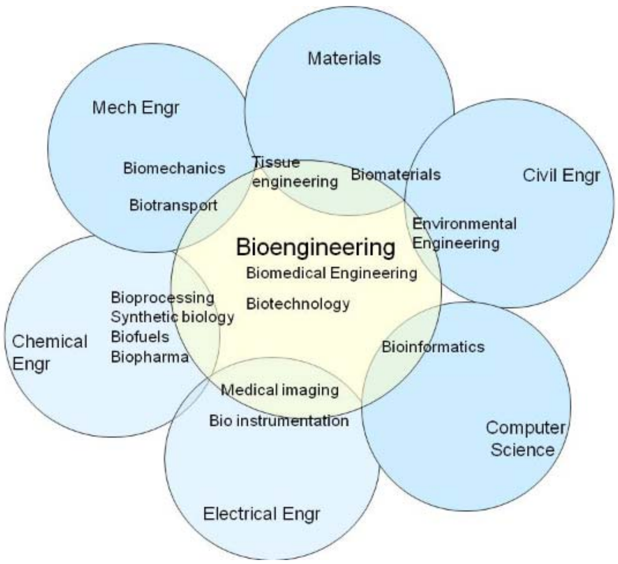
Keywords: Bioengineering, nano-enabled, therapeutic., risks, and health

Introduction

Nanotechnology can be utilise in all stages of bioengineering industry and especially in the food cycles- from farm to fork (Weiss 2004) [62]. The application of nanotechnology in Bioengineering is an area which opens up huge possibilities for the Bioengineering industry (Sekhon, 2010) [53]. Nanotechnology pertain the delineation, fabrication and/or manipulation of structures, devices or materials which have at least 1-100 nm in length (Duncan, 2011) [24]. Bioengineering is a relatively new discipline that combines many aspects of traditional engineering fields such as chemical, electrical and mechanical engineering. Examples of bioengineering includes, artificial hips, knees and other joints ultrasound, MRI and other medical imaging techniques, using engineered organisms for chemical, food and pharmaceutical manufacturing industry (University of Toledo, 2014). The applications of nanotechnology in bioengineering sector are Biomedical Nanotechnology and safety (e.g., detection of pathogens in food), food security (e.g., intelligent, active, and smart packaging systems), food processing (e.g., encapsulation of flavor or odor enhancer; food textural or quality improvement; new gelation or viscofying agents) Swiss, 2004; Kuzma and Verhage 2006; Morrison 2006; Knauer and Bucheli 2009; Boom, 2011; Manimegalai, *et al*. 2011; Neethirajan and Jayas 2011; Senturk, *et al*. 2013 Joseph Coles and Frewer 2013; Raliya, *et al*, 2013; ; Lopes *et al.*, 2013; Chen *et al*., 2014; (Sekhon, 2014; Bernardes, *et al.*, 2014) [57, 34, 30, 33, 8. 37, 45, 54, 18, 50, 36, 15, 53, 6]. Nano-enabled materials (NEMs) are used medical devices for improvement of health care and in the improvement and functionality of food product. Nano-enabled materials (NEMs) are desirable food packaging application due to increased surface reactivity and dispersibility. However, various studies shows that various nano particles like nanocellulose, nanosilver, nanoclays etc. migrating out of packaging material at low levels and can cause health risks to consumers.

Eco-toxicology is multidisciplinary field that combine toxicology and ecology (Joel, 2015) [29]. There is a need to play special attention to nano-eco-toxicology and guidelines and regulatory documents related to the use of nano-enabled materials bioengineering such as biomedical devices, biotechnology, agriculture and food industry. In spite of a big-bang of growth in this area, food nanotechnology is still a less-knowledge subfield of the vast nanotechnology wave, even between professionals (Duncan, 2011) [24]. This research will a provide comprehensive knowledge and developments in nanotechnology as it applies to the bioengineering sector and its safety use.

The diagram below shows the various areas and course affiliated to bioengineering.



