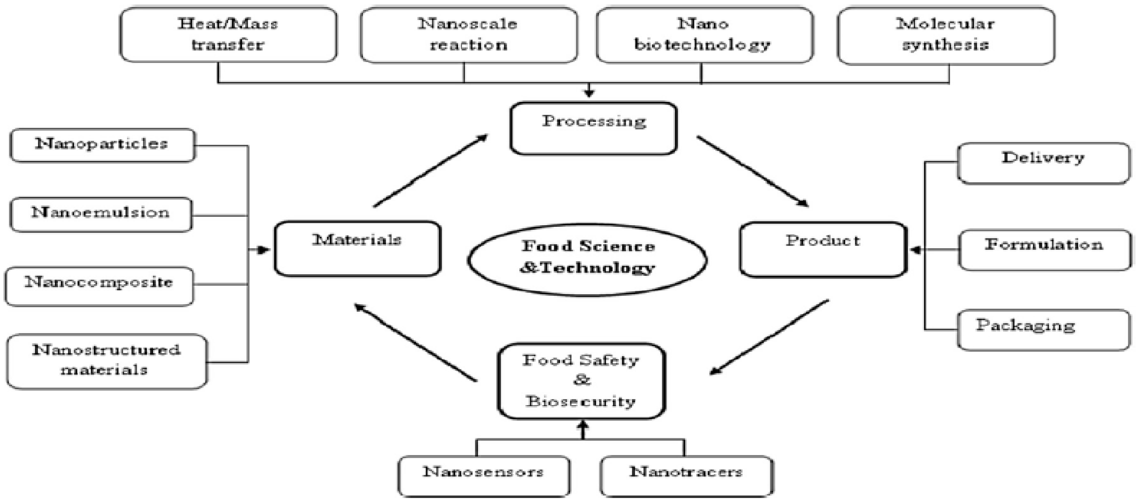
**Nanotechnology in Food Industry**

Nanotechnology offers much promise to food science. Food nanotechnology includes a range of potential applications, including alterations to the properties of foods (e.g., nano additives and nano-ingredients), improvements to the delivery, quality, and safety of food; and the development of enhanced food packaging (i.e., food contact materials). For example, scientists are creating food packages that contain nano-sized particles devised to warn consumers that a food product is unsafe to eat, and are inventing nanoencapsulated materials that can distribute nutrients to human cells. The food industry has been researching how nanoscience can be used to improve food since 1999, and there are signs that the research and development of food nanotechnologies is likely to grow quickly in the coming years. Nanotechnology is expected to influence numerous areas of food science in ways that will benefit both the food industry and consumers. For example, nanotechnology is being used to improve the quality and safety of food. Nano sensors are being developed that can detect and signal the presence of spoilage microorganisms, and potentially even differentiate the presence of pathogenic from benign microorganisms. Nanotechnology is also being used to create healthier foods that can deliver nutrients and medications to different parts of the human body and can alleviate allergenic.

Nanotechnologies involve the manipulation of matter at a very small scale generally between 1 and 100 nanometres. They exploit novel properties and functions that occur in matter at this scale. Nanomaterials and nanoparticles may include any of the following nano forms: nanoparticles, nanotubes, fullerenes, nanofibres, nanowhiskers, nanosheets. A *nanoparticle* is defined as a discrete entity that has three dimensions of the order of 100 nm or less. A *nanomaterial* is defined as an “insoluble or biopersistent and intentionally manufactured material with one or more external dimensions, or an internal structure, on the scale from 1 to 100 nanometres. *Nanotubes* have a cylindrical lattice arrangement of material; fullerenes have a spherical molecular arrangement; and *nanofibres* have a length to diameter ratio of at least and are in the nano range. *Nanowhiskers* are fine fibres in the nano range; they are 5-20 nm in cross-section with lengths of several micrometres. *Nanosheets* are an arrangement of material where only one dimension is in the nano range. Many of these different nano forms are either in use or under investigation for use within the food industry.

