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# Encapsulation of functional foods in nanoemulsion

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**Abstract**
Recently, the demand for brand spanking new merchandise with healthy and useful compounds have enlarged over recent years in several industries. That's the food trade and nutraceutical case with the trend to consume "functional foods" that are designed to enhance human health, well-being and performance. Thus, completely different techniques for nanoencapsulation processes were developed. The choice of the most efficient technique depends on many parameters, like the character of the encapsulant, food formulation, food process, the ultimate application, and also the value of the method. This review states completely different strategies of encapsulation together with the deserves of nano emulsion and encapsulation as suggested to deliver the practical substance for health advantages.

**Keywords:** Emulsion, functional food, nano emulsion, encapsulation, nanotechnology

## Introduction
The idea to create functional meals is in line with the eastern notion that "medicine and food have a shared genesis". A regulation system was established by the Ministry of Health and Welfare to permit some foods with proven health advantages (Arai, 1996) [1]. Nanotechnology (NT), which covers a wide range of multidisciplinary research, development, and industrial activity involves the production, processing, and application of materials that have one or more measurements of the order of 100 nm or less (Chaudhry *et al*., 2008) [10]. A nanoparticle is described as a small object that acts as a whole unit in terms of transport and properties (Chellaram *et al*., 2014) [3]. The history of food nanotechnology dates back to the Pasteurization process, established by Pasteur to kill the pathogenic bacteria (1000 nm), who initiated the revolution in food processing and improved food quality standards (Chellaram *et al*., 2014) [3].

**Table 1:** Shows examples of functional foods, their components and their potential health benefits for human health

| Bioactive Components | Source | Potential Health Benefits |
|---|---|---|
| Lutein | Green vegetables | Contribute to the maintenance of healthy vision |
| Insoluble fiber | Wheat/oat bran | May decrease the risk of colon cancer |
| Lactobacillus | Yoghurt/fermented dairy products | May improve gastrointestinal health |
| Soy protein | Soy-based products | May decrease risk of cardiovascular diseases |
| Omega-3 fatty acids | Salmon, tuna and fish/marine oils | May decrease risk of cardiovascular diseases and improve brain health, visual functions |
| Lycopene | Tomato or red vegetables | May decrease risk ofprostate cancer |
| Phytosterols | All plants | May decrease risk of cardiovascular diseases, cholesterol reduction effects |

**Table 2:** Examples of bioactive compounds in foods and their potential health benefits. (IFT. 2005, Heasman M *et al*., 2001, Hasler CM, 2002, Bigliardi B *et al*., 2013) [7, 4, 5, 6]

| Bioactive components | Use-Related Problems |
|---|---|
| Carotenoids (e.g., lycopene) | Not soluble in water, prone to light, oxygen, auto-oxidation, solid at food storage and body temperature. |
| Omega-3 fatty acids | Not soluble in water, more susceptible to oxidation, affect food flavor and taste. |
| Phytosterols | Hydrophobic, High melting point, form insoluble crystals. |
| Flavonoids (e.g., catechins) | Strong bitter taste, low solubility. |
| Minerals (e.g., iron) | React with other food ingredients, the catalyst for oxidation of oils, promote protein aggregation, alter the taste, and discolor food. |

Many macro-scale aspects of food, together with texture, taste, and different sensory options, in addition to processability and stability overtime the period, are also altered as an outcome of dominant food molecules at the nanoscale (Cushen *et al*., 2012; Sekhon, 2010) [8, 9]. Most developments of applied science, in food science, involve sterilization of the feel of food elements, encapsulating food elements or additives, developing new tastes and sensations, dominant the discharge of flavors, and/or increasing the bioavailability of biological process elements (Chaudhry *et al*., 2008b) [10]. To boot, the development of coloring, AN extension of time period and preservation, detection of microbes and antibacterial drug properties and intelligent packaging materials square measure all associated with nanofood. Also, nanofood includes not solely the processed food class however conjointly entire areas from cultivation to packaging (Kour *et al*., 2015) [73].

Emulsions are described as the dispersion of two immiscible liquids, with the dispersed phase consisting of spherical droplets and the continuous phase consisting of the liquid surrounding them (Tadros *et al*., 2004; McClements *et al*., 2007; Acosta, 2009) [13, 14, 15]. Emulsions are classified as coarse emulsions, microemulsions, or nano emulsions as per the size and stability of their droplets (Komaiko and McClements, 2016) [16].

