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(54) **DELIVERY AND CONTROLLED RELEASE OF ENCAPSULATED LIPOPHILIC NUTRIENTS**

ABGABE UND KONTROLLIERTE FREISETZUNG VON EINGEKAPSELTEN LIPOPHILEN NÄHRSTOFFEN

ADMINISTRATION ET LIBERATION REGULEE DE NUTRIMENTS LIPOPHILES ENCAPSULES

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- **GUZEY DEMET, MCCLEMENTS DAVID JULIAN: "Impact of Electrostatic Interactions on Formation and Stability of Emulsions Containing Oil Droplets Coated by Beta-Lactoglobulin-Pectin Complexes" JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY, vol. 55, 19 December 2006 (2006-12-19), pages 475-485, XP002498820**
- **GUZEY ET AL: "Formation, stability and properties of multilayer emulsions for application in the food industry" ADVANCES IN COLLOID AND INTERFACE SCIENCE, ELSEVIER, vol. 128-130, 26 February 2007 (2007-02-26), pages 227-248, XP005881072 ISSN: 0001-8686**
- **HARNSILAWAT THEPKUNYA, PONGSAWATMANIT RUNGNAPHAR, MCCLEMENTS DAVID J.: "Influence of pH and Ionic Strength on Formation and Stability of Emulsions Containing Oil Droplets Coated by Beta-Lactoglobulin-Alginate Interfaces" BIOMACROMOLECULES, vol. 7, 3 May 2006 (2006-05-03), pages 2052-2058, XP002498821**

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Description

PRIORITY CLAIM

[0001] This application claims priority to U.S. Utility Application Serial No. 11/846,212, filed August 28, 2007 and entitled, *Delivery and Controlled Release of Encapsulated Lipophilic Nutrients* (Attorney Docket No.006943.01011),

FIELD OF THE INVENTION

[0002] The present invention relates to the field of delivering lipophilic nutrients in an acidic aqueous system for controlled release to a consumer, more particularly encapsulated lipophilic nutrients in acidic aqueous systems such as food and beverage products.

BACKGROUND

[0003] Certain functional nutrients have been discovered to have beneficial health effects. Lipophilic nutrients, such as, for example, omega-3 and omega-6 fatty acids, form an important part of the human diet. These are referred to generally as "essential fatty acids," at least some of which are understood in many cases to constitute important components of cell membranes, regulate the body's use of cholesterol, and control the production of substances that affect many other bodily processes. For example, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), long-chain forms of omega-3 fatty acids, are understood in many cases to support brain and cardiovascular health and functions, amongst other health benefits. To increase or optimize health benefits from essential fatty acids, it has been suggested that consumption of omega-3 fatty acids should be increased.

[0004] Previously, water-insoluble lipophilic nutrients were incorporated directly into an aqueous system in one of four physical forms: a solution (with a compatible solvent), an extract, an emulsion, or a micellular dispersion (a so-called microemulsion). While all of these approaches serve to disperse the lipophilic nutrient in an aqueous system, they do not provide any additional benefits like controlled (triggered) release or extended protection against hydrolysis and oxidation. Commercially available fish oils can be high in omega 3 fatty acids, and in some cases are "encapsulated but these commercially available fish oils have not proven physically or taste-stable in acidic food and beverage products. This results in negative hedonistic changes to the food or beverage product, such as unpleasant fishy flavors and aromas after ingestion, particularly a fishy aftertaste caused by belching fish oil from the stomach. Additionally, omega-3 fatty acids are unstable to degradation, e.g., by oxidation or hydrolysis, when exposed to air, water and/or light

[0005] It would be desirable to provide a composition containing lipophilic nutrients which can reduce or eliminate the unpleasant taste and odor of the lipophilic nutrients, and which can be incorporated into a beverage product, food product, or other aqueous system suitable for consumption by a human or animal. It would also be desirable to provide lipophilic nutrients in a stable form for use in aqueous systems such as food and beverage products, so that the lipophilic nutrient is stable to oxidation and hydrolysis during the shelf life of the food or beverage product. It would also be desirable to provide a composition which releases lipophilic nutrients in the lower gastroinstestinal tract rather than the stomach.

[0006] Application US 2007/0104849 A1 is directed to beverage compositions and methods for their preparation using multilayer emulsion coating components for degraditive stability.

[0007] Journal article "Impact of Electrostatic Interactions on Formation and Stability of Emulsions Containing Oil Droplets Coated by β-Lactoglobulin-Pectin Complexes" JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY, voL 55,19 December 2006, pages 475-485, is directed to interfacial protein-polysaccharide complexes that can be used to improve the physical stability of oil-in-water emulsions.

[0008] Journal article "Formation, stability and properties of multilayer emulsions for application in the food industry" ADVANCES IN COLLOID AND INTERLACE SCIENCE, voL 128-130, 26 February 2007, pages 227-248, is directed to formation of multilayered interfaces around oil droplets in oil-in-water emulsions.

[0009] Journal article "Influence of pH and Ionic Strength on Formation and Stability of Emulsions Containing Oil Droplets Coated by β-Lactoglobulin-Alginate Interfaces" BIOMACROMOLECULES, vol. 7,3 May 2006, pages 2052-2058, is directed to the use of corn oil-in-water multilayered emulsions containing oil droplets coated by β-lactoglobulin and sodium alginate.

[0010] Journal article "Influence of alginate, pH and ultrasound treatment on palm oil-in-water emulsions stabilized by β-lactoglobulin" COLLOIDS AND SURFACES A: PHYSIOCHEMICAL AND ENGINEERING ASPECTS, vol. 287, 15 September 2006, pages 59-67, is directed to testing palm oil-in-water multilayered emulsions stabilized by using a variety of analytical techniques.

[0011] Journal article "Microencapsulation of lipophilic drugs in chitosan-coated alginate microspheres" INTERNATIONAL JOURNAL OF PHARMACEUTICS, vol. 187,30 September 1999, pages 115-123, is directed to the use of chitosan-coated alginate microspheres containing a lipophilic marker dissolved in an edible oil.

BRIEF SUMMARY OF THE INVENTION

[0012] Aspects of the invention are directed to delivery systems for lipophile nutrients which may be incorporated into food and beverage products such as, for example a ready-to-drink acidic beverage. By encapsulating the lipophilic nutrient, any negative effects (e.g., oxidation, off flavor, unpleasant aroma, etc.) can be reduced. Control-

led release of the encapsulated lipophilic nutrient in the lower gastrointestinal tract reduces aftertaste, and also enhances bioavailability and overall physiological efficacy of the lipophilic nutrient.

[0013] One aspect of the invention is directed to complex coacervate delivery systems comprising an aqueous dispersion of complex coacervates. The complex coacervates have a shell comprising at least one food-grade cationic polymer and at least one food-grade anionic polymer, and a core comprising at least one lipophilic nutrient. The complex coacervate delivery system upon ingestion is operative to substantially release the lipophilic nutrient in the lower gastrointestinal tract.

[0014] The invention is directed to complex coacervate delivery systems according to the appended claims.

