ORGANOGELS FROM ULTRASMALL PEPTIDES THAT CAN BE USED FOR BIOLOGICAL AND NON-BIOLOGICAL APPLICATIONS

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DATE OF CONCEPTION

June 20, 2010

TITLE

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BACKGROUND

Organogels are composed of a liquid organic phase which is immobilized in a three-dimensional scaffold made from self-assembled or cross-linked gelators. To date, reported peptide organogels requires complex methodologies to fabricate scaffolds, for example, use of oxidized glutathione and its derivatives for organogelation by heating [1] or use of cosolvents such as 1,1,1,3,3,3-Hexafluoro-2-propanol to formulate diphenylalanine based organogels [2]. Hence, a more facile to handle and cheap technology would be advantagous. There is also a demand for gelators that are of low-cost, easy to synthesize, stable and versatile to produce organogels in different solvent systems.

DETAILED DESCRIPTION OF TECHNOLOGY

The present invention provides a facile and low-cost technology to formulate organogels. The technology involves simply dissolving the ultrasmall self-assembling natural peptides (dimer to hexamer, low molecular weight (LMW) gelators) in organic solutions (up to 99.9% organic solvent or 98% oil).

Some of these peptides have been previously used in a patent application for formulating hydrogels (IBN/P/05948/01/PCT; IBN Ref: IBN-241). The dimer, Ac-ID-COOH (L) is a new and additional member from this class and hence, the smallest aliphatic peptide that can be used for formulating organogels (Annex B, Fig. 2).

These peptides not only self-assemble, but also can interact with complex macromolecular structures. Thus, they are able to facilitate the design and development of technologies with synthetic and biological systems. The organogels formed from peptides are stabilized due to the weak interactions between the peptide aggregates and solvent systems. These include interactions such as hydrophobic, non-covalent bondings, van der Waals, electrostatic, hydrogen bonding and/or π-π interactions (in the case of aromatic head group), etc. The properties of the peptide gelators such as polarity, size and thermo reversibility also play a key role in the formulation of organogels. These peptides are also biocompatible, and this can be used for formulating the organogels for biological applications.

The peptides can entrap up to 99.9% of organic solvents (Annex B, Figs. 2-5a). We found that these peptide organogels could successfully immobilize quantum dots (QD). Furthermore, fluorescent measurement studies on QD-loaded peptide organogels showed a complete overlap of emission peaks with that of QDs in solution (Annex B, Fig. 5b). This indicates that the QDs were stable in peptide organogels. These peptide organogels have high organic solvent content and can immobilize inorganic and organic materials. Thus, this technology can be further

explored, besides biomedical applications, for the development of devices, sensors or substrates in the electronic and chemical industries.

The peptides also form organogels in lipophilic (e.g. oil, up to 98%) solvent systems (Annex B, Fig. 6a), indicating the versatility of these peptides as an organogelator. These lipophilic solvent-based peptide organogels can be explored for encapsulating hydrophobic, therapeutic or non-therapeutic materials. For example, the active pharmaceutical ingredients loaded in peptide organogels can be clinically used as topical, oral, implantable or parenteral delivery systems. Furthermore, these peptide formulations of organogels in herbal, edible and/or essential oils allow for the applications of these systems in the fields of cosmetic, food and pharmaceutical technologies. Thus depending on the material immobilized by peptide organogels, it can be further used for both biological and non-biological applications.

Since these peptides are amphiphilic, they emulsify the solvent mixture of aqueous and organic phases to form a stable gel or emulsion systems (Annex B, Figs. 6b and 6c). Furthermore, we found that these peptide emulsion systems could encapsulate the alcian dye (Annex B, Fig. 6d). Hence, these peptide gelators can be utilized to formulate particulate- and emulsion-based technologies for therapeutic and non-therapeutic applications.

In summary, this invention provides a facile and simple technology for formulating various types of organogels in different solvent phase systems in the presence of our ultrasmall peptide gelators (dimer to hexamer). Furthermore, these peptide organogels can be explored for encapsulating both hydrophilic and hydrophobic materials for biological and non-biological applications. In the future, these peptide gelators, such as dimer, can also be conjugated to polymers, dendrimers, inorganic, organic, therapeutic and/or non-therapeutic materials for various applications.