Nano emulsions, additionally referred to as submicron emulsions, ultrafine emulsions, and mini emulsions, are submicron-sized mixture particulate systems that are kinetically and thermodynamically stable identical dispersions that are created from 2 immiscible liquids, like oil-water, stable by an associate surface film created from an appropriate chemical agent and cosurfactant to make one section. With such Nano emulsions, a range of surfactants with completely different properties (ionic or non-ionic) are utilized. Nonionic surfactants (Sorbitan esters, polysorbates), anionic surfactants (Potassium laurate, Na lauryl sulfate), cationic surfactants (Quaternary ammonium halide) and zwitterions surfactants were the foremost extensively utilized among them (Quaternary ammonium halide). Oil-in-water emulsions with typical drop diameters starting from fifty to one thousand nm were the primary nanoemulsions.

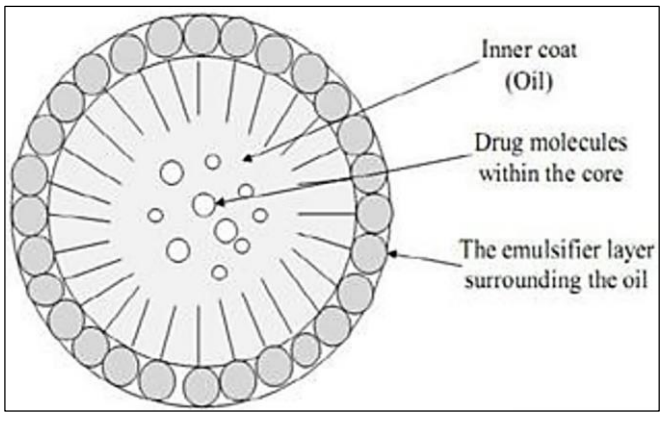


**Fig 1:** Structure of Nanoemulsion droplet

**Merits of nanoemulsion**

Nano emulsion is one of the foremost effective ways for increasing oleophilic medicines' water solubility, which will increase the drug's bioavailability within the circulation. As an outcome of the droplets nanoscale, they need larger surface surfaces, that affects the drug's transport characteristics, that could be an essential consider drug delivery (sustained and targeted).

1. Plasma concentration profiles and bioavailability are a lot duplicable once the medication is administered in nanoemulsion formulation.
2. The fine oil droplets are seen to empty quickly from the abdomen and increase optimum API distribution throughout the enteral tract. As a result, it reduces the irritation that may occur once a medication is connected with the gut wall for an Associate in a Nursing extended amount of your time.
3. Formulations supported nanoemulsions have a more solubilization capability than formulations supported straightforward micellar solutions. Nanoemulsions are thermodynamically stable, which supplies them a plus over unstable dispersion systems like emulsions and suspensions. Nanoemulsions are straightforward to form with low energy input, like reduced heat and combining, and they have a protracted period.
4. They even have really low surface tension and heaps of o/w surface area.
5. They even have a quicker commencement of action (no beyond regular time for dispersion) and fewer inter-subject variability in terms of puke fluid volume than standard self-emulsifying systems.
6. Nanoemulsions, like microemulsions, could have nice kinetic stability and optical transparency.
7. As a result the structures in nanoemulsions are considerably smaller than the visible wavelength, even at high loadings, most nanoemulsions look optically clear.
8. Nanoemulsions are used to transport peptides that are simply hydrolyzed (degraded) by enzymes within the alimentary tract.

**Encapsulation**

Encapsulation may be a technique by which the sensitive ingredients are packed at intervals a coating/wall material. The wall material safeguards the sensitive ingredients against adverse reactions and controls the discharging of the ingredients (Bakowska-Barczak & Kolodziejczyk, 2011) [17]. Additionally, the encapsulation method will convert liquids into powders, which are straightforward to handle.

Microencapsulation (ME) is the enclosing of tiny solid particles, and liquid droplets/gases in a very coating (1-1000 um). Maine is with success applied to entrap natural compounds, like essential oils (EOs) or vegetal extracts containing polyphenols with well-known antimicrobial properties (Nazzaro *et al*., 2012) [63]. This site represents a vital place to begin for industries, which may try new natural and safe materials or systems of packaging capable of prolonging the shelf-life of foods, like extremely spoilable recent foods (vegetables, fruits, meat, etc.),

While not decreasing their characteristics in terms of quality and hygiene. Many of the Eos have antimicrobial properties against many foodborne pathogens and may be doubtless employed in completely different food matrices, as well as meat products (De Martino *et al*., 2009) [18]. However, limits to their use are joined to the aroma that may be unpleasant for shoppers or have low water solubility and volatility.