[0015] The complex coacervate delivery systems comprise an aqueous dispersion of substantially non-agglomerated complex coacervates. In certain exemplary embodiments, the complex coacervates have a substantially non-crosslinked, substantially non-gelled shell comprising gelatin and gum acacia in a weight to weight ratio of about 4:1, and a core comprising an omega-3 fatty acid. In certain exemplary embodiments, all or at least a majority of the complex coacervates have a particle size within the range of 0.1 μm to 5.0 μm, e.g., at least a majority of the complex coacervates have a particle size within the range of 0.1 μm to 2.0 μm, or within the range of 0.3 μm to 0.5 μm. The complex coacervate delivery system is stable at pH values within the range of 2.8 to 4.0. The complex coacervate delivery system upon ingestion is operative to substantially release the omega-3 fatty acid in the lower gastrointestinal tract at a pH value within the range of about pH 6.0 and above.

[0016] Other aspects of the invention are directed to beverage products that deliver lipophilic nutrients beneficial for general health and well-being, without compromising to any significant extent the taste characteristics of the beverage product. The lipophilic nutrients can be added to beverage products having associated health benefits, as well as other beverage products that may not typically be perceived as having nutritional and health benefits, to promote healthy lifestyles. A beverage product is provided which includes a complex coacervate delivery system comprising an aqueous dispersion of complex coacervates. The complex coacervates are according to the appended claims. The beverage product has a pH of about 1.5 to about 5.0. Upon ingestion of the beverage product, complex coacervate delivery system is operative to substantially release the lipophilic nutrient in the lower gastrointestinal tract in a pH-controlled manner.

[0017] Other aspects of the invention are directed to food products which include a complex coacervate delivery system comprising an aqueous dispersion of complex coacervates. The complex coacervates are according to the appended claims. The food product can have a pH of about 1.5 to about 5.0. Upon ingestion of the food product, the complex coacervate delivery system is operative to substantially release the lipophilic nutrient in the lower gastrointestinal tract in a pH-controlled manner.

[0018] Other aspects of the invention are directed to complex coacervate delivery systems comprising an aqueous dispersion of complex coacervates. The complex coacervates are according to the appended claims. The complex coacervate delivery system is operative to substantially release the lipophilic nutrient in a pH-controlled manner. In certain exemplary embodiments, the cationic polymer comprises at least one of Eudragit E, Eudragit E 100, and Eudragit E PO.

[0019] These and other aspects, along with advantages and features of the present invention herein disclosed, will become apparent through reference to the following detailed description.

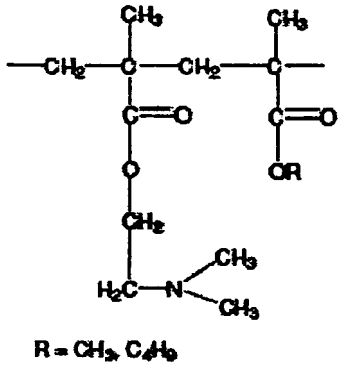
DETAILED DESCRIPTION

[0020] Aspects of the invention relate to complex coacervate delivery systems disclosed herein for lipophilic nutrients, which provide a stable composition suitable for inclusion in food and beverage products, that is, the complex coacervates are stable for shelf-storage, for use in making foods and beverages, and for shelf-storage when included in acidic food and beverages, etc. The complex coacervate delivery systems also provide pH-controlled release of the one or more lipophilic nutrients in the neutral to basic conditions of the lower gastrointestinal tract. That is, the complex coacervates in the complex coacervate delivery systems dissociate upon entering the part of the gastrointestinal tract below the stomach where the pH becomes substantially neutral or alkaline. As used herein, "pH-controlled release" (optionally referred to as release in a pH-controlled manner, or pH-dependent release, or pH-triggered release, or the like) means that the complex coacervates release at least the majority of the encapsulated lipophilic nutrient when the pH of the complex coacervate delivery system or the environment in which it is placed reaches or goes beyond a certain pH value, e.g., at any pH value within a specified range, or at one or more pH values within a specified range. The complex coacervate delivery system reduces or eliminates the unpleasant taste and odor of many lipophilic nutrients such as fish oil, reduces degradation, e.g. by oxidation or hydrolysis, of unstable lipophilic nutrients, and delays release of the lipophilic nutrient until the lower gastrointestinal tract, where good absorption and bioavailability occurs. The complex coacervate delivery system may be incorporated into a food or beverage product associated with health benefits, for example orange juice, to provide enhanced nutritional value. Additionally, the complex coacervate delivery system may be incorporated into food and beverage products, for example carbonated soft drinks. By encapsulating such lipophilic nutrients in a complex coacervate delivery system, possible negative hedonic, visual and physical changes to the food or beverage product may be reduced or avoided. The resulting food and beverage product is appealing to

the consumer, as well as being stable and having an adequate shelf life.

[0021] A complex coacervate delivery system is provided comprising an aqueous dispersion of complex coacervates. As used herein, a "delivery system" is a composition or a mixture of components which can be used to carry the complex coacervates encapsulating the lipophilic nutrient and to provide or deliver them into a system or environment or the like, e.g. into a food or beverage intended for consumption by humans or animals. As used herein, an "aqueous dispersion" is defined as particles distributed throughout a medium of liquid water, e.g., as a suspension, a colloid, an emulsion, a sol, etc. The medium of liquid water may be pure water, or may be a mixture of water with at least one water-miscible solvent, such as, for example, ethanol or other alcohols, propylene glycol, glycerin, dimethylsulfoxide, dimethylformamide, etc. In certain exemplary embodiments, there may be a substantial concentration of water-miscible solvent in the aqueous dispersion of the complex coacervate delivery system, such as, between about 1% and about 20% by volume, for example 5%, 10%, or 15%. In other exemplary embodiments, the complex coacervate delivery system is diluted into a beverage or food product and the concentration of water-miscible solvent is negligible. As used herein, a "complex coacervate" is a particle having a shell comprising at least two oppositely charged polymers (that is, cationic polymers of at least one type and anionic polymers of at least one type) which substantially encapsulates a core material. At least a majority of the complex coacervates have a particle size within the range of about 0.1 μm to about 5.0 μm, preferably within the range of about 0.1 μm to about 2.0 μm, most preferably within the range of about 0.3 μm to about 0.5 μm. The particle sizes disclosed here include any or at least one value within the disclosed ranges as well as the endpoints of the ranges. The complex coacervates are substantially non-agglomerated, but comprise a single shell encapsulating a single core. The core includes at least one water-insoluble, lipophilic nutrient, for example a liquid such as an oil. As used herein, a "lipophilic nutrient" is a substance that provides nourishment needed for life or growth or good health, which has an amenity for or is capable of dissolving in lipids, fats, oils, or non-polar solvents (e.g., a non-polar, hydrophobic substance). The shell includes a net positive charged (cationic) polymer and a net negative charged (anionic) polymer. It is believed that the net charge of each polymer is dependent on the pH of the environment and the isoelectric point of each polymer, which is in turn dependent on the density of ionizable groups in each polymer and the pKa values of those groups. Thus, disclosure here of complex coacervates comprising cationic and anionic polymers refers to the charge of the polymers in the environment or reaction conditions used for formation of the complex coacervates. Complex coacervates of the type used here are presently understood to be stabilized at least in part by the electrostatic attraction between the oppositely charged polymers, and thus are selected or designed to release upon a particular physiological trigger, specifically a pH change. In certain exemplary embodiments, the complex coacervates are not substantially additionally stabilized, for example by substantial gelling, substantial crosslinking, or substantial hardening of the complex coacervate shell. Gelling, crosslinking, and hardening are believed to hinder pH-controlled dissociation of the complex coacervates and the resulting release of lipophilic nutrients.