Biomedical applications in nanotechnology

1. Nanostructured materials for biological sensing

characterizing of the entire genomes and proteomes of humans and other organisms have given a flood of new protein and nucleic acid targets on the biomedical research community, and have made the development of new ways of detecting and quantitating these targets rapidly and simply an urgent need, and using nanostructured materials as substrates for the production of new biomedical sensors, which have prove useful as components of medical diagnostic systems.

2. Nanoparticle-based drug delivery

Delivery of therapeutic agents to target sites in the body by the use of polymer nanoparticles are proving to be one useful method for encapsulating therapeutics and delivering in an effective manner. The creation of new polymer nanomaterials, and examining their ability to deliver small-molecule or biopolymeric agents. (Benoit, 2006) [5].

3. Imaging, transport, and toxicity properties of semiconductor nano crystals

The uses of Semiconductor nanocrystals, or quantum dots, are proving to be very useful as new reagents for biomedical imaging. Nanocrystals are also finding their way into numerous consumer products.

4. Nanobiomechanics

In recent years, through efforts in single molecule force spectroscopy, the role of mechanics at the molecular and cellular level have been shown to play a critical role in biology. Researchers employ the atomic force microscope, optical tweezers, magnetic tweezers, bioforce probe and micro cantilevers to study the mechanics which serve to influence life at the sub-cellular level University of Toledo 2014).

Prospective food applications of nanotechnology

Functionalized nano-enabled materials are finding their uses in different sectors of the food industry, comprising unprecedented packaging materials with improved barrier properties, novel nanosensors, and competent and targeted nutrient transportation system (Augustin and Sanguansri, 2009) [3]. There is necessity to understand interplay with the food matrix and as well as with biological compartment of nano-enabled materials of different types and shapes that are used in food industry (Ranjan, *et al*. 2014) [51]. Bio-separation of proteins, intelligent delivery of nutrients, encapsulation of food additives, rapid sampling of biological and chemical contaminants and nano-encapsulation of nutraceuticals are few more rising areas of application of nanotechnology in food industry (Neethirajan and Jayas 2011, Lopes, *et al*. 2013, Momin, *et al*. 2013, Sastry, *et al*. 2013) [45, 36, 42, 32]. Studies show that to trace carcinogenic pathogens and biosensors for better and contamination free food, there is increasing uses of techniques and tools developed by transformative nanotechnology (Shrivastava and Dash 2009) [55].

Enrichment of food with nutraceuticals is an important goal, and as a vital macronutrient in food, proteins have extraordinary functional properties comprising their ability to form emulsions and gels, which make them to be ideal material for the encapsulation of bioactive compounds (Chen and Yada 2011) [16]. For efficient nutraceuticals nanocarriers, food proteins plays an important role because of their extraordinary qualities, like- biodegradability, non-antigenicity, high nutritional value, abundant renewable sources and excellent binding capacity to various nutraceuticals.

Food safety is ensured by modern and improved product traceability by discarding all the stale products from the market during the recall process. (Chen and Yada 2011) [16] delineated that tracing devices based on nanotechnology can reintegrate multiple serviceable devices that give important information like sensors for detection of spoilage causing micro-organisms, allergens, detection of pathogens and other contaminants in food. Nano-enabled materials are in demand due to their antimicrobial properties. Studies show that nanosilver can destroy 650 pathogens in food, whereas most antimicrobial substances kills only 5-6 such harmful pathogens when used in food packaging.

Nano-enabled materials like carbon nanotubes can be used in food packaging to extend its mechanical properties. Recent studies show that carbon nanotubes have excellent antimicrobial effects and *Escherichia coli* bacteria destroyed on quick contact with aggregates of carbon nanotubes (). Even *Escherichia coli* puncture by thin long nanotubes and cause cellular damage (Kang, *et al*. 2007) [31].