**Application of nanotechnology in food processing and food packaging**

Nanotechnology has been touted as the next revolution in many industries, including food processing and packaging. The applications of nano-based technology in food industry may include nanoparticulate delivery systems (e.g. micelles, liposomes, nanoemulsion, biopolymeric nanoparticles, and cubosomes), packaging, food safety and biosecurity (e.g. nanosensors), and nanotoxicity. The application of nanotechnology in food science and technology is given in Figure below.




***Nanoencapsulation***

Nanoencapsulation is defined as a technology to pack substances in miniature making use of techniques such as nanocomposite, nanoemulsification and provides final product functionality that includes controlled release of the core. The protection of bioactive compounds, such as vitamins, antioxidants, proteins, and lipids as well as carbohydrates may be achieved using this technique for the production of functional foods with enhanced functionality and stability. The different techniques developed for the production of nanocapsules have been reported along with examples of their application. Scientists have developed a novel patented technology that has the ability to nanoencapsulate a multitude of bioactive and active ingredients in nutraceutical products.

These nanocapsules were found to break down and were absorbed as common foods after they have delivered their active ingredients. The recent innovation in encapsulation and controlled release technologies, as well as a design principle of novel food delivery systems has been reported. Nanoencapsulation can make significant savings for formulators, as it can reduce the amount of active ingredients needed. Researchers examined the encapsulation and controlled release of active food ingredients using nanotechnological approaches. Octenyl succinic anhydride-ε-polylysine has the potential to become bifunctional molecules that can be used as either surfactants or emulsifiers in the encapsulation of nutraceuticals or drugs or as antimicrobial agents. Hydrophobically modified starch formed micelles encapsulated curcumin.

Lipid-based nanoencapsulation systems enhance the performance of antioxidants by improving their solubility and bioavailability, *in vitro* and *in vivo* stability, and preventing their unwanted interactions with other food components. The main lipid-based nanoencapsulation systems that can be used for the protection and delivery of foods and nutraceuticals are nanoliposomes, nanocochleates, and archaeosomes. 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.

Coenzyme Q10 nanoliposomes were produced with the desired encapsulation quality and stability. Colloidosomes are minute capsules made of particles one tenth the size of a human cell and assemble themselves into a hollow shell. Molecules of any substance can be placed inside this shell. Scientists believe that fat blockers, medicine, and vitamins could be placed into the colloidosomes. A method was proposed to form water-soluble nanoparticles with entrapped β-carotene of controlled functionality. Scientists formulated beta-carotene within a nanostructured lipid carrier that allows the normally hydrophobic beta-carotene to be easily dispersed and stabilized in beverages.

Nanoencapsulation technologies have the potential to meet food industry challenges concerning the effective delivery of health functional ingredients and controlled release of flavor compounds. Zein, the prolamine in corn endosperm binds and enrobes lipids, keeping them from deteriorative changes. Further, zein has been shown to adsorb fatty acids and produce periodic structures, most interestingly, nanoscale layers of cooperatively assembled fatty acid and zein sheets. Soy lecithin is the main structural ingredient in the formation of aqueous nano-dispersions that carry high loads of water-insoluble actives. These actives include water-insoluble nutraceuticals, fat-soluble vitamins, and flavors. The encapsulated actives disperse easily into water-based products, showing improved stability and increased bioavailability. A separate study has shown a seven-fold increase in intestinal cell uptake of CoQ10 in nano-dispersions versus traditional powder formulations.

Nano-cochleates are nano-coiled particles that wrap around micronutrients and have the ability to stabilize and protect an extended range of micronutrients and the potential to increase the nutritional value of processed foods. Nanocochleates consists of a purified soy based phospholipid that contains at least about 75% by weight of lipid that can be phosphotidyl serine, dioleoylphosphatidylserine, phosphatidic acid, phosphatidylinositol, phosphatidyl glycerol and/or a mixture of one or more of these lipids with other lipids. Additionally or alternatively, the lipid can include phosphatidylcholine, phosphatidylethanolamine, diphosphotidylglycerol, dioleoyl phosphatidic acid, distearoyl phosphatidylserine, dimyristoyl phosphatidylserine, and dipalmitoyl phosphatidylgycerol.

