

Claims

1. A process for the production of a microcapsule comprising an active ingredient or inactive precursor thereof, wherein the process comprises the following steps:
- 5 a) providing a surface-reacted calcium carbonate, wherein the surface-reacted calcium carbonate is a reaction product of natural ground calcium carbonate or precipitated calcium carbonate with carbon dioxide and one or more H_3O^+ ion donors, wherein the carbon dioxide is formed in situ by the H_3O^+ ion donors treatment,
- b) providing an active ingredient or inactive precursor thereof,
- 10 c) contacting the active ingredient or inactive precursor thereof with the surface-reacted calcium carbonate to obtain a loaded surface-reacted calcium carbonate, and
- d) encasing the loaded surface-reacted calcium carbonate with a multilayer shell by consecutively depositing at least two complementary layers using layer-by-layer assembly onto the loaded surface-reacted calcium carbonate.
- 15 2. The process according to claim 1, wherein the process further comprises the step of
- e) reacting the microcapsule obtained in step d) with an acidic compound to decompose the loaded surface-reacted calcium carbonate within the multilayer shell, preferably the acidic compound is selected from the group consisting of hydrochloric acid, hydrobromic acid, sulphuric acid, nitric acid, acetic acid, formic acid, hydrogen sulfate, dihydrogen phosphate, hydrogen phosphate, calcium
- 20 scavenging agents, preferably ethylene diamine tetraacetic acid, and salts and mixtures thereof, and more preferably the acidic compound is hydrochloric acid.
3. The process according to claim 2, wherein step e) is carried out in an aqueous medium, preferably wherein the acidic compound is added until the pH of the aqueous medium is in the range from 1 to 6, more preferably from 1.5 to 5, even more preferably from 2 to 4.5, and most preferably
- 25 from 2.5 to 3.5.
4. The process according to any one of the preceding claims, wherein the surface-reacted calcium carbonate has
- a BET specific surface area from 20 to 200 g/m^2 , preferably 40 to 150 g/m^2 , more preferably 70 to 120 g/m^2 ; and/or
- 30 - a volume median particle size d_{50} from 0.1 to 75 μm , preferably from 0.5 to 50 μm , more preferably from 1 to 40 μm , even more preferably from 1.2 to 30 μm , and most preferably from 1.5 to 15 μm ; and/or
- a volume top cut particle size d_{98} from 0.2 to 150 μm , preferably from 1 to 100 μm , more preferably from 2 to 80 μm , even more preferably from 2.4 to 60 μm , and most preferably from 3 to
- 35 30 μm ; and/or
- an intra-particle intruded specific pore volume in the range from 0.1 to 2.5 cm^3/g , more preferably from 0.2 to 2.2 cm^3/g , still more preferably from 0.4 to 2.0 cm^3/g and most preferably from 0.6 to 1.8 cm^3/g , determined by mercury porosimetry measurement.

5. The process according to any one of the preceding claims, wherein the active ingredient is a pharmaceutically active ingredient, a cosmetic active ingredient, a nutraceutical active ingredient, a biocide, a pesticide, a wetting agent, a UV protecting agent, a scavenger, a pro-drug, a precursor of a cosmetic active ingredient, a precursor of a nutraceutical active ingredient, a precursor of a biocide, a precursor of a pesticide, a precursor of a wetting agent, a precursor of a UV protecting agent, a precursor of a scavenger, or a mixture thereof, preferably the active ingredient or inactive precursor thereof is a macromolecular active ingredient or an inactive precursor thereof, more preferably a protein, and most preferably lactoferrin, bovine serum albumin, or an enzyme.
6. The process according to any one of the preceding claims, wherein the at least two complementary layers are formed from encapsulants independently selected from the group consisting of nanomaterials, macromolecular encapsulants and mixtures thereof, preferably the encapsulants are independently selected from the group consisting of polysaccharides, polyphenols, proteins, nucleic acids, cationic polyelectrolytes, anionic polyelectrolytes, nanomaterials and mixtures thereof, more preferably the encapsulants are independently selected from the group consisting of tannic acid, polyacrylic acid, poly(4-vinylpyridine), poly(glutamic acid), poly(lactic acid), chondroitin sulphate, dextran sulphate, poly(styrene sulfonate), sodium alginate, hyaluronic acid, polyphosphoric acid, polyvinyl sulfonic acid, polyvinyl phosphonic acid, polysulfates, dextrans, gum arabic, pectin, anionic cellulose derivatives, preferably carboxymethyl cellulose, pepsin, poly(dimethylammonium chloride), poly(ethylene oxide), poly(allylamine hydrochloride), poly(lysine), poly(lactic-co-glycolic acid), poly(arginine), protamine sulphate, polyethyleneimine, chitosan, glycol chitosan, montmorillonite, polyvinylamine, amine-containing polymers, such as polyamidoamine-epichlorohydrin and poly[2-(dimethylamino)ethyl methacrylate], bovine serum albumin, corresponding salts thereof, metal nanoparticles, metal oxide nanoparticles, carbon nanotubes, graphene, graphene oxide, nanoclays, and mixtures thereof, even more preferably the encapsulants are selected from the group consisting of tannic acid, poly(styrene sulfonate), poly(allylamine hydrochloride), bovine serum albumin, pepsin, corresponding salts thereof, and mixtures thereof, and most preferably the encapsulants are independently selected from the group consisting of tannic acid, pepsin, and corresponding salts thereof.
7. The process according to any one of the preceding claims, wherein step d) comprises the steps of
- i) incubating the loaded surface-reacted calcium carbonate in a first liquid medium comprising a first encapsulant to encase the loaded surface-reacted calcium carbonate with a first layer,
 - ii) removing the first liquid medium and washing the loaded surface-reacted calcium carbonate obtained in step i) one or more times with a first solvent, preferably water,
 - iii) incubating the loaded surface-reacted calcium carbonate obtained in step ii) in a second liquid medium comprising a second encapsulant being complementary to the first encapsulant to encase the loaded surface-reacted calcium carbonate with a second layer,
 - iv) removing the second liquid medium and washing the loaded surface-reacted calcium carbonate obtained in step iii) one or more times with a second solvent, preferably water, and
 - v) optionally repeating steps i) to iv) one or more times with the same or different first and second encapsulants and the same or different first and second liquid media and/or solvents.

