Journal of Agricultural Engineering and Food Technology
p-ISSN: 2350-0085; e-ISSN: 2350-0263; Volume 6, Issue 2; April-June, 2019, pp. 138-141

http://www.krishisanskriti.org/Publication.html

Nano-Delivery Systems for Tea Polyphenols: Applications in Food Fortification

Minaxi Sharma*, Ramandeep Kaur, Shiv Kumar, Krishan Kumar and Tajendra Singh

Department of Food Technology, Eternal University, Baru Sahib, Himachal Pradesh-173101
E-mail: minaxi86sharma@gmail.com

Abstract —*In the last decade, fortification of natural occurring polyphenols in the food products have been modified and tea polyphenols are among the most promising bioactive phytophenols. Dietary tea polyphenols (catechin, epicatechin, epicatechin-gallate and epigallo-catechin-gallate) has gained a lot of interest due to its positive effects on human health. In addition, it is having anti-oxidative, anti-mutagenic, anti-carcinogenic, anti-microbial, anti-inflammatory, anti-proliferative, anti-hypertensive, anti-thrombogenic and lipid-lowering effects and gained substantial attention in the food and pharmaceutical industries. However, the use of polyphenols in food products is limited because of its sensitivity to processing, temperature, pH, oxygen, exposure to light, enzymes. The sensorial attributes such as bitterness and astringency exhibited by tea polyphenols also signifies a major drawback for their incorporation into food system. To combat these problems, technological interventions are available to preserve the stability, activity and bioavailability of the phytophenols. Recently, novel micro/nano encapsulation strategies are trending as useful tools to fabricate into micro/nanostructured materials. These novel tools are having several advantages, which includes enhancement of solubility, bioavailability, stability, delivery of the bioactive ingredients, and protect them from physical and chemical degradation. Here we are focusing the micro/nano encapsulation of tea polyphenols by using different coating materials and their delivery in food products.*

INTRODUCTION

Nano-delivery systems of natural phyto-phenols for aqueous food applications are continuously emerging with a wide spectrum to entrap their maximum potential. Recently, tea polyphenols are gaining much interest of researchers and industrialists to harvest their potentiality in aqueous food formulations. Tea polyphenols are the major polyphenolic substances found in green tea and have beneficial health roles being enriched with high antioxidant potential. Numerous researchers reported that the tea polyphenols as non-nutrient bioactive compounds have several health beneficial properties like antioxidant, anticancer, anti-obesity, atherosclerosis and other pharmacological functions [5]. Poor bioavailability [8], un-stability to processing conditions, interactions with other nutrients, irreversible toxic side effects in food systems, results in decrease the efficacy and restrict their use in foods. Keeping in the mind these constraints regarding the use of tea polyphenols in aqueous food system, the researchers have been increasing attention to protect these polyphenols from reactions with oxygen and light etc. Till date, nano-sized delivery systems have recently revolutionized to overcome these problems and are the best approach to encapsulate such polyphenols to enhance the oral bioavailability, efficacy and stability of tea polyphenols. Several studies have been focused on utilization of nanoscale vehicles to improve the bioavailability of TPP [21]. Nano technology is a potential tool to meet consumer demand on food products. Currently modernized lifestyle and consumers awareness towards foods, has forced the food industry to develop new nano-technological interventions capable of fulfilling consumer's nutritional and health demands, simultaneously enhancing the efficacy and bioavailability of potential bioactive ingredients [15]. Considering the health concerns, food industry has focused on avoiding harmful synthetic food additives and on developing novel food products containing health-promoting ingredients. As a result, the concept of "Functional foods" has revolutionized as it serves as a frontier between nutrition and health, providing a long term beneficial physiological/health effect beyond the nutritional properties.