Nanoencapsulation is desirable to develop designer probiotic bacterial preparations that could be delivered to certain parts of the gastro-intestinal tract where they interact with specific receptors. These nanoencapsulated designer probiotic bacterial preparations may act as *de novo* vaccines, with the capability of modulating immune responses. Biopolymer assemblies stabilized by various types of noncovalent forces have recently shown considerable progress.

A starch-like nanoparticle can help stop lipids from oxidizing and therefore improve the stability of oil-in-water emulsions. The health benefits of curcumin, the natural pigment that gives the spice turmeric its yellow colour, could be enhanced by encapsulation in nanoemulsions. The health promotion properties of polyphenols have attracted a lot of attention in recent years. Nanoemulsions could improve stability and oral bioavailability of epigallocatechin gallate and curcumin. A stearin-rich milk fraction was used, alone or in combination with α-tocopherol, for the preparation of oil-in-water sodium caseinate-stabilized nanoemulsions. Immobilization of α-tocopherol in fat droplets, composed by high melting temperature milk fat triglycerides, provided protection against degradation.

***Nanoemulsions***

The use of nanoemulsions is an example of how a nanotechnology can be applied to an existing process which can prove beneficial for the food industry. The small droplet size gives nanoemulsions unique rheological and textural properties which render them transparent and pleasant to the touch; both of these unique features can be desirable in the food industry and the cosmetics industry. Using nanoemulsions in food products can facilitate the use of less fat without a compromise in creaminess, thus offering the consumer a healthier option. Products of this type include low fat nanostructured mayonnaise, spreads and ice creams. A 2.5% fat ice cream is commercially available worldwide from a recognised premium ice cream brand which claims to have no flavour defects due to the low fat content, however no nanotechnology claim is made by the product. More choice of such low fat ice cream is available in the United States where many brands have introduced them. As the size of the droplets in an emulsion is reduced, the less likely the emulsion will break down and separate. In this way nanoemulsification may reduce the need for certain stabilisers in a product. Nanoemulsions look set to play a future role in revolutionising the production of spreads and mayonnaise.

Nanoemulsions have been developed for use in the decontamination of food packaging equipment and in the packaging of food. A typical example is a nanomicelle-based product claimed to contain natural glycerin. It removes pesticide residues from fruits and vegetables, as well as the oil/dirt from cutlery. Nanoemulsions have recently received a lot of attention from the food industry due to their high clarity. These enable the addition of nanoemulsified bioactives and flavors to a beverage without a change in product appearance. Nanoemulsions are effective against a variety of food pathogens, including Gram-negative bacteria. They can be used for surface decontamination of food processing plants and for reduction of surface contamination of chicken skin. The growth of *Salmonella typhimurium* colonies has been eliminated by treatment with nanoemulsion. Based on the physicochemical properties of the microencapsulated fish oil, sugar beet pectin must be considered as an alternative to milk proteins and gum arabic for the encapsulation of functional food ingredients. The nanoemulsions showed great promise for use in beverage and other applications. Various types of nanoemulsion, including single-layer, double-layers and triple-layers nanoemulsions, could be produced, depending on the polyelectrolytes, such as alginate and chitosan. Solid lipid nanoparticles are formed by controlled crystallization of food nanoemulsions and have been reported for delivery of bioactives, such as lycopene and carotenoids. The major advantages of solid lipid nanoparticles include large-scale production without the use of organic solvents, high concentration of functional compounds in the system, long term stability, and the ability to be spray dried into powder form.

***Nanonutraceuticals***

Nutraceutical compounds such as bioactive proteins are used in functional foods to impart a health benefit to consumers in addition to the nutrition that the food itself offers.

