REPORT

Potential of nano-emulsions as phytochemical delivery system for food preservation

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Abstract: Nature is a rich source of bioactive phytochemicals. These plant based compounds have rich scope as antioxidants, antimicrobial compounds and food preservatives and so for long time to be used in meat, fruits, vegetables and processed food items, either as added preservative or as coating material in various food applications, but the major limitation is their limited solubility in a food grade medium. Nano-emulsion is a best choice as a medium having vast area of application. The major advantage of nano-emulsion would be the solubility of a vast group of compounds, due to the presence of water and lipid phases. In this way, nano-emulsions can be proved to be the most suitable candidate as phytochemical delivery system for food preservation. In present article, the use of phytochemicals as potent food preservatives has been reviewed, in context of solubility of phytochemicals in nano-emulsion and applications of food grade nano-emulsions to food systems.

Keywords: Phytochemicals, nano-emulsion, delivery system.

INTRODUCTION

Food preservation is a vital process to combat its deterioration (Lacroix and Ouattara, 2000; Yilmaz, 2006). Spoilage has two main mechanisms; oxidation and microbial growth. Oxidation causes major loss in quality, including organoleptic alterations and loss in nutritional value in food matrix, resulting negatively for adaptation behaviour of consumer (Amanatidou *et al.*, 2000; Herrero *et al.*, 2006). Advanced stages of oxidation may lead to highly reactive and potentially toxic end products in foods (Laguerre *et al.*, 2007).

Traditional approaches for storage involve thermal processing at high or low temperature, acidification, the use of sugars or salt in high concentrations, drying to lower water activity and/or use of chemical preservatives (Chirife, 1993; Devlieghere *et al.*, 2004). New and more effective methods for shelf life extension and quality enhancement are needed to improve food production and food security (Fitzgerald *et al.*, 2003; Mahmoud *et al.*, 2006).

The use of a natural phytochemical extract to replace current synthetic chemicals results in more clean products, which are also considered as functional products (Aeschbach *et al.*, 1994; Gould, 1996; Roldan *et al.*, 2008; Tajkarimi *et al.*, 2010). Polyphenolic compounds in plant have received much attention because of their varied roles in biological systems (Al-Zoreky, 2009), including their free radical scavenging activity, making them a potential antioxidants in food systems (Yoshida *et al.*, 1989).Various natural sources and/or their by-products have been proven to be more effective preservatives than chemical additives, includes spices, herbs, fruit peels and/or their extracts (Rehman *et al.*, 2004; Torres *et al.*, 2002).

However scientists have not yet gained extensive knowledge about the antioxidative power of compounds from plant sources (Laguerre *et al.*, 2007). Hurdles in achieving the full potential of natural phytochemicals are their limited solubility, uncontrolled release and limited physical stability (Sagalowicz and Leser, 2010). Better applications of natural sources of antioxidants can be achieved by designing delivery mediums with improved maximum solubility (Bala *et al.*, 2006). Water and oil are the predominant choices as the delivery media in foods but do not dissolve phytochemicals to a reasonable extent, if solely used (Flanagan and Singh, 2006). This limited solubility is due to the incompatibility of the functional food with the food matrix such as fat soluble vitamins added to aqueous food (Lopez-Rubio *et al.*, 2006). Therefore it is a strong need to develop good nano-

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emulsion based delivery systems for natural, biologically active compounds suitable for the multicomponent nature of foods (fig. 1).

Phytochemicals as antioxidants

The antioxidant potential of the natural polyphenolic constituents have already been shown in several studies to be more effective than vitamin C or E (Rice-Evans *et al.*, 1997). Similarly, varying degrees of antioxidant activity of cloudberry, willow herb and beetroot extracts on cooked meat has been noticed (Rey *et al.*, 2005). For natural antioxidants to be most effective in the food systems such as meats it is vital to have a uniform distribution throughout the product (Waszkowiak and Dolata, 2007). This necessitates the use of some carrier systems for application of antioxidants. Hence, for them to show effectiveness any developed nano-emulsion systems should be loaded with high quantities of antioxidant compounds (Yuan *et al.*, 2008). Use of effective delivery medium and exploring optimum plant extracts could help improve the quality of fresh cut fruits and vegetable. Green tea extracts have been tested against its antioxidant potential in fruits and vegetable producing better antioxidant status of the end product but without any change in sensory appeals (Chiu and Lai, 2010).