1) The ultrasmall peptides are versatile gelators as they can entrap a wide variety of solvent systems to form organogels (Annex B, Fig. 1). In addition, their gelation can be achieved using a simple and low-cost methodology (Annex B, Figs. 2, 3, 4a, 4b, 5a, 6a, 6b, 6c).
2) The organic solvent-based peptide organogels formed stable QD-loaded formulations. Thus, these peptide organogels can be explored for immobilizing inorganic and organic materials for developing sensors and electronic devices.
3) Oil-based peptide organogels are stable and possess high mechanical strength. This system can be used for the immobilization of hydrophobic materials.
4) Addition of an aqueous and organic phase in the presence of ultrasmall peptides facilitates the formation of stable emulsions, microgels or particulate delivery systems (Annex B, Figs. 6b and 6c). This delivery system provides a carrier system for both hydrophilic and hydrophobic materials.
5) Therapeutics, biologics, dyes (Annex B, Fig. 6c), prodrugs and/or active pharmaceutical ingredients can be immobilized in these delivery

systems. The tailored release of active ingredients from these delivery systems can be achieved by modulating the solvent systems and peptide properties.

The ultrasmall peptide organogels can be used as matrices/scaffolds for the delivery of drugs, cosmetics and food in biological applications.

The organic solvent-based peptide organogels can be used as encapsulation matrices and membranes for inorganic and organic materials for the development of electronic devices, sensors, chips etc.

In the near term, the technology will enable the development of:

1. Peptide, peptide derivative or synthetic analog based organogels in lipophilic solvents for the encapsulation and delivery of therapeutic and non-therapeutic materials.
2. Oil+aqueous, organic solvent+oil or organic solvent+oil+aqueous phase systems in the presence of peptides for formulating suspensions, emulsions, creams, and ointments. These formulations can be used for encapsulating and/or immobilizing the active ingredients from pharmaceutical, cosmetic and food industries.
3. Particulate delivery systems using the peptide, peptide derivative or synthetic analog. The formed particulate systems can be used to develop microgels, emulsions or suspensions for encapsulating inorganic or organic materials.
4. Peptide, peptide derivative or synthetic analog based organogels in the organic solvents to immobilize inorganic particles such as quantum dots. This system can be utilized in the development of sensors and devices.

Organogels from ultrasmall peptides that can be used for biological and non-biological applications.

The present invention provides a facile and low-cost technology to formulate organogels. The technology involves simply dissolving the ultrasmall self-assembling natural peptides (dimer to hexamer, low molecular weight [LMW] gelators) in organic solutions (up to 99.9% organic solvent or 98% oil).

Some of these peptides have been previously used in a patent application for formulating hydrogels [IBN/P/05948/01/PCT; IBN Ref: IBN-241]. The dimer, Ac-ID-COOH (L) is a new and additional member from this class and hence, the smallest aliphatic peptide that can be used for formulating organogels (Annex B, Fig. 2).

These peptides not only self-assemble but can also interact with complex macromolecular structures. Thus they are able to facilitate the design and development of technologies with synthetic and biological systems. The organogels formed from peptides are stabilized due to the weak interactions between the peptide aggregates and solvent systems. These includes interactions such as hydrophobic, non-covalent bondings, van der Waals, electrostatic, hydrogen bonding and/or π-π interactions (in case of aromatic head group) etc.

The properties of the peptide gelators such as polarity, size and thermo reversibility also play a key role in formulation of organogels. These peptides are also biocompatible and thus this can be used for formulating the organogels for biological applications.

The peptides can entrap up to 99.9% of organic solvents (Annex B, Figs. 2-5a). We found that these peptide organogels could successfully immobilize quantum dots (QD). Furthermore, fluorescent measurement studies on QD loaded peptide organogels showed a complete overlap of emission peaks with that of QD in solution (Annex B, Fig. 5b). This indicates that the quantum dots were stable in peptide organogels. These peptide organogels have high organic solvent content and can immobilize inorganic and organic materials. Thus, this technology can be further explored, besides biomedical applications, for the development of devices, sensors or substrates in the electronic and chemical industries.

