BIOCHIP JOURNAL, Vol. 2, No. 3, 183-185, September 2008

Mini Review

Some Cases in Applications of Nanotechnology to Food and Agricultural Systems

Yong-Jin Cho[1], Chul-Jin Kim[1], Namsoo Kim[1], Chong-Tai Kim[1] & Bosoon Park[2]

[1]Food Nano-Biotechnology Research Center,
Korea Food Research Institute, Seongnam 463-746, Korea
[2]USDA, ARS, Russell Research Center, Athens, GA 30605, USA
Correspondence and requests for materials should be addressed to Y.-J. Cho (yjcho@kfri.re.kr)

Accepted 14 August 2008

Abstract

Food nanotechnolgy is an emerging technology. Many scientists and engineers have recognized well the potential of nanotechnology to lead all the industries in the 21st century. Even though successful applications of nanotechnology to foods are still limited, some basic concepts based on nano-scale have been established well. In food engineering field, two major applications related to nanotechnology, that is, food nano-sensing and food nano-structured ingredients are being expected. In the former field, better food quality and safety evaluation can be achieved by using nanotechnology. In the latter, food processing can be largely improved in the aspects of solubilization, delivery and color in food systems. Meanwhile, food nanotechnolgy as a new technology is requiring reviews of potentially adverse effects as well as many positive effects.

Keywords: Food nanotechnology, Food safety and quality, Functional food

Introduction

Since the application of nanotechnology to the agricultural and food industries was first addressed by USDA roadmap in 2003, the nanotechnology would transform the entire food industry, changing the way food is produced, processed, packaged, transported, and consumed. A recent study predicts that the nanofood market will grow from $2.6 billion to $20.4 billion by 2010 and the largest market for Nanofood in the future will be Asia[1].

Nanotechnology has the potential to revolutionize the agricultural and food industry with new tools for the molecular treatment of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients etc. Smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens. In the near future nanostructured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used. Nanotechnology will also protect the environment indirectly through the use of alternative (renewable) energy supplies, and filters or catalysts to reduce pollution and clean-up existing pollutants[1-3].

In a similar strategy to ensure food safety, researchers have developed a portable nanosensor to detect chemicals, pathogens and toxins in food. This circumvents the need to send samples to laboratories (which is both costly and lengthy), allowing food to be analyzed for safety and quality at the farm, abattoir, during transport, processing or at the packaging plant. The project is also developing a device using DNA biochips to detect pathogens- a technique that could also be applied to determine the presence of different kinds of harmful bacteria in meat or fish, or fungi affecting fruit. The project also has plans to develop microarray sensors that can be used to identify pesticides on fruit and vegetables[8].

Herein, some cases in applications of nanotechnology to food and agricultural systems, which were from the ongoing project by Korea Food Research Institute and USDA ARS Russell Research Center, were described briefly.

Potential Nanotechnology Applications in the Food Industry

Nanotechnology is an enabling technology that has the potential to revolutionize the food industry. Nanotechnology can be applied to develop nanoscale materials, controlled delivery systems, contaminant detection and to create nanodevices for molecular and cellular biology. Nanotechnology can provide for the future development of far more precise and effective methods of, and other forms of, manipulation of food polymers and polymeric assemblages to provide tailor-made improvements to food quality and food safety. Nanotechnology promises not only the creation of novel and precisely defined material properties, it also promises that these materials will have self-assembling, self-healing and maintaining properties[1-3].

Among several potential nanotechnology application of pathogenic bacteria or food toxin detection, followings are most promising food nanotechnology, which are bio-functional nanorods for food pathogen detection; surface enhanced Raman spectroscopy (SERS) for bacterial detection; single molecule detection for food toxin[8].

