Electronic Supplementary Material (ESI) for Food & Function.

Table 1 Summary of different delivery carriers for phytosterols

Carrier	Formulation components	Major findings	Reference
Nanoemulsion	β-sitosterol, catechin, polyunsaturated lipid	After emulsified, the melting points and crystallinity of β-sitosterol were reduced	(Wang et al., 2019)
Nanoemulsion	Phytosterol lecithin, monoacyl glycerol, soy lecithin, bulk milk fat	The decreasing in droplet size plays a great impact on lowering crystallization of PS and improving physicochemical stability of emulsion	(Zychowski et al., 2018)
Nanoemulsion	Phytosterol, whey protein, bulk milk fat	Phytosterols at lower concentrations (0.3 wt%) worked together whey protein to reduce effectively interfacial tension.	(Zychowski et al., 2016)
Nanoemulsion	Echium oil, phytosterol esters, phenolic compounds, Tween 20	Sinapic acid and rutin showed the highest antioxidant action for phytosterols in emulsion.	(Espinosa et al., 2015)
Microemulsion	Phytosterols, simvastatin sucrose monolaurate, propylene glycol, and oleyl lactate	This microemulsion elevated the dissolution for PSs in the water-free system	(Fisher et al., 2013)
Microemulsion	Ergosterol, Tween 80，Cremophor EL，Cremophor RH40，PEG400， ethanol	In the microemulsions, the water dispersibility of PSs in microemulsions was 1000 times higher than that of free PSs in water and the oral bioavailability of PSs was increased 2.56-fold and 4.5-fold than their unemulsified form.	(Yi et al., 2012)
Microemulsion	β-Sitosterol ester, β-sitosterol, linoleic acid	Beta-sitosterol self-micro emulsion showed a higher lipid-lowering effect than the β-sitosterol powder and tablets.	(Yuan et al., 2019)
Microemulsion	Sitosterol, oryzanol, medium-chain triglycerides, tween 20	The emulsions had a good stability and high encapsulation efficiency of more than 80% for 30 days storage period	(Khalid et al., 2017)
Microemulsion	Phytosterols, lemon essential oil, polyoxyethylene hydrogenated castor oil, Tween60, polyethylene glycol 400	Microemulsion showed encapsulation efficiency of 89.65% and increased the bioavailability of phytosterols more than three times	(Chuanxun et al., 2019)
oleogel	Phytosterols, oryzanol, sunflower oil	It showed good textural and rheological properties that employed as an alternative of the pig backfat successfully	(Panagiotopoulou et al., 2016)
oleogel	Phytosterols, glycerol monostearate，lecithin，liquid coconut oil	phytosterol-based oleogels containing glycerol monostearate show a substantially higher flow consistency index than that with lecithin did	(Li et al., 2022)
oleogel	β-sitosterol, γ-oryzanol，	chocolate with β-sitosterol/γ-oryzanol	(Sun et al., 2021)

	stearic acid, lecithin, corn oil	oleogel display the strongest gel-forming capacity, the densest gel crystallization network, and similar sensory properties of dark chocolate	
Liposome	β-sitosterol, stigmasterol, ergosterol and lanosterol, lecithin, insulin	Liposomes ergosterol have better capacity in maintaining stability in simulated gastrointestinal fluid than liposomes prepared with cholesterol	(Cui et al., 2015)
Liposome	β-sitosterol, stigmasterol, campsterol, soybean lecithin, ascorbic acid, cholesterol	The presence of phytosterols affected the liposome stability and encapsulation efficiency of liposome.	(Alexander et al., 2012)
Liposome	β-Sitosterol, lecithin, curcumin	The stability, encapsulation effectiveness, were greatly enhanced with the content of β-sitosterol was raised from 20 to 33 %	(Tai et al., 2019)
Liposome	Phytosterol, phytosterol esters, soybean lecithin	Liposome with soy phospholipids, which can encapsulate 35% of PSs. PSs at relatively lower concentration preferentially co-assemble into phospholipid bilayers without the formation of crystals. With the contents of PSs increase at the saturation in system, PSs can be incorporated into the lumen of liposomes and possibly form small crystals.	(Wang et al., 2017)
NLC	β-sitosterol, green tea extract, grapeseed oil, fish oil, squalene, Tween 20，Tween 80	The NLCs showed higher antioxidant capacity up to 92% as compared to the free β-sitosterol (36.5%).	(Lacatusu et al., 2012)
SLN	Cmonostearate glycerol, distearate glycerol, tristearate, lecithin	PS-GMS acquired the highest bioaccessibility due to their sensitivity to the intestinal hydrolysis. An increase in the number of acyl chains of glycerides change their spatial arrangement and inhibits the hydrolysis of ester bonds by enzymes	(Guo et al., 2022)
NLC	β-sitosterol, propolis wax, glyceryl behenate, pomegranate seed oil, Tween 80	NLC with relatively good physical and chemical stability and ensured the delivery of β-sitosterol to various food Less oil in their formulation may result in larger size and lower encapsulation efficiency.	(Soleimanian et al., 2018)
NLC	β-sitosterol, Precirol，Miglyol，PEG aqueous phase Poloxamer 407	NLCs with optimal formulation displayed encapsulation efficiency of 99.96%, uniform size distribution and increased antioxidant capacity The stability of NLCs in butter preserved no change during the 3-month storage.	(Bagherpour et al., 2017)