Phytochemicals as potent food preservatives

Natural antimicrobials and antioxidants are highly desirable in the food industry to hinder the natural deteriorative process and stop the growth of health hazard microbes (Herrero *et al*., 2006; Tajkarimi *et al*., 2010). Essential oils are being used as antimicrobial agent for fresh cut fruits (Oms-Oliu *et al*., 2008). Meat is well known to be prone for oxidative and microbial deterioration during processing, transport and storage (Kanatt *et al*., 2008). Rosemary extracts are being used as natural preservative for food (Torres *et al*., 2002), especially for meat products (Yu *et al*., 2002).

Solubility of phytochemicals in nano-emulsion

The reaction dynamics also depends upon other factors such as the location in the food and the solvent conditions such as pH in surrounding food environment (Kulmyrzaev *et al*., 2000; McClements and Coupland, 1996). The effectiveness of natural extracts from plant sources for their antimicrobial/bioactivity activity is greatly influenced by their solubility (Tripoli *et al*., 2007). Most of the phytochemicals are either not soluble or poorly soluble. For example, β-carotene is insoluble in water and marginally soluble in oil (Yuan *et al*., 2008). This limitation of solubility can greatly reduce the functionality of the phytochemicals, as the lipophilic nature of these natural sources of preservation is considered main hurdle for use in the food industry (Devlieghere *et al*., 2004). Due to Polar paradox, the hydrophobic antioxidants are more active in oil/water such as polar emulsions and membranes systems, than in bulk oils or water. But phytochemicals have been reported to achieve higher solubilisation in emulsion systems (Flanagan and Singh, 2006).

Phytochemical based nano-emulsions

Nano-emulsions have recently gained much popularity in development of drugs, cosmetics and nutraceutical for their advantages of solubility enhancements, optical transparency and stability against sedimentation, creaming (Forgiarini *et al*., 2001) and flexibility for solubility of a diverse range of compounds (Djordjevic *et al*., 2004) to deliver different bioactive constituents into food and drug matrices (Waszkowiak and Dolata, 2007). Nanoparticle based drug delivery is an exciting area of potential use (Gaonkar and Prabhakar, 2002). These nano-emulsions make the functional ingredients highly soluble and available in the delivery systems (Chin and Nakajima, 2005) and so considered as to be a promising delivery system for bioactive compounds in food systems (Flanagan and Singh, 2006; Gutiérrez *et al*., 2008).

Food grade nano-emulsions reported in literature are often too complex and involve many different components besides being sensitive to environmental changes (Sagalowicz and Leser, 2010). The soybean oil (long chain triglycerides oil) as dispersed phase for food application is used in nano-emulsions (Gutiérrez *et al*., 2008). Such systems could be applied to multi component food matrix. The food grade oils could be replaced with R-(+) limonene, since the oil is of low molecular weight, and has better surfactant properties, leading to easier formation of nano-emulsions (Garti *et al*., 2005). This field needs to be further explored by food industry professionals (Chin and Nakajima, 2005). The major obstacle for developing applications for such systems is to achieve enough stability for application development because all reported systems were tested soon after formation (Gutiérrez *et al*., 2008).

The phytosterols concentration was reported to decrease with an increase in the aqueous phase of the micellar solution. The concentration dropped to 2400 ppm at an aqueous concentration of 96% (Garti *et al*., 2005). These micelles have higher solubilisation of phytosterols that could not be solubilised in water (Garti *et al*., 2005). Similarly, it is reported that the level of solubilisation of phytosterols achieved in the micellar solutions was 150,000 ppm, while solubilisation in R-(+)- limonene was six times lower, as 25,000 ppm (Garti *et al*., 2005).

Bioavailability of phytochemical based nano-emulsion

There is a need for edible nano-emulsion based delivery systems to encapsulate, protect and release bioactive and functional lipophilic constituents, controlling lipid bioavailability, targeting the delivery of bioactive components within the gastrointestinal tract; and designing food matrices that delay lipid digestion and