[0022] Exemplary polymers for use in the complex coacervates delivery systems disclosed here include oppositely charged polymers that form complex coacervates at an acidic pH, e.g., a pH value below about pH 6.0, in certain exemplary embodiments, a pH value within the range of about 1.5 to about 5.0, in certain exemplary embodiments, a pH value within the range of about 2.8 to about 4.0. The complex coacervates disclosed here are stable at an acidic pH, e.g., a pH value within the range below about pH 6.0, in certain exemplary embodiments, a pH value within the range of about 1.5 to about 5.0, in certain exemplary embodiments, a pH value within the range of about 2.8 to about 4.0. In certain exemplary embodiments, the complex coacervates are stable at a pH within such recited ranges in the sense that they are stable at any pH value within the recited range, including the endpoints. In other exemplary embodiments, the complex coacervates are stable at one or more pH values within the recited range, including the endpoints, but are not stable at every pH value within the recited range. As used herein, "stable" means that at least a majority of the complex coacervates do not dissociate and release the lipophilic nutrients. In certain exemplary embodiments, the oppositely charged cationic and anionic polymers are food-grade biopolymers. As used herein, "food-grade" is defined as any material that is deemed by the United States Food and Drug Administration to be safe for use in food and beverage products. Exemplary food-grade cationic polymers include but are not limited to proteins such as dairy proteins, including whey proteins, caseins and fractions thereof, gelatin, corn zein protein, bovine serum albumin, egg albumin, grain protein extracts, e.g. protein from wheat, barley, rye, oats, etc., vegetable proteins, microbial proteins, legume proteins, proteins from tree nuts, proteins from ground nuts, and polysaccharides such as chitosan. Other exemplary cationic polymers include but are not limited to Eudragit E, Eudragit E 100, and Eudragit E PO. Eudragit E 100 has an average molecular weight of approximately 150,000, with repeating units having the following structure:



[0023] Exemplary food-grade anionic polymers include but are not limited to polysaccharides such as pectin, carrageenan, alginate, xanthan gum, modified celluloses, e.g., carboxymethylcellulose, gum acacia, gum ghatti, gum karaya, gum tragacanth, locust bean gum, guar gum, psyllium seed gum, quince seed gum, larch gum (arabinogalactans), stractan gum, agar, furcellaran, modified starches, gellan gum, fucoidan, and the like. An exemplary complex coacervate shell comprises gelatin and gum acacia. There are many possible combinations of oppositely charged polymers that are useful for forming the complex coacervates disclosed here. The weight to weight ratio of cationic polymer to anionic polymer can be from about 10:1 to about 1:10, and is preferably about 4:1.

[0024] When included in an acidic food or beverage product, e.g. a food or beverage product having a pH value within the range below about pH 6.0, in certain exemplary embodiments, a pH value within the range of about 1.5 to about 5.0, in certain exemplary embodiments, a pH value within the range of about 2.8 to about 4.0, the complex coacervate delivery systems disclosed here provide a stable dispersion of encapsulated lipophilic nutrient. Upon ingestion of the food or beverage product, that is, upon being consumed by a human or animal, the complex coacervate delivery systems are also stable and the complex coacervates do not substantially dissociate in the acidic environment of the stomach, where the pH is typically about pH 1-4. Since the lipophilic nutrient remains substantially encapsulated in the stomach, unpleasant aftertaste and bad breath from belching of free lipophilic nutrient is greatly reduced. The complex coacervate delivery system substantially releases the lipophilic nutrient in a pH-controlled manner in the lower gastrointestional tract, e.g. the small intestine, thus enhancing bioavailability and overall physiological efficacy of the encapsulated lipophilic nutrient. It is believed that neutral to basic conditions of the lower gastrointestinal tract, e.g. typically having a pH value within the range of about pH 6.0 and above, and in certain exemplary embodiments having a pH value within the range of about pH 7.0 and above, trigger dissociation of the complex coacervates and release of the encapsulated lipophilic nutrient due to weakening of the electrostatic forces that stabilize the complex coacervate shell. It should be understood that in at least certain exemplary embodiments, the complex coacervates cam release the encapsulated lipophilic nutrient in a pH-controlled manner in almost any system, for exemple, under *in vitro* conditions such as a simple aqueous dispersion at any or one or more selected pH values about 6.0 and above, or about 7.0 and above. In certain exemplary embodiments, the complex coacervates may not release the encapsulated lipophilic nutrient in a pH-controlled manner under *in vitro* conditions, but undergoes pH-controlled release *in vivo* in a human or animal lower gastrointestinal tract at any or at least one pH value about 6.0 and above or about 7.0 and above, where additional biological, chemical and/or mechanical factors act upon the complex coacervate. In addition, it is contemplated that complex coacervate delivery systems according to aspects of the present invention will exhibit additional desired physical properties. For example, it is contemplated that complex coacervate delivery systems will have an acceptable mouthfeel, taste, aroma, and appearance.

[0025] It is believed that conditions of the lower gastrointestinal tract, e.g. typically having a pH value within the range of about pH 6.0 and above, and in certain exemplary embodiments having a pH value within the range of about pH 7.0 and above, trigger dissociation of the complex coacervates and release of the encapsulated lipophilic nutrient due to weakening of the electrostatic forces that stabilize the complex coacervate shell.

[0026] In certain exemplary embodiments, the lipophilic nutrients include fat soluble vitamins, (e.g., vitamins A, D, E, and K), tocotrienols, carotenoids, xanthophylls. (e.g., lycopene, lutein, astaxanthin, and zeazanthin), fat-soluble nutraceuticals including phytosterols, stanols and esters thereof, Coenzyme Q10 and ubiquinol, hydrophobic amino acids and peptides, essential oils and extracts, and fatty acids. Fatty acids may include, for example, conjugated linolenic acid (CLA), omega-6 fatty acids, and omega-3 fatty acids. Suitable omega-3 fatty acids include, e.g., short-chain omega-3 fatty acids such as alpha-linolenic acid (ALA), which are derived from plant sources, for example flaxseed, and long-chain omega-3 fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The long-chain omega-3 fatty acids can be derived from, for example, marine or fish oils. Such oils can be extracted from various types of fish or marine animals, such as anchovies, capelin, cod, herring, mackerel, menhaden, salmon, sardines, shark and tuna, or from marine vegetation, such as micro-algae, or a combination thereof. Other sources of omega-3 fatty acids include liver and brain tissue and eggs.