The peptides also form organogels in lipophilic (e.g. oil, upto 98%) solvent systems (Annex B, Fig. 6a), indicating the versatility of these peptides as an organogelator. These lipophilic solvent based peptide organogels can be explored for encapsulating hydrophobic, therapeutic or non-therapeutic materials. For example the active pharmaceutical ingredients loaded in peptide organogels can be clinically used as topical, oral, implantable or parenteral delivery systems. Furthermore, these peptide formulations of organogels in herbal, edible and /or essential oils allows for the application of these systems in the field of cosmetic, food or pharmaceutical technologies. Thus depending on the material immobilized by peptide organogels, it can be further used for both biological and non-biological applications.

Since these peptides are amphiphilic, they emulsify the solvent mixture of aqueous and organic phase to form a stable gel or emulsion systems (Annex B, Figs. 6b and 6c). Furthermore, we found that these peptide emulsion systems could encapsulate the alcian dye (Annex B, Fig. 6d). Hence, these peptide gelators can be utilized to formulate particulate and emulsion based technologies for therapeutic and non-therapeutic applications.

In conclusion, this invention provides a facile and simple technology for formulating various types of organogels in different solvent phase systems in the presence of our ultrasmall peptide gelators (dimer to hexamer). Furthermore, these peptide organogels can be explored for encapsulating both hydrophilic and hydrophobic materials for biological and non-biological applications. In the future, these peptide gelators such as dimer, can also be conjugated to polymers, dendrimers, inorganic, organic, therapeutic and/or non-therapeutic materials for various applications.

2. Description

Peptide organogels can be formulated by dissolving the ultrasmall peptides in organic liquids. These organic liquids include organic solvents, oils or solvent mixtures such as oil-organic solvent, oil-aqueous or oil-aqueous-organic solvents.

In the course of our studies different solvents were screened from polar to non-polar solvents such as methanol and hexane. Optimization of peptide organogels for various applications can be achieved by tuning the combinations and ratios of peptides and solvent systems.

2.1. Ultrasmall peptide organogel in organic solvent

Ultrasmall peptides with a polar head group, such as $AcLD_6$ (L) and $AcID_3$ (L) or aromatic head group such as $AcIF_3$ (L) and $AcIW_3$ (L) formed organogels in organic solvents as seen in figure 1 and 2. The resulting organogels showed visible changes in their appearance when altering peptide concentrations (Figs. 3a and 3b) and organic solvents.

2.1.1. Formulation

The formulation of peptide organogels depends on many factors such as peptide concentration, polarity of the organic solvent, peptide sequence and type of solvent used. For example, increasing peptide concentration reduces the gelation time for the formulation of peptide organogels (Annex B, Fig. 3).

2.1.2. Morphology of peptide organogel in organic solvents

The morphology of organogels was observed under field-emission scanning electron microscopy (FESEM).

2.1.5. Incorporating materials

Materials such as quantum dots (as seen in figure 4b) or metal nanoparticles (eg. gold nanoparticle), can be incorporated in the peptide organogels by encapsulation, immobilization (in the bulk phase) or conjugation to the peptide gelators. These peptide organogels can be further used in the design and development of sensors and devices.

2.2. Ultrasmall peptide organogels in: (a) lipophilic (b) organic solvent-lipophilic (c) lipophilic-aqueous (d) organic solvent-lipophilic-aqueous systems.

Ultrasmall peptides formed organogels in oil and oil-based solvent mixtures.

2.2.1. Formulation

The formation of lipophilic solvent-based peptide organogels depend on many factors – such as peptide concentration, type of oil, ratio of solvent and oil, peptide sequence, peptide size, and formulation technique such as heating, sonication or use of cosolvents, as seen in figures 6a, 6b, 6c.

