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Review

The intertwine of nanotechnology with the food industry

Alshammari Fanar Hamad [a], Jong-Hun Han [a], Byung-Chun Kim [b], Irfan A. Rather [a],*

[a] Department of Applied Microbiology and Biotechnology, School of Biotechnology, Yeungnam University, Gyeongsan, Gyeongbuk 712749, Republic of Korea
[b] Probionic Corp. Research and Production Division, Jeonju-si, Jeollabuk-do 54810, Republic of Korea

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ABSTRACT

The past decade has proven the competence of nanotechnology in almost all known fields. The evolution of nanotechnology today in the area of the food industry has been largely and has had a lot of contribution in the food processing, food package, and food preservation. The increasing global human population has come with growing population to be fed, and food production is not adjusted to at par with the growing population. This mismatch has shown the real essence of food preservation so that food products can reach to people on a global scale. The introduction of nanotechnology in the food industry has made it easy to transport foods to different parts of the world by extending the shelf-life of most food products. Even with this beneficial aspect of nanotechnology, it has not been proven an entire full-proof measure, and the field is still open to changing technology. It suffices to note that nanotechnology has to a big extent succeed in curbing the extent of food wastage due to food spoilage by the microbial infestation. Nanotechnology has focused on fresh foods, ensuring a healthier food by employing nano-delivery systems in the process. The delivery systems are the ones, which carries the food supplements. However, these are certain sets of regulations that must be followed to tame or control the health related risks of nanotechnology in food industries. This paper outlines the role of nanotechnology at different levels of the food industry including, packaging of food, processing of food and the various preservation techniques all aiming to increase the shelf life of the food products.
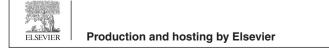
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* Corresponding author.
  E-mail addresses: rather@ynu.ac.kr, erfaan21@gmail.com (I.A. Rather).

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1. Introduction

The quest to improve and devise better food preservation techniques by man has existed since the prehistoric times. This antedates from the times that man used to preserve fresh kill in caves. The caves had a dampened environment which kept the kill fresh for some time. The invention of refrigeration techniques in

Table 1
Summary of the current uses of nanotechnology in food industry (Miller and Senjen, 2008).

Type of product	Product name and manufacturer	Nano content	Purpose
Nutritional supplement	Nanoceuticals 'mycrohydrin' powder, RBC Lifesciences	Molecular cages 1–5 nm diameter made from silicamineral hydride complex	Nano-sized mycrohydrin has increased potency and bioavailability. Exposure to moisture releases H- ions and acts as a powerful antioxidant
Food contact material (crockery)	Nano silver baby mug, baby dream	Nanoparticles of silver	Nano-sized silver particles have increased antibacterial properties
Food packaging	Adhesive for McDonald's burger containers, Ecosynthetix	50–150 nm starch nanospheres	These nanoparticles have 400 times the surface area of natural starch particles. When used as an adhesive they require less water and thus less time and energy to dry
Food packaging	Durethan KU 2-2601 plastic wrapping, Bayer	Nanoparticles of silica in a polymer-based nanocomposite	Nanoparticles of silica in the plastic prevent the penetration of oxygen and gas of the product's shelf life
Nutritional drink	Oat chocolate Nutritional drink mix, Toddler health	300 nm particles of iron (SunActive Fe)	Nano-sized iron particles have increased reactivity and bioavailability
Food contact material (cooking equipment)	Nano silver cutting board, A-Do Global	Nanoparticles of silver	Nano-sized silver particles have increased antibacterial properties

the 21st century then ensued. The use of cellars as well as cold streams were other traditional methods used for food preservation (Alfadul and Elneshwy, 2010). Fermentation and drying existed in the early BCs and what is used today are just improved and modified versions of these concepts (Chellaram et al., 2014). There are a number of popular methods of food preservation that have been used by man in day to day basis including sun drying, roasting, fermenting, salting, smoking, oven baking, carbonation of foods and chemical use or artificial preservatives. The basic working principle behind all these preservation methods rotated around two ideas; slowing down the multiplication of microbial agents or killing them. However, none of the methods were to put use with the complete understanding of the scientific mechanisms behind each of them. There has been evidence of the utilization of these methods of food preservation in the past where the Romans were famous for the introduction and use of pickling for prevention of microbial infestation of the food, while the Egyptians were known for using sun-drying to prevent their foods from spoiling (Abbas et al., 2009). Food jellying by use of honey or sugar was associated with the Greeks as a preservation technique. The first technology innovative breakthrough in preservation techniques came in 1784 by William Cullen who made a crude method of artificial refrigeration. Canning technique and salting of food began in the early 1800s to keep food fresh for a longer period (Abbas et al., 2009). Many scholars in the early 1800s made significant discoveries in preservation techniques; Nicolas Appert, known for the invention of vacuum bottling for the supply of the French troops with food, opened the way for tinning and then canning by Peter Durand in 1810. In 1862, Louis Pasteur introduced pasteurization that enabled wine, beer, and milk to have an extended shelf life. Despite these much improvements, there was the need for a permanent, sustainable and a more reliable solution for the food preservation due to the crude nature of the preservation techniques then which could not keep food for longer.

