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Original Article

Nanotechnology in Food Science, Health and Social Perspectives, Factors Affecting Occurrence, Toxicological Significance on Human Health and Micro-Technologies Applied to Food Proteins

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Abstract:

Electronics, communications, energy generation, computers, cosmetics, medicine, and health are just a few areas where micro and nanotechnology have played a crucial role for a long time. In more recent times, they have likewise transformed the food and agricultural industries, particularly in relation to packaging and issues of food safety and quality. The initial intent of the phrases "nanotechnology" and "microtechnology" was to describe technological advancements that extended beyond the realm of micrometer-scale material and engineering control. These days, they mean a certain kind of hardtech processing that involves manipulating molecules and atoms individually. "Nanotechnology" and "microtechnology" both originate from the Greek prefixes "nano" and "micro," respectively. Micro (10 -6 m= 1 m m) is the unique scale that pertains to the data in microtechnology. Conversely, the nanometre scale (10 -9 m = 1 nm) is what is being referred to in nanotechnology. Design, characterisation, manufacture, and application of microscale and nanoscale systems and components—which can also include components related to food or health—are thus the primary foci of microtechnologies and nanotechnologies. Their interplay with other fundamental or cutting-edge technologies is resulting in more sophisticated advancements that will likely have a greater influence all the way through the food supply chain, from farming and processing to warehousing and shipping, ultimately leading to better food tracking, traceability, and safety. Humans obtain the building blocks for life from the complicated combinations of components that make up food. The use of heat (fire) to prepare food has been one of many evolutionary shifts in human diets throughout the millennia, with the goal of improving flavour, digestibility, taste, and overall food quality. After Homo erectus, Homo neanderthalensis, and archaic Homo sapiens were extinct (around 50,000 to 100,000 years ago), it's possible that modern humans ate largely uncooked meat, grains, and vegetables. It goes without saying that human diets have changed significantly throughout the years, particularly with the invention of cooking, which is fundamental to every human culture. That "cooking food, especially starchy food, as an innovation has, perhaps more than any other in human history, enabled people to extend the ranges into habitats that were impossible to live in before" sums up the impact of cooking on human evolution and social behaviour the best. A wide range of processing techniques were made available to the food business throughout the industrial revolution. These included the ability to store food for an extended period of time, as well as the addition of procedures to enhance texture, flavour, and safety by eliminating harmful microbes, enzymes, and toxins. Carbohydrates, proteins, lipids, and trace amounts of vitamins, minerals, and minor nutrients make up the modern human diet, which supplies energy for a healthy lifestyle. The digestive process cannot occur without water, even though it is not a nutrient. All sorts of foods—grains, fruits, vegetables, milk, meat, eggs—contain these components, which have clearly defined chemical structures and reactive functional groups like -COOH, -NH 2, and -OH. Volatile and nonvolatile byproducts with distinct properties, including those that are beneficial (flavour) and those that are unwanted (toxicants, such as acrylamide), are inevitable outcomes of any procedure that involves heating carbohydrates, lipids, proteins, and nitrite (a preservative) to moderate to high temperatures. No more than three classes of possible dietary carcinogens—nitrosamines, polyaromatic hydrocarbons (PAHs), and heterocyclic aromatic amines—existed prior to early 2002. Their prevalence, characteristics, analysis, and mitigation strategies have been the subject of a large body of scientific literature. In light of the possibility for toxicity, a new class of acrylamide was added. To better understand the processes leading to the formation of acrylamide and to define steps for its reduction while maintaining the highly desirable organoleptic (sensory aroma, colour, feel, and taste) characteristics of the food, unprecedented extensive independent and collaborative research projects were initiated in response to this announcement and the heightened health concerns (potential human neurotoxin).