2.2.3. Mechanical properties of the peptide organogels

First rheology studies showed that the organogels possess good mechanical properties, since the Tan (G"/G') is less than 1 (~ 0.2-0.3), with a storage modulus (G') of 1100 Pa and 10050Pa for oil and solvent mixture based organogels, respectively, and a loss modulus (G") of 120 Pa and 1200 Pa for oil and solvent mixture based organogels, respectively (Annex Figs. 6a and 6b). Further studies will be conducted for the confirmation of these data.

2.2.4. Incorporating therapeutic materials

Bioactive therapeutics such as prodrugs, drugs, excipients, dyes (Annex B, Fig. 6d), pigments, inorganic and organic materials can be incorporated into the peptide based organogels, emulsions or particulate delivery systems for biomedical applications. This can be achieved by encapsulation, immobilization (in the bulk phase) or conjugation to the peptide organogelators. These gels can be subsequently used in pharmaceutical, cosmetic and food technologies.

References:

(1) Lyon RP, Atkins WM. Self-Assembly and Gelation of Oxidized Glutathione in Organic Solvents. Journal of the American Chemical Society **2001**, 123(19):4408-4413.

(2) Yan X, Cui Y, He Q, Wang K, Li J. Organogels Based on Self-Assembly of Diphenylalanine Peptide and Their Application To Immobilize Quantum Dots. Chemistry of Materials **2008**, 20(4):1522-1526.

Claims

1. Organogel comprising
an organic solvent and
a peptide having the general formula

$$Z\text{-}(X)_a\text{-}(Y)_b\text{-}Z'_c,$$

wherein
Z is an N-terminal protecting group;
X is, at each occurrence, independently selected from the group consisting of aliphatic amino acids and aliphatic amino acid derivatives;
Y is selected from the group consisting of polar amino acids, polar amino acid derivatives, aromatic amino acids and aromatic amino acid derivatives;
Z' is a C-terminal protecting group;
a is an integer selected from 1 to 6;
b is 1 or 2, preferably 1; and
c is 0 or 1.

2. Organogel according to claim 1, wherein said organic solvent is selected from polar organic solvents, preferably selected from the group consisting of alcohols, such as methanol, ethanol, propanol, isopropanol, isopentanol and 2-methoxyethanol, ketones, such as acetone, methylethyl ketone, methyl n-propyl ketone, methyl isopropyl ketone and methyl isoamyl ketone, ethers, such as ethylene glycol monobutyl ether and propylene glycol monomethyl ether, methyl acetate, ethyl acetate, propyl acetate, n-butyl acetate, chloroform, acetonitrile, glycerol, dimethyl sulfoxide, N,N-dimethyl formamide, tetrahydrofuran, pyridine, 1,4-dioxane, dimethyl acetamide, N-methylpyrrolidone, propylene carbonate and mixtures thereof.

3. Organogel according to claim 1, wherein said organic solvent is selected from non-polar organic solvents, preferably selected from the group consisting of benzene, chlorobenzene, o-dichlorobenzene, toluene, o-xylene, dichloromethane, 1,1,2-trichlorotrifluoroethane, pentane, cyclopentane, hexane, cyclohexane, heptane, iso octane, diethylether, petroleum ether,

pyridine, carbon tetrachloride, fatty acids, fatty acid esters and mixtures thereof.

4. Organogel according to claim 1, wherein said organic solvent is selected from oils, preferably selected from the group consisting of vegetable oils, essential oils, petrochemical oils, synthetic oils and mixtures thereof.

5. Organogel according to any of the foregoing claims, wherein said organic solvent is a mixture of at least one polar or non-polar organic solvent as defined in claims 2 and 3 and at least one oil as defined in claim 4.

6. Organogel according to any of the foregoing claims, wherein said organic solvent is a physiologically acceptable solvent.

7. Organogel according to any of the foregoing claims, wherein said aliphatic amino acids are selected from the group consisting of alanine (Ala, A), homoallylglycine, homopropargylglycine, isoleucine (Ile, I), norleucine, leucine (Leu, L), valine (Val, V) and glycine (Gly, G), preferably from the group consisting of alanine (Ala, A), isoleucine (Ile, I), leucine (Leu, L), valine (Val, V) and glycine (Gly, G).