Nano-enabled materials enhance material functionalities such as extended durability, flame resistance, temperature, flexibility, barrier properties, optical and recycling properties (Chaudhry, *et al*. 2008; Buzea, *et al*. 2007; Cushen, *et al*. 2012) [14, 13, 19]. Improved barrier properties are achieved by incorporating nano-enabled particles in a polymer matrix, which slows down the diffusion of gas into the food (Cushen, M *et al*. 2012; Peelman, N *et al*. 2013) [19, 49]. Nano-enabled materials are used to make intelligent packaging, which can indicate the user to the presence of microbes, chemical contaminants, fungi or gases indicating spoilage or taint. The packaging sector is influenced by nanotechnology as it has the great potential to delaying oxidation and control over moisture migration, respiration rates, growth of microbes and volatile flavor and aromas (Ottaway, 2009) [48].

Potential harmful medical effects of nanoparticles

1. The ability of nanoparticles to have molecules sticking to their surface depends on the surface characteristics of the particles and can be relevant for drug delivery uses. Indeed, it is possible to deliver a drug directly to a specific cell in the body by designing the surface of a nanoparticle so that it adsorbs specifically onto the surface of the target cell, but the interaction with living systems is also affected by the dimensions of the nanoparticles. For instance, nanoparticles no bigger than a few nanometres may reach well inside the biomolecules, which is not possible for larger nanoparticles. Nanoparticles may cross cell membranes. It has been reported that inhaled nanoparticles can reach the blood and may reach other target sites such as the liver, heart or blood cells. Key factors in the interaction with living structures include nanoparticle dose, the ability of nanoparticles to spread within the body, as well as their solubility. Some nanoparticles dissolve easily and their effects on living organisms are the same as the effects of the chemical they are made of. However, other nanoparticles do not degrade or dissolve readily. Instead, they may accumulate in biological systems and persist for a long time, which makes such nanoparticles of particular concern.
2. Inhaled particulate matter can be deposited throughout the human respiratory tract, and an important fraction of inhaled nanoparticles deposit in the lungs. Nanoparticles can potentially move from the lungs to other organs such as the brain, the liver, the spleen and possibly the foetus in pregnant women. Data on these pathways is extremely limited but the actual number of particles that move from one organ to another can be considerable, depending on exposure time. Even within the nanoscale, size is important and small nanoparticles have been shown to be more able to reach secondary organs than larger ones. Another potential route of inhaled nanoparticles within the body is the olfactory nerve; nanoparticles may cross the mucous membrane inside the nose and then reach the brain through the olfactory nerve. Out of three human studies, only one showed a passage of inhaled nanoparticles into the bloodstream. Materials which by themselves are not very harmful could be toxic if they are inhaled in the form of nanoparticles. The effects of inhaled nanoparticles in the body may include lung inflammation and heart problems. Studies in humans show that breathing in diesel soot causes a general inflammatory response and alters the system that regulates the involuntary functions in the cardiovascular system, such as control of heart rate. (Morris and Chapman, 2001–2016).

Assesing the Risks: Nano-Eco-Toxicology, Health Risks and Regulations

Nano-Eco-Toxicology

Combination of toxicology and ecology gives a multidisciplinary field known as ecotoxicology; it is the study of the effect of toxic compounds on biological organisms, especially at the population, community and ecosystem level (Butler, 1978) [12]. Studies show that nano-particles which are able to retain their particle size, properties and reactivity after penetration in environment can posse's poisonous effects on target as well as non target organisms, since material being harmless in majority form often become poisonous when they attain nanosize (Dolez, 2015; Hussain, *et al*. 2005; Borm, *et al*. 2006; Fröhlich and Curr 2013; Unsworth, *et al*. 2015) [22, 27, 9, 25, 59]. Toxicity of nano-enabled materials can be determine by following determinants such as, size, aggregation, chemical composition, surface functionalization, crystallinity, and change in particle characteristics with time and water chemistry (Buzea, *et al*. 2007; Marambio-Jones *et al*. 2010) [13, 38]. Special attention should be given to non-biodegradable substances because of risks of accumulation and durability in soil, plants and mammals, which may afterwards result in several morbid processes (Vaculíková, *et al*. 2015; Jong and Borm 2008; Handy *et al*. 2008; Barcelo and Farré 2012; Brenner S 2014; Vaculíková, *et al*. 2014) [61, 21, 4, 26, 10, 60]. Paracelsus known as the father of modern toxicology is attributed with the statement that "all things are poison and not without poison; only the dose makes a thing not a poison" (Andrew, 2006) [2]. Now a days when we are dealing with new emerging technologies this statement express the need to understand how and how much a substance is harmful to the body, if risk is to be understood and managed (Andrew, 2006) [2].

