

# Food decontamination using nanomaterials

## Introduction

Food contamination is a major concern in many countries because it can cause fatal illnesses. *Salmonella*, *Escherichia coli O157:H7*, *Staphylococcus aureus*, *Clostridium*, *Campylobacter* and *Listeria monocytogenes* are common agents for food contamination in the United States.<sup>1</sup> In 2011, the Food Safety Modernization Act (FSMA) was signed by the U.S. President to prevent food borne illness in 48 million Americans. According to the FSMA, the US Food and Drug Administration (FDA) will have mandatory science-based preventive controls across the food supply. Physical, chemical, or biological technologies are being applied for food decontamination.<sup>2,3</sup> The selection of a certain technology depends on its efficacy in removing certain pathogens to the safe level, the sensory quality of the final product as well as energy efficiency and cost.<sup>3</sup> Combination of more than one technology could synergistically work better and result in greater antimicrobial effect than any single treatment.<sup>2</sup> However, process costs and operational complications are limiting factors for such combination. New disinfection methods and media are needed to overcome the disadvantages of the current technologies.<sup>3</sup> Nanomaterials are emerging and promising fungicidal, algicidal, and bactericidal media that could be applied for the disinfection of food products. The objective of this article is to review the potential use of nanomaterials for the decontamination of food materials and to define potential research needs for the application of nanomaterials as food decontaminants.

## Nanoparticles for food decontamination

Nanoparticles are particles with sizes ranged from 1 to 100 nanometers in at least one dimension.<sup>4</sup> They have high reactivity due to their large surface area to volume ratio and therefore they are used as antibacterial agents in aqueous and solid media.<sup>5</sup> Nano-iron was used as a health supplement and water decontamination agent to breakdown contaminant and kill microorganism<sup>6</sup> Zhan<sup>7</sup> applied amine modified magnetic nanoparticles ( $\text{Fe}_3\text{O}_4\text{-SiO}_2\text{-NH}_2$ ) for rapid removal of both pathogenic bacteria and viruses from water. Silver nanoparticles (AgNPs) are widely used in pharmaceuticals, cosmetics, medical devices, foodware, clothing and water purification due to their antimicrobial properties and low toxicity toward mammalian cells.<sup>4,8</sup> To our knowledge little has been done to use nanoparticles as antibacterial coatings for food materials including grains and nuts. Nawrocka et al.,<sup>9</sup> used AgNPs as antipathogen coating for wheat grains. No information was presented on the bacterial species and the reduction potential of AgNPs.

## Nanoemulsions for food decontamination

Nanoemulsions are dispersions of droplets of one liquid in another immiscible liquid with length scales in the range from 1 to 100nm.<sup>10,11</sup> They can be made of food-based, non-toxic, and non-corrosive materials. Compared with conventional emulsions, nanoemulsions have high physical stability, high bioavailability and low turbidity. Therefore, they are attractive systems for food, cosmetics and pharmaceutical industries.<sup>12</sup> They are effective in the inactivation of gram-negative bacteria, bacterial spores, enveloped viruses, and fungal spores.<sup>13</sup> They can be used for surface decontamination of food packaging equipment and chicken skin.<sup>14</sup> Nanomicelle-based

Volume 1 Issue 2 - 2015

Hamed ME,<sup>1</sup> Mashad,<sup>1,2</sup> Zhongli Pan<sup>1,3</sup><sup>1</sup>Department of Biological and Agricultural Engineering, University of California, USA<sup>2</sup>Agricultural Engineering Department, Mansoura University, Egypt<sup>3</sup>HealthyProcessed Foods Research Unit, Western Regional Research Center, USA

**Correspondence:** Hamed ME Mashad, Agricultural Engineering Department, Mansoura University, Egypt, Email [heelmashad@ucdavis.edu](mailto:heelmashad@ucdavis.edu)

**Received:** June 10, 2015 | **Published:** July 27, 2015

product, containing natural glycerin, was used to remove pesticide residues from fruits and vegetables.<sup>6</sup> Up to 3 log (10) CFU/g (99.9%) reductions in *L. monocytogenes*, *S. Typhimurium* and *E. coli O157:H7* could be obtained after dipping samples in oregano nanoemulsions (0.05% or 0.1%) for one minute and storing samples at 4°C for 72hr.<sup>15</sup> Diluted food-grade basil oil nanoemulsion showed at least 40% reduction of pure *E. coli* culture after 60min.<sup>12</sup>

## Mechanism of bacteria inhibition by nanomaterials

Several mechanisms have been discovered for the effect of nanomaterials on the inhibition of microorganisms. The inhibitory effect of nanoparticles (e.g., AGNPs) could be due to the release of free Ag<sup>+</sup> that could:

- Deactivate cellular enzymes and DNA by coordinating to electron-donating groups such as thiols, carboxylates, amides, imidazoles, indoles, hydroxyls sensitivity.<sup>16</sup>
- Disrupt membrane permeability, and ultimately leading to cell lysis and death,<sup>8,17</sup> and/or
- Penetrate bacterial cell and turn DNA into a condensed form and at the same time react with cell proteins causing the damage or the death on the microorganisms.<sup>16</sup> Nanoemulsions fuse with cell membrane of microorganisms causing cell lysis.<sup>13</sup>