TEA (*CAMELLIA SINENSIS*) POLYPHENOLS

Tea is one of the most popular beverages consumed by humans for thousands of years, worldwide. The total amount of tea production and consumption, worldwide, black tea is 78%, green tea is 20%, and oolong tea is <2% [9]. Theaflavin and thearubigin are major polyphenols present in black tea. Green tea contains polyphenolic compounds, which include flavanols, flavandiols, flavonoids, and phenolic acids which accounts 30% of the dry weight of green tea leaves. Unfermented green tea has major polyphenolic compounds as "green tea catechins" belongs to flavonol groups. Tea contains catechins as major polyphenol, which include (-)-epicatechin, (-)-epigallocatechin, (-)-epicatechin-3-gallate (ECGC), with ECGC being the major catechin. Being an important member, epigallocatechin has numerous beneficial properties such as antioxidant, anticancer properties, inhibit lipid oxidation, and weight loss activities [1].

Tea polyphenols targeted for human health

Abundant scientific and epidemiological evidences explained worldwide, that the green and black tea contains the polyphenolic compounds can reduce the risk of cancer in a variety of animal tissues [3, 9-10]. The potential health effects of tea catechins depend on the amount consumed and on their bioavailability. Oxidative damage to biomolecules has been implicated in the pathology of a number of chronic diseases, including cardiovascular diseases, cancers, and neurodegenerative diseases as shown in Fig. 1. The known in vitro antioxidant properties of catechins and other polyphenolic compounds in tea have led to considerable interest in the potential health benefits of tea consumption.

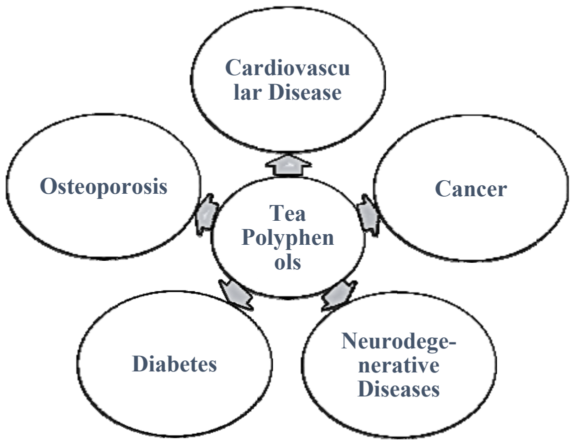

Figure 1: Different types of tea polyphenols exhibit beneficial effects on human health.

Numerous epidemiologic studies have addressed the relationships between tea consumption and the incidence of cardiovascular diseases and cancer in humans. Green tea has been found to be associated with lower risk of cardiovascular diseases through decreased serum cholesterol and triglyceride and provides protection against peroxidation of lipids in kidney. Epigallocatechin also having weight reducing effects by increasing thermo-genic reactions in the body [2]. The ability of casein micelles to deliver epigallocatechin gallate (EGCG), against HT-29 colon cells were reported by Haratifar et al. [7]. They hypothesized that the epigallocatechin gallate-casein complexes were able to decrease the proliferation of HT-29 colon cells, and concluded that the bioavailability may not be reduced by nanoencapsulation.

NANO-DELIVERY SYSTEMS FOR TEA POLYPHENOLS

From the last few decades, there has been considerable attention focused on the development of novel nano-delivery systems for natural polyphenols. An ideal nano-delivery system should deliver the bioactive component at controlled release rate directed by the body in given time, and it should facilitate the targeted release to the site of action. There are different techniques used for production of nano-encapsulated foods including characterization and fortification techniques. The application of nanotechnology in functional food industry includes several nanodelivery systems: nanoemulsions, nanostructured lipid carriers (NLC), pickering emulsions, solid-lipid NPs (SLN), nanofibers, nanosuspensions, nanocapsules, nanotubes, liposomes and nanoliposomes, biopolymeric nanoparticles (NPs) and micelles made of proteins, polysaccharides and their complexes or conjugates, and combinations with lipid or mineral components as shown in Fig. 2. However, only few nano-products incorporated with nano-delivery vehicles are available in the market due to the current social issues and strict regulatory standards for food products.