Health Risks

While there is noteworthy involvement of nanotechnology in the food sector regarding benefits and while quantitative risk analysis consider many factors, the potential risks to human health and the environment have yet to be resolved**.** There are three ways of exposure have primary involvement for NEMs-inhalation, ingestion and dermal penetration (Oberdörster, *et al*. 2005) [46, 47].

Ingestion exposure is the most significant source with regards to food contact materials (Cushen, *et al*. 2012) [19]. The health risks raise by NEMs for FCMs is rectifying by NEMs toxicity, migration rate and consumption rate of particular food (Cushen, *et al*. 2012) [19]. Studies show that migration shoots up with duration of storage and content of the nanomaterial in FCM (Cushen, *et al*. 2013; Song, *et al*. 2011) [20, 56].

Exposure by dermal penetration is important issue when handling NEMs (Lipka, J *et al*. 2010) [35]. Moreover, NEMs when come in contact with skin posse's potential risks to health subject to their ability to penetrate through the outer protective layers and reach the epidermis and the resultant impact they may have on body.

Exposure through inhalation of airborne material have significant impact (Maynard *et al*. 2005) [39, 41] with aerosol exposure the evaluation or determination of health risks generally based on assumption that toxicity is interrelate with the mass and chemical composition of inhaled material. It has been reported that considerable reductions in respiratory disease with reduced exposures (Maynard *et al*. 2004) [40].

A number of review articles communicate possible mechanisms of interaction however still there is a need to mechanistic understanding of NEMs behavior in the body and ill health (Oberdörster, *et al*. 2005; Maynard and Kuempel 2005; Donaldson, *et al*. 2000) [46, 47, 39, 23].

Regulations

Recent research exhibits the some NEMs can act as differently in the body in comparison to conventional materials, and can cause health risks that are not entrapped within established risk assessment paradigms (Andrew, 2006) [2]. There is very less published research on the importance of characteristics unique to nanoscale (as opposed to properties that scale with size), and most risk based research appears to be focused on first generation nano-enabled materials, despite the concurrent development of second and third generation technologies (Roco and AIChE 2004) [52].

Despite current risk-based uncertainty and the complexity of overseeing the emergence of 'safe' nanotechnologies, one certainty is the need for further research and better data. A recent analysis of current environment, safety and health impact research indicated that there is a significant amount of preemptive work addressing potential risks of nanomaterials (Maynard, 2005) [39, 41]. However the same analysis concluded that there is a lack of overall strategy in the current research portfolio, and that without a clear strategic framework, greater resources, and increased partnerships and collaboration, critical questions are unlikely to be answered in a timely manner (Andrew, 2006) [2].

Conclusion

The use of nanotechnology in bioengineering industry has the vast potential to improve the quality of human health, by making them, healthier and providing efficient and quality medical products and good nutritious food, However,. Nanotechnology can be used to improve nutritional value of food products, enhance their flavor, taste, aroma, texture, also used to reduce calorie by reducing fat content of food products, to encapsulate nutrients, such as vitamins, to ensure they do not vanish during a product shelf life. They are also use in medical devices and in the pharmaceutical industrial. There is significant proof of potential risks of nanomaterials and this call for careful uses of nanomaterials in its applications to produce various products for human use.

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