Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 6, Issue, 08, pp.8032-8035, August, 2014

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

REVIEW ARTICLE

NANOPARTICLES: A DELIVERY SYSTEM FOR BIOACTIVE FOOD COMPONENTS

*[1]Umar Garba, [2]Aminu Shehu Abubakar and [3]Muhamammad Said Bashir

[1]Department of Food Technology and Nutrition, Lovely Professional University Phagwara, Punjab, India
[2]Department of Agronomy, Lovely Professional University Phagwara, Punjab, India
[3]Department of Biotechnology, Lovely Professional University Phagwara, Punjab India

ARTICLE INFO

Article History:
Received 14th May, 2014
Received in revised form
20th June, 2014
Accepted 20th July, 2014
Published online 31st August, 2014

Key words:
Nano particles,
Bioactive food components,
Nanoemulsion,
Solid lipid nanoparticles,
Nanoencapsulation

ABSTRACT

The delivery systems of bioactive food components through nanoencapsulation provide maximum stability, protection and permit the release of encapsulated compound during mastication and digestion for efficient absorption into the body system. Bioactive compounds are secondary metabolite of plant which forms the constituent of foods or dietary supplements responsible for the health benefit other than provision of basic nutrition. They are grouped into isoprenoids, fatty acids, proteins and amino acids, polysaccharides and minerals. These compounds are found useful in treating coronary heart diseases, inflammation, immune disorder, and psychiatric disorder etc. The use of nanoparticles to deliver a bioactive compound provides greater advantage due to their greater surface to mass ratio and their ability to absorb and carry the compounds to the required destination with minimal destruction, increased absorption and bioavailability. However, the fate of the bioactive compounds depends on its physicochemical properties and release site. Depending on the compatibility of the target bioactive compound, nanoparticles properties and the required application, the delivery system has been grouped as either solid (including lipid nanoparticles, nano-crystals, and polymeric nanoparticles) or liquid system (nanoemulsions, nanoliposomes, and nanopolymersomes).

INTRODUCTION

The word Nanoparticles (NPs) is derived from the Greek word "nano" which denotes a factor of 10^{-9} and the technology dealing with these materials is called nanotechnology. Nanotechnology, according to the National Nanotechnology Initiative (NNI) and the National Science Foundation (NSF, USA) is defined as the ability to understand, control, and manipulate matter at their individual atomic and molecular levels, as well as the "super-molecular" level (ranging from 0.1 to 100nm) of cluster molecules, in order to produce materials, devices, and systems with new properties and functions. Nanoparticles exhibit unique features which significantly differ from that of their macroscopic or bulk counterparts. They have the capacity to work at the molecular level, atom by atoms, thereby forming a large structure with new molecular organisation (Misra *et al*., 2013). The greater surface to mass ratio of NPs as compared to other particles, the quantum properties and the ability to absorb and carry other compounds (such as drugs, probes and proteins) make them more increasingly attractive for medical purposes (Jong and Borm, 2008). Inclusion of bioactive compounds in diet has been clinically proved to have health benefits (Lasoń, 2011), and offers many benefits to the consumer such as increase absorption, uptake and improved nutrients and supplements bioavailability. It also has the potential to change the distribution of substances in the body (FAO/WHO, 2010). Bioactive food components are constituent of food or dietary supplements responsible for health benefit other than basic nutrition. They are categorised in to groups which composed of isoprenoides (carotenoides, saponines, tocotrienoles, tocopheroles), fatty acids (monounsaturated fatty acid, poly unsaturated fatty acid, ω-3, and conjugated linolic acid), phenolic compounds (flavonoles, flavonones, anthrocyanines, lignins,tannins), proteins and amino acids (isothiocynatte, allyl-S components, capsaicinoides) polysaccharides (ascorbic acid, oligosaccharides) and minerals (Weiss, 2008a).

Nanotechnology has contributed significantly to the development of nanometric delivery systems, which allow encapsulation of bioactive materials in nano-size particles to combat the problem of deterioration during processing and increase activity by enhancing the mass transfer rate to the required active areas (Gökmen, 2013). Nanoencapsulation is important as it give protection to sensitive bioactive food components against oxidation, enzyme degradation and pH before reaching the target. Discomfort due to consumption of unpleasant taste bioactive material is also eliminated (Fathi *et al*., 2012). This delivery system of bioactive food components is achieved through the use of carbohydrate, protein or lipid.