Ambient conditions (pH, temperature, oxygen) can either enhance or decrease the stability of tea polyphenols, thus influencing its biological activity. The use of stabilizers/emulsifiers and nanoencapsulation system can significantly increase the stability of tea polyphenols. (-)-Epigallocatechin-3-gallate is the most abundant catechin present in green tea which is the most effective cancer chemopreventive polyphenol [12]. Liu et al. [13], reported that chitosan nanoparticles loaded with tea polyphenols in gelatin films with controlled-release properties. Tea polyphenol released faster and greater from films in 50% ethanol (4 °C) than in 95% ethanol (25 °C) fatty food stimulant due to the swelling by water. Films maintained their structures in 95% ethanol after 240 h but not in 50% ethanol. Liu et al., [12], investigated that chitosan can be used as a promising carrier for the encapsulation of water-soluble TP. They formulated the inclusion complexes of tea polyphenol by cross-linking chitosan hydrochloride (CSH) and sulfobutyl ether-β-cyclodextrin sodium (SBE-β-CD). The encapsulation efficiency increased with increasing CSH concentration or decreasing CSH/SBE-β-CD mass ratio whereas observed decreased significantly with increasing tea polyphenols content. In contrast, the extreme entrapment of EGCG-ICs and/or free EGCG in the aggregated CSNs restricted the release of EGCG, thus inhibiting the antioxidant activities [14].

Phytoferritin when glycosylated by chitosan to fabricate ferritin-chitosan Maillard reaction-products (FCMPs) for EGCG encapsulation showed that the FCMPs were more resistant to pepsin and trypsin digestion as compared with ferritin alone [18]. Interestingly, the proanthocyanidin, milk and soy protein inhibited the EGCG release. In addition, they reported that the absorption of encapsulated EGCG in FCMPs significantly improved in Caco-2 monolayer model as compared with free EGCG. Yang et al. [19], further investigated interactions between native, thermally modified lactoferrin (LF) and (−)-epigallocatechin-3-gallate (EGCG) at pH 3.5, 5.0, and 6.5. they reported that LF−EGCG complexes were nanoparticles at pH 3.5 and 5.0, whereas at pH 6.5, they were sub-micrometer particles. They further reported that

EGCG exhibited a strong affinity for native lactoferrin as compared to thermally modified lactoferrin at pH 5.0 and 6.5.

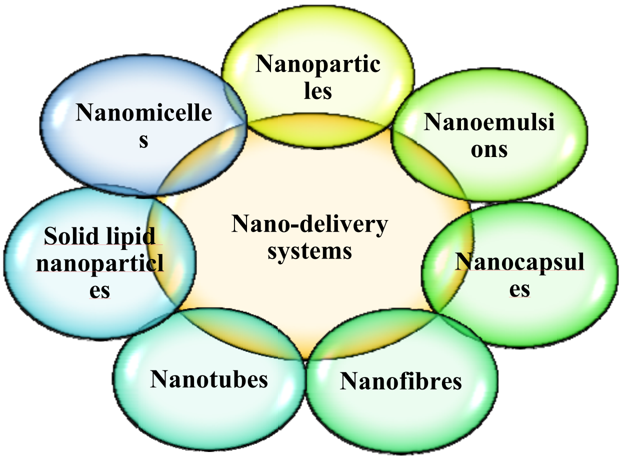

Figure 2: Different types of nano-delivery systems for encapsulating bioactive ingredients for functional foods applications

Lipid nanoparticles, liposomes, and niosomes have been widely used to enhance the stability of EGCG in physiological environments, to promote its sustainable release and improve bioavailability [5-6, 16-17, 20,]. Liposomal encapsulation of these phenolic compounds permitted a higher retention in low-fat cheese with optimum release under gastrointestinal conditions, and increase the antioxidative functionality of cheese. Soy lecithin liposomes were developed by encapsulating catechin and epigallocatechin gallate (EGCG), and incorporated into low-fat hard cheese. The fortification of low-fat cheese with liposome-encapsulated catechin or EGCG significantly increased the total phenolic content, and antioxidant activity [17]. Gómez-Mascaraque et al. [4], formulated food-grade gelatin capsules by electrospraying technique to encapsulate (−)-epigallocatechin gallate (EGCG). The capsules were observed with high encapsulation efficiencies about 100%. They reported further that the free EGCG in PBS lost a 30% of their antioxidant activity being completely degraded in 100 h, but the encapsulated EGCG retained its whole antioxidant activity within this time period. The use of quercetin nanoparticles to fortify dairy beverages may not only result in the protection of the compound's bioactivity, but actually contribute to its improvement [11].