This technique is generally achieved in two steps. Firstly, an emulsion of the volatile compound is made in an aqueous dispersion of a wall material which also functions as the emulsifier. The microencapsulated emulsion must next be dried under carefully monitored conditions to reduce

encapsulation loss. In food biotechnology, capsules can be also used to entrap or enclose microorganisms by segregating them from the external environment with a coating of hydrocolloids, such that the cells are released in the appropriate gut compartment, at the right time. Probiotic encapsulation's major goal is to shield cells from an unfavorable environment and enable their release in the colon in a viable and metabolically active form (Nazzaro *et al*., 2012) [63]. One crucial factor that affects the sensory qualities of foods is the size of the capsules.

There are several kinds of encapsulation systems that can be assembled from food-grade components. Nano-encapsulation systems are encapsulation systems with particle diameters (At least in one dimension) less than 100 nm; these systems are of particular interest because they not only offer stability to the entrapped bioactive compounds but also have the potential to increase the absorption and bioavailability of the entrapped material. (Onwulata CI. 2012, McClements DJ *et al*., 2009) [25, 19]

Encapsulating several bioactive chemicals into these nanocarrier particles can increase their bioavailability, stability and dispersibility (Wang S *et al*., 2014) [20] However, there is still a sizable gap in the regulatory structure, and the majority of nations continue to control nanomaterials through existing law. A critical first step in avoiding consumers from being misinformed about the use of nanotechnology in food is improving the legal environment. Other measures, such as the assurance that food-grade materials are used in the manufacture of nano-systems, may be done to increase customers' confidence in meals including nanotechnology-based ingredients while legislation is still being adjusted. Cost is also another crucial factor; scaling up nanoencapsulation technologies is currently quite pricey.

**Table 4:** Nano-structured systems for delivery of nutrients

| Delivery Systems | Descriptions | Potential Application |
|---|---|---|
| Nano-emulsions | Stable dispersion, droplet size on order of 100 nm, uses different lipids and emulsifiers. | Delivery and Stabilization of lipophilic compounds. |
| Solid lipid nanoparticles | Emulsified systems made with crystalline or semicrystalline lipids. | Delivery and Stabilization of hydrophobic materials. |
| | Stabilized by an emulsifier coating. | |
| Liposomes | Vesicles formed with phospholipid bi-layer with aqueous interior. Single layer of multi-layers. | Delivery of both hydrophilic and hydrophobic compounds. |
| Microemulsions | Stable mixtures of water, oil and surfactants. Size range 5~100 nm. | Solubilisation and delivery of hydrophobic and hydrophilic compounds. |
| Casein micelles | Self-assembled nanostructures in milk size range 20~300 nm | Delivery of minerals, proteins and vitamins. |
| Protein nanoparticles | Hydrogels and nanoparticles formed by controlled aggregation of proteins. | Delivery of various hydrophilic compounds, provide nanoscale structure to food to affect texture and mouthfeel. |
| Protein fibrils | Some proteins can form fibrils and nanotubes under certain processing conditions. | Delivery of various hydrophilic compounds, affect texture of foods. |
| Protein-polysaccharide nanoconjugates | Covalent conjugation or electrostatic complexation between proteins and polysaccharides. | Delivery of both hydrophobic and hydrophilic compounds. |

**(Sources:** McClements DJ, *et al*., 2009, Wang S, *et al*., 2014, Singh H, *et al*., 2012, Tadros T, *et al*., 2004, Flanagan J, 2006, Van der Linden E *et al*., 2007) [19, 20, 21, 13, 22, 23].

The high cost of manufacture and the difficulty in locating surfactants that are suitable for use in food-grade nanoemulsions-the majority of those used to create nanoemulsions in other industrial applications-are the key obstacles to the development of food nanoemulsions.

The main advantages of nanotechnology for the microencapsulation of food ingredients are (Khare & Vasisht, 2014) [24]

1. The bioavailability of tastes and dietary components may improve as the surface area increases: This is crucial for taste compounds with low solubility and/or low thresholds for detecting flavor and odor.
2. Improvement in solubility of low water-soluble ingredients.
3. Optically transparent (Important in beverage application): Nano emulsions and microemulsions that have oil droplet sizes of less than 100 nm are optically transparent.
4. Higher ingredient retention during processing (Volatile organic carbon reduction) during spray drying.
5. Closer to the actual molecular remedy (Homogeneity in system properties, such as density).
6. Increased activity levels of encapsulated ingredients, e.g., antimicrobials in nanoemulsion/micro emulsion forms.