Corresponding author: Umar Garba,
Department of Food Technology and Nutrition, Lovely Professional University Phagwara, Punjab, India.

However lipid based nanocarrier system predominates due to the different complicated chemical or heat requirements involved in the use of protein or carbohydrate (Fathi *et al*., 2012). The new approach is now attracting more attention from researchers (Misra *et al*., 2013) and is advantageous as it is use to prevent chemical degradation of functional ingredients through encapsulation with droplets of nano-emulsion (McClements and Decker, 2000).

Bioactive compounds such as carotenoid, omega-3 fatty acids, phytosterols, are some of the major component of functional foods important in improving health and well being of consumers. Incorporation of these components into the food system however, require the design of a technical encapsulation matrix capable of providing maximum stability, protection and also permit the release of encapsulated components during mastication and digestion for efficient absorption into the body system (Weiss *et al*., 2008b). These components have been found effective against coronary heart diseases, inflammation, and immune and psychiatric disorders etc when incorporated in the diet (Gökmen, 2013). Though, components such as carotenoid are highly dependent on the carrier and unstable when isolated from plant or animal sources; their lipophilic nature leads to low absorption and limited bioavailability in human beings. Solid lipid nanoparticles are found to be the best solution to this problem (Lasońq, 2011). The fate of bioactive compounds depends on its physicochemical properties and release site (Borel *et al*., 2014).

Delivery systems for bioactive components

There are a lot of researches going on to exploit the used of food-grade nanodispersion such as nanoemulsion and solid lipid nanoparticles in delivering bioactive lipophilic food components. The system has been classified as either solid or liquid, each of which provides a distinct advantage, depending on the compatibility of nanoparticles properties with that of the bioactive compounds and the intended application. The solid nanodelivery systems include lipid nanoparticles, nano-crystals, and polymeric nanoparticles, while the liquid systems include nanoemulsions, nanoliposomes, and nanopolymersomes (Borel *et al*., 2014).

Solid based nanoparticles delivery Systems

Solid lipid nanoparticles

A solid lipid nanoparticles (SLN) are novel encapsulation system initially developed in the pharmaceutical industries to deliver bioactive compounds (Weiss *et al*., 2008b; Qian, 2013). They composed of a core of solid lipid with bioactive material having part of the lipid matrix. Such particles are stabilized using surfactant layer or a mixture of surfactants (Lasoń, 2011). It is formed by homogenisation at temperature (≈ 80°C) above the melting point of lipid phase (tripalmitin), followed by cooling the water-in-oil emulsion to obtain the crystallized nanoemulsions with the dispersed phase being composed of a mixture of solid carrier lipid bioactive components (Weiss *et al*., 2008; Qian, 2013). Yang *et al*. (2014) developed a delivery system for lipophilic bioactive compounds at ambient temperature using high pressure homogenization from barley protein nanoparticles. In this preparation, no organic solvents or cross linking agents were involved. At a protein weight concentration of up to 5% and oil/protein ratio maintained within the range of 1 to 1.5%, an optimum nanoparticles with regular spherical shape, small size (90- 150nm) and narrow size distribution (PDI <0.3) were achieved. The nanoparticles show high zeta-potential (about -35mV), high payload (51.4 – 54.5%) and good stability without the use of surfactants. Although the bulk protein matrices degraded in the simulated gastric tract, during the release test, smaller nanoparticles were released and bioactive compounds were protected by a layer of barley protein. *In vitro* studies revealed that barley protein nanoparticles are relatively safe and could be internalized by caco-2 cells and built up in the cytoplasm.