Keywords: Food Science, Nanotechnology, Factors, Toxicological Significance, Human Health, Food Proteins

Introduction

Chemical interactions between functional groups in endogenous and/or external materials are initiated by heating raw materials when tissues are softened and pathogens are killed. The byproducts of these chemical reactions might be either useful or harmful. To limit the growth of Clostridium botulinum, foods have been treated with rock salts for generations. Sodium nitrite was determined to be the active component at a later date. The native crimson colour of cured foods, including pork, was also preserved when sodium nitrite was used [1, 2]. Norwegian farm animals fed a herring meal preserved with high levels of sodium nitrite had severe liver problems and malignancies, demonstrating the dangers of sodium nitrite. It was determined that N-nitroso-N,N-dimethylamine (NDMA) was the chemical that caused the harmful effects. It is possible to create NDMA by reacting dimethylamine with nitrosyl cation, which is formed when nitrite ions are present in the right environments. Because of this, people began talking about it [3], and soon enough, many in the food industry began to wonder if sodium nitrite, which is used to cure meat, should still be in human meals. Researchers were given the mission of creating accurate analytical tools to detect nitrosamines like NDMA in fried bacon, sausages, and other cured meats. While the crispiness and flavour of bacon strips are achieved by frying them at very high temperatures (primarily due to aldehydes and ketones), this method also promotes the development of nitrosamines, such as NDMA [4-6]. By the mid-1980s, a number of analytical techniques had enabled several national and international regulatory authorities to set limits of salt in products at 200 ppm, with the exception of bacon, which was limited to 150 ppm. Prior to this, there had been no regulation on the use of sodium nitrite for food preservation. A standard of 45 parts per million (i.e., 45 mg/L) for nitrate and fewer than 3.2 parts per million (i.e., less than 3.2 mg/L) for nitrite has been set by the Canadian Federal-Provincial-Territorial Committee on Drinking Water. From 1972 to 1997, a span of 25 years, the average amounts of nitrite in cured beef from Canada varied from 28 to 44 parts per million. The National Academy of Sciences in the United States reported in 1981 that nitrite intake can be derived from cured meat (39%), baked products and cereal (34%), vegetables (including leaves and roots) (16%), and water (21%). Excessive use of nitrogen fertiliser is associated with nitrite, which is found in vegetables and water.

Factors affecting occurrence/formation

The cooking method, temperature, and duration significantly impact the generation of N-nitrosamines. Compared to microwave heating, conventional heating invariably results in a higher production of nitroso compounds. The main volatiles released when bacon is cooked in a skillet or microwave are N-nitrosopyroline (NPYR) and N-nitroso-N,Ndimethylamine (NDMA), however the quantities released are significantly more when using conventional methods as opposed to microwave heating.

Methods for analysis

Nitrosamines, which may be extracted and detected using a variety of methods, are present in human diets in both volatile and non-volatile forms. By utilising AOAC procedures, nitrosamines, such as NDMA, and other volatile compounds can be extracted. The extraction efficiency of solid phase microextraction methods (SPME) remain problematic, despite their use. Gas chromatography (GC) in nitrogen mode with a nitrogen-phosphorus detector (NPD) is used to detect and quantify N-nitrosamines on packed and/or capillary columns. It was reported that NDMA in beer may be measured using SPME-MS (mass spectrometry). New analytical methods for determining N-nitrosamines in food have been detailed in a recent study.

Risks related to toxicology

Highly carcinogenic N-nitrosamines are mainly consumed by humans through food. Consumption of cured meats cooked at high temperatures, vegetables, beer, water, and smoking are the main human exposure routes to NDMA. The risk of pancreatic cancer is increased by eating processed meats, according to a research from the University of Hawaii that monitored almost 200,000 men and women for 7 years. Those who ate the most processed meats (sausage and hot dogs) had a 67% higher risk of pancreatic cancer compared to those who ate the least amount of meat. The authors did not definitively state that the fat or the meat was to blame for the increased occurrences, but they did express the opinion that it was not. According to their speculation, the origins originated in the processing steps that could have resulted in the production of nitrosamines and heterocyclic amines. Even now, nitrite is still used in processed and cured meats that are ready to consume, which is harmful, particularly to unborn children. Ingesting foods such as bacon, bologna, hot dogs, pepperoni, smoked ham, sausages, salami and other items containing residual nitrite can lead to the formation of residues of N-nitrosamines in the stomach when they react with endogenous amines. Consumption of cured meats by low-income pregnant women has been associated with an increased risk of infantile leukaemia and paediatric brain tumours, according to multiple epidemiological studies. The declining nitrite content in cured meats over the years, however, suggests that this conclusion is not universally accepted [7, 8]. The elevated nitrate levels in the groundwater have also raised some eyebrows. A number of recent studies have connected elevated levels of nitrate in water to an increased risk of diabetes and Alzheimer's disease, and they have called for a decrease in the usage of nitrate fertilizers.