**Table 5:** Techniques Employed for Preparation of Nanoemulsions

| Technique | Formulation | Conclusions | References |
|---|---|---|---|
| High pressure homogenization | Oral lipid nanoemulsion (Primaquine) | Enhanced oral bioavailability, 10-200 nm particle size | Singh KK, *et al*., 2008 [26] |
| Pseudoternary phase diagram + spontaneous emulsification method | Ramipril nanoemulsion | Increased bioavailability, droplet size 80.9 nm | Shafiq S, *et al*., 2007 [27] |
| High pressure homogenization | O/W nano emulsions | Improved skin hydration and elasticity | Yilmaz E, *et al*., 2006 [28] |
| Spontaneous emulsification | O/W nanoemulsion (Aceclofenac) | Nanoemulsion with potential for transdermal delivery of aceclofenac | Shakeel F, *et al*., 2007 [29] |
| Spontaneous emulsification | Celecoxib nanoemulsion | Enhanced physical and chemical stability of celecoxib in nanoemulsion | Shakeel F, *et al*., 2008 [30] |
| High pressure homogenization | Lecithin-based nanoemulsions | Improved permeation rates of progesterone with long-term stability | Klang V, *et al*., 2010 [31] |

| | | | |
|---|---|---|---|
| | (Progesterone) | | |
| High pressure homogenization | Prednicarbate nanoemulsion | Increased chemical stability of the drug in formulation | Baspinar Y. *et al*., 2010 [32] |
| Phase inversion temperature method | Acyclovir-loaded multiple W/O/W | Excellent physicochemical | Schwarz JC, *et al*., 2012 [33] |
| | Nanoemulsions | Stability for 6 moat RT, mean droplet size of 100 nm | |
| Spontaneous nanoemulsions method | Clotrimazole nanoemulsion | Improved solubility of clotrimazole, mean globule size <25 nm | Borhade V, *et al*., 2012 [34] |
| Ultrasonic emulsification method | Basil oil nanoemulsion | Nanoemulsions with droplet size of 29.6 nm, for food preservation | Ghosh V, *et al*., 2013 [35] |
| Phase inversion composition method | Efavirenz nanoemulsion | Enhanced bioavailability, globule size <30 nm | Kotta S, *et al*., 2014 [36] |
| High-pressure homogenizer | Dimethyl silicone dry nanoemulsion inhalation | Effective in acute lung injury, particle size of 19.8 nm | Zhu L, *et al*., 2015 [37] |
| High-pressure homogenizer | Parenteral lecithin-based nanoemulsions (Risperidone) | Enhanced brain availability of risperidone with a mean particle size of 160 nm | Baboota S, *et al*., 2007 [38] |
| Microfluidization method | Pitavastatin-containing nanoemulsions | Enhanced permeation | Başpınar Y, *et al*., 2015 [39] |
| High-pressure homogenization + ultrasound | Nanoemulsion | Reduced energy demand for emulsification, low particle dimensions and higher stability | Calligaris S, *et al*., 2016 [40] |
| Sonication method | Saponin-stabilized quercetin-loaded o/w nanoemulsion | Stable for 45 d at RT, mean particle size of 52±10 nm | Kaur K, *et al*., 2016 [41] |
| High-pressure homogenization | Paclitaxel-baicalein nanoemulsion | Strategy to overcome multidrug resistance | Meng L, *et al*., 2016 [42] |
| Nanoemulsion templating | PLGA nanoparticles | Imaging agents for biomedical purposes | Fornaguera C, *et al*., 2016 [43] |
| Spontaneous emulsification method | Chitosan films with cinnamaldehyde nanoemulsions | Good UV barrier properties | Chen H, *et al*., 2016 [44] |

**Flavonoids**

Flavonoids are phenolic compounds that are isolated from natural sources and are a type of plant secondary metabolite. They are the most frequent phenolic chemicals found in flowering plants and in human and animal diets. The flavan nucleus has three rings (C6 (A)-C3 (B)-C6 (C) and is the most basic structure. Flavonoids are classified into five classes depending on the position of the ring B linkage: anthocyanins, chalcones, flavones, flavanones, flavanols and isoflavonoids (Panche, A.N., *et al*., 2016) [1].

Flavonoids are of importance to the food sector since they have a variety of biological functions. Antioxidant, anticancer, anti-inflammatory, hepatoprotective, lipid and carbohydrate metabolism regulator and antiviral characteristics are the flavonoids' most often reported bioactive effects. They have gained more attention in therapeutic effects in different diseases such as chronic disorders including metabolic, neurodegenerative diseases (Alzheimer), cancer, autoimmune illness, cardiovascular disorders (Panche, A.N., *et al*., 2016) [1], and recently, as a possible potential antiviral against COVID-19 (Russo, M., *et al*., 2020) [2].