Nanostructured lipid carrier (NLC)

Nanostructured lipid carriers are delivery system for partially crystallized lipid particles (having mean radii of at most 100 nm) dispersed in an aqueous phase of emulsifier. Important nutraceutical are delivered using this system with high drug loading, encapsulation efficiency and stability. The size and physical state of the solid phase present the most influencing performance of lipid dispersions. NLC dispel the limitation of poor water-solubility, chemical instability, and low bioavailability encountered during fortification of aqueous-based foods with nutraceutical ingredients. Thus, nanostructured lipid carrier can be a substitute to other nanocarrier and can be suitable for application in food and beverages (Tamjidi *et al*., 2013).

Liquid based nanoparticle delivery systems

Nanoemulsion

Nanoemulsions are isotropic system comprising of two immiscible liquid (such as oil and water) mixed to form a single phase of clear dispersion and stabilized using desirable surfactants. Nanoemulsions are thermodynamically stabled with droplets sizes in the range of 20-200 nm (Shah *et al*., 2010; Haritha *et al*., 2013; Chouksey *et al*., 2011). The thermodynamical stability makes nanoemulsion to require little energy input and possesses a long shelf life (Chouksey *et al*., 2011a). The small size droplet of nanoemulsion makes it look transparent and its stability is enhanced by Brownian motion which plays important role in preventing creaming (Fernandez *et al*., 2004). A distinguishing feature of nanoemulsion is their ability to retain droplets size distribution even upon dilution with water compared as opposed to microemulsion (Fathi *et al*., 2012). To prevent the droplet from recombining into larger droplet, a thin encapsulating layer can be introduced to stabilize the system. This layer is made up of proteins or phospholipids acting as surfactant (Sanguansri and Augustin, 2006). Nanoemulsions are dispersion of nanoscale droplet formed by mixing two immiscible phases, by the application of great shear force. The rupture of this droplet can be possible by application of ultra-sonication or micro fluidisation. Higher amount of surfactant is required to stabilise the nanoemulsion (Augustin and Hemar 2009).

Nanoemulsions have been grouped, depending on the constituent materials involved, into oil in water, water in oil or bi-continuous. Bi-continuous carries interdispersed micro domains of oil in the system (Haritha *et al*., 2013). A number of approaches have been reported in the production of nanoemulsion, some of which include phase inversion technique, sonication method, higher pressure homogenization, micro fluidization and spontaneous emulsification (Depnath *et al*., 2011; Haritha *et al*., 2013; Shah *et al*., 2010). The initial stage of nanoemulsion preparation is the selection of the suitable oil phase on which other components depend upon. Oil with a good solubilisation potential is imperative. The choice of surfactant follows and this plays a major role. This could be either ionic or anionic; however the use of ionic surfactant is discouraged due to toxicity effects.