Factors affecting occurrence/formation

More than twenty HAA-forming chemicals have been detected in cooked meats, including beef, pork, chicken, and fish, since the initial instance of their creation was documented. Cooking meat at high temperatures (>150°C) results in the formation of two main types of HAAs. The majority of these compounds have a 2-iminoimidazo group attached to either a pyridine ring (PhIP), quinoxaline (IQ, MeIQ), or quinoline (MeIQx, MeIgQx). Carbolines are the non-IQ type products that are generated at temperatures above 250°C (structures not indicated). Cooked meat products can have HAA formation and concentrations that can differ by more than 100-fold depending on the meat's origin and type (beef, chicken, pork), as well as the cooking temperature, duration, and doneness (just done, well done, and extremely well done are all results of a combination of these factors). There is a lot of evidence that the levels of MeIQ and PhIP are affected by temperature. Total amounts of HAAs were found to be higher when beef patties were cooked at 400°F (204°C) for 5 minutes each side compared to 375°F (191°C) for the same amount of time. The amounts of MeIQx and PhIP also increased with temperature, with MeIQx being slightly higher. Pork often had lower PhIP production compared to chicken and beef. Although HAAs were not found in most pork items that were cooked to medium-rare, the pan-fried pork chop that was cooked to medium-well had nearly three times the amount of MeIQx as the well-done pork (1.3 ng/g vs. 3.8 ng/g). The most abundant HAAs, according to a recent study that used liquid-chromatography-electron spray ionization/tandem mass spectrometry to quantify 13 different HAAs in cooked beef, pork, and chicken, were found in barbecued chicken (up to 305 m g/kg, or 305 ng/g), broiled bacon (16 m g/kg, or 16 ng/g), and pan-fried bacon (4.9 m g/kg, or 4.9 ng/g). Steak, well-done pan-fried beef, and beef gravy had the highest concentrations of 7-MeIgQx HAAs in beef (about 30 m g/kg, or 30 ng/g). The health benefits of eating fish, which are associated with its high omega-3 fatty acid content, are widely promoted. Grilling, broiling, frying, and barbecuing fish at temperatures ranging from 150°C to 250°C is a common method for cooking fish, just like other meats (personal preferences). Depending on the cooking method, fish is likely to release varying amounts of mutagenic and carcinogenic HAAs. Researchers have shown that barbecuing sardines and Atlantic salmon for different periods of time (rare, 5 minutes per side), medium, 6 minutes per side, and well done, 7 minutes per side) at temperatures ranging from 280 to 300 degrees Celsius does, in fact, produce HAAs. Cooked meats often contain the highest concentrations of PhIP and MIQx, the two most prevalent HAAs. It is produced by heating muscle meat through intricate reaction pathways between 180 and 225 degrees Celsius. A model system study found that the presence of glucose enhanced PhIP development, while the absence of sugar resulted in extremely modest quantities of PhIP production. The following procedures were suggested by other model studies: I. The phenylalanine is heated to form phenylacetaldehyde; (ii) the aldol addition product is obtained by condensing with creatinine; and (iii) the aldol condensation product is obtained by rapidly dehydrating. Both the model system and fried meat were found to contain the condensation product, but not the addition product, according to LS-MS. Last but not least, phenylalanine (PhIP) is produced by reacting the condensation result with sugar and any one of many amino acids.

Impact of toxicology on human well-being

Acrylamide is known to be neurotoxic to humans and a mutagen to rats. In 2006, the Expert Committee on Food Additives and Contaminants, which is a joint effort by the World Health Organisation and the Joint Food and Agriculture Organisation, concluded that acrylamide in food could pose a health risk. Acrylamide was added to the list of hazardous compounds and a monitoring program was launched by Health Canada in 2009. Following discussions with member states of the European Union and the European Environment Agency, the European Chemical Agency recommended adding acrylamide to the list of compounds of Very High

Concern, which includes dangerous chemicals. Epidemiological studies have not established a causal relationship between acrylamide in food and cancer as of yet.