Nanomaterials can be used as bioactives in functional foods. Reducing the particle size of bioactives may improve the availability, delivery properties and solubility of the bioactives and thus their biological activity because the biological activity of a substance depends on its ability to be transferred across intestinal membranes into the blood. In addition, nanotechnologies can be utilised to improve the stability of such micronutrients during processing, storage and distribution. Commercial success in this area has been achieved by Omega-3 fatty acids, and certain beneficial probiotic bacteria species, lycopene, Vitamin D2 and beta-Carotene have demonstrated potential commercial success in research studies. Maintaining nutraceuticals in a stable state throughout the production process is invariably challenging. The prospect of the production of nutraceuticals at the nanoscale, which will have increased stability throughout the processing chain, will be of significant interest to food processors trying to maximise nutrient content and hence will ultimately be of benefit to consumers.

***Nanofood Additives***

A key application area of nanotechnology for food processing is the development of certain nano-structured (also termed as nano-textured) foodstuffs, such as spreads, mayonnaises, creams, yoghurts and ice creams. The nano-structuring of food materials has been claimed for new tastes, improved textures, consistency and stability of emulsions, compared to equivalent conventionally processed products. A typical product of this technology could be in the form of a low-fat nano-textured product that is as 'creamy' as the full-fat alternative, and hence would offer a 'healthy' option to the consumer.

One such example under R&D is that of a mayonnaise which is composed of nanomicelles that contain nanodroplets of water inside. The mayonnaise would offer taste and texture attributes similar to the full-fat equivalent, but with a substantial reduction in the amount of fat intake by the consumer. Another area of application involves the use of nano-sized or nano-encapsulated food additives. This type of application is expected to exploit a much larger segment of the (health) food sector, encompassing colours, preservatives, flavourings and supplements. The main advantage is said to be a better dispersability of water-insoluble additives in foodstuffs without the use of additional fat or surfactants, and enhanced tastes and flavours due to enlarged surface area of nano-sized additives over conventional forms. A range of consumer products containing nano-sized additives is already available in the supplements, nutraceuticals and (health) food sectors. These include minerals, antimicrobials, vitamins, antioxidants, etc. Virtually all of these products also claim enhanced absorption and bioavailability in the body compared to their conventional equivalents.

Nano-encapsulation is the technological extension of micro-encapsulation that has been used by the industry for (health) food ingredients and additives for many years. Nano-encapsulation offers benefits that are similar to, but better than, micro-encapsulation, in terms of preserving the ingredients and additives during processing and storage, masking unpleasant tastes and flavours, controlling the release of additives, as well as enhanced uptake of the encapsulated nutrients and supplements.

Following food packaging, nano-encapsulation is currently the largest area of nanotechnology applications in the (heath) food sector. Nano-encapsulation in the form of nanomicelles, liposomes or protein-based carrier systems has been used to develop delivery systems for additives and supplements in food and beverage products. A growing number of (health) food and nutraceutical products based on nanocarrier technology are already available on the market. These include a number of food additives and supplements. Other products containing nano-antimicrobials and nano-antioxidants, etc., are also commercially available. The concept of nanodelivery systems seems to have originated from research on targeted delivery of drugs and therapeutics. However, the use of similar technology in foodstuffs is interesting in the sense that whilst it can offer increased absorption, uptake and bioavailability, it also has the potential to alter tissue distribution of the substances in the body. For example, certain water-soluble compounds can be rendered fat dispersible through nanocarrier technology. Vice versa, fat-dispersible compounds can be rendered water dispersible. It is hoped that these nanocarriers are completely broken down and their contents are released in the GI tract. As such, the encapsulated compounds will not be any different from their conventional equivalents. However, if a nanocarrier system is capable of delivering the encapsulated substance to the bloodstream, its absorption, tissue distribution and bioavailability may be drastically different from the conventional forms. This raises the concern that some nanocarriers may act as a ‘Trojan Horse’ and facilitate translocation of the encapsulated substances or other foreign materials to unintended parts of the body.