The bioavailability of flavonoids is less and may vary drastically with different flavonoid classes and individual compounds in a specific group (Gonzales, G.B., *et al*., 2015) [3]. Genetic engineering is a recent tool to enhance plant performance and generate other sources of production such as microorganisms. However, microbial production of flavonoids has been achieved only at a laboratory scale, maybe due to obstacles such as adding expensive precursor substances (Santos-Buelga, C., *et al*., 2016) [4].

The main route of absorption of flavonoids is the gastrointestinal system because the primary sources of flavonoids are plants, fruits, and derivatives. Due to its low distribution of the food material to the lumen of the intestine, their low bioavailability, the makeup of the microbiota, and their ineffective absorption by intestinal epithelial cells, flavonoids have been linked to various steps of the process of digestion, including degradation influence the activity of gastrointestinal hydrolytic enzymes. (Pei, R., *et al*., 2020, Gonzales, G.B., *et al*., 2015) [5, 3].

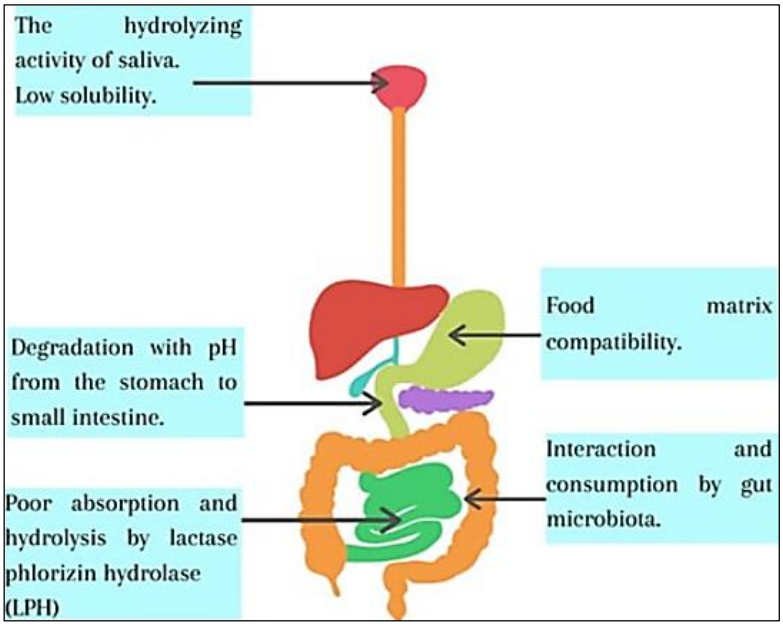


**Fig 2:** Summary of the factors accounting for the low bioavailability of flavonoids

The increase in bioavailability is due to the nature of nanoemulsions. They have two phases: the oil phase and the water phase stabilized by an interfacial film of surfactant. It improves nanoparticle solubility in the gastrointestinal fluid. Moreover, nanoemulsions might enhance the permeability through the intestinal wall and protect bioactive cells from enzymatic degradation in the GIT. These formulations can successfully reduce poor water-soluble flavonoid compounds' unfavorable oral absorption. (Liu Q. *et al*., 2019) [7].