Implementing nanotechnology into the field of food science

One definition of nanotechnology is the use of atomic, molecular, or cluster-level manipulation or self-assembly to create materials or technologies with novel characteristics. Despite being in its infancy, nanotechnology is expected to witness tremendous expansion in the food industry. Nanotechnology, one of the most important technological developments of the 21st century, has the potential to revolutionise many industries and fields of study. Several of the largest food corporations in the world are investigating its possible applications in food packaging, quality control, and safety because of the immense importance of this industry. There are two main ways nanotechnology can be applied to the food industry: the bottom-up approach and the top-down approach. Reducing the size of the tiniest structures is what top-down architecture is all about. Physical activities involving the food matrix, such as grinding or milling, can make this approach a reality in the food science field, for instance. This method is comparable to dry-milling technology, which is commonly used to reduce wheat flour to a finer consistency while increasing its water-binding capacity, or to increasing the antioxidant activity of green tea powder by increasing its dismutase activity and the range of active oxygen-eliminating potency. In the last scenario, a larger ratio of nutritional polyphenol digestion and absorption is made possible by shrinking the size to 0.5-1 m utilising dry-milling technology. The opposite is true with bottom-up tech, which draws inspiration from the biological ideas of self-organization and self-assembly. The formation of nanostructures by the manipulation of individual atoms or molecules is central to this notion. The bottom-up approach is shown by the creation of more stable biological structures, such as casein micelles or starch, or by folding globular proteins [12–15]. For the same chemical makeup, nanoparticles have a greater biological activity than larger-sized particles due to their more dispersed surface area per mass unit. When it comes to functional meals, this takes on extra significance because nanoparticles in these foods have shown to have a stronger impact on human health, reducing the occurrence of serious diseases like cancer and other similar conditions. Nanoparticles are more easily absorbed because of their reduced size, which also improves their solubility and increases their resistance to gastrointestinal enzymes and microflora. Prebiotics, vitamins, minerals, omega-3 and omega-6 fatty acids, and other nutrients now appear to work better when given in the form of nanoparticles. From a nutritional and health standpoint, however, there are some worries regarding nanoparticle buildup in the body and possible adverse effects, so it's crucial that study into this area continues so that we can make the most of the possible good effects. The food sector stands to gain from nanotechnologies, which present remarkable possibilities for the downsizing of micelles, emulsions, and liposomes, respectively, into nanomicelles, nanoemulsions, and cubosomes [16–21]. Additionally, nanotechnology has the potential to enhance food safety by creating nanosensors that can detect harmful pollutants, pesticides, or infectious microbes in water and all the way down the food chain. The construction of nanocapsules that can selectively bind and remove harmful substances from food matrices is another example of nanotechnology, as is the usage of nutraceuticals that contain edible oils and are enclosed within nanocapsules to enhance their use as nutraceuticals.