## Risk on nanomaterials

No evidence of unusual toxicity effects of nano emulsions and micelles could be determined in both experimental animals and humans. There is a dearth of information on the safety and potential effects of different nanoparticles to human and animal, using chronic oral exposure to nanoparticles combined with a broad screen.<sup>6</sup> No data on possible genotoxicity, carcinogenesis and teratogenicity, is available for most of the available nanoparticles.<sup>18</sup>

## Conclusion

Nanomaterials including nano emulsions are promising decontamination media for the reduction of food contaminating pathogens. The main challenges for the application of nano

emulsions in food systems are the production cost, product safety and acceptance.<sup>19</sup> Nanoparticles could be applied as antimicrobial coatings for grains and nuts. However, they should have combined desirable attributes such as potent antibacterial efficacy, low toxicity, environmental safety and ease of manufacturing.<sup>17</sup> There is a need to study the effect of different nanomaterials on the decontamination of different food materials. Moreover, there is a need to compare the efficacy of the nanomaterials and other chemicals and technologies for the decontamination of grains, nuts and fresh produce. There is also a need to study the effect of using nanomaterials as carriers of conventional disinfection chemicals so that it could be possible to reduce the chemicals doses used in food disinfection applications.

## Acknowledgements

None.

## Conflict of interest

The author declares no conflict of interest.

## References

1. Mead PS, Slutsker L, Dietz V, et al. Food-related illness and death in the United States. *Emerg Infect Dis.* 1999;5(5):607–625.
2. Ricke SC, Kundinger MM, Miller DR, et al. Alternatives to antibiotics: chemical and physical antimicrobial interventions and foodborne pathogen response. *Poult Sci.* 2005;84(4):667–675.
3. Pan Z, Bingol G, Brandl MT, et al. Review of current technologies for reduction of Salmonella populations on almonds. *Food and Bioprocess Technology - An International Journal.* 2012;5(6):2046–2057.
4. Zhang H. *Application of Silver Nanoparticles in Drinking Water Purification.* University of Rhode Island; 2013. 29 p.
5. Guzmán MG, Dille J, Godet S. Synthesis of silver nanoparticles by chemical reduction method and their antibacterial activity. *International J Chem Biol Eng.* 2009;2(3):104–111.
6. FAO/WHO. *Expert meeting on the application of nanotechnologies in the food and agriculture sectors: potential food safety implications.* Meeting report. Rome; 2010. p. 1–109.
7. Zhan S, Yang Y, Shen Z, et al. Efficient removal of pathogenic bacteria and viruses by multifunctional amine-modified magnetic nanoparticles. *J Hazard Mater.* 2014;274:115–123.
8. Choi O, Deng KK, Kim NJ, et al. The inhibitory effects of silver nanoparticles, silver ions, and silver chloride colloids on microbial growth. *Water Res.* 2008;42(12):3066–3074.
9. Nawrocka A, Cieśla J. Influence of silver nanoparticles on food components in wheat. *Int Agrophys.* 2010;27:49–55.
10. Mason TG, Wilking JN, Meleson K, et al. Nanoemulsions: formation, structure and physical properties. *J Phys: Condens Matter.* 2006;18:635–666.
11. McClements DJ. Edible nanoemulsions: fabrication, properties, and functional performance. *Soft Matter.* 2011;7:2297–2316.
12. Ghosh V, Mukherjee A, Chandrasekaran N. Ultrasonic emulsification of food-grade nanoemulsion formulation and evaluation of its bactericidal activity. *Ultrasonics Sonochemistry.* 2013;20(1):338–344.
13. Nanoemulsions. Centre for Biologic Nanotechnology Available from: (Accessed June 2015); 2015.
14. Sekhon BS. Food nanotechnology-an overview. *Nanotechnol Sci Appl.* 2010;3:1–15.
15. Bhargava K, Conti DS, da Rocha SR, et al. Application of an oregano oil nanoemulsion to the control of foodborne bacteria on fresh lettuce. *Food Microbiol.* 2015;47:69–73.
16. Feng QL, Wu J, Chen GQ, et al. A mechanistic study of the antibacterial effect of silver ions on Escherichia coli and Staphylococcus aureus. *J Biomed Mater Res.* 2000;52(4):662–668.
17. Sambhy V, MacBride MM, Peterson BR, et al. Silver bromide nanoparticle/polymer composites: dual action tunable antimicrobial materials. *J Am Chem Soc.* 2006;128(30):9798–9808.
18. Bouwmeester H, Dekkers S, Noordam M, et al. Health impact of nanotechnologies in food production. *Report.* 2007;2007:014.
19. Silva HD, Cerqueira MA, Vicente AA. Nanoemulsions for food applications: development and characterization. *Food Bioprocess Technol.* 2012;5(3):854–867.