Nanoencapsulation is capable to generate innovative characteristics in food systems such as texture, taste, and other sensory attributes like coloring, strength, processability, and stability during shelf-life leading to a great number of new products. From the above research explanations, it is concluded that there are several examples of the applications of nano-delivery systems for tea polyphenols in pharmaceutical and drug industry, but the studies were done to analyse the sensory or nutritional characteristics, and safety concerns for their applications in food products are very few. So, there is still need to explore the innovative methods of nano-delivery systems for tea polyphenols in food applications; their targeted release in human gut; their effect on the organoleptic characteristics; and their safety and regulatory issues, while using in food systems.

CONCLUSIONS

Tea polyphenols are the bests suited antioxidants to combat several modern lifestyle diseases in human beings. Widespread researches are emerging in the area of novel nano-delivery vehicles targeted to plant bio-actives and their extracts to chelate their potential for human health. Nanoencapsulation technology has great potential to develop innovative functional foods with biological benefits of tea polyphenols. Nano-encapsulation of tea polyphenols are very scarce and there should more attention be paid to develop more suitable carriers which can reduce the toxicity, enhance their bioavailability and facilitate their targeted releases. However, regardless of huge potentials associated with these nano-delivery systems for tea polyphenols, they are still unknown to current food market because of very less knowledge regarding their specific legislation, regulatory procedures etc. which restricts their use in functional foods.

REFERENCES

[1] Amin, T., and Bhat, S. V., "A review on phytosome technology as a novel approach to improve the bioavailability of nutraceuticals", International Journal of Advancements in Research & Technology, 1(3), 2012, pp. 43–57.

[2] Di Pierro, F., Menghi, A. B., Barreca, A., Lucarelli, M., and Calandrelli, A., "Green select phytosome as an adjunct to a low-calorie diet for treatment of obesity: a clinical trial", Alternative Medicine Review, 14(2), 2009, pp. 154–160.

[3] Dreosti, I. E., Wargovich, M. J., and Yang, C. S., "Inhibition of carcinogenesis by tea: the evidence from experimental studies", Crit Rev Food Sci Nutr, 37, 1997, pp. 761–70.

[4] Gómez-Mascaraque, L. G., Lagarón, J. M., and López-Rubio, A., "Electrosprayed gelatin submicroparticles as edible carriers for the encapsulation of polyphenols of interest in functional foods", Food Hydrocolloids, 49, 2015, pp. 42–52.

[5] Granja, A., Frias, I., Neves, A. R., Pinheiro, M., and Reis, S., "Therapeutic Potential of Epigallocatechin Gallate Nanodelivery Systems", BioMed Research International, 2017b, pp. 1–15.

[6] Granja, A., Vieira, A. C., Chaves, L. L., Nunes, C., Neves, A. R., Pinheiro, M., and Reis, S.. "Folate-targeted nanostructured lipid carriers for enhanced oral delivery of epigallocatechin-3-gallate", Food Chemistry, 237, 2017a, pp. 803–10.

[7] Haratifar, S., Meckling, K. A., and Corredig, M., "Antiproliferative activity of tea catechins associated with casein micelles, using HT29 colon cancer cells", Journal of Dairy Science, 97(2), 2014, pp. 672–678.

[8] Hu, B., Ting, Y., Yang, X., Tang, W., Zeng, X., and Huang, Q., "Nano-chemoprevention by encapsulation of (−)-epigallocatechin-3-gallate with bioactive peptides/chitosan nanoparticles for enhancement of its bioavailability", Chemical Communications, 48(18), 2012, pp. 2421-2423.

