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(54) Title: LIPID NANOCAPSULES, PREPARATION METHOD AND USE AS MEDICINE

(54) Titre : NANOCAPSULES LIPIDIQUES, PROCEDE DE PREPARATION ET UTILISATION COMME MEDICAMENT

(57) **Abstract:** The invention concerns nanocapsules, in particular with an average size less than 50 nm, consisting of an essentially lipid core liquid or semiliquid at room temperature, coated with an essentially lipid film solid at room temperature having a thickness of 2 - 10 nm. The invention also concerns a method for preparing same which consists in producing a reverse phase of an aqueous emulsion brought about by several temperature raising and lowering cycles. Said lipid nanocapsules are particularly designed for producing a medicine.

(57) **Abrégé :** La présente invention concerne des nanocapsules, en particulier de taille moyenne inférieure à 50 nm, constituées d'un coeur essentiellement lipidique liquide ou semi-liquide à température ambiante, enrobé d'un film essentiellement lipidique solide à température ambiante d'épaisseur 2 - 10 nm. Elle concerne également un procédé pour leur préparation qui consiste en l'inversion de phase d'une émulsion huile/eau provoquée par plusieurs cycles de montée et de descente en température. Les nanocapsules lipidiques de l'invention sont particulièrement destinées à la fabrication d'un médicament.

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LIPID NANOCAPSULES, PREPARATION PROCESS AND USE AS MEDICAMENT

The present invention relates to lipid nanocapsules, to a process for preparing them and to their use for manufacturing a medicament intended especially to be administered by injection, orally or nasally.

In recent years, many groups have developed the formulation of solid lipid nanoparticles or lipid nanospheres (Müller, R.H. and Mehnert, European Journal of Pharmaceutics and Biopharmaceutics, 41(1): 62-69, 1995; W., Gasco, M.R., Pharmaceutical Technology Europe: 52-57, December 1997; EP 605 497). This is an alternative to the use of liposomes or polymer particles. These lipid particles have the advantage of being formulated in the absence of solvent. They allow the encapsulation of both lipophilic and hydrophilic products in the form of ion pairs, for example (Cavalli, R. et al., S.T.P. Pharma Sciences, 2(6): 514-518, 1992; and Cavalli, R. et al., International Journal of Pharmaceutics, 117: 243-246, 1995). These particles may be stable for several years in the absence of light, at 8°C (Freitas, C. and Müller, R.H., Journal of Microencapsulation, 1 (16): 59-71, 1999).

Two techniques are commonly used to prepare lipid nanoparticles:

- homogenization of a hot emulsion (Schwarz, C. et al., Journal of Controlled Release, 30: 83-96, 1994; Müller, R.H. et al., European Journal of Pharmaceutics and Biopharmaceutics, 41(1): 62-69, 1995) or of a cold emulsion (Zur Mühlen, A. and Mehnert W., Pharmazie, 53: 552-555, 1998; EP 605 497), or
- the quench of a microemulsion in the presence of co-surfactants such as butanol. The size of the nanoparticles obtained is generally greater than

100 nm (Cavalli, R. et al., European Journal of Pharmaceutics and Biopharmaceutics, 43(2): 110-115, 1996; Morel, S. et al., International Journal of Pharmaceutics, 132: 259-261, 1996).

Cavalli et al. (International Journal of Pharmaceutics, 2(6): 514-518, 1992; and Pharmazie, 53: 392-396, 1998) describe the use of a nontoxic bile salt, taurodeoxycholate, by injection for the formation of nanospheres greater than or equal to 55 nm in size.

The present invention relates to nanocapsules rather than nanospheres. The term "nanocapsules" means particles consisting of a core that is liquid or semiliquid at room temperature, coated with a film that is solid at room temperature, as opposed to nanospheres, which are matrix particles, ie particles whose entire mass is solid. When the nanospheres contain a pharmaceutically active principle, this active principle is finely dispersed in the solid matrix.

In the context of the present invention, the term "room temperature" means a temperature between 15 and 25°C.

One aspect of the present invention provides nanocapsules with an average size of less than 150 nm, preferably less than 100 nm and more preferably less than 50 nm. The nanocapsules each consist of an essentially lipid core that is liquid or semiliquid at room temperature, coated with an essentially lipid film that is solid at room temperature.

Given their size, the nanocapsules of the invention are colloidal lipid particles.

The polydispersity index of the nanocapsules of the invention may advantageously be between 5% and 15%

The thickness of the solid film may advantageously be between 2 and 10 nm. It can also be about one tenth of the diameter of the particles.

The core of the nanocapsules may consist essentially of a fatty substance that can be liquid or semiliquid at room temperature, for example a triglyceride or a fatty acid ester, representing 20% to 60% and preferably 25% to 50% by weight of the nanocapsules.

The solid film coating the nanocapsules may preferably consists essentially of a lipophilic surfactant, for example a lecithin whose proportion of phosphatidylcholine is between 40% and 80%. The solid film may also contain a hydrophilic surfactant, for example Solutol® HS 15.

The hydrophilic surfactant contained in the solid film coating the nanocapsules preferably represents between 2% and 10% by weight of the nanocapsules, preferably about 8%.

The triglyceride constituting the core of the nanocapsules may be chosen especially from C_8 to C_{12} triglycerides, for example capric and caprylic acid triglycerides and mixtures thereof.

The fatty acid ester may be chosen from C_8 to C_{18} fatty acid esters, for example ethyl palmitate, ethyl oleate, ethyl myristate, isopropyl myristate, octyldodecyl myristate, and mixtures thereof. The fatty acid ester is preferably C_8 to C_{12}.

The nanocapsules may particularly be suitable for formulating pharmaceutical active principles. In this case, the lipophilic surfactant may advantageously be solid at 20°C and liquid at about 37°C.

The amount of lipophilic surfactant contained in the solid film coating the nanocapsules may be set such that the liquid fatty substance/solid surfactant compound mass ratio is chosen between 1 and 15, preferably between 1.5 and 13 and more preferably between 3 and 8.

Another aspect of the present invention provides a process for preparing the nanocapsules described above.

The process of the invention is based on the phase inversion of an oil/water emulsion brought about by several cycles of raising and lowering temperature.

The process of the invention consists in

a) - preparing an oil/water emulsion containing an oily fatty phase, a nonionic hydrophilic surfactant, a lipophilic surfactant that is solid at 20°C and optionally a pharmaceutically active principle that is soluble or dispersible in the oily fatty phase, or a pharmaceutically active principle that is soluble or dispersible in the aqueous phase,

- bringing about the phase inversion of said oil/water emulsion by increasing the temperature up to a temperature T_2 above the phase inversion temperature (PIT) to obtain a water/oil emulsion, followed by a reduction in the temperature down to a temperature T_1, $T_1 < PIT < T_2$,

- carrying out at least one or more temperature cycles around the phase inversion zone between T_1 and T_2, until a translucent suspension is observed,

b) quenching the oil/water emulsion at a temperature in the region of T_1, preferably greater than T_1, to obtain stable nanocapsules.

The nanocapsules obtained according to the process of the invention may advantageously be free of co-surfactants, for instance C_1-C_4 alcohols.

The number of cycles applied to the emulsion may depend on the amount of energy required to form the nanocapsules.

The phase inversion may be visualized by canceling out the conductivity of the formation when the water/oil emulsion is formed.

The process of the invention may comprise two steps.

The first step may consist of weighing all the constituents, heating them above a temperature T_2 with gentle stirring (for example magnetic stirring) and then optionally cooling them to a temperature T_1 ($T_1<T_2$). After a certain number of temperature cycles, a water/oil emulsion may be obtained.

The phase inversion between the oil/water emulsion and the water/oil emulsion can be reflected by a reduction in the conductivity when the temperature increases until it is canceled out. The average temperature of the phase inversion zone may correspond to the phase inversion temperature (PIT). The organization of the system in the form of nanocapsules can be reflected visually by a change in the appearance of the initial system, which changes from opaque-white to translucent-white. This change may take place at a temperature below the PIT. This temperature can generally be between 6 and 15°C below the PIT.

T_1 may be a temperature at which the conductivity is at least equal to 90-95% of the conductivity measured at 20°C.

T_2 may be the temperature at which the conductivity becomes canceled out.

The second step may consist of a sudden cooling (or quench) of the oil/water emulsion to a temperature in the region of T_1, preferably above T_1, with magnetic stirring, by diluting it between threefold and tenfold using deionized water at 2°C ± 1°C added to the fine emulsion. The particles obtained may be kept stirring for 5 minutes.

In one preferred embodiment, the fatty phase may be a fatty acid triglyceride, the solid lipophilic surfactant may be a lecithin and the hydrophilic surfactant may be Solutol® HS15. Under these conditions, T_1 = 60°C, T_2 = 85°C and the number of cycles can be equal to 3.

The liquid substance/solid surfactant compound ratio can be chosen between 1 and 15, preferably between 1.5 and 13 and more preferably between 3 and 8.

The oil/water emulsion may advantageously contain 1% to 3% of lipophilic surfactant, 5% to 15% of hydrophilic surfactant, 5% to 15% of oily fatty substance and 64% to 89% of water (the percentages are expressed on a weight basis).

The higher the HLB value of the liquid fatty substance, the higher the phase inversion temperature. On the other hand, the HLB value of the fatty substance does not appear to have an influence on the size of the nanocapsules.

Thus, when the size of the triglyceride end groups increases, their HLB value decreases and the phase inversion temperature decreases.

The HLB value, or hydrophilic/lipophilic balance, is as defined by C. Larpent in Treatise K.342 of Editions TECHNIQUES DE L'INGENIEUR.

The particle size decreases when the proportion of hydrophilic surfactant increases and when the proportion of surfactants (hydrophilic and lipophilic) increases. Specifically, the surfactant brings about a decrease in the interface tension and thus a stabilization of the system, which promotes the production of small particles.

Moreover, the particle size increases when the proportion of oil increases.

According to one preferred embodiment, the fatty phase may be Labrafac® WL 1349, the lipophilic surfactant may be Lipoid® S 75-3 and the nonionic hydrophilic surfactant may be Solutol® HS 15. These compounds have the following characteristics:

- Labrafac® lipophile WL 1349 (Gattefossé, Saint-Priest, France). This is an oil composed of caprylic and capric acid (C_8 and C_{10}) medium-chain triglycerides. Its density is from 0.930 to 0.960 at 20°C. Its HLB value is about 1.

- Lipoid® S 75-3 (Lipoid GmbH, Ludwigshafen, Germany). Lipoid® S 75-3 corresponds to soybean lecithin. Soybean lecithin contains about 69% phosphatidylcholine and 9% phosphatidylethanolamine. They are thus surfactant compounds. This constituent is the only constituent that is solid at 37°C and at room temperature in the formulation. It is commonly used for the formulation of injectable particles.

- Solutol® HS 15 (BASF, Ludwigshafen, Germany). This is a polyethylene glycol-660 2-hydroxystearate. It thus acts as a nonionic hydrophilic surfactant in the formulation. It may be used by injection (via the iv route in mice $LD_{50} > 3.16$ g/kg, in rats $1.0 < LD_{50} < 1.47$ g/kg).

The aqueous phase of the oil/water emulsion may also contain 1% to 4% of a salt, for instance sodium chloride. Changing the salt concentration can bring about a shift in the phase inversion zone. The higher the salt concentration, the lower the phase inversion temperature. This phenomenon may be advantageous for encapsulating hydrophobic heat-sensitive active principles. Their incorporation may be performed at a lower temperature.

Another aspect of the present invention provides a use of the nanocapsules for the manufacture of a medicament administered by injection, especially intravenous injection, orally or nasally.

When the active principle is sparingly soluble in the oily phase, a cosolvent may be added, for example N, N-dimethylacetamide.

The nanocapsules can more particularly be suitable for the administration of the following active principles:

- antiinfectious agents, including antimycotic agents and antibiotics,
- anticancer agents,
- active principles intended for the Central Nervous System, which must cross the blood-brain barrier, such as antiparkinson agents and more generally active principles for treating neurodegenerative diseases.

The pharmaceutically active principle may be firstly soluble or dispersible in an oily fatty phase, and in this case it can be incorporated in the core of the nanocapsule. To do this, it can be incorporated at the stage of the first step of preparing the oil/water emulsion which may also contain the oily fatty phase, a

nonionic hydrophilic surfactant and a lipophilic surfactant that may be solid at 20°C.

The pharmaceutically active principle may also be of water-soluble nature or dispersible in an aqueous phase, and in such a case it may be bound to the surface of the nanocapsules only after the final phase of preparing the stable nanocapsules. Such a water-soluble active principle may be of any nature, including proteins, peptides, oligonucleotides and DNA plasmids. Such an active principle may be attached to the surface of the nanocapsules by introducing said active principle into the solution in which are dispersed stable nanocapsules obtained after the process. The presence of a nonionic hydrophilic surfactant can promote the interaction bonds between the water-soluble active principle and the free surface of the nanocapsules.

The water-soluble active principle may also be introduced into the aqueous phase during the first step of initial oil/water preparation.

The invention is illustrated by the examples that follow, with reference to Figures 1 to 4.

Figure 1 is a photograph of the nanocapsules of the invention obtained in Example 1. The scale is 1 cm to 50 nm.

Figure 2 shows the change in the average particle size as a function of the proportion of hydrophilic surfactant (Solutol®).

Figure 3 shows the change in conductivity as a function of the temperature for various salt concentrations. In curve 1, the salt concentration is 2.0% by weight. In curve 2, the concentration is 3.4% by weight.

Figure 4 shows the change in the conductivity of an oil/water (O/W) emulsion described in Example 1, as a function of the temperature after three cycles of raising and lowering the temperature between 60 and 85°C.

Example 1: Nanocapsules not containing active principle

A) Preparation of the nanocapsules

5 g of an emulsion containing 75 mg of Lipoid® S75-3, 504 mg of Labrafac® WL 1349 lipophile, 504 mg of Solutol® HS 15, 3.829 g of water and 88 mg of sodium chloride are prepared.

The ingredients are combined in the same beaker and placed under magnetic stirring. Heat is applied until a temperature of 85°C is reached. The system is allowed to cool to a temperature of 60°C with magnetic stirring. This cycle (between 85°C and 60°C) is performed until a canceling out of the conductivity as a function of the temperature is observed (Figure 4). The phase inversion takes place after three cycles. At the final cooling, quenching is carried out by adding 12.5 ml of distilled water at 2°C ± 1°C to the mixture at 70°C. The system is then maintained under magnetic stirring for 5 minutes.

The particles obtained under the conditions described above, after three temperature cycles, have a mean size of 43 ± 7 nm. Their size polydispersity is 0.071. Transmission electron microscopy using phosphotungstic acid made it possible to reveal particles with a mean size of about 50 nm (see Figure 1). Moreover, an observation made by atomic force microscopy in contact mode (Park Scientific Instruments apparatus, Geneva, Switzerland) shows that the nanocapsules are indeed solid at a temperature of 25°C.

B) Change in the proportions of hydrophilic surfactant

Table 1 below shows different formulations of nanocapsules prepared with variable concentrations of hydrophilic surfactant.

	Mass %							
Lipoid S75-3	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
Labrafac® WL 1349	10.08	10.08	10.08	10.08	10.08	10.08	10.08	10.08
Solutol® HS 15	**5.00**	**7.50**	**10.08**	**15.00**	**20.00**	**22.50**	**25.00**	**30.00**
Water	81.65	79.10	76.60	71.68	66.68	64.18	61.68	56.68
NaCl	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76

TABLE I

Decreasing the concentration of Solutol® HS 15 results in an increase in the mean particle size (Figure 2). Mean sizes going from 23 to 128 nm are thus observed for Solutol® proportions going from 30% to 5% of the total formulation, respectively. The size thus depends on the concentration of hydrophilic surfactant.

C) Changes in the proportions of Lipoid® and Solutol® surfactants

Table II below shows formulations of nanocapsules prepared with various surfactant concentrations.

	Mass %		
	A	**B**	**C**
Lipoid® S75-3	**0.78%**	**1.51%**	**2.35%**
Labrafac® WL 1349	10.08%	10.08%	10.08%
Solutol® HS 15	**5.22%**	**10.08%**	**15.65%**
Water	82.16%	76.60%	10.16%
NaCl	1.76%	1.76%	1.76%
Proportion of surfactants	**6.00%**	**11.59%**	**18.00%**

TABLE II

Increasing the proportion of surfactants in the formulation brings about a reduction in the mean size. Specifically, formulation A gives particles with a mean size of 85 ± 7 nm (P = 0.124). For formulations B and C, the mean sizes become 43 ± 7 nm (P = 0.071) and 29 ± 8 nm (P = 0.148), respectively.

D) Change in the NaCl concentration

Table III below shows two formulations of nanocapsules prepared with two different concentrations of NaCl salt.

	Mass %	
Lipoid® S75-3	1.73%	1.70%
Labrafac® WL 1349	5.76%	2.84%
Solutol® HS15	2.88%	5.68%
Water	87.61%	86.36%
NaCl	2.02%	3.40%

TABLE III

Changing the salt concentration brings about a shift in the phase inversion zone. The higher the salt concentration, the lower the phase inversion temperature (Figure 3). This phenomenon will be advantageous for the encapsulation of hydrophobic heat-

sensitive active principles. Their incorporation may be performed at a lower temperature.

With these formulations, particles similar in size to the previous sizes may be obtained, despite the different salt concentrations.

Example 2: Encapsulation of a lipophilic active principle, Sudan III

The formulation corresponds to that of Example 1: 5 g of the initial emulsion are prepared by weighing out 75 mg of Lipoid® S75-3, 504 mg of Labrafac® lipophile and 504 mg of Solutol®, 3.829 g of water and 88 mg of sodium chloride. 200 mg of Sudan III dissolved in liquid petroleum jelly are added. The mixture is weighed out in the same beaker and placed under magnetic stirring. Heat is applied until a temperature of 85°C is reached. The system is allowed to cool to a temperature of 60°C with magnetic stirring. This cycle (between 85°C and 60°C) is performed three times. At the final cooling, an quenching at 70°C is carried out by adding 12.5 ml of distilled water at 2°C ± 1°C. The system is then maintained under magnetic stirring for 5 minutes.

The encapsulation of Sudan III made it possible to obtain particles of a similar size to the particles of Example 1, for the same proportions of surfactants and of fatty phase, ie 45 ± 12 nm (P = 0.138). To the naked eye, the sample appears a uniform pink.

Example 3: Encapsulation of progesterone

The formulation corresponds to that of Example 1: 5 g of the initial emulsion are prepared by weighing out 75 mg of Lipoid® S75-3, 504 mg of Labrafac® lipophile and 504 mg of Solutol®, 3.829 g of water and 88 mg of sodium chloride. 10 mg of progesterone are added. The

mixture is weighed out in the same beaker and placed under magnetic stirring. Heat is applied until a temperature of 85°C is reached. The system is allowed to cool to a temperature of 60°C with magnetic stirring. This cycle (between 85°C and 60°C) is performed three times. At the final cooling, an quenching at 70°C is carried out by adding 12.5 ml of distilled water at 2°C ± 1°C. The system is then maintained under magnetic stirring for 5 minutes.

The encapsulation of progesterone makes it possible to obtain particles of similar sizes to the particles of Example 1, ie 45 ± 12 nm (P = 0.112). The progesterone is not found in the aqueous phase at a concentration above its solubility. Specifically, a centrifugation at 200 000 rpm for 30 minutes gives a light precipitate whose composition was studied by DSC. This precipitate does not contain progesterone. Since progesterone is virtually insoluble in water, this indicates an incorporation of the active principle into the nanocapsules.

Example 4: Encapsulation of a busulfan suspension

A) Suspension of busulfan (at a concentration of 0.25 mg/ml)

The first step of the encapsulation of busulfan consists in dissolving it in N,N-dimethylacetamide. A solution containing 24 mg of busulfan per ml of N,N-dimethylacetamide is thus prepared. 175 mg of this solution are taken and added to 504 mg of Labrafac®. 75 mg of Lipoid® S75-3, 504 mg of Solutol®, 3.829 g of water and 88 mg of sodium chloride are also weighed out. The initial emulsion is thus at a concentration of 0.88 mg/g of emulsion. The ingredients are combined in the same beaker and placed under magnetic stirring. Heat is applied until a temperature of 85°C is reached. The system is allowed to cool to a temperature of 60°C

with magnetic stirring. This cycle (between 85°C and 60°C) is performed three times. At the final cooling, an quenching at 70°C is carried out by adding 12.5 ml of distilled water at 2°C ± 1°C. The system is then maintained under magnetic stirring for 5 minutes. The final concentration, ie after quenching, that is to say dilution, is 0.25 mg/ml.

The size of the particles obtained is slightly larger than that of Example 1 on account of the higher proportion of fatty phase (63 ± 5 nm). As for progesterone, busulfan is not found in the aqueous phase at a concentration above its solubility. Specifically, no crystals are visible by optical microscopy in the aqueous phase after encapsulation. Now, since busulfan is virtually insoluble in water, this indicates an incorporation of the busulfan into the nanocapsules.

B) Suspension of busulfan (at a concentration of 0.50 mg/ml)

A particle suspensation at 0.50 mg/l is prepared under the same conditions as above after dissolving 50 mg of busulfan in 1 ml of N,N-dimethylacetamide. 175 mg of this solution are taken and added to 504 mg of Labrafac®. 75 mg of Lipoid® S75-3, 504 mg of Solutol®, 3.829 g of water and 88 mg of sodium chloride are also weighed out. The initial emulsion is thus at a concentration of 1.76 mg/ml of emulsion. The ingredients are combined in the same beaker and placed under magnetic stirring. Heat is applied until a temperature of 85°C is reached. The system is allowed to cool to a temperature of 60°C with magnetic stirring. This cycle (between