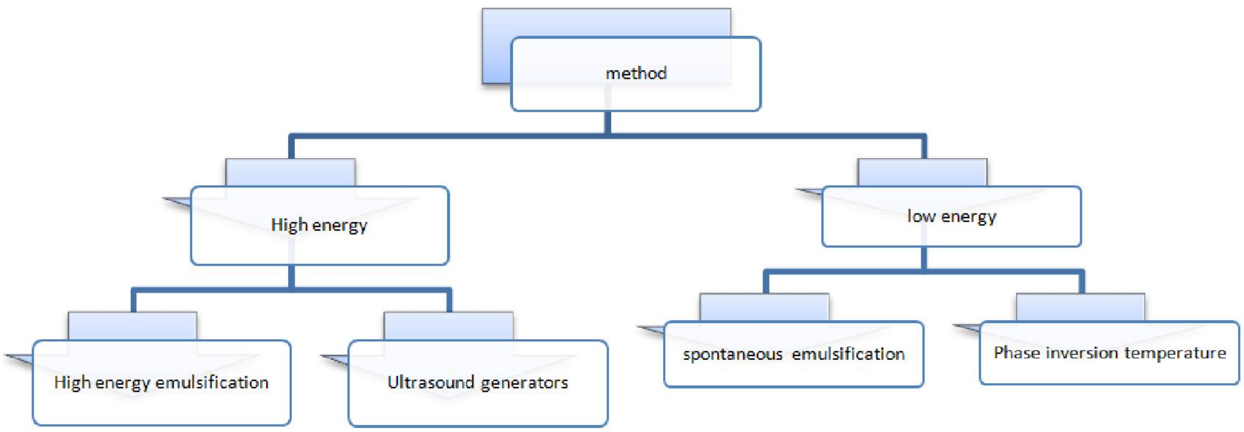

Figure 1. Methods of producing nanoemulsion

Depnath *et al*. (2011) Nanoemulsion exhibits characteristic properties such as higher solubilisation capacity, high kinetic stability and optical transparency, provision of ultra low interfacial tension and reduced inter-subject variability in terms of gastrointestinal tract fluid volume (Depnath *et al*., 2011). The use of nanoemulsion enhances solubility and absorption of bioactive substances. They are used for delivery of poorly-soluble food components such as fish oil and lipophilic vitamins (Fathi *et al*., 2012). They have efficient transport mechanism due to large surface area to volume ratio and do not pose any threat such as creaming, flocculation, coalescence and sedimentation as seen in macroemulsion (Shah *et al*., 2010)

Qian (2013) studied the design of efficient delivery systems for encapsulation of carotenoids and other lipophilic bioactive component. When β-carotene was encapsulated within nanoemulsion-based delivery systems with tween 80 (non-ionic surfactant) as emulsifier and long chain triglycerides (LCT) acting as carrier, the bioavailability was relatively high (about 66%) due to the large sizes of the mixed micelles capable of solubilising the bioactive molecules. In contrast, bioavailability of β-carotene in orange oil nanoemulsion and medium chain triglycerides (MCT) was negligible due to the absence or small formation of mixed micelles to solubilise the β-carotene. A spontaneous emulsification method has been used to study the nanoemulsion based delivery system of bioactive omega-3 polyunsaturated oils. Their finding indicates the suitability of using nanoemulsion to incorporate polyunsaturated oil in food Gullotta *et al*. (2014)

Conclusion

Nano delivery of bioactive components by incorporation into the food system require the design of a technical encapsulation matrix capable of providing maximum stability, protection and also permit an efficient release of encapsulated components into the body system. There is a need of intense study be carried out to investigate the compatibility of the component and the delivery system. Though, components such as carotenoid are highly dependent on the carrier and unstable when isolated from plant or animal sources, their lipophilic nature leads to low absorption and limited bioavailability in human beings. A suitable method such as the use of solid lipid nanoparticles should therefore be adopted to ensure successful delivery of components such as carotenoids.

REFERENCES

Augustin, M.A., and Hemar, Y. 2009. Nano- and micro-structured assemblies for encapsulation of food ingredients. *Chem Soc Rev*., 38(4): 902-912.

Borel, T., and Sabliov, C.M. 2014. Nanodelivery of Bioactive Components for Food Applications: Types of Delivery Systems, Properties, and their Effect on ADME Profiles and Toxicity of Nanoparticles. Annual Review of Food Science and Technology. DOI: 10.1146/annurev-food-030713-092354.

Cha, D.S. and Chinnan, M.S. 2004. Biopolymer based antimicrobial packaging: *Review, Crit. Rev.Food Sci*. Nutr., 44: 223-237.

Chouksey, R., Jain, A.K., Pandey, H. and Maithil, A. 2011a. Development and bioavailability studies of atorvastatin nanoemulsion. *Int. J. of Pharm and Life Sci*., 2(8):982-988

Chouksey, R.K., Pandey, H.K., Maithil, A. and Jain, A.K. 2011. Nanoemulsion: A Review. Inventi Rapid: Pharm Tech., 2(1), 231-235

Debnath, S. Satayanarayana, and Kumar, G.V. 2011. Nanoemulsion- a method to improve the solubility of lipophilic drugs. PHARMANEST. *Inter J Adv Pharm Sci*., 2(2-3):72-83.

FAO/ WHO. 2010. Food and Agriculture Organization of the United Nations/World Health Organization. FAO/WHO Expert Meeting on the Application of Nanotechnologies in the Food and Agriculture Sectors: Potential Food Safety Implications: Meeting Report. Rome.130 pp. Existing and projected applications of nanotechnology in the food and agriculture sectors.

Fathi, M., Mozafari, M.R., and Mohebbi, M. 2012. Nanoencapsulation of food ingredients using lipid based delivery systems. *Trends in Food Sci Tech*., 13: 13-27.