***Nanotechology in Food Analysis***

Detection and characterization of nano delivery systems is an essential part of understanding the benefits, as well as the potential toxicity of these systems in food. A detailed description of food nano delivery systems based on lipids, proteins, and/or polysaccharides, and the current analytical techniques used for the identification and characterization of these delivery systems in food products has been reported. The analytical approaches have been subdivided into three groups; separation techniques, imaging techniques, and characterization techniques. The recent progress made in analytical nanotechnology, as applied to the food industry and to food analysis; with particular emphasis on nanosensing have been reported. The electronic nose is a device that uses an array of chemical sensors tied to a data-processing system that mimics the way a nose works. A new strategy for feature selection has been introduced to Microsoft-based electronic nose applications. Its fine performance has been demonstrated using two Microsoft e-nose databases. Detection of fruit odors using an electronic nose has been reported. Methods have been reported to estimate chemical and physical properties of pears from the electronic nose signal. The electronic nose could also be a useful and innovative tool to monitor strawberry aroma changes during osmotic dehydration. A typical nanosensor ‘electronic nose’ can be used for quality control of milk during industrial processing. Nanotechnology-based electronic nose applications include: monitoring and control (for example, direct measuring of specific stages of a process, such as baking); more accurate volatiles measurement than measuring temperature and the time taken currently in baking to monitor product quality, quality assurance (eg, timely warning in a refrigerated environment on whether a ham is no longer safe to eat). Nanosensors are integrated in food packaging to show if the food product is still fit for human consumption. Nanosensors have been developed for food safety and quality control in the European project GOODFOOD (2004–2007) and Nanosieves can be used for filtration of beer or of milk for cheese production. Nanofiber of microbial cellulose produced by fermentation was also studied to develop novel nanostructured materials.

Detection and characterization of nano delivery systems are an essential part of understanding the benefits, as well as the potential toxicity of these systems, in food. Scientists showed that for a sufficient characterization, the nano delivery systems need to be separated from the food matrix, for which high-performance liquid chromatography or field flow fractionation are the most promising techniques. Subsequently, online photon correlation spectroscopy and mass spectrometry proved a convenient combination of techniques to characterize a wide variety of nano delivery systems. The detection and characteristics of engineered nanoparticles in food has been reported. A rapid and cost-effective method has been reported that simultaneously detects three food-borne pathogenic bacteria, *Salmonella typhimurium, Shigella flexneri, and E. coli* O157:H7, via an approach that combines magnetic microparticles for the enrichment and antibody-conjugated semiconductor quantum dots as fluorescence markers. Nanosensors can detect allergen proteins to prevent adverse reactions to foods, such as peanuts, tree nuts, and gluten.

### *Natural Nanostructures in Food*

Whilst nanotechnologies offer exciting opportunities for the development of new tastes and textures through the development of nanostructures, emulsions and micelles in foodstuffs, it is known that our food already contains certain natural nanostructures. The three basic food constituents are proteins, carbohydrates and fats. Many food proteins and carbohydrate starches exist naturally in the nanoscale and simple triglyceride lipids are about 2 nm long. Food substances are also metabolised in the body at a nanoscale. Although proteins, carbohydrates and lipids are each digested in the gastrointestinal tract (GIT) in a different way, a common factor is that they are all broken down to nanostructures before assimilation. It has, therefore, been argued that our body is already used to dealing with nanostructures in the GIT, and that foods processed at the nanoscale would simply be more readily digestible, absorbed and bioavailable in the body. However, it remains to be seen whether nanoscale processing of food materials might produce structures that are different from those that occur naturally.

## Nanotechnology in Food Packaging

Nanotechnology has the potential to generate new food packaging. Nanocomposites can improve mechanical strength; reduce weight; increase heat resistance; and improve barrier against oxygen, carbon dioxide, ultraviolet radiation, moisture, and volatiles of food package materials. Fine nanoparticulates (100 nm or less) are incorporated into plastics to improve the properties over those of conventional counterparts. Polymer nanocomposites are thermoplastic polymers that have nanoscale inclusions, 2%–8% by weight. Nanoscale inclusions consist of nanoclays, carbon nanoparticles, nanoscale metals and oxides, and polymeric resins. Nanocomposites are characterized by extremely high surface-to-volume ratio, making them highly reactive in comparison to their macroscale counterparts, and thus presenting fundamentally different properties.