Food packaging and nanotechnology

Several businesses and universities have been interested in researching and developing smart packaging technologies that can increase food shelf life for quite some time. These devices might detect changes in temperature and humidity, among other environmental factors, and notify businesses and consumers when there's a chance that a particular food item could be tainted with microbes, toxins, or other biotic or abiotic contaminants. One way nanotechnology can help is by altering packaging materials to make packaged meals safer and better. There hasn't been a more widespread use of nanotechnology in the food industry than this [22-25]. Here are the most important uses of food contact materials (FCMs): The addition of nanomaterials to FCMs enhances their packaging qualities, including their flexibility, resistance to temperature and moisture, and ability to create gas barriers. Adding nanoparticles that can scavenge oxygen or kill microbes makes FCMs useful. Nanosensors integrated within FCMs serve as "intelligent" packaging matrices, allowing for constant monitoring of food condition. Nanoparticles that, when combined with certain polymer-nanomaterial composites, render the packaging matrix biodegradable. If you want to alter the attributes of packaging materials like density, transparency, and manufacturing processes without altering their chemical characteristics, then all it takes is a little amount of nanoparticles. Indeed, in some instances, the incorporation of specific nanoparticles can enhance the thermal and mechanical performance of packaging, making it more stable and long-lasting, more resistant to heat and flame, and better with regard to optical, viscosity, and recycling qualities. The result is nanocomposites that include nanoparticles at concentrations of up to 5% (w/w). The gas barrier properties of nanocomposites can be enhanced and gas permeation limited by the addition of nanominerals like bentonite (or montmorillonite), a common and inexpensive volcanic product. This property makes nanocomposites useful in many different contexts, including the packaging of cheeses, cereals, processed meats, baked goods, and extrusion-coating applications for dairy products and fruit juices. They are also used in the coextrusion process for beer and carbonated drink product The food sector makes use of a variety of natural nano-materials as nano-encapsulation agents, including starch, cellulose, polylactic acid, gelatin, collagen, and chitosan. One of the many uses for these matrices in food packaging is to encapsulate bioactive substances including prebiotics, vitamins, flavours, flavonoids, and polyphenols for controlled release. Starch and its derivatives are among the most commonly used biopolymers for food packaging, and they can be even better with the help of nanotechnology. Nanotechnology has the potential to improve food quality and prolong its shelf life by acting as a barrier to gases, moisture, and solutes while also transporting various active compounds including antioxidants and antimicrobials [26–29]. The significance of these bio-nanocomposites lies in their nanoscale dispersion, which has a size less than 1,000 nm. Nanotechnology has the potential to enhance gas-barrier characteristics and brittleness in other biopolymers, including biopolyesters made from biological monomers like polylactic acid, polyhydroxybutyrate, or polycaprolacton. Nanoclay, when utilised as a filler, can also enhance the physical qualities of these materials. The global packaging market is currently worth over $3.5 billion. Numerous food corporations are pouring substantial resources into research and development of nanotechnology-based smart packaging systems. For use as a nanosensor in food packaging, Kraft has created an electronic tongue. The presence of gases produced during rotting might trigger a colorimetric variation in the nanosensor, which in turn provides a clear signal as to the food's freshness status. A worldwide corporation called Bayer is working on a new kind of packing material that outperforms the ones on the market in terms of speed, strength, and resistance. Typical of hybrid systems, this one is enhanced with silicate nanoparticles, which can reduce the entry of gases like oxygen and, by extension, moisture and food spoiling. Some companies are building nanosystems with engineered luminescent proteins that can bind to the surface of certain pathogens, like Salmonella spp. and Escherichia coli, and then produce a visible glow that changes in intensity according to the level of contamination. This technology is being developed as a solution to the problem of food safety (NanoBio Luminescence Detection). Spray, BioMark, and AgroMicron are based in Singapore. The creation of novel materials that can more accurately detect poisons, harmful chemicals, and pathogens is another area where nanotechnologies are helping to make systems and goods safer and cheaper. The current techniques take many days to detect the presence of harmful microbes or diseases. Use of DNA device biochips for continuous monitoring of various food systems' safety (e.g., meat, fish products, or fruit contaminated by fungi and yeasts) or microarray sensors for monitoring and detection of xenobiotics in produce and the environment allows nanosystems to detect xenobiotics instantly. From the factory to the warehouse to the customer's hands, many products are tracked using a combination of nanotechnology and other technologies including RFID identification and microprocessors. Nanotronics, a product of the merging of nanotechnology with electronics, has made the use of such tags simpler, less expensive, and more efficient [30–34]. Food manufacturers are showing a growing interest in nanotechnologies in the beverage industry. To avoid undesirable side effects, including the reaction between alcohol and regular plastic, which reduces the product's shelf life and quality, one of the primary objectives is to develop alternative materials that can replace glass, primarily for alcoholic drinks. Inoperm, a novel nanocomposite incorporating clay nanoparticles, has emerged in recent years; it outperforms glass in terms of strength, weight, and fragility. Beer and other alcoholic carbonated beverages retained more of their original flavour and aroma for up to six months longer because it reduced carbon dioxide loss and limited oxygen entry into the bottle. An important interdisciplinary link among various research and development areas, including food safety, nutrigenomics, technology development, biological renewal in the food sector and biological production, consumer needs, innovations in feed and food, and systems biology in food research, could be formed by the development of new food packaging systems, one of the topics in the EU 7th Framework Programmed. Biodegradable polymers are seeing renewed interest in the food business thanks to nanotechnology. Among the most popular molecules used for this purpose is zein, a prolamin found in maize protein. It dissolves in ethanol or acetone and may be converted into biodegradable zein films that have excellent tensile and water barrier qualities [35, 36]. Nanotechnology has many potential applications for the organised zein nanobeads and nanoparticles, including biodegradable materials for bioactive food packaging and plastic reinforcement, edible carriers for flavour biomolecules, and nutraceutical encapsulation. By including silicate complexes (such as bentonite or saponite) or polysaccharides and lipids, which enhance the films' physical properties, the barrier property of biodegradable polymers like zein polymer can be enhanced. Several materials derived from natural sources have already been investigated for potential nanoscale applications [37–41]. Milk proteins, like alpha-lactalbumin, can be partially hydrolysed to produce alpha-lactalbumin nanotubes, which can enhance the viscosity and stiffness of the final product. The 8 nm size of the nanotubes' cavities makes them ideal for binding other food components; furthermore, these nanotubes can encapsulate and protect vital nutraceuticals or hide unpleasant smells and flavours. These nanotubes can be classified as food-grade materials due to their source. If they are safe, they could have a reasonably easy time breaking into the global market and finding new uses in nanoencapsulation of nutrients, supplements, or medications.