The word "nano" in simple terms means something small, tiny and atomic in nature (García et al., 2010). The application of "nano" into science led to a field called Nanotechnology. The dynamism of this approach has resulted in nanotechnology being the appeal made by the century. It finds its use in each area of science and technology, and food science has not been left behind. Nanotechnology has had a thriving application in several other sectors, and its application in food science is a recent event. Food safety and quality is something of a great concern and must always be looked into in totality as life lies there. Researchers have found various technologies in an attempt to improve the quality and safety of food. The involvement of nanotechnology in the food industry has led to the production of food with better thermal stability, better solubility, novel, and with higher oral bioavailability (Semo et al., 2007). These elements are all key towards achieving a better and healthy life, the reason why we eat. Incorporation of functional elements in food has been an area of research for a long time, and nanotechnology did pave for it way leading to developments such as nanoemulsions and nanocomposites (Avella et al., 2005). Nanotechnology has proved to serve in the field of food science diligently. From increasing the shelf-life of food product, better tracking and tracing of contaminants, upgraded storage of food, to the incorporation of health supplements or antibacterial agents in food, it is indeed a great contribution by nanotechnology in food science (Neo et al., 2013). The advantages and novelties that have come with nanotechnology application in food science are summarized in Table 1.

The market value of food packaging industry has increased by US$2.5 billion in the year 2012 (Scott and Chen, 2013). Incorporation of nanotechnology has significantly increased the shelf life of foods with better management of spoilage extent of food products. This has solved the food shortage crises by ensuring food reaches to masses. It is pertinent to note that with this technology, the problem of food shortage in some parts of the world can now be solved with a lot of ease. Several forms of nanosystems; solid nanoparticles, nanofibers, nanocapsules are some of the nonmaterial that have found their way in the food processing, packaging, and preservation sectors (Duncan, 2011).

2. Food processing

The preservation of food by use of techniques to a form that it is consumable is a simple definition of food processing. Whatever means is chosen for the preservation, it is important to note that the food quality and flavor should not be interfered with, and should remain as intact as possible. Nutraceuticals incorporation, nutrient delivery, viscosifying and deletion agents, vitamin and mineral fortification as well as flavor nanoencapsulation are some of the ways of food processing with nanomaterial (Huang et al., 2010). Fresh foods are no longer the sole purpose of food processing, production of healthier foods is also an important aspect, which has led to processed foods having micronutrients nowadays an element that has been proved to satisfy many consumers (Weiss et al., 2006).

2.1. Nanoencapsulation

Food processing method aided by nanocapsules has several benefits: it is simple to handle, protects against oxidation, improves stability, its ability to retain the highly volatile ingredients, it makes taste, has a control release triggered by moisture, continuous delivery of multiple active ingredients, pH-triggered controlled release, its organoleptic perception last for a longer duration, and has an increased bioavailability (Chaudhry et al., 2008). Nanocapsules ensures food preservation as it entraps odor and any other unwanted component in food as it delivers the component to the target. Nanocapsule ability to carry its component through the gut, which in this case, is the food supplement that ensures the bioavailability of the component. It can also be utilized for the delivery of lipophilic health supplements, vitamins and minerals, in food in the process enhancing the nutrient content of the food (Dreher, 2004). Encapsulation ensures the hidden component navigate even in unfavorable conditions to be delivered at the target.

2.2. Nanoemulsions

Nanoemulsions are utilized in the production of food products for sweeteners, flavored oils, salad dressing beverages, as well as other processed foods. The operation is by the release of different flavors with several stimulants such as heat, pH, ultrasonic waves and many others (Kumar, 2000). They efficiently retain the characteristics and prevent them from enzymatic reactions as well as oxidation. Nanoemulsions have several advantages over the conventional emulsions, as they are thermally stable, and are smaller in size. Due to their large surface area, nanoemulsions can interact with a number of biological components such as enzymes in the gastrointestinal tract (GIT). For example, lipase readily digests the smaller droplets of nanoemulsions in GIT (Zarif, 2003). In addition, nanoemulsions in the form of carbohydrates or proteins have improved the texture that aids in ice cream uniformity (Hogan et al., 2001). Nanoemulsions are well-known to contain antimicrobial agents, which are more efficient on Gram-positive bacteria. Due to this reason, nanoemulsions have been used for decontamination purposes of food packaging articles (Wang et al., 2012). Nanoemulsions made from tributyl phosphate, soybean or nonionic surfactants have been used to check microbial growth hence reducing the extent of food-spoilage. (Sanguansri and Augustin, 2006).