[0027] In at least certain exemplary embodiments, at least one of EPA and DHA is included in the complex coacervate delivery system. When included as a mixture, the ratio of EPA to DHA may vary depending on the source of the omega-3 fatty acids (e.g., fish oils), the

manner in which the omega-3 fatty acids are mixed, and the food or beverage product to be produced. The EPA:DHA ratio will vary to suit a particular application and can include, for example, 0:100, 100:0, 2:1, or 3:2. In certain exemplary embodiments, the mixture of omega-3 fatty acids comprises about 55-65% EPA and about 45-35% DHA. In a particular application the EPA:DHA ratio is about 60:40; however, other ratios are contemplated and within the scope of the invention.

[0028] In certain exemplary embodiments, a desired amount of a lipophilic nutrient in the above-described complex coacervate delivery system is included in a food or beverage product. The complex coacervate delivery system may be added to the food or beverage product in any number of ways, as will be appreciated by those of ordinary skill in the art given the benefit of this disclosure. In certain exemplary embodiments, the complex coacervate delivery system is sufficiently mixed in the food or beverage product to provide a substantially uniform distribution, for example a stable dispersion. Mixing should be accomplished such that the complex coacervates are not destroyed. If the complex coacervates are destroyed, oxidation of the lipophilic nutrient may result. The mixer(s) can be selected for a specific application based, at least in part, on the type and amount of ingredients used, the viscosity of the ingredients used, the amount of product to be produced, the flow rate, and the sensitivity of ingredients, such as the complex coacervate delivery system, to shear forces or shear stress.

[0029] The amount of lipophilic nutrient included in a food or beverage product may vary depending on the application and nutritional content desired. In one embodiment, the food or beverage product comprises orange juice including about 5-5000 mg of omega-3 fatty acids per 8 fluid ounces (0.24 liters) (serving size). The amount to be added will vary to suit a particular application and can be based, at least in part, on nutritional value, taste, shelf-life, efficacy levels approved, qualified health claims, and combinations thereof. Other amounts are also contemplated and within the scope of the invention. For example, it may be desired to provide at least 32 mg of omega-3 fatty acids (combined EPA and DHA) per 8 fluid ounces of the food or beverage product to meet the United States Food and Drug Administration (FDA) excellent source nutrient content claim requirements, or 16 mg per 8 fluid ounces to meet the FDA good source nutrient content claim requirements.

[0030] Encapsulation of lipophilic nutrients using the above-described complex coacervate delivery system stabilizes the lipophilic nutrient, protecting it from degradation by, for example, oxidation and hydrolysis. When included in an acidic food or beverage product, the complex coacervate delivery system can provide a stable dispersion of lipophilic nutrient over a suitable shelf-life for the food or beverage product. In certain exemplary embodiments, the finished food or beverage product including complex coacervate delivery systems disclosed here have a shelf-life greater than one week, e.g., about 1-12 months and possibly up to 24 months or longer under ambient conditions (e.g., room temperature of between 70°F and 80°F and controlled light exposure), depending on the level of processing the product undergoes, the type of packaging, and the materials used for packaging the product. In other embodiments, the finished product with the complex coacervate delivery system may have a shelf-life of about 12 weeks up to about 20 weeks under refrigerated conditions. In other embodiments, the finished product may be stored indefinitely under frozen conditions. Additional factors that may affect the shelf-life of the product include, for example, the nature of the base formula (e.g., an acidic beverage sweetened with sugar has a longer shelf-life than an acidic beverage sweetened with aspartame) and environmental conditions (e.g., exposure to high temperatures and sunlight is deleterious to ready-to-drink beverages).

[0031] Certain exemplary embodiments of the beverage products disclosed here include ready-to-drink beverages, beverage concentrates, syrups, shelf-stable beverages, refridgerated beverages, frozen beverages, and the like. Preferably, the beverage product is acidic, e.g. having a pH value within the range below about pH 6.0, in certain exemplary embodiments, a pH value within the range of about 1.5 to about 5.0, or in certain exemplary embodiments, a pH value within the range of about 2.8 to about 4.0. Beverage products include but are not limited to, e.g., carbonated and non-carbonated soft drinks, fountain beverages, liquid concentrates, fruit juice and fruit juice-flavored drinks, sports drinks, energy drinks, fortified/enhanced water drinks, soy drinks, vegetable drinks, grain-based drinks (e.g. malt beverages), fermented drinks (e.g., yogurt and kefir) coffee beverages, tea beverages, dairy beverages, and mixtures thereof. Exemplary fruit juice sources include citrus fruit, e.g. orange, grapefruit, lemon and lime, berry, e.g. cranberry, raspberry, blueberry and strawberry, apple, grape, pineapple, prune, pear, peach, cherry, mango, and pomegranate. Beverage products include bottle, can, and carton products and fountain syrup applications.

[0032] Certain exemplary embodiments of the food products disclosed here include fermented food products, yogurt, sour cream, cheese, salsa, ranch dip, fruit sauces, fruit jellies, fruit jams, fruit preserves, and the like. Preferably, the food product is acidic, e.g. having a pH value within the range below about pH 6.0, in certain exemplary embodiments, a pH value within the range of about 1.5 to about 5.0, or in certain exemplary embodiments, a pH value within the range of about 2.8 to about 4.0. All variations, alternatives, options, etc., discussed elsewhere in this disclosure apply to food embodiments of the invention, for example, any disclosed complex coacervate comprising any cationic or anionic polymer in any ratio, any lipophilic nutrients, and any particle size can be used in food embodiments in any combination suitable for application to food products.

[0033] The food or beverage product may optionally include other additional ingredients. Optional additional

ingredients include, for example, vitamins, minerals, sweeteners, flavorings, colorings, edible particulates, thickeners, emulsifiers, acidulants, electrolytes, anti-foaming agents, proteins, carbohydrates, preservatives, and mixtures thereof. Other ingredients are also contemplated. The ingredients can be added at various points during processing, including before or after pasteurization, and before or after addition of the complex coacervate delivery system.

[0034] In at least certain exemplary embodiments, food and beverage products disclosed here may be pasteurized. The pasteurization process may include, for example, ultra high temperature (UHT) treatment and/or high temperature-short time (HTST) treatment. The UHT treatment includes subjecting the food or beverage product to high temperatures, such as by direct steam injection or steam infusion, or by indirect heating in a heat exchanger. Generally, after the product is pasteurized, the product can be cooled as required by the particular product composition/configuration and/or the package filling application. For example, in one embodiment, the food or beverage product is subjected to heating to about 185°F (85°C) to about 250°F (121°C) for a short period of time, for example, about 1 to 60 seconds, then cooled quickly to about 36°F (2.2°C) +/10°F (5°C) for refrigerated products, to ambient temperature for shelf stable or refrigerated products, and to about 185°F (85°C) +/-10°F (5°C) for hot-fill applications for shelf-stable products. The pasteurization process is typically conducted in a closed system, so as not to expose the food or beverage product to atmosphere or other possible sources of contamination. Other pasteurization or sterilization techniques may also be useful, such as, for example, aseptic or retort processing. In addition, multiple pasteurization processes may be carried out in series or parallel, as necessitated by the food or beverage product or ingredients.