8. Organogel according to any of the foregoing claims, wherein said polar amino acids are selected from the group consisting of aspartic acid (Asp, D), asparagine (Asn, N), glutamic acid (Glu, E), glutamine (Gln, Q), 5-N-ethyl-glutamine (theanine), citrulline, thio-citrulline, cysteine (Cys, C), homocysteine, methionine (Met, M), ethionine, selenomethionine, telluromethionine, serine (Ser, S), homoserine, arginine (Arg, R), homoarginine, ornithine, threonine (Thr, T), L-Dopa, tryptophan (Trp, W), thyroxine, allo-threonine, lysine (Lys, K), N(6)-carboxymethyllysine, tyrosine (Tyr, Y) and histidine (His, H), preferably from the group consisting of aspartic acid (Asp, D), glutamic acid (Glu, E), serine (Ser, S), threonine (Thr, T) and lysine (Lys, K), more preferably from the group consisting of aspartic acid (Asp, D) and glutamic acid (Glu, E).

9. Organogel according to any of the foregoing claims, wherein said aromatic amino acids are selected from the group consisting of phenylalanine (Phe, F), tryptophan (Trp, W), tyrosine (Tyr, Y), histidine (His, H) and L-Dopa.

10. Organogel according to any of the foregoing claims, wherein said peptide is selected from the group consisting of Z-LIVAGC-Z'_n, Z-LIVAGD-Z'_n, Z-LIVAGF-Z'_n, Z-LIVAGW-Z'_n, Z-ILVAGD-Z'_n, Z-LIVAAD-Z'_n, Z-LAVAGD-Z'_n, Z-AIVAGD-Z'_n, Z-LIVAGE-Z'_n, Z-LIVAGK-Z'_n, Z-LIVAGS-Z'_n, Z-ILVAGS-Z'_n, Z-AIVAGS-Z'_n, Z-LIVAGT-Z'_n, Z-AIVAGT-Z'_n, Z-LIVAD-Z'_n, Z-LIVGD-Z'_n, Z-IVAD-Z'_n, Z-IIID-Z'_n, Z-IIIK-Z'_n, Z-IVD-Z'_n, Z-IVF-Z'_n, Z-IVW-Z'_n, Z-IID-Z'_n, Z-LVE-Z'_n, Z-IVE-Z'_n, Z-LVD-Z'_n, Z-VIE-Z'_n, Z-VID-Z'_n, Z-VLD-Z'_n, Z-VLE-Z'_n, Z-LLE-Z'_n, Z-LLD-Z'_n, Z-IIE-Z'_n, Z-ID-Z'_n, Z-IE-Z'_n, Z-IW-Z'_n, Z-IF-Z'_n, Z-IY-Z'_n.

11. Organogel according to any of the foregoing claims, wherein said N-terminal protecting group has the general formula –C(O)–R, wherein R is selected from the group consisting of H, alkyl and substituted alkyl.

12. Organogel according to claim 11, wherein R is selected from the group consisting of methyl, ethyl, propyl, isopropyl, butyl and isobutyl.

13. Organogel according to any of the foregoing claims, wherein said N-terminal protecting group is an acetyl group.

14. Organogel according to any of the foregoing claims, wherein the C-terminus of said peptide is amidated, wherein, preferably, the C-terminus has the formula –CONHR, with R being selected from the group consisting of H, alkyl and substituted alkyl.

15. Organogel according to any of claims 1 to 13, wherein the C-terminus of said peptide is esterified, wherein, preferably, the C-terminus has the formula – CO_2R , with R being selected from the group consisting of alkyls and substituted alkyls.

16. Organogel according to any of claims 1 to 13, wherein the C-terminal amino acid of said peptide is a peptidomimetic amino acid, wherein, preferably, the C1 carboxyl group of said peptidomimetic amino acid is replaced with an alcohol, ester, aldehyde or ketone group.