Nanotechnology for Food Safety and Quality

Early detection of biological and chemical contaminants such as pathogenic bacteria and/or toxin in food systems is potential application of nanotechnology. The exciting possibility of bionanotechnolgy into sensors holds the potential of increased sensitivity and a significantly reduced response-time to sense contaminants. Nanobiosensors utilize nanoparticles, which conjugated fluorescent bio-markers with different colors. These nanoparticles are then able to selectively bind themselves to various food pathogens. The advantage of such a system is that literally hundreds and potentially thousands of nanoparticles can be placed on a single nanobiosensor to rapidly, accurately and affordably detect the presence of any number of different bacteria and pathogens. The application of nanotechnologies on the detection of pathogenic organisms in food and the development of nanosensors for food safety is being studied by research group of USDA, ARS and University of Georgia. The focus of the research performed at USDA-UGA is on the development of rapid method for the detection of food pathogens with nanoscale sensing technology[4,5,8].

Research group in Athens, GA has developed bio-functionalized nanosubstrates to detect food pathogenic bacteria. In this study, they present a rapid and sensitive *Salmonella* detection method. Heterostructured Silicon/gold nanorod array fabricated by glancing angle deposition method is functionalized with anti-salmonella antibodies and organic dye molecules. Due to the high aspect ratio nature of the Si nanorods, dye molecules attached to the Si nanorods produce an enhanced fluorescence upon capture and detection of *Salmonella*. This bio-functional hetero-nanorod detection method has great potential in the food safety industry as well as in diagnostics[5].

Recently, highly sensitive sensors based on nanostructures and their unique physical or chemical properties have emerged and have shown great potential for pathogen detection. Some of these methods include detections by luminescence using quantum dots, localized surface plasmon resonance of metallic nanoparticles, enhanced florescence, dye immobilized nanoparticle, or Raman reporter molecule immobilized metallic nanoparticles. All the nanostructures used for the biosensing applications have two characteristics: first, they contain certain recognition mechanisms specified to the analyte, for example, antibodies or enzymes, and second, they are able to generate a distinguishing signal from the analyte. This signal could be generated by the nanostructures themselves or produced by signaling molecules immobilized or contained in the nanostructures. For single component nanostructure, it can be difficult to immobilize the recognition molecules and signaling molecules simultaneously. Hetero-nanostructure provides a promising platform to solve this problem. Using a hetero-nanostructured platform, different functional molecules can be immobilized to the different parts of the hetero -nanostructure to enhance selectivity and specificity of detection. In this study, we show that Au/Si "matchstick" nanorods used as a scaffold can be functionalized for conjugation with anti-*Salmonella* antibodies and a fluorescence dye (Alexa 488) to rapidly and sensitively detect *Salmonella*[5,8].

The researchers have developed diagnostic methods for rapid and sensitive identification of food pathogenic bacteria such as E.Coli O157 : H7, Salmonella, Staphylococcus as well as viruses and other biomedical pathogens. Since current diagnostic methods for bacteria in particular, e.g. isolation, PCR, antigen detection and serology, are time-consuming, cumbersome, or lack of sensitivity, new method using nanotechnology with aligned Ag nanorod arrays, prepared by oblique angle vapor deposition (OAD), as surface-enhanced Raman scattering (SERS) substrates was potential for the identification and quantization of food pathogens. The OAD method of substrate preparation facilitates the selection of nanorod size, shape, density, alignment, orientation, and composition, while the procedure is reproducible and relatively simple to implement. This nanotechnology method addresses the fundamental nanostructural design of metallic nanorod arrays and their influence on SERS enhancement, as well as the development of a spectroscopic biosensor assay for bacteria detection based on these unique nanostructured SERS probes. They presented results of multivariate statistical analyses on the SERS spectra of different viral and bacterial species that indicate that it is possible to identify, differentiate and classify bacteria and other pathogens based on their intrinsic SERS spectra, even down to the strain level[8].