Advancements in nanotechnology, processing, and food quality

Other areas of food science are also being profoundly affected by nanotechnology. The food business appears to be primarily focused on finding better and more efficient ways to make food that is both safer to eat and has a longer shelf life, all while maintaining the same nutritional value, colour, flavour, texture, and consistency. The potential for improved absorption, as well as the presence and controlled release of nutritional molecules inside the body, are other crucial factors considered when designing functional foods. The food industry can benefit from nanotechnologies in all of these areas: longer shelf life, improved stability, removal of unwanted molecules (e.g., through nanofiltration), and the ability for consumers to tailor their nutritional practices to their specific needs through the use of nanosensors and nanocapsules. By improving the absorption of nano-sized minerals and supplements, nanotechnologies can improve the nutritional content of food [42–44]. They can also create new flavours and creamier textures by nanostructuring food ingredients, all while reducing or eliminating the need for added fat. With the help of nanotechnology, scientists and food manufacturers could create new "on demand" foods that contain specific biomolecules that can stay inactive in the food until they enter the host body, where they can become reactive and provide nutrients to cells only when they're needed. This would be a great way to meet the growing demand for healthier and more functional foods. Actually, scientific advancements have made it possible to create nanocapsules that can be added to food and have nutrients released in a controlled manner. Alternatively, in order to improve the absorption of certain nutrients into the body, certain foods are fortified or nanocapsules containing vitamins, polyphenols, or micronutrients are added to already existing foods. Nanocapsules can be engineered to withstand a variety of thermal and physical stresses in specific applications. Incorporating nanocapsules containing omega-3 fatty acid-rich tuna fish oil into Tip-Top bread is a recent development. Nanocapsules encase the tuna fish oil, which is only broken down once inside the body to release its active ingredients [43-47]. Nutralease, an Israeli startup, has created nanoparticles that can be incorporated into cells through the use of technology for nano-sized self-assembled liquid structures. The fat-based expanded micelles have a water-filled interior layer and a maximum diameter of 30 nm, resembling the particles. This structure can accommodate a variety of nutraceuticals, including polyphenols and antioxidants like lutein, lycopene, beta-carotene, and phytosterols. These substances can be more readily taken into the bloodstream after passing through the gut via the proprietary method, where they are released and metabolised by gut bacteria. Similarly, it is reported that nanocapsules capable of competing for bile solubilization have been developed, and can be useful to decrease blood cholesterol levels by up to 15%. Clearly further research on efficacy, safety, and toxicity are required in this emerging area.