[9] Katiyar, S. K., and Mukhtar. H., "Tea in chemoprevention of cancer: epidemiologic and experimental studies", Int J Oncol, 8, 1996, pp. 221–38.
[10] Kohlmeier, L., Weterings, K. G. C., Steck S., and Kok, F. J., "Tea and cancer prevention: an evaluation of the epidemiologic literature", Nutr Cancer, 27, 1997, pp. 1–13.
[11] Li, H., Zhao, X., Ma, Y., Zhai, G., Li, L., and Lou, H., "Enhancement of gastrointestinal absorption of quercetin by solid lipid nanoparticles", J. Control. Release, 133, 2009, pp. 238–244.
[12] Liu, F., Antoniou, J., Li, Y., Majeed, H., Liang, R., Ma, Y., Ma, J., and Zhong, F., "Chitosan/sulfobutylether-β-cyclodextrin nanoparticles as a potential approach for tea polyphenol encapsulation", Food Hydrocolloids, 57, 2016a, pp. 291-300.
[13] Liu, F., Avena-Bustillos, R. J., Chiou, B.-S., Li, Y., Ma, Y., Williams, T. G., Wood, D. F., McHugh, T. H., and Zhong, F., "Controlled-release of tea polyphenol from gelatin films incorporated with different ratios of free/nanoencapsulated tea polyphenols into fatty food simulants", Food Hydrocolloids, 62, 2017, pp. 212-221.
[14] Liu, F., Majeed, H., Antoniou, J., Li, Y., Ma, Y., Yokoyama, W., Ma, J., and Zhong, F., "pH and temperature stability of (−)-epigallocatechin-3-gallate-β-cyclodextrin inclusion complex-loaded chitosan nanoparticles", Carbohydrate Polymers, 149, 2016b, pp. 340-347.
[15] Oliveira, A., Amaro, A. L. and Pintado, M., "Impact of food matrix components on nutritional and functional properties of fruit-based products", Curr. Opin. Food Sci, 22, 2018, pp. 153–159.
[16] Rashidinejad, A., Birch, E. J., Sun-Waterhouse, D., and Everett. D. W., "Delivery of green tea catechin and epigallocatechin gallate in liposomes incorporated into low-fat hard cheese", Food Chemistry, 156, 2014, pp. 176–83.
[17] Rashidinejad, A., Birch, E. J., Sun-Waterhouse, D., and Everett. D. W., "Effect of liposomal encapsulation on the recovery and antioxidant properties of green tea catechins incorporated into a hard low-fat cheese following in vitro simulated gastrointestinal digestion", Food and Bioproducts Processing, 100, 2016, pp. 238–45.
[18] Yang, R., Liu, Y., Gao, Y., Wang, Y., Blanchard, C., and Zhou, Z., "Ferritin glycosylated by chitosan as a novel EGCG nano-carrier: Structure, stability, and absorption analysis", International Journal of Biological Macromolecules, 105, 2017, pp. 252-261.
[19] Yang, W., Xu, C., Liu, F., Yuan, F., and Gao, Y., "Native and thermally modified protein–polyphenol coassemblies: lactoferrin-based nanoparticles and submicrometer particles as protective vehicles for (−)-Epigallocatechin-3-gallate. Journal of Agricultural and Food Chemistry, 62(44), 2014, pp. 10816–10827.
[20] Zhang, J., Nie, S.F. and Wang, S., "Nanoencapsulation enhances epigallocatechin-3-gallate stability and its antiatherogenic bioactivities in macrophages", Journal of Agricultural and Food Chemistry, 61(38), 2013, 9200–9.
[21] Zhou, H., Sun, X., Zhang, L., Zhang, P., Li, J., and Liu, Y-N., "Fabrication of biopolymeric complex coacervation core micelles for efficient tea polyphenol delivery via a green process", Langmuir, 28, 2012, pp. 14553−14561.