Since atomic force microscope (AFM) was first invented by Binning *et al*. in 1986, it was widely applied; and its application is extraordinarily attractive in molecule biology study. Recently, a derivative technique based on AFM, single molecular recognition force microscopy (SMRFM) plays an important role for nanotechnology by combining chemical force microscope and Magnetic AC imaging mode. Through the SMRFM, both surface image and the interaction force information could be obtained. For the SMRFM, tip modification is extremely important, since it directly determines the quality of the image and probability of the force measurement. Various methods have been applied to chemically functionalize AFM tips. Those are three main classes: silanization of tip surface; hydrosilylation of tip surface and polymerization; and SAM on metal coated tip surface. After the tip modification, the PEG (poly ethylene glycol) cross-linker is further grafted to the functionalized surface followed by the target molecule bonds with the cross-linker[8].

Nanotechnology for Functional Food Applications

Nanotechnology also promises to provide a means of manipulating food products to more effectively and efficiently deliver nutrients, proteins and antioxidants to precisely target nutritional and health benefits to a specific site to enhance their efficacy and bioavailability. The use of nanotechnology includes encapsulating necessary nutrients, flavors and colors and releasing them properly in a timely manner as well as prolonging release time. This capability of nanotechnology is able to benefit functional food industry as well as regular food and nutraceutical food industry[4].

Nanopaticles, nanoemulsions, nanocomposites and nanostructured materials are typical applications of nanotechnology to nutraceuticals and functional foods, ingredients of which come in different chemical and physical forms. These nanotechnology based forms pursue active control in food delivery systems. If, in food systems, amphiphilic nano-materials which have both polar and nonpolar porperties are dispersed in a polar solvent like water, spontaneous self-assembling happens due to hydrophobic interactions. These nano-structured systems which include micelles, nano-liposomes, lamellar structures and so on are rich arrays of thermodynamically stable phases[4].

Biopolymers which include proteins and polysaccharides in food grade can produce biopolymeric nanoparticles. A single biopolymer like BSA-chitosan, ovalbumin-chitosan or β-lactoglubulin-chitosan can be used to separate into smaller nanoparticles, using self-association by aggregation and segregation. In a certain environment, food functional ingredients can be encapsulated into the form of biopolymeric nanoparticles and they can be released in a distinct environment. Nano-encapsulations with functional ingredients such as resveratrol, capsaincin, lycopene and others have been reported as successful applications of nanoemulsions. There are many different methods to produce nanoparticles. Among them, reverse micelles, RESS (rapid expansion of supercritical solution), and SAS (supercritical anti-solvent) are being mainly used to manufacture food nanoparticles[6,7].

In food ingredients, an effect of size on food functionality may be expected. Actually, lycopene with smaller size showed better food functionality. However, food nanotechnolgy as a new technology is requiring reviews of potentially adverse effects as well as many positive effects[2].

Acknowledgements

This study was carried out as part of the research project of “Development of Food Nanotechnology”, Korea Food Research Institute, Republic of Korea.

References

1. Cho, Y.J. *et al*. Future Demand in Technology Development Program for Agriculture and Forestry (Vol. 3 Agro-Nanotechnology Development). Research Report, Agriculture R & D Promotion Center (2006).
2. Cho, Y.J. Overview on current and future food nanotechnology. Invited Lecture in The 74th Annual Meeting of Korean Society of Food Science and Technology, BEXCO, Busan (2007).
3. Cho, Y.J. Food nanotechnology: present and perspective. *Food Engineering Progress* **11**, 145-152 (2007).
4. Cho, Y.J. *et al*. Development of Food Nanotechnology. Research Report No. E071000, Korea Food Research Institute (2007).
5. Fu, J. *et al*. Au/Si hetero-nanorod-based biosensor for Salmonella detection. *Nanotechnology* (on-line version) **19**, 155502 (2008).
6. Kim, C.T. *et al*. Preparation of nanoemulsions and nanoaprticles as delivery systems for bioactive ingredients in food. Proceedings of Particles 2007, 42 (2007).
7. Kim, C.T. *et al*. Novel fabrication technology of food nanoemulsions. *Food Science and Industry* **41**, 33-45 (2008).
8. Park, B. Nanobiosensor for foodborne pathogenic bacteria detection. Proceedings of Nano Korea 2008, 165-167 (2008).