Fernandeza, P., Andr´e, V., Riegera, J. and Kuhnle, A. 2004. Nano-emulsion formation by emulsion phase inversion. Colloids and Surfaces A: Physicochem. Eng. Aspects., 251: 53–58.

Gökmen, V. 2013. Nano-encapsulation improves thermal stability of bioactive compounds Omega fatty acids and silymarin in bread. *Agro Food Ind*., 24(3): 62-65.

Gullotta, A., Saberi, A.M., Nicoli, M.C., McClements, D.J. 2014. Nanoemulsion-based delivery systems for polyunsaturated (ω-3) oils: formation using a spontaneous emulsification method. *J. Agric. Food Chem*., 62(7):1720–1725.

Hamouda, T., and Baker, Jr, J.R. 2000. Antimicrobial mechanism of action of surfactant lipid preparations in enteric Gram-negative bacilli. *J Applied Microb*., 89: 397-403.

Hamouda, T., Myc, A., Donovan, B., Shih, A.Y., Reuter, J.D. and Baker, Jr, J.R. 2001. A novel surfactant nanoemulsion with a unique non-irritant topical antimicrobial activity against bacteria, enveloped viruses and fungi. Microbiological Research., 156: 1-7.

Haritha, Syed, P.B., Koteswara, R.P., Vedantham, C.A. 2013. Brief introduction to methods of preparation, applications and characterization of nanoemulsion drug delivery systems. *Indian J Res Pharm and Biotech*., 1(1): 25-28.

Jong, W.H.D. and Borm, P.J.A. 2008. Drug delivery and nanoparticles: applications and hazards. *Inter J Nanomedicine*., 3(2):133- 149.

Lasoń, E. and Ogonowski, J. 2011. Solid Lipid Nanoparticles – characteristics, application and obtaining. Chemik., 65(10):960-967.

Lason, E. and Ogonowski, J. 2011. Soild Lipid Nanoparticles – characteristics, application and obtaining. Institute of Organic Chemistry and Technology, Cracow University of Technology, Cracow 65,10, 960-967. Jong WHD and Borm P.J.A. 2008.

McClements, D.J. and Decker, E.A. 2000. Lipid oxidation in oil-in-water emulsions: impact of molecular environment on chemical reactions in heterogeneous food systems. *J. Food Sci*., 65:1270-1282.

Misra, A.M., Misra, M. and Singh, R. 2013. Nanotechnology in Agriculture and Food Industry. *Int. J. Pure Appl. Sci. Technol*., 16(2):1-9.

Qian, C. 2013. Food-grade nanodispersions for encapsulation, protection and delivery of bioactive food components. Doctoral Dissertations Available from Proquest Paper AAI3556279. http://scholarworks.umass.edu/dissertations/AAI355627.

Sanguansri, P. and Augustin, M.A. 2006. Nanoscale materials development – a food industry perspective. *Trends in Food Sci & Tech*., 17(10):547-556.

Shah, P., Bhalodia, D. and Shelat, P. 2010. Nanoemulsion: a pharmaceutical review. *Sys Rev Pharm*., 1(1): 24-32.

Tamjidi, F., Shahedi, M., Varshosaz, J. and Nasirpour, A. 2003. Nanostructured lipid carriers (NLC): A potential delivery system for bioactive food molecules. *Innovative Food Sci and Emerging Tech*., 19:29-43.

Weiss, J., Decker, E.A., McClements, D.J., Kristbergsson, K., Helgason, T. and Awad, T. 2008. Solid Lipid Nanoparticles as Delivery Systems for Bioactive Food Components. *Food Biophysics*., 3(2):146-154.

Weiss, J., McClements, J., Helgason, T., Awad, T. and Decker, E. 2008. Solid lipid nanoparticles as novel nutraceutical carriers in foods. Emulsion Workshop November 13-14th, Amherst, MA.

Yang, J., Zhou, Y. and Chen, L. 2014. Elaboration and characterization of barley protein nanoparticles as an oral delivery system for lipophilic bioactive compounds. *Food Funct*., 5: 92-101.

****