17. Organogel according to any of the foregoing claims, wherein a is an integer selected from 1 to 5, preferably 2 to 5, and wherein, preferably, said aliphatic amino acids and aliphatic amino acid derivatives exhibit an overall decrease in hydrophobicity from the N-terminus to the C-terminus of said peptide.

18. Organogel according to any of the foregoing claims, wherein said peptide is present at a concentration in the range of from 0.1 % to 30 % (w/w), preferably 0.1 % to 20 % (w/w), more preferably 0.1 % to 10 % (w/w), more preferably 0.1 % to 5 % (w/w), even more preferably 0.1 % to 3 % (w/w), with respect to the total weight of said organogel.

19. Organogel according to any of the foregoing claims, wherein said organogel has a tan δ of less than 1, preferably less than 0.5.

20. Organogel according to any of the foregoing claims, further comprising at least one additional substance.

21. Organogel according to claim 20, wherein said at least one additional substance is encapsulated by said organogel, immobilized in the bulk phase of said organogel or conjugated to said peptide.

22. Organogel according to claim 20 or 21, wherein said at least one additional substance is a bioactive agent, wherein said bioactive agent is preferably selected from the group consisting of nucleic acids, (poly)peptides, virus particles, oligosaccharides, polysaccharides, vitamins, sialic acids, antigens, vaccines, drugs, prodrugs and other organic or inorganic bioactive compounds.

23. Organogel according to claim 20 or 21, wherein said at least one additional substance is selected from the group consisting of dyes, pigments, quantum dot nanoparticles and other nanoparticles, preferably metal or semiconductor nanoparticles.

24. Method of producing an organogel according to any of claims 1 to 23, said method comprising at least one of the following steps:
- dissolving a peptide as defined in any of claims 1 and 7 to 18 in a solvent as defined in any of claims 1 to 6;
- heating a peptide as defined in any of claims 1 and 7 to 18 in a solvent as defined in any of claims 1 to 6;
- sonicating a peptide as defined in any of claims 1 and 7 to 18 in a solvent as defined in any of claims 1 to 6.

25. Use of a peptide as defined in any of claims 1 and 7 to 18 as gelator in an organogel.

26. Use of an organogel according to any of claims 1 to 23 in a pharmaceutical formulation, a cosmetic or personal care product, a food product or a device.

27. Pharmaceutical formulation comprising an organogel according to any of claims 1 to 23.

28. Pharmaceutical formulation according to claim 27, wherein said pharmaceutical formulation is a controlled or sustained release pharmaceutical formulation.

29. Cosmetic or personal care product comprising an organogel according to any of claims 1 to 23.

30. Food product comprising an organogel according to any of claims 1 to 23.

31. Device comprising an organogel according to any of claims 1 to 23.

32. Device according to claim 31, wherein said device is a sensor device.

33. Device according to claim 31 or 32, wherein said device is an electronic device.

34. Emulsion comprising
an organic solvent,
a polar solvent, preferably an aqueous solution, and
a peptide having the general formula

$$Z\text{-}(X)_a\text{-}(Y)_b\text{-}Z'_c,$$

wherein
Z is an N-terminal protecting group;
X is, at each occurrence, independently selected from the group consisting of aliphatic amino acids and aliphatic amino acid derivatives;
Y is selected from the group consisting of polar amino acids, polar amino acid derivatives, aromatic amino acids and aromatic amino acid derivatives, preferably polar amino acids and polar amino acid derivatives;
Z' is a C-terminal protecting group;
a is an integer selected from 1 to 6;
b is 1 or 2, preferably 1; and
c is 0 or 1.

35. Emulsion according to claim 34, said organic solvent is selected from polar organic solvents, preferably selected from the group consisting of alcohols, such as methanol, ethanol, propanol, isopropanol, isopentanol and 2-methoxyethanol, ketones, such as acetone, methylethyl ketone, methyl n-propyl ketone, methyl isopropyl ketone and methyl isoamyl ketone, ethers, such as ethylene glycol monobutyl ether and propylene glycol monomethyl ether, methyl acetate, ethyl acetate, propyl acetate, n-butyl acetate, chloroform, acetonitrile, glycerol, dimethyl sulfoxide, N,N-dimethyl formamide, tetrahydrofuran, pyridine, 1,4-dioxane, dimethyl acetamide, N-methylpyrrolidone, propylene carbonate and mixtures thereof.