[0035] Food and beverage products may, in addition, be post processed. Post processing is typically carried out following addition of the complex coacervate delivery system. Post processing can include, for example, cooling the product and filling it into container for packaging and shipping. Post processing may also include deaeration of the product to less than 4.0 ppm oxygen, preferably less than 2.0 ppm and more preferably less than 1.0 ppm oxygen. Deaeration, however, and other post processing tasks may be carried out prior to processing, prior to pasteurization, prior to mixing with the complex coacervate delivery system and/or at the same time as adding the complex coacervate delivery system. In addition, an inert gas (e.g., nitrogen or argon) headspace may be maintained during the intermediary processing of the product and final packaging. Additionally/alternatively, an oxygen or UV barrier and/or oxygen scavengers could be used in the final packaging.

[0036] The following examples are specific embodiments of the present invention but are not intended to limit it.

EXAMPLE 1

[0037] A complex coacervate delivery system was prepared using the following methods. A 25 mL aqueous solution of 2% by weight gum acacia was prepared. Fish oil high in omega-3 fatty acid (1.3 mL) was added to the 25 mL gum acacia solution. The mixture was sonicated for two minutes, alternating pulsing on for 1 second and off for 1 second, to form an oil-in-water emulsion. Then, a 100 mL aqueous solution of 2% by weight gelatin type A pre-heated to 50°C was added slowly to the emulsion while stirring the mixture at 500 rpm. Maintaining the temperature at 50°C, the pH was lowered to between 4.8 and 5.0 using 0.1 M phosphoric acid. Then the mixture was cooled in an ice bath. Once the temperature reached 5-10°C, the pH was lowered to between 4.0 to 4.5 using another portion of 0.1 M phosphoric acid to allow formation of coacervate complexes of cationic gelatin and anionic gum acacia encapsulating droplets of fish oil. Particle size of the complex coacervates was about 2.0 to about 3.0 μm.

[0038] It should be noted that the sonication in Example 1 could be replaced or supplemented with high-speed homogenization.

EXAMPLE 2

[0039] Fish oil high in omega-3 fatty acid (1.3 mL) was added to 25 mL aqueous solution of 0.4% by weight modified starch containing 0.83% polyvinyl alcohol, of which pH was pre-adjusted to 2.6 using citrate buffer. The mixture was sonicated for two minutes in the same manner as described in Example 1. Then, a 5 mL aqueous solution of 0.5% by weight whey protein (pH 2.6 in 10 mM citrate buffer) was added to the mixture and further sonicated for another 30 seconds. Particle size of thus formed complex coacervates was about 0.5 - 1 μm.

[0040] It should be noted that the modified starch in Example 2 could be replaced wholly or partly with gum acacia and/or other anionic polymers. The whey protein in Example 2 could be replaced wholly or in part with chitosan, gelatin, and/or other cationic polymers. The polyvinyl alcohol in Example 2 could be replaced wholly or partly with modified starch, polyethylene glycol, maltodextrin DE5, guar gum, and/or hydroxypropylmethylcellulose (HPMC). Also, it should be noted that the concentration of modified starch in Example 2 could be increased up to 4% by weight or more.

[0041] Also, it should be noted that the acid in Examples 1 and 2 could be selected from other organic and inorganic acids, such as, for example, phosphoric acid, ascorbic acid, citric acid, acetic acid, malic acid, tartaric acid, glucono delta-lactone, succinic acid, and any combination thereof.

EXAMPLE 3

[0042] The amount of encapsulated oil produced in Ex-

ample 2 was estimated by subtracting unencapsulated oil from total oil in the system. For extracting unencapsulated free oil, the particle suspension was mixed with hexane at 1:1 ratio and spun at 14,000 rpm for 15 minutes. The hexane layer was then collected and analyzed as described in Examples 4 and 5. Total oil in the system (encapsulated oil and unencapsulated free oil) was extracted as follows. Particle suspension was brought to pH 6.7-6.8 using 1N NaOH solution and heated to 50°C to dissolve the coacervate coats surrounding oil droplets. The suspension was mixed with hexane at 1:1 ratio and spun at 14,000 rpm for 15 minutes. The hexane layer was then collected and analyzed as described in Examples 4 and 5.

EXAMPLE 4

[0043] Five ml of methylating reagent (BCl_3-methanol) was added to 2 ml of hexane layer collected as described in Example 3, mixed well by shaking, and then placed in a heat block and heated at 60°C for 10 min. The methylated solution was allowed to return to room temperature, mixed for 1 min. using a vortex mixer, and left until two layers (hexane and water) separated. The top layer was transferred into a glass vial, to which an equal volume of internal standard (0.01 mg/ml methyl laurate in hexane) was added prior to GC/MS analysis.

EXAMPLE 5

[0044] Methylated omega-3 fatty acids were analyzed using the Agilent 5973N GC/MS. One μl of each sample was injected onto the column (Restek Rtx-1, Crossbond 100% dimethylypolysiloxane, 30 m x 250 μm x 1.00 μm) that was programmed for a 5 min. solvent delay at 100°C, followed by heating to 250°C at a rate of 20°C/min., holding at 250°C for 5 min., and then heating to 320°C at a rate of 20°C/min. Helium was used as a carrier gas and flowed at 1 ml/min.

EXAMPLE 6

[0045] A complex coacervate delivery system was prepared in the same way as in Example 1, by replacing the gum acacia solution with a 5% by weight aqueous solution of modified starch, and replacing the gelatin solution with a 0.5% by weight aqueous solution of whey protein. No apparent difference was observed whether starting with modified starch or whey protein.

EXAMPLE 7

[0046] A complex coacervate delivery system was prepared in the same way as Example 1 with weighting agents added to the fish oil to increase its density. Exemplary weighting agents include ester gum, sucrose acetate isobutyrate, and brominated vegetable oil, among others.

EXAMPLE 8

[0047] A complex coacervate delivery system was prepared in the same way as Example 1 with a 5% by weight aqueous solution of polyvinylalcohol added.

EXAMPLE 9

[0048] A complex coacervate delivery system was prepared in the same way as in Example 1, replacing the gelatin and gum acacia solutions with a 0.083% by weight aqueous solution of chitosan, a 0.33 % by weight aqueous solution of modified starch, and a 0.67% by weight aqueous solution of polyvinylalcohol.

EXAMPLE 10

[0049] Eudragit E polymers can be used as the cationic polymer in Examples 1 and 2. In this case, the Eudragit E polymer is first dissolved in ethanol, then the ethanolic solution is added to the coacervation system, of which the pH is pre-adjusted to less than pH 5.0. Once the complex coacervates form, 90-95% of ethanol in the system is removed by ultrafiltration. Alternatively, Eudragit E polymers can be dissolved in any other water-miscible organic solvents, such as, for example, other alcohols, propylene glycol, glycerin, dimethylsulfoxide, or dimethylformamide. Alternatively, Eudragit E polymers can be dissolved in acidic aqueous solutions with a pH less than pH 5.0. The acidic aqueous solution can be prepared with various organic and inorganic acids, such as, for example, phosphoric acid, ascorbic acid, citric acid, acetic acid, malic acid, tartaric acid, glucono delta-lactone, succinic acid, and any combination thereof.