3. Food packaging and food preservation

Food packaging procedures and practices ensure that the quality of food remains intact and are safe for consumption. Packaging provides physical protection keeping food products safe from external interference, temperature, and microbial infestation by eliminating oxygen and other gases that may lead to food spoilage. Nanotechnology has put into place certain specific areas under packaging that have reduced environmental pollution through employing biodegradable materials for packaging. The introduction of antimicrobials, plastics with high barriers, and measures for detection of contaminants are some areas nanotechnology has addressed during packaging. Food treatment and handling to prevent the loss of its characteristics is referred to as food preservation. Freezing, drying, and canning is some of the conventional ways of food preservation. However, nanotechnology has come with better and more reliable techniques to help in food preservation such as use of nanosensors (Kang et al., 2007a,b; Biswal et al., 2012; Senturk et al., 2013; Su et al., 2013), nanocomposites (Yotova et al., 2013; Davis et al., 2013; Thirumurugan et al., 2013), and nanoparticle in packing (Horner et al., 2006; Acosta, 2009; Bouwmeester et al., 2009).

3.1. Nanosensors

Nanosensors assist in the detection of any subtle changes in food color as well as any gasses produced due to spoilage. In addition, nanosensors have a high sensitivity and selectivity to these changes making them more efficient than the conventional methods of sensors (Mannino and Scampicchio, 2007). The gas sensors are made of gold, platinum, and palladium. Aflatoxin B1 toxin that is found in milk can be detected by the gold-based nanoparticles (Mao et al., 2006). In some cases, the packaging is made of DNA and single walled carbon nanotubes that greatly improves the sensitivity of the sensors. The field of agriculture can also put to use the nanosensors where pesticides on the surface of vegetables and fruits can be detected. Some nanosensors have also been used to identify carcinogens in food materials (Meetoo, 2011).

3.2. Nanocomposites

A combination of nanoparticles with polymers makes the nanocomposites. Nanocomposites reinforce the polymers in the combination thus enhancing the property. The high versatility of the chemical functionality of nanocomposites makes them suitable for the development of high barrier properties (Pandey et al., 2013). Nanocomposites aid in maintaining the food products fresh for some amount of time irrespective of the bacterial infestation of the food product. They minimize carbon dioxide leakages from carbonated beverages bottles by acting as gas barriers (Pandey et al., 2013). It thus increases the shelf life of the product. Manufacturing industries could use nanocomposites in place of cans and glass bottles to layer their bottles and save on cost in the process. Enzyme immobilization, a type of nanocomposite is widely used due to its faster rates of transfer and its large surface area. The enzymes are incorporated into the nano-clays and used for packaging (Burdo, 2005).

3.3. Nanoparticles

One of the important advantages of nanoparticles in food processing is upgrading food stability, color, and property of flow. Previously, nanoparticles were used for drug delivery; now they are used in similar fashion in the food industry. Their effectiveness depends on their bioavailability. Silicate and other nanoparticles are used to limit oxygen flow in packaging containers (Jones et al., 2008); moisture leakage is also checked and reduced hence the food remains fresh for a longer duration. Certain nanoparticles exist that selectively bind to pathogens thus removing them altogether in the process (Nam et al., 2003).

4. Future prospectus

The nanosystems that have been put into place are at the onset of their use in food industry, this has been viewed as challenges, but this is quite expected in any system at an early stage. The future lies with researchers developing better and sufficient nanocarriers with increased bioavailability and not compromising the taste, quality or appearance of food while incorporation of carriers goes on. The idea of smart packaging should be fully exploited where the markers of antigen-specific are used to make films of polymer nanocomposite via nanoparticles incorporation and food packaging (Cho et al., 2008). The antigen-specific markers will help detect and isolate the organism responsible for spoilage. The new nanosystems being applied should all focus on achieving environment-friendly status as well as have minimal toxic effects to the consumers and the food.

5. Conclusion

The intervention of nanotechnology in the food industry has brought a number of changes in food packing, preservation, and processing. These changes have significantly increased the shelf life of foods with better management of spoilage extent of food products. This has solved the food shortage crises by ensuring food reaches to masses. It is pertinent to note that with this technology, the problem of food shortage in some parts of the world can now be solved with a lot of ease.

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