Emerging technologies and their impact on food safety

The many uses of nanotechnology in our everyday life are a major factor in its quick and broad adoption across many sectors. Nanotechnology is altering the world in every way, including the food industry, which is already seeing profound effects on the nutrition and food service sectors. Agriculture, food packaging, and the fight against microbiological contamination are just a few of the main food industries that have been profoundly impacted by nanotechnology. The wide range of uses for nanomaterials in the food industry has led to their mass production around the world. These include nanopowders, nanotubes, nano-fibers, quantum dots, and metal and metal oxide nanoparticles. Some worry that employed nanomaterials might have negative impacts on health or the environment due to their unusual characteristics, such as a huge surface area, intense activity, and tiny size. Nonetheless, this worry may be moot due to the enormous progress in other sectors. Anything with a size between one hundred nanometres and one thousand nanometres is considered to be part of the nanotechnology field. Thanks to recent developments in technology, scientists are now able to fabricate atomically or molecularly precise structures. Nanobiotechnology, nano-chemistry, nano information technology, etc. are just a few examples of the new interdisciplinary fields that have emerged as a result of the fast development of these approaches in various scientific and technological domains. Their improved suitability for use in a variety of sectors is a result of recent developments in nanomaterials. Yet, there is a risk that these materials will pollute the environment or possibly be toxic to humans. There is a lack of information about the safety of nanoparticles used in the food and nutrition industry [48-50]. And keep in mind that certain nanoparticles can make it into our bodies. A nanotoxicity catastrophe could be on the horizon, according to a study from the British Royal Society. Until the potential dangers of nanoparticle exposure to humans and the environment are fully understood, this research recommends that consumers stay away from products that include nanotechnology. Various entry mechanisms, including digestion, inhalation, and skin absorption, are the primary cause for concern when it comes to human exposure to nanoparticles. It is possible for nanoparticles to enter the circulation after ingestion, where they could settle in various tissues like the brain or even set off immunological reactions. These microscopic particles have characteristics shared with asbestos. Some writers have looked at the possibility of genetic modification due to nanoparticles in food or food that has been nanoengineered. Action Group on Erosion, Technology and Concentration (ETC Group) is one of several non-governmental organisations (NGOs) that has demanded a hold on the introduction of nanotechnology products until their safety can be shown. Regardless of the arguments, nanotechnology is already influencing food processing, packaging, and agriculture, therefore people are looking to governments and food manufacturers for guarantees that their food is safe. Because nanoparticles are so special, more and more businesses are starting to sell nanoproducts. For instance, in 2006, nanotechnology in agricultural and food processing received USD 20 billion in products from the food sector. Advocates stress that this has the potential to enhance food safety, nutritional content, quantity, and quality in order to cater to an expanding population. In this article, we will go over a few uses of nanotechnology in the food industry and related fields, as well as some of the potential negative impacts on people and the environment..

Food Nanosensors

As sensors, nanomaterials can monitor the food supply for signs of contamination and help keep it under control. They are able to identify various dietary pollutants, including microbes. As a result, they find application as sensors in the food industry and in packaging facilities. They are able to track the state of food while it is in transit or storage. They have the ability to identify edible plants that are lacking in nutrients and then use nutrient dispensers to provide those nutrients to those plants at just the right time. Nanomaterials have practically limitless potential in the food sector for usage as nanotracers and nanosensors.

Food Safety

Ingesting foods and drinks that contain nanomaterials exposes people to these incredibly tiny particles with a high reactive surface area and whose safety is unclear. After entering the bloodstream through the digestive tract, they have the ability to bioaccumulate in different parts of the body, which could cause harmful consequences. Therefore, the public is concerned about the food industry's use of nanotechnology. Perceived safety is crucial for the public's acceptance of foods and food products that use nanomaterials. "The food industry will only reap the benefits of nanotechnology if issues related to safety are addressed and companies are more open about what they are doing," states an editorial titled "Nanofood for Thought" in the journal Nature Nanotechnology. Concerning the safety of food and animal feed, a scientific group from the European Food Safety Agency issued a statement on nanoscience and nanotechnology in March 2009. In May 2011, a document was published outlining practical recommendations for regulators to follow when evaluating industry applications for engineered nanomaterials in food additives, flavourings, enzymes, novel foods, feed additives, pesticides, novel foods contact materials, and novel foods. The document aimed to help evaluate the risks associated with these applications. A proposed set of rules for the incorporation of nanomaterials into animal feed has been released by the United States Food and Drug Administration (FDA). To guarantee public safety and increase public awareness about the safe use of nanoparticles in our food supply, additional study is needed to evaluate the impact of these materials on human health. There have been reports of various test procedures for evaluating the safety of nanomaterials. But at this time, there are no gold-standard methods for determining if nanoparticles in feed or food are harmful. The International Alliance for Nano Environment, the U.S. National Research Council, and the Harmonisation of Human Health and Safety are among the groups working on such procedures. Animal feed and food both require a standardised worldwide regulatory framework for nanotechnology evaluation.