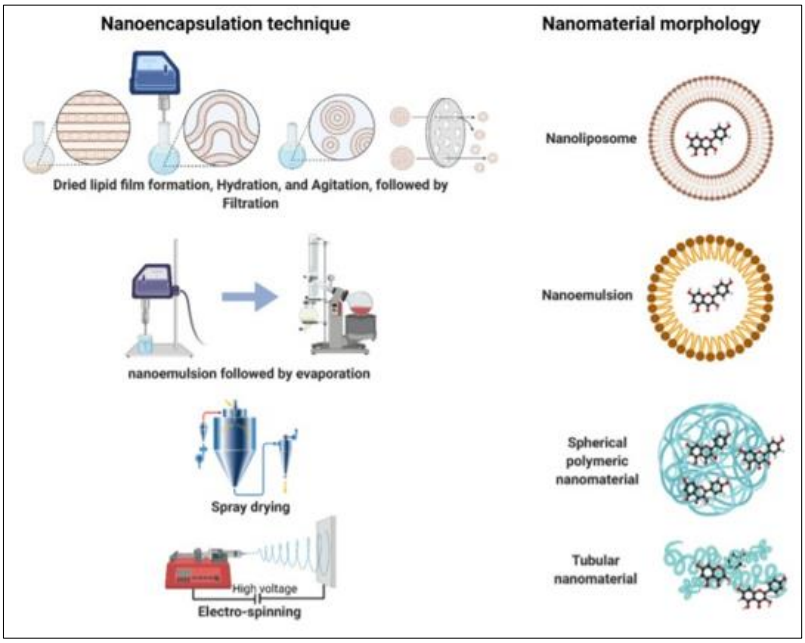


**Fig 3:** Most used techniques for nanoencapsulation of flavonoids

**Table 6:** Nanoencapsulation methods applied for flavonoids

| Technique | Morphology | Merits | Demerits |
|---|---|---|---|
| Nanoemulsion | Vesicles/spherical | Encapsulate high concentrations. Low energy. | High cost. Unstable during long-term storage. |
| Nanoliposome | Bilayer lipid vesicles | Stable against environmental factors. | Difficult to scale up Sensitivity to mechanical stress |
| Spray drying | Spherical/compact | Industrial scale Less time processing Hydrophobic Compounds without emulsifiers Low operating cost | High-Temperature Retention of a compound is generally less |
| Electro-spinning | Tubular | Absence of heat High surface retention High encapsulation yield & porosity | Limitation in industrial scale. Challenge in setting parameters |

According to Chen and Inbaraj (Chen, B., *et al*., 2019) [10], anthocyanins are water-soluble flavonoids that might enhance their physicochemical stability in nanoemulsions with different oil, water, surfactant, and cosurfactant ratios for

topical skin application and urinary tract infection. After 30 days in storage, the W/O anthocyanin nanoemulsions are still stable. They demonstrated no phase separation and the samples had a 385-day half-life, antioxidant activity and significant polyphenol retention rates. (Rabelo, C.A.S., *et al*., 2018) [11].

**Polyphenols**

All vascular plants and a few marine organisms produce polyphenols (PPH), a large class of ubiquitous and diverse chemicals. These organic compounds, which range in complexity from basic molecules to large structures, all contain benzenic cycles with one or more hydroxyl functionalities. These active ingredients are crucial for development, procreation, illness, virus, and predator resistance (Beckman C, 2000) [45]. Indeed, Klejdus (2010) [46] demonstrated that despite the fact that microalgae and cyanobacteria are more evolutionary primitive than terrestrial plants, they contain many types of flavonoids, including isoflavones, flavanones, flavonols and dihydrochalcones. In medicine, polyphenols contribute to the promotion of health and reduction of the risk of common chronic diseases (Liu R H., 2003) [72].

Several studies show an inverse correlation between the consumption of polyphenols and the risk of major illnesses such as cancer, cardiovascular diseases, type 2 diabetes mellitus, neurodegenerative diseases, and osteoporosis (Pandey and Rizvi, 2009) [47]. The chemical structure and molecular weight of polyphenols, as well as their low water solubility, poor stability in the gastrointestinal system, substantial phase II metabolism, and quick elimination, all contribute to their low bioavailability in general. (Scalbert A and Williamson G, 2000) [48].

As a consequence, clinical applications of PPH are limited. To avoid these drawbacks, nano delivery systems able to manage the structural integrity of the bioactive molecules have been developed (Etheridge ML., *et al*., 2013, Acosta E., 2009, Nair HB., *et al*., 2010) [49, 15, 51]. Numerous techniques for nanoencapsulation have been created using physical, physicochemical and chemical principles, such as spray drying, ionic gelation, hydrophobic interactions, etc.

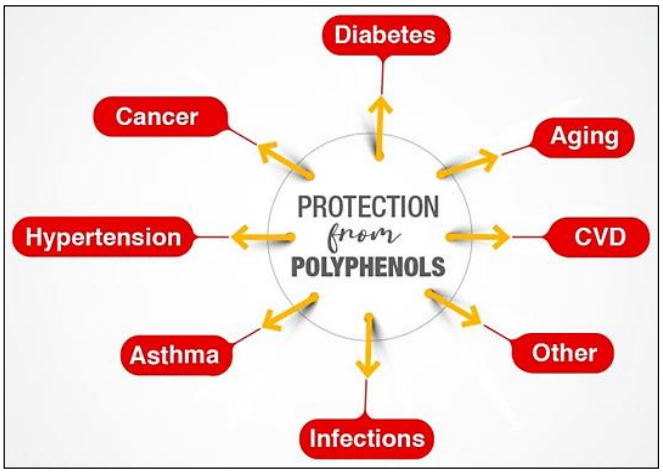


**Fig 4:** Therapeutic effects of Polyphenols

**Polyphenols bioavailability and the use of nano vectors**

Due to limited absorption in the human GI tract after consumption, substantial biotransformation in the gut and quick body elimination, polyphenols have a low bioavailability (Milbury PE., *et al*., 2010) [52].