[0050] To prepare 2.0-3.0 μm complex coacervates, a 25 mL aqueous solution of 2% by weight gum acacia is prepared. Fish oil high in omega-3 fatty acid (1.3 mL) is added to the 25 mL gum acacia solution. The mixture is sonicated for two minutes, alternating pulsing on for 1 second and off for 1 second, to form an oil-in-water emulsion. The pH is lowered to between pH 4.0 to 4.5 using 0.1 M phosphoric acid. Then, a 5 mL ethanolic solution of 5% by weight Eudragit E 100 is added slowly to the emulsion while stirring the mixture at 500 rpm. Ethanol and polymers that have not participated in the complex coacervation are then removed by ultrafiltration.

EXAMPLE 11

[0051] To prepare 0.5-1 μm complex coacervates, fish oil high in omega-3 fatty acid (1.3 mL) is added to a 25 mL aqueous solution of 0.4% by weight modified starch containing 0.83% polyvinyl alcohol, of which pH is pre-adjusted to pH 2.6 using citrate buffer. The mixture is sonicated for two minutes, alternating pulsing on for 1 second and off for 1 second, to form an oil-in-water emulsion. Then, a 5 mL ethanolic solution of 0.5% by weight Eudragit E 100 is added and the mixture is further soni-

cated for another 30 seconds. Ethanol and polymers that have not participated in the complex coacervation are then removed by ultrafiltration.

Claims

1. A complex coacervate delivery system comprising an aqueous dispersion of complex coacervates;
wherein the complex coacervates are substantially non-agglomerated but comprise a single shell encapsulating a single core, which single shell comprises at least one food grade cationic polymer and at least one food grade anionic polymer;
wherein the core comprises at least one lipophilic nutrient;
wherein the complex coacervate delivery system is operative on ingestion, to substantially release the lipophilic nutrient in the lower gastrointestinal tract in a pH-controlled manner at one or more pH values within the range of pH 6.0 and above.

2. The complex coacervate delivery system of claim 1, which is stable at at least one pH value within the range of 1.5 to 5.0, or which is stable at at least one pH value within the range of 2.8 to 4.0.

3. The complex coacervate delivery system of claim 1, wherein the lipophilic nutrient comprises at least one of fatty acids, fat soluble vitamins, vitamin A, vitamin D, vitamin E, vitamin K, tocotrienols, carotenoids, xanthophylls, lycopene, lutein, astaxanthin, zeazanthin, fat-soluble nutraceuticals, phytosterols, stanols and esters thereof, Coenzyme Q10, ubiquinol, hydrophobic amino acids and peptides, essential oils and extracts, preferably wherein the fatty acid comprises at least one of conjugated linolenic acid (CLA), one or more omega-3 fatty acids, and one or more omega-6 fatty acids, more preferably wherein the omega-3 fatty acid comprises at least one of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), or wherein the omega-3 fatty acid comprises 55-65% EPA and 45-35% DHA.

4. The complex coacervate delivery system of claim 1, wherein the core further comprises at least one weighting agent, preferably wherein the weighting agent comprises at least one of ester gum, sucrose acetate isobutyrate, and brominated vegetable oil.

5. The complex coacervate delivery system of claim 1, wherein at least a majority of the complex coacervates have a particle size within the range of 0.1 μm to 5.0 μm, or wherein at least a majority of the complex coacervates have a particle size within the range of 0.1 μm to 2.0 μm, or
wherein at least a majority of the complex coacervates have a particle size within the range of 0.3 μm to 0.5 μm, or
wherein the cationic polymer comprises at least one of dairy proteins, whey proteins, caseins and fractions thereof, gelatin, corn zein protein, bovine serum albumin, egg albumin, grain protein extracts, vegetable proteins, microbial proteins, legume proteins, proteins from tree nuts, proteins from ground nuts, and chitosan, or wherein the anionic polymer comprises at least one of pectin, carrageenan, alginate, xanthan gum, modified celluloses, carboxymethylcellulose, gum acacia, gum ghatti, gum karaya, gum tragacanth, locust bean gum, guar gum, psyllium seed gum, quince seed gum, larch gum, stractan gum, agar, furcellaran, modified starches, gellan gum, and fucoidan, or
wherein the cationic polymer comprises gelatin and the anionic polymer comprises gum acacia, or
wherein the weight to weight ratio of cationic polymer to anionic polymer is from 10:1 to 1:10, or
wherein the weight to weight ratio of cationic polymer to anionic polymer is about 4:1, or
wherein the single shell is substantially non-crosslinked, or
wherein the single shell is substantially non-gelled, or
wherein the complex coacervates are substantially non-agglomerated.

6. The complex coacervate delivery system of claim 1, wherein the single shell is a substantially non-crosslinked, substantially non-gelled shell comprising gelatin and gum acacia in a weight to weight ratio of about 4:1; and the core comprises an omega-3 fatty acid;
wherein the complex coacervates have a particle size of 0.1 μm to 0.5 μm;
wherein the complex coacervate delivery system has a pH value within the range of 2.8 to 4.0 and wherein the liphohilic agent is an omega 3 fatty acid.

7. A beverage product comprising a complex coacervate delivery system according to claim 1, wherein the beverage product has a pH value within the range of 1.5 to 5.0

8. The beverage product of claim 7, wherein the beverage product comprises a ready-to-drink beverage, or wherein the beverage product is selected from the group consisting of carbonated beverages, non-carbonated beverages, fountain beverages, liquid concentrates, fruit juices, fruit juice-flavored drinks, sports drinks, energy drinks, fortified/enhanced water drinks, soy drinks, vegetable drinks, grain-based drinks, malt beverages, fermented drinks, yogurt drinks, kefir, coffee beverages, tea beverages, dairy beverages, and mixtures thereof.

9. A food product comprising a complex coacervate de-

livery system according to claim 1, wherein:

wherein the food product is selected from the group consisting of fermented food products, yogurt, sour cream, cheese, salsa, ranch dip, fruit sauces, fruit jellies, fruit jams, and fruit preserves.

10. The complex coacervate delivery system of claim 1, wherein the cationic polymer comprises at least one of Eudragit E, Eudragit E 100, and Eudragit E PO, or, wherein the anionic polymer comprises at least one of pectin, carrageenan, alginate, xanthan gum, modified celluloses, carboxymethylcellulose, gum acacia, gum ghatti, gum karaya, gum tragacanth, locust bean gum, guar gum, psyllium seed gum, quince seed gum, larch gum, stractan gum, agar, furcellaran, mofied starches, gellan gum, and fucoidan.

Patentansprüche

1. Abgabesystem für komplexe Koazervate, das eine wässrige Dispersion von komplexen Koazervaten umfasst;
wobei die komplexen Koazervate im Wesentlichen nicht agglomeriert sind, sondern eine einzelne Hülle, die einen einzelnen Kern einkapselt, umfassen, wobei die einzelne Hülle mindestens ein kationisches Polymer in Lebensmittelqualität und mindestens ein anionisches Polymer in Lebensmittelqualität umfasst;
wobei der Kern mindestens einen lipophilen Nährstoff umfasst;
wobei das Abgabesystem für komplexe Koazervate bei Aufnahme funktionsfähig ist, um im Wesentlichen den lipophilen Nährstoff im unteren Gastrointestinaltrakt auf eine pH-gesteuerte Weise bei einem oder mehreren pH-Werten innerhalb des Bereichs von pH = 6,0 und darüber freizusetzen.