Moreover, nanocomposites could also be characterized by an antimicrobial activity. Packaging containing nanosensors are coming to food stores to give information of enzymes produced in the breakdown of food molecules making them unsafe for human consumption. The packages could also be used to let air and other enzymes out but not in, thus increasing shelf life, as well as the reduction of man-made preservatives in our foods. Another important potential application of nanoparticles in food packaging is the degradation of ripening gas, such as ethylene. In view of the above, the idea to insert active nanoparticles into polymer matrices could bring the twofold advantage to improve the performance of food packaging material and to impart it an additional functionality (antimicrobial, antioxidant, scavenger), thus promoting the prolongation of the shelf life of the packaged product. Researchers reported the challenges of using nanotechnology to create low-cost packaging that assists in functionality, weight, and ease of processing. The new hybrid plastic, comprising polyamide and layered silicate barriers, makes it much more difficult for oxygen to pass through to the packaged goods than does conventional films made of polyamide. Durethan, is a nanocomposite film enriched with an enormous number of silicate nanoparticles that reduce entry of oxygen and other gases and the exit of moisture, thus preventing food from spoiling.

Natural biopolymer-based nanocomposite packaging materials with bio-functional properties have a huge potential for application in the active food packaging industry. Recent advances in the preparation of natural biopolymer-based films and their nanocomposites, and their potential use in packaging applications were reported. The other improvements in nanotechnology for food packaging include carbon nanotubes that can be used in food packaging to improve its mechanical properties. It has been recently discovered that they might exhibit powerful antimicrobial effects. For example, *Escherichia coli* bacteria died on immediate direct contact with aggregates of carbon nanotubes.

Polymer-clay nanocomposite has emerged as a novel food packaging material due to benefits, such as enhanced mechanical, thermal, and barrier properties. Scientists have discussed the potential use of these polymer composites as novel food packaging materials with emphasis on preparation, characterization, properties, recent developments and future prospects. More flexible packaging methods will provide the consumers with fresher and customized products. Nanowheels, nanofibers and nanotubes are being investigated as a means to improve the properties of food packages. Nanotechnology has the potential to influence the packaging sector by delaying oxidation and controlling moisture migration, microbial growth, respiration rates, and volatile flavors and aromas. A methodology used to produce polymer nanocomposites with low-cost fibrous materials similar to expensive carbon nanotubes exhibiting optimized dispersion, interfacial bonding, and attractive physical and other properties has been reported. Chitosan-based nanocomposite films, especially silver-containing ones, showed a promising range of antimicrobial activity. PEG coating nanoparticles loaded with garlic essential oil could be used to control the store-product pests. Phytoglycogen octenyl succinate nanoparticles with ε-polylysine significantly increased the shelf life of the product. Here, the nanoparticle created a stronger defense against oxygen, free radical and metal ions that cause lipid oxidation. Researchers are using silicate nanoparticles to provide a barrier to gasses (for example oxygen), or moisture in a plastic film used for packaging. This could reduce the possibly of food spoiling or drying out.

Smart packaging responds to environmental conditions or repairs it or alert a consumer to contamination and/or the presence of pathogens. The nanoparticles are dispersed throughout the plastic and are able to block oxygen, carbon dioxide and moisture from reaching fresh meats or other foods. The nanoclay also makes the plastic lighter, stronger and more heat resistant. Researchers have developed the intelligent packaging that will release a preservative if the food within begins to spoil. This "release on command" preservative packaging operates by using a bio switch developed through nanotechnology. 'Smart' food packaging will warn when oxygen has got inside, or if food is going off. Such packaging is already in use in brewing and dairy production and consists of nanofilters that can filter out micro-organisms and even viruses. In lab experiments, the color has been removed from beetroot juice, leaving the flavor; and red wine turned into white. Lactose can now be filtered from milk, and replaced with another sugar – making all milk suitable for the lactose-intolerant. Nano-capsules delivered chemicals in rapeseed cooking oil, will stop cholesterol entering the bloodstream. Nano packaging with self cleaning abilities or nanoscale filters will allow the removal of all bacteria from milk or water without boiling. In the area of nanolaminated coatings on the bioavailability of encapsulated lipids, bioactive lipophilic or fat-liking compounds could be incorporated into foods or beverages, which may increase the ingredient's stability, palatability, desirability, and bioactivity. Functionalized nanostructured materials are finding applications in many sectors of the food industry, including novel nanosensors, new packaging materials with improved mechanical and barrier properties, and efficient and targeted nutrient delivery systems. An improved understanding of the benefits and the risks of the technology, based on sound scientific data, will help gain the acceptance of nanotechnology by the food industry.