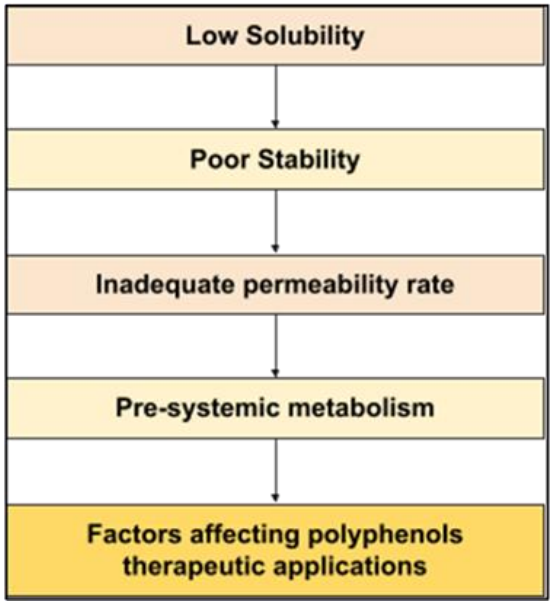


**Fig 5:** Factors affecting Polyphenols therapeutic applications

Encapsulation in nanovectors including cyclodextrins, matrix systems, solid dispersions, and liposomes has emerged more recently as an unique tactic to enhance the delivery, distribution and bioactivity of polyphenols. (Musthaba., *et al*., 2009) [53]. Such systems differ for the internal structure (core-shell-like or matrix) and the physical state of the encapsulated active substances. Moreover, the effective use of nanoparticles as drug delivery systems requires polyphenol encapsulation efficiency (EE) of, at least, sixty per cent.

**Nanoparticles as potential delivery systems of polyphenols**
**Epigallocatechin-3-gallate (EGCG)**

Epigallocatechin-3-gallate is a water-soluble flavonoid found predominantly in green tea leaves (Camellia sinensis) that acts in the prevention of some forms of cancer, cardiovascular diseases, type 2 diabetes mellitus and osteoporosis. Epigallocatechin-3-gallate is highly susceptible to degradation in the intestinal milieu and via oxidative processes. Efforts to promote the intake, enhance the stability, and increase bioavailability of EGCG are directed to incorporate this flavanol into nanosized delivery vectors.