2. Abgabesystem für komplexe Koazervate nach Anspruch 1, das bei mindestens einem pH-Wert innerhalb des Bereichs von 1,5 bis 5,0 stabil ist oder das bei mindestens einem pH-Wert innerhalb des Bereichs von 2,8 bis 4,0 stabil ist.

3. Abgabesystem für komplexe Koazervate nach Anspruch 1, wobei der lipophile Nährstoff mindestens einen von Fettsäuren, fettlöslichen Vitaminen, Vitamin A, Vitamin D, Vitamin E, Vitamin K, Tocotrienolen, Carotenoiden, Xantophyllen, Lycopin, Lutein, Astaxanthin, Zeaxanthin, fettlöslichen Nutrazeutika, Phytosterolen, Stanolen und Estern davon, Koenzym Q10, Ubichinol, hydrophoben Aminosäuren und Peptiden, essentiellen Ölen und Extrakten umfasst, wobei bevorzugt die Fettsäure mindestens eine von konjugierter Linolensäure (CLA), einer oder mehreren Omega-3-Fettsäuren und einer oder mehreren Omega-6-Fettsäuren umfasst, wobei stärker bevorzugt die Omega-3-Fettsäure mindestens eine von Eicosapentaenylsäure (EPA) und Docosahexaensäure (DHA) umfasst oder wobei die Omega-3-Fettsäure 55 bis 65 % EPA und 45-35 % DHA umfasst.

4. Abgabesystem für komplexe Koazervate nach Anspruch 1, wobei der Kern weiter mindestens einen Füllstoff umfasst, wobei bevorzugt der Füllstoff mindestens einen von Estergummi, Sucroseacetatisobutyrat und bromiertem Pflanzenöl umfasst.

5. Abgabesystem für komplexe Koazervate nach Anspruch 1, wobei mindestens eine Mehrheit der komplexen Koazervate eine Teilchengröße innerhalb des Bereichs von 0,1 μm bis 5,0 μm aufweist oder wobei mindestens eine Mehrheit der komplexen Koazervate eine Teilchengröße innerhalb des Bereichs von 0,1 μm bis 2,0 μm aufweist oder
wobei mindestens eine Mehrheit der komplexen Konzentrate eine Teilchengröße innerhalb des Bereichs von 0,3 μm bis 5,0 μm aufweist oder
wobei das kationische Polymer mindestens eines von Milchproteinen, Molkeproteinen, Kaseinen und Fraktionen davon, Gelatine, Maiszeinprotein, Rinderserumalbumin, Eieralbumin, Kornproteinextrakten, pflanzlichen Proteinen, mikrobiellen Proteinen, Leguminosenproteinen, Proteinen aus Baumnüssen, Proteinen aus Bodennüssen und Chitosan umfasst oder
wobei das anionische Polymer mindestens eines von Pektin, Carrageen, Alginat, Xanthangummi, modifizierten Zellulosen, Carboxymethylcellulose, Akaziengummi, Ghattigummi, Karayagummi, Tragantgummi, Johannisbrotkernmehl, Guarkernmehl, Flohsamenschalengummi, Quittensamengummi, Lärchengummi, Stractangummi, Agar, Furcellaran, modifizierten Stärken, Gellan und Fucoidan umfasst oder
wobei das kationische Polymer Gelatine und das anionische Polymer Akaziengummi umfasst oder
wobei das Gewicht-zu-Gewicht-Verhältnis von kationischem Polymer zu anionischem Polymer von 10:1 bis 1:10 ist oder
wobei das Gewicht-zu-Gewicht-Verhältnis von kationischem Polymer zu anionischem Polymer ungefähr 4:1 ist oder
wobei die einzelne Hülle im Wesentlichen nicht vernetzt ist oder
wobei die einzelne Hülle im Wesentlichen nicht geliert ist oder
wobei die komplexen Koazervate im Wesentlichen nicht agglomeriert sind.

6. Abgabesystem für komplexe Koazervate nach Anspruch 1,
wobei die einzelne Hülle eine im Wesentlichen nicht

vernetzte, im Wesentlichen nicht gelierte Hülle ist, die Gelatine und Akaziengummi in einem Gewicht-zu-Gewicht-Verhältnis von ungefähr 4:1 umfasst und der Kern eine Omega-3-Fettsäure umfasst;
wobei die komplexen Koazervate eine Teilchengröße von 0,1 μm bis 0,5 μm aufweisen;
wobei das Abgabesystem für komplexe Koazervate einen pH-Wert innerhalb des Bereichs von 2,8 bis 4,0 aufweist und wobei das lipophile Mittel eine Omega-3-Fettsäure ist.

7. Getränkeprodukt, das ein Abgabesystem für komplexe Koazervate gemäß Anspruch 1 umfasst, wobei das Getränkeprodukt einen pH-Wert innerhalb des Bereichs von 1,5 bis 5,0 aufweist.

8. Getränkeprodukt nach Anspruch 7, wobei das Getränkeprodukt ein trinkfertiges Getränk umfasst oder wobei das Getränkeprodukt ausgewählt ist aus der Gruppe bestehend aus kohlensäurchaltigen Getränken, stillen Getränken, Quellgetränken, Flüssigkonzentraten, Fruchtsäften, fruchtsaftaromatisierten Getränken, Sportgetränken, Energiegetränken, angereicherten/verbesserten Wassergetränken, Sojagetränken, pflanzlichen Getränken, kornbasierten Getränken, Malzgetränken, fermentierten Getränken, Joghurtgetränken, Kefir, Kaffeegetränken, Teegetränken, Milchgetränken und Mischungen davon.

9. Nahrungsmittelprodukt, das ein Abgabesystem für komplexe Koazervate gemäß Anspruch 1 umfasst, wobei:

wobei das Nahrungsmittelprodukt ausgewählt ist aus der Gruppe bestehend aus fermentierten Nahrungsmittelprodukten, Joghurt, saurer Sahne, Käse, Salsa, Ranchdip, Fruchtsoßen, Fruchtgelees, Fruchtkonfitüren und Fruchtkonserven.

10. Abgabesystem für komplexe Koazervate nach Anspruch 1, wobei das kationische Polymer mindestens eines von Eudragit E, Eudragit E 100 oder Eudragit E PO umfasst, oder
wobei das anionische Polymer mindestens eines von Pektin, Carrageen, Alginat, Xanthangummi, modifizierten Zellulosen, Carboxymethylcellulose, Akaziengummi, Ghattigummi, Karayagummi, Tragantgummi, Johannisbrotkernmehl, Guarkernmehl, Flohsamenschalengummi, Quittensamengummi, Lärchengummi, Stractangummi, Agar, Furcellaran, modifizierten Stärken, Gellan und Fucoidan umfasst.