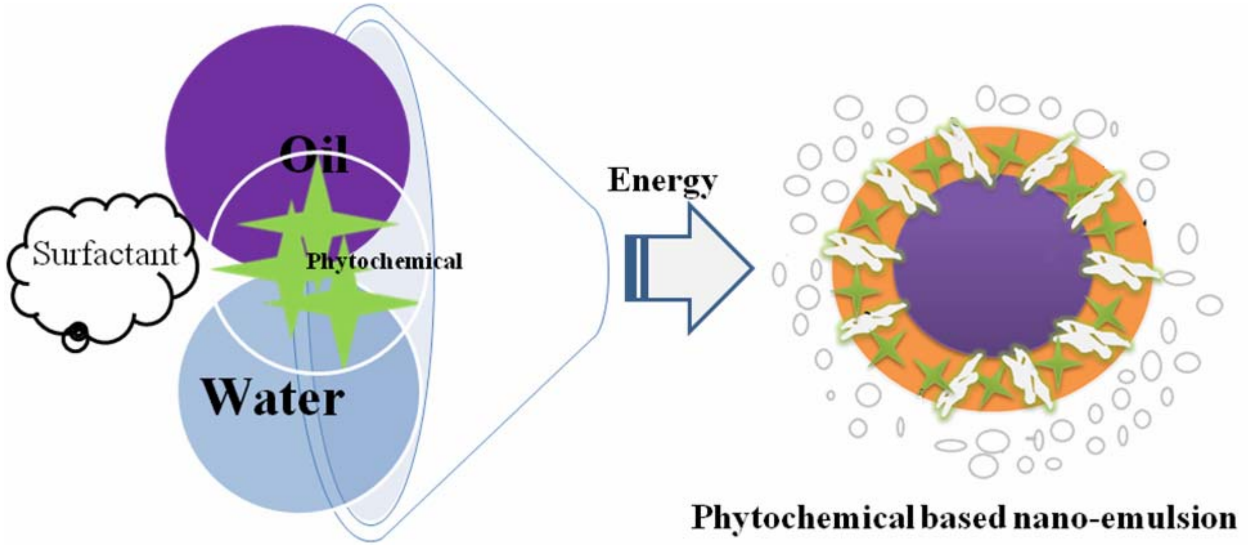

Fig. 1: Concept of Phytochemical based nano-emulsion system

induce satiety (McClements and Li, 2010). Given the wide use of dietary supplements (most of which are phytochemicals), with their potential toxicity and safety concerns with some of these supplements, nanotechnology is a promising tool for limiting the dosage while increasing bioavailability and bioactivities (Wang *et al.*, 2014).

Over the last decade, nanoparticle-mediated drug delivery represents one promising strategy to successfully increase the central nervous system (CNS) penetration of several therapeutic moieties. Different nanocarriers are proved to be promising to treat and diagnose Alzheimer disease, by delivering the drug active compounds at a constant rate at target in host (Sahni *et al.*, 2011). Similarly, the oral bioavailability and anti-diabetic efficacy of berberine (BER) is increased by nanoemuslion based system (Wang *et al.*, 2011). An initial evidence for transdermal delivery of D-limonene nano-emulsions of phytochemical components shows that the smaller the emulsion size, the better the encapsulated ration and permeation of D-limonene (Lu *et al.*, 2014). Mice tests for nanodroplet formulation of pomegranate seed oil (PSO) against Neurodegenerative disease significantly delayed in disease presentation. These nano-emulsions proved to reduce lipid oxidation and neuronal loss, indicating a strong neuroprotective effect (Mizrahi *et al.*, 2014).

Curcumin has been reported to have many biological activities, but its application as a functional ingredient is currently limited because of its poor water-solubility and bio-accessibility. The bio-accessibility of curcumin is higher in emulsions form (Ahmed *et al.*, 2012). Like curcumin and quercetin, circulating resveratrol is rapidly metabolized, and consequently, blood concentrations of free resveratrol are at low micromolar levels (Baur and Sinclair, 2006). Different from free resveratrol, nanoencapsulated resveratrol exhibited a sustained release pattern. Both nanodelivery systems can be considered suitable carriers for oral administration, conferring protection to the incorporated resveratrol and allowing a controlled release after uptake (Neves *et al.*, 2013).

CONCLUSION

Nature has vast sources of phytochemicals having range of bioactivities such as antioxidants, preservatives, drugs and others. These phytochemicals are preserved in plants as a well solubilised system but the major limitation in using these bioactive compounds is delivery to a human or animal body system. The selective solvent system (polar or non-polar) leads to the targeted solubility of these compounds or the group of compounds. In such cases a complete and diverse range of compounds could not be delivered to any subject.

Nano-emulsions are being considered as a comprehensive solution for above mentioned problem. Due to higher interfacial area, nano-emulsion could act as effective delivery media for both lipophilic and hydrophilic additives. These emulsions are being used to develop preservatives, antioxidants and even drug compositions with a significant improvement in bioavailability of these compounds.

In addition to be used in food industry, nano-emulsion based drugs are becoming promising candidates to treat various diseases, such as diabetes and also neurodegenerative diseases.

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