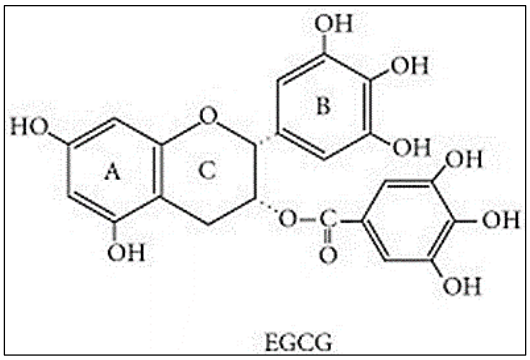


**Fig 6:** Epigallocatechin-3-gallate (EGCG) structure

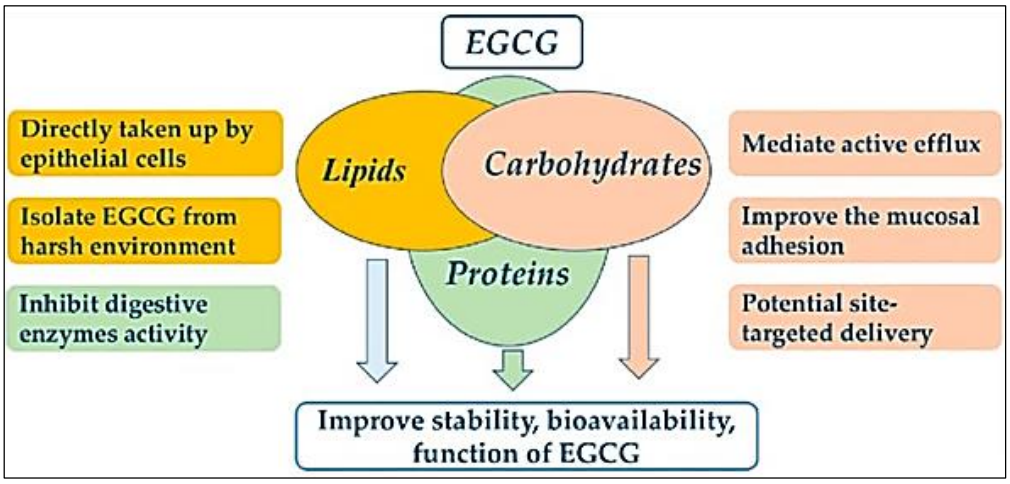


**Fig 7:** The potential mechanisms of food-grade encapsulate for improving EGCG bioavailability

**Table 7:** Nano delivery systems for epigallocatechin gallate

| Nano vectors | Type of Delivery Systems | References |
|---|---|---|
| Polyester nanoparticles | Poly (L-lactide)-poly (Ethylene glycol), (PLA-PEG) nanoparticles | Siddiqui IA *et al*., 2009 [54] |
| | PLGA-PEG nanoparticles functionalized with the prostate specific membrane antigen (PSMA) inhibitor on the surface | Sanna V *et al*., 2011 [55] |
| | PLGA biodegradable nanoparticles | Italia JL *et al*., 2008 [56] |
| Serum albumin nanoparticles | Bovine serum albumin (BSA) nanoparticles | Zu YG *et al*., 2009 [57] |
| Carbohydrate matrix | Carbohydrate matrix composed of maltodextrin (60%) and gum arabic (40%) Gelatin nanoparticle, Chitosan nanoparticles | Rocha S *et al*., 2011 [58] Smith A *et al*., 2010 [59] Shutava TG *et al*., 2009 [74] Dube A *et al*., 2010 [62] |

Siddiqui *et al*. (2009) [54] reported the encapsulation of EGCG in poly (L-lactide)-poly (Ethylene glycol), (PLA-PEG) nanoparticles and assessed its efficacy against human prostate cancer (PC3) cells both in vitro and *in vivo*. The results showed that encapsulated EGCG retained its biological effectiveness with an over 10-fold dose advantage form exerting its efficacy in the inhibition of PC3 proliferation. Moreover, PLA-PEG nanoparticles were biocompatible and permitted the control of the time and rate of polymer degradation. Additionally, epigallocatechin-3-gallate was added to bovine serum albumin (BSA) nanoparticles, which had a mean particle size of 200 nm, and their effects on PC3 cells were assessed. (Zu YG *et al*., 2009) [57]. In this work, PC3 cells lethality was positively correlated with the nanoparticle's uptake amount. The specific targeting to prostate cancer cells was obtained also with Poly (Lactide-co-glycolide)-Poly (ethylene glycol) (PLGA-PEG) nanoparticles encapsulating EGCG and functionalized with the prostate-specific membrane antigen (PSMA) inhibitor (Sanna V *et al*., 2011) [55].

Other PLGA-based nano vectors for EGCG were synthesized by Italia *et al*. (2008) [56] with a loading efficiency of 70 % and high antioxidant efficiency *in vivo*. These nanoparticles, given by oral administration, acted 3 times more quickly of solutions of free epigallocatechin-3-gallate administered parenterally. A further nanosized delivery systems encapsulating epigallocatechin gallate is constituted by a carbohydrate matrix composed of maltodextrin (60%) and gum arabic (40%) with EE of 85% (Zu YG *et al*., 2009) [57]. These particles were able to inhibit steps of the tumorigenesis

process. Smith *et al*. (2010) [59] immobilized EGCG on lipid-coated nanoparticles with a bioavailability, after encapsulation, increased twice-fold compared to that of the free form. Epigallocatechin gallate inside the membrane preserved its antioxidant activity and blocked the production of hepatocyte growth factor (HGF) from cancer cell lines MDA-MD-231. On these bases were also prepared gelatin nanoparticles loaded with EGCG with an interesting inhibitory effect on HGF-induced cell scattering (Shutava TG *et al*., 2009) [74].

Finally, epigallocatechin3-gallate was encapsulated into chitosan nanoparticles (sizing 165 nm and exhibiting a zeta potential of 33 mV) by Dube *et al*. (2010) [62] in order to evaluate the ability of chitosan tripolyphosphate nanoparticles to increase EGCG stability and bioavailability. They found that EGCG chitosan nanoparticles incubated in alkaline solution took more time to degrade to 50% of the initial level, compared to pure epigallocatechin.

## Conclusion

The applications of engineering within the food sector are new and nascent, however, they're foreseen to grow chop-chop within the returning years. However, nanotechnology-derived foods are new shoppers and it remains unclear how public perception, attitudes, selections, and acceptance can impact the long run of such applications within the food sector. The food trade is additionally looking for brand new technologies to boost the nutritionary worth, period, and traceability of their food merchandise. They're conjointly going to develop and enhance tastes, cut back the quantity of salt, sugar, fat, and preservatives, address food-related diseases, develop targeted nutrition for various lifestyles and aging populations, and maintain the property of food production, process, and food safety. Nanoencapsulation would be an honest resolution in creating practical parts a lot easier to consume.

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