New horizons for nanotechnology in food science may be achieved by further research on nanoscale structures and methods to control interactions between single molecules. Advances in processes for producing nanostructured materials coupled with appropriate formulation strategies have enabled the production and stabilization of nanoparticles that have potential applications in the food and related industries. The food processing industry should ensure consumer confidence and acceptance of nanofoods. Scientists are not yet certain how various nanomaterials will behave when they cross membranes, such as the blood–brain barrier, or when they are inhaled during production. The safety of a given compound in a food should not automatically apply to a nanoversion of the compound, due to possible novel properties and characteristics.

**Potential Risk of Food Nanotechnology**

With these potential benefits of any technology some risks will also come. On one hand, while nanoscale components already occur naturally in many foods, the food nanotechnologies may pose direct risks to human health. Recent research shows that inhaled nanoparticles can accumulate in the lungs and cause chronic diseases due to their small scale.

Food-related nanotechnologies may also pose indirect threats to human health. For example, food could be contaminated by the use of nano-sized pesticides and nanoparticles could migrate into food from nano-packaging. There is also the possibility that nanoparticles could bioconcentrate in the environment and alter the food chain.

Many food substances or ingredients have nanostructures in nature and are present at micro- or nanometer in size. Food proteins, which are globular particles between 10s and 100s of nanometers in size, are true nanoparticles. Linear polysaccharides with one-dimensional nanostructures are less than 1 nm in thickness, and starch polysaccharides having small 3-D crystalline nanostructures are only 10s of nanometers in thickness. In the food industry, many attempts have been made to manufacture micro- or nanosized food materials by the top-down (e.g. grinding down) or bottom-up (e.g. aggregation of substances) approaches. In general, physicochemical properties including particle size and size distribution, agglomeration state, shape, crystal structure, chemical composition, surface area, surface chemistry, surface charge, and porosity may all be important for understanding the toxic effects of nanomaterials. However, it remains to be determined whether the unique physicochemical properties of nanomaterials will introduce new mechanisms of injury and result in unpredictable harmful effects.

Nanotechnology opens up a whole universe of new possibilities for the food industry (e.g. food packaging), but the entry of manufactured nanoparticles into food chain may result in an accumulation of the toxic contaminant in foods and adversely affect human health. There are questions if the food materials of nanometer sized (or up to a few microns) should be categorized as new or unnatural materials while compared with their larger forms. Although the nanomaterials might be toxic and cause harmful effects beyond the expectation, research efforts have also revealed that the ways of making nanomaterials and processing may not necessarily produce products with harmful effects: for instance, the toxicity of certain substance (e.g. selenium) might be significantly reduced while its particle size was decreased to nanoscale. It was also reported that pure carbon nanotubes administered to the trachea of mice might cause death; whereas, doping carbon nanotubes with nitrogen reduced their toxicity and the risk of death, paving the way for the use of the technology in food packaging. On the basis of a ‘‘Precautionary Principle’’, more investigations on the toxicity of nanoparticles contacting with food products, however, should be performed to dispel the doubts. In spite of the fact that most of the existing nanotoxicity studies are generally focusing on nonfood materials or consumer products, those relevant research findings can still be useful hints for understanding the potential toxicity of the nanotechnology-based food materials.