Conclusion

The food business stands to gain a great deal by implementing nanotechnology. From manufacturing to processing, packaging, transportation, shelf life, and bioavailability, this new technology is influencing the entire food system. As a result of their exceptional qualities, nanoparticles will find increasing commercial use in the food business. Nanomaterials' presence in the human body will only grow. Consequently, the public's primary concern is the potential health effects of nanoparticles in food. For the sake of manufacturing uniformity, customer safety, and possible product benefits, the capacity to measure the nanomaterial across the entire life cycle is essential. Nanomaterials in food and food-related items must be safe for the public to accept them. The use of nanotechnology in food requires a standardised international regulatory framework. Chemical food safety issues involving the toxicants mentioned are major worries for researchers, processors, regulators, healthcare workers, and consumers alike. Consumers' desires for nutritious, flavourful, fragrant, appetising, and healthy products that are not contaminated with toxicants caused by processing will drive future innovations in snack and meal processing technologies. Until new technology emerges, processing foods and snacks using heat and preservatives is essential for ensuring their safety while still meeting nutritional needs and creating tasty snacks. A recent meta-analysis study found that consuming preservative-containing meats (chicken, beef, hog, and lamb) as well as deli meats increased the risk of coronary heart disease (CHD) by 42% and type 2 diabetes mellitus by 19%, although unprocessed red meats did not demonstrate this trend. Research into this area is definitely warranted in order to gain a better grasp of the possible mechanisms behind the impacts that have been reported. In order to better understand health consequences and meet trading requirements, there will be a significant need for toxicological data from national and international regulatory organisations. In order to further decrease toxicant levels in ready-to-eat meals and snacks, research into the creation of new crop types and processing technologies (combining conventional and microwave radiation, for example) should be continued. A number of initiatives have been launched in these domains. Potato growers, processors, and marketers in the United Kingdom, for instance, have banded together to find potato breeding lines and varieties that are low in asparagine and sugar. Finding potatoes with a minimal acrylamide risk while retaining colour and flavour is the goal. Although potato types with reduced sugar levels have been developed, the research on the flavourful potential of foods made from these potatoes is limited. Researchers, food companies, and regulatory bodies are all working together well, and that partnership will only grow. While there is a push to incorporate antioxidant-rich substances into food, little is known about how these nutrients interact with the naturally existing sugars and amino acids in processed meals. There has to be a greater effort to educate and teach people about home cooking through more communication. Ample instances of future directions and trends may be found in recent literature and regulatory measures in the United States, Canada, and the European Union. For instance, it is necessary to prove beyond a reasonable doubt that acrylamide in food causes major health problems. A risk-benefit analysis of the preventative measures should also be conducted. The selectivity, sensitivity, and speed of analysis made possible by micro- and nanotechnologies are driving their increasing application across the board in the food science industry. As a result, their use is likely to become standard in the near future. Food packaging, quality, and safety are three areas where promising results and applications are now under development. Micro- or nano-sized polysaccharides and other natural biopolymers have several potential applications, including the encapsulation of vitamins, prebiotics, and probiotics; drug delivery systems; nutraceuticals; and the creation of "new" food products. We need more studies that weigh the pros and cons of possible outcomes.

Decelerations

Ethics approval and consent to participate

Not Applicable

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Conflicts of Interest

The authors declare no conflict of interest.

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