8. The process according to claim 7, wherein the first encapsulant is a protein and the second encapsulant is a polyphenol; or the first encapsulant is a polyphenol and the second encapsulant is a protein; or the first encapsulant is a cationic polyelectrolyte and the second encapsulant is an anionic polyelectrolyte; or the first encapsulant is an anionic polyelectrolyte and the second encapsulant is a cationic polyelectrolyte; preferably
- 5 - one of the first encapsulant or the second encapsulant is selected from the group consisting of tannic acid, polyacrylic acid, poly(glutamic acid), poly(lactic acid), poly(lactic-co-glycolic acid), chondroitin sulphate, dextran sulphate, poly(styrene sulfonate), montmorillonite, alginic acid, sodium alginate, polyphosphoric acid, polyvinyl sulfonic acid, polyvinyl phosphonic acid, polysulfates, gum arabic, poly(ethylene oxide), anionic cellulose derivatives, preferably carboxymethyl cellulose, corresponding salts thereof, and mixtures thereof, preferably the one of the first encapsulant or the second encapsulant is selected from the group consisting of tannic acid, poly(styrene sulfonate), corresponding salts thereof, and mixtures thereof, and
- 10 the other one of the first or the second encapsulant is selected from the group consisting of pepsin, poly(dimethylammonium chloride), poly(allylamine hydrochloride), poly(lysine), poly(arginine), protamine sulphate, polyethyleneimine, poly(4-vinylpyridine), chitosan, glycol chitosan, polyvinylamine, amine-containing polymers, preferably polyamidoamine-epichlorohydrin or poly[2-(dimethylamino)ethyl methacrylate], bovine serum albumin, corresponding salts thereof, and mixtures thereof, preferably the other one of the first encapsulant or the second encapsulant is selected from the group consisting of
- 15 pepsin, poly(allylamine hydrochloride), corresponding salts thereof, and mixtures thereof.
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9. The process according to any one of the preceding claims, wherein the process further comprises the step of f) drying the microcapsule, preferably the drying is freeze-drying.
10. A microcapsule comprising an active ingredient or inactive precursor thereof obtainable by a process according to any one of claims 1 to 9.
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11. The microcapsule according to claim 10, wherein the microcapsule has a particle size in the range from 0.2 to 80 μm , preferably 0.5 to 60 μm , more preferably from 1 to 40 μm , even more preferably from 1 to 20 μm , and most preferably from 2 to 10 μm , determined by scanning electron microscopy, and/or wherein the microcapsule comprises from 1 to 5, preferably 2 or 3 individual loaded surface-reacted calcium carbonate particles.
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12. The microcapsule according to claim 10 or 11, wherein the microcapsule comprises the active ingredient or inactive precursor thereof in an amount of at least 5 wt.-%, preferably at least 10 wt.-%, more preferably at least 25 wt.-%, and most preferably at least 50 wt.-%, based on the total weight of the microcapsule.
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13. Use of a surface-reacted calcium carbonate as a template for encapsulating an active ingredient or inactive precursor thereof using layer-by-layer assembly, wherein the surface-reacted calcium carbonate is a reaction product of natural ground calcium carbonate or precipitated calcium carbonate with carbon dioxide and one or more H_3O^+ ion donors, wherein the carbon dioxide is formed in situ by the H_3O^+ ion donors treatment.

14. A product comprising the microcapsule according to any one of claims 10 to 12, wherein the product is a pharmaceutical product, a foodstuff, a feedstuff, a food supplement, a feed supplement, a cosmetic product, a paper product, a painting product, a coating product, or an agricultural product.
15. Use of a microcapsule according to any one of claims 10 to 12 in pharmaceutical, cosmetic,
5 nutraceutical, paper, paint, coating, biological, industrial or agricultural applications.