NLC	Phytosterols, fully hydrogenated soybean oil, and soybean oil, soybean lecithin, ethoxylated sorbitan monooleate	The nanoparticles in aqueous dispersion have lower temperatures for crystallization and presented higher thermal resistance.	(da Silva Santos et al., 2019)
NLC	β-sitosterol, beeswax, pomegranate seed oil, Tween 80 and phospholipids	β-sitosterol loading in NLCs exhibited increased solubility and gradual release and reduced total cholesterol and mouse plasma LDL-cholesterol levels	(Soleimanian et al., 2020)
Protein-based nanoparticles	Phytosterol powder, Whey protein concentrate, soy protein isolate and sodium caseinate	Protein-based nanoparticles exhibited smaller particle sizes, higher packaging efficiency and loading capacity, better water redispersion and lower crystallinity of PS among them.	(Cao et al., 2016)
Protein-based nanoparticles	Stigmasterol, zein and organic solvents	The nanoparticles were produced with homogenous size, smooth surface, high encapsulation efficiency (97%) and stability	(Feng et al., 2019)
Carbohydrate-based nanoparticles	Phytosterol, Nanoporous starch aerogels (NSA) supercritical CO2	The PS-NSA decrease the crystallinity and improve the water solubility and acquired a 20-fold higher bioaccessibility than the crude PSs	(Ubeyitogullari et al., 2017)
Carbohydrate-based nanoparticles	Phytosterol, Nanoporous starch aerogels (NSA) supercritical CO_2	Allow preparation of low- and nonfat food enriched with phytosterol and increase their bioaccessibility from 16 to 53% in non-fat bars	(Ubeyitogullari & Ciftci, 2019)
Complex coacervation of biopolymers nanoparticles	Phytosterol, soy protein isolate, pectin	Nanoparticles with 5:1 ratio of SPI/pectin exhibited higher encapsulation efficiency of 87.9% and better stability against gastric acid conditions	(Feng et al., 2021)
Complex coacervation of biopolymers nanoparticles	Beta-sitosterol and echium seed oil, gelatin, Arabic gum	Gelatin-Arabic gum nanoparticles showed encapsulation efficiency for α-linolenic, stearidonic acid, and β-sitosterol of 96, 90, and 74%, respectively at 30 days storage period	(Comunian et al., 2018)
Complex coacervation of biopolymers nanoparticles	Stigmasterol, zein and pectin	The loaded stigmasterols in nanoparticles can be delivered to the intestine successfully and release 99.07% of them	(Feng et al., 2020)
Complex coacervation of biopolymers nanoparticles	Phytosterol, sodium caseinate (SC), pectin	The SC/pectin-based phytosterols NPs owning high encapsulation efficiency (91%). The bioaccessibility of PSs was increased by 43.8% comparing with SC-based NPs	(Gan et al., 2022)
Complex coacervation of	Ergosterol, whey protein isolate (WPI), chitosan	WPI/chitosan nanoparticles with high yield and encapsulation efficiency by optimizing	(Rudke et al., 2019)

biopolymers nanoparticles	the parameters of the complex coacervation and microencapsulation

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