Revendications

1. Système de délivrance de coacervats complexes comprenant une dispersion aqueuse de coacervats complexes ;
dans lequel les coacervats complexes sont essentiellement non agglomérés, mais comprennent une enveloppe unique encapsulant un noyau unique, laquelle enveloppe unique comprend au moins un polymère cationique de qualité alimentaire et au moins un polymère anionique de qualité alimentaire ;
dans lequel le noyau comprend au moins un nutriment lipophile ;
le système de délivrance de coacervats complexes étant fonctionnel lors de l'ingestion, pour essentiellement libérer le nutriment lipophile dans le tractus gastro-intestinal inférieur d'une manière régulée par le pH à une ou plusieurs valeurs de pH comprises dans la plage de pH supérieure ou égale à 6,0.

2. Système de délivrance de coacervats complexes selon la revendication 1, qui est stable à au moins une valeur de pH comprise dans la plage allant de 1,5 à 5,0, ou qui est stable à au moins une valeur de pH comprise dans la plage allant de 2,8 à 4,0.

3. Système de délivrance de coacervats complexes selon la revendication 1, dans lequel le nutriment lipophile comprend au moins l'un des composants choisis parmi les acides gras, les vitamines solubles dans une matière grasse, la vitamine A, la vitamine D, la vitamine E, la vitamine K, les tocotriénols, les caroténoïdes, les xanthophylles, le lycopène, la lutéine, l'astaxanthine, la zéaxanthine, les produits nutraceutiques solubles dans une matière grasse, les phytostérols, les stanols et leurs esters, la Coenzyme Q10, l'ubiquinol, les acides aminés hydrophobes et les peptides, les huiles essentielles et les extraits, de préférence dans lequel l'acide gras comprend au moins un acide choisi parmi l'acide linolénique conjugué (CLA), un ou plusieurs acides gras oméga-3, et un ou plusieurs acides gras oméga-6, plus préférablement dans lequel l'acide gras oméga-3 comprend au moins un acide choisi parmi l'acide éicosapentaénoïque (EPA) et l'acide docosahexaénoïque (DHA), ou dans lequel l'acide gras oméga-3 comprend de 55 à 65 % d'EPA et de 45 à 35 % de DHA.

4. Système de délivrance de coacervats complexes selon la revendication 1, dans lequel le noyau comprend en outre au moins une charge, de préférence dans lequel la charge comprend au moins l'un des composants choisis parmi une gomme d'ester, l'acétate isobutyrate de saccharose et une huile végétale bromée.

5. Système de délivrance de coacervats complexes selon la revendication 1, dans lequel au moins une majorité des coacervats complexes a une taille de particule comprise dans la plage allant de 0,1 μm à 5,0 μm, ou

dans lequel au moins une majorité des coacervats complexes a une taille de particule comprise dans la plage allant de 0,1 μm à 2,0 μm, ou
dans lequel au moins une majorité des coacervats complexes a une taille de particule comprise dans la plage allant de 0,3 μm à 0,5 μm, ou
dans lequel le polymère cationique comprend au moins l'un des composants choisis parmi les protéines de lait, les protéines de lactosérum, les caséines et leurs fractions, la gélatine, la protéine zéine de maïs, l'albumine sérique bovine, l'albumine d'oeuf, les extraits de protéines de céréales, les protéines végétales, les protéines microbiennes, les protéines de légumineuses, les protéines de noix, les protéines d'arachides, et le chitosan, ou
dans lequel le polymère anionique comprend au moins l'un des composants choisis parmi la pectine, le carraghénane, l'alginate, la gomme xanthane, les celluloses modifiées, la carboxyméthylcellulose, la gomme arabique, la gomme ghatti, la gomme karaya, la gomme adragante, la gomme de caroube, la gomme de guar, la gomme de graines de psyllium, la gomme de graines de coing, la gomme de mélèze, l'arabinogalactane, l'agar-agar, le furcellarane, les amidons modifiés, la gomme de gellane, et le fucoïdane, ou
dans lequel le polymère cationique comprend la gélatine et le polymère anionique comprend la gomme arabique, ou
dans lequel le rapport en poids du polymère cationique au polymère anionique est de 10:1 à 1:10, ou
dans lequel le rapport en poids du polymère cationique au polymère anionique est d'environ 4:1, ou
dans lequel l'enveloppe unique est essentiellement non réticulée, ou
dans lequel l'enveloppe unique est essentiellement non gélifiée, ou
dans lequel les coacervats complexes sont essentiellement non agglomérés.

6. Système de délivrance de coacervats complexes selon la revendication 1,
dans lequel l'enveloppe unique est une enveloppe essentiellement non réticulée, essentiellement non gélifiée comprenant de la gélatine et de la gomme arabique selon un rapport en poids d'environ 4:1 ; et le noyau comprend un acide gras oméga-3 ;
dans lequel les coacervats complexes ont une taille de particule de 0,1 μm à 0,5 μm ;
le système de délivrance de coacervats complexes ayant une valeur de pH comprise dans la plage allant de 2,8 à 4,0 et dans lequel l'agent lipophile est un acide gras oméga-3.

7. Boisson comprenant un système de délivrance de coacervats complexes selon la revendication 1, la boisson ayant une valeur de pH comprise dans la plage allant de 1,5 à 5,0.

8. Boisson selon la revendication 7, la boisson comprenant une boisson prête à boire, ou la boisson étant choisie dans le groupe constitué par les boissons gazeuses, les boissons non gazeuses, les boissons pour distributeur, les concentrés liquides, les jus de fruits, les boissons à arôme de fruit, les boissons pour le sport, les boissons énergisantes, les eaux fortifiées/enrichies, les boissons au soja, les boissons aux légumes, les boissons à base de céréales, les boissons à base de malt, les boissons fermentées, les yoghourts à boire, le kéfir, les cafés, les thés, les boissons à base de lait, et les mélanges de ceux-ci.

9. Aliment comprenant un système de délivrance de coacervats complexes selon la revendication 1, l'aliment étant choisi dans le groupe constitué par les aliments fermentés, les yoghourts, les crèmes fraîches, les fromages, les sauces piquantes, les sauces à la crème, les sauces à base de fruits, les gelées de fruits, les confitures de fruits, et les conserves de fruits.

10. Système de délivrance de coacervats complexes selon la revendication 1, dans lequel le polymère cationique comprend au moins l'un des composants choisis parmi Eudragit E, Eudragit E100 et Eudragit E PO, ou
dans lequel le polymère anionique comprend au moins l'un des composants choisis parmi la pectine, le carraghénane, l'alginate, la gomme xanthane, les celluloses modifiées, la carboxyméthylcellulose, la gomme arabique, la gomme ghatti, la gomme karaya, la gomme adragante, la gomme de caroube, la gomme de guar, la gomme de graines de psyllium, la gomme de graines de coing, la gomme de mélèze, l'arabinogalactane, l'agar-agar, le furcellarane, les amidons modifiés, la gomme de gellane, et le fucoïdane.

REFERENCES CITED IN THE DESCRIPTION

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