36. Emulsion according to claim 34, wherein said organic solvent is selected from non-polar organic solvents, preferably selected from the group consisting of benzene, chlorobenzene, o-dichlorobenzene, toluene, o-xylene, dichloromethane, 1,1,2-trichlorotrifluoroethane, pentane, cyclopentane, hexane, cyclohexane, heptane, iso octane, diethylether, petroleum ether, pyridine, carbon tetrachloride, fatty acids, fatty acid esters and mixtures thereof.

37. Emulsion according to claim 34, wherein said organic solvent is selected from oils, preferably selected from the group consisting of vegetable oils, essential oils, petrochemical oils, synthetic oils and mixtures thereof.

38. Emulsion according to any of claims 34 to 37, wherein said organic solvent is a mixture of at least one polar or non-polar organic solvent as defined in claims 35 and 36 and at least one oil as defined in claim 37.

39. Emulsion according to any of claims 34 to 38, wherein said organic solvent is a physiologically acceptable solvent.

40. Emulsion according to any of claims 34 to 39, wherein said aliphatic amino acids are selected from the group consisting of alanine (Ala, A), homoallylglycine, homopropargylglycine, isoleucine (Ile, I), norleucine, leucine (Leu, L), valine (Val, V) and glycine (Gly, G), preferably from the group consisting of alanine (Ala, A), isoleucine (Ile, I), leucine (Leu, L), valine (Val, V) and glycine (Gly, G).

41. Emulsion according to any of claims 34 to 40, wherein said polar amino acids are selected from the group consisting of aspartic acid (Asp, D), asparagine (Asn, N), glutamic acid (Glu, E), glutamine (Gln, Q), 5-N-ethyl-glutamine (theanine), citrulline, thio-citrulline, cysteine (Cys, C), homocysteine, methionine (Met, M), ethionine, selenomethionine, telluromethionine, serine (Ser, S), homoserine, arginine (Arg, R), homoarginine, ornithine, threonine (Thr, T), L-Dopa, tryptophan (Trp, W), thyroxine, allo-threonine, lysine (Lys, K), N(6)-carboxymethyllysine, tyrosine (Tyr, Y) and histidine (His, H),

preferably from the group consisting of aspartic acid (Asp, D), glutamic acid (Glu, E), serine (Ser, S), threonine (Thr, T) and lysine (Lys, K), more preferably from the group consisting of aspartic acid (Asp, D) and glutamic acid (Glu, E).

42. Emulsion according to any of claims 34 to 41, wherein said aromatic amino acids are selected from the group consisting of phenylalanine (Phe, F), tryptophan (Trp, W), tyrosine (Tyr, Y), histidine (His, H) and L-Dopa.

43. Emulsion according to any of claims 34 to 42, wherein said peptide is selected from the group consisting of Z-LIVAGC-Z'_n, Z-LIVAGD-Z'_n, Z-LIVAGF-Z'_n, Z-LIVAGW-Z'_n, Z-ILVAGD-Z'_n, Z-LIVAAD-Z'_n, Z-LAVAGD-Z'_n, Z-AIVAGD-Z'_n, Z-LIVAGE-Z'_n, Z-LIVAGK-Z'_n, Z-LIVAGS-Z'_n, Z-ILVAGS-Z'_n, Z-AIVAGS-Z'_n, Z-LIVAGT-Z'_n, Z-AIVAGT-Z'_n, Z-LIVAD-Z'_n, Z-LIVGD-Z'_n, Z-IVAD-Z'_n, Z-IIID-Z'_n, Z-IIIK-Z'_n, Z-IVD-Z'_n, Z-IVF-Z'_n, Z-IVW-Z'_n, Z-IID-Z'_n, Z-LVE-Z'_n, Z-IVE-Z'_n, Z-LVD-Z'_n, Z-VIE-Z'_n, Z-VID-Z'_n, Z-VLD-Z'_n, Z-VLE-Z'_n, Z-LLE-Z'_n, Z-LLD-Z'_n, Z-IIE-Z'_n, Z-ID-Z'_n, Z-IE-Z'_n, Z-IW-Z'_n, Z-IF-Z'_n, Z-IY-Z'_n.

44. Emulsion according to any of claims 34 to 43, wherein said N-terminal protecting group has the general formula –C(O)–R, wherein R is selected from the group consisting of H, alkyl and substituted alkyl.

45. Emulsion according to claim 44, wherein R is selected from the group consisting of methyl, ethyl, propyl, isopropyl, butyl and isobutyl.

46. Emulsion according to any of claims 34 to 45, wherein said N-terminal protecting group is an acetyl group.

47. Emulsion according to any of claims 34 to 46, wherein the C-terminus of said peptide is amidated, wherein, preferably, the C-terminus has the formula –CONHR, with R being selected from the group consisting of H, alkyl and substituted alkyl.

48. Emulsion according to any of any of claims 34 to 46, wherein the C-terminus of said peptide is esterified, wherein, preferably, the C-terminus has the formula $-CO_2R$, with R being selected from the group consisting of alkyls and substituted alkyls.

49. Emulsion according to any of claims 34 to 46, wherein the C-terminal amino acid of said peptide is a peptidomimetic amino acid, wherein, preferably, the C1 carboxyl group of said peptidomimetic amino acid is replaced with an alcohol, ester, aldehyde or ketone group.

50. Emulsion according to any of claims 34 to 49, wherein a is an integer selected from 1 to 5, preferably 2 to 5, and wherein, preferably, said aliphatic amino acids and aliphatic amino acid derivatives exhibit an overall decrease in hydrophobicity from the N-terminus to the C-terminus of said peptide.

51. Emulsion according to any of claims 34 to 50, wherein said peptide is present at a concentration in the range of from 0.1 % to 30 % (w/v), preferably 0.1 % to 20 % (w/v), more preferably 0.1 % to 10 % (w/v), more preferably 0.1 % to 5 % (w/v), even more preferably 0.1 % to 3 % (w/v), with respect to the total volume of said emulsion.

52. Emulsion according to any of claims 34 to 51, further comprising at least one additional substance.

53. Emulsion according to claim 52, wherein said additional substance is a bioactive agent, wherein said bioactive agent is preferably selected from the group consisting of nucleic acids, (poly)peptides, virus particles, oligosaccharides, polysaccharides, vitamins, sialic acids, antigens, vaccines, drugs, prodrugs and other organic or inorganic bioactive compounds.

54. Emulsion according to claim 52, wherein said additional substance is a dye, opacifier or pigment.

55. Emulsion according to claim 52, wherein said additional substance is a wax, such as beeswax and carnauba wax.

56. Method of producing an emulsion according to any of claims 34 to 55, said method comprising at least one of the following steps:
- dissolving a peptide as defined in any of claims 34 and 40 to 51 in a solvent as defined in any of claims 34 to 39;
- sonicating a peptide as defined in any of claims 34 and 40 to 51 in a solvent as defined in any of claims 34 to 39;
- homogenizing a peptide as defined in any of claims 34 and 40 to 51 in a solvent as defined in any of claims 34 to 39;
- phase separation coacervation and/or precipitation and/or using a co-solvent with a peptide as defined in any of claims 34 and 40 to 51 in a solvent as defined in any of claims 34 to 39.

57. Use of a peptide as defined in any of claims 34 and 40 to 51 as an emulsifier.

58. Use according to claim 57, wherein said peptide forms micelles.

59. Use of an emulsion according to any of claims 34 to 55 in a pharmaceutical formulation, a cosmetic or personal care product or a food product.

60. Pharmaceutical formulation comprising an emulsion according to any of claims 34 to 55.

61. Cosmetic or personal care product comprising an emulsion according to any of claims 34 to 55.

62. Food product comprising an emulsion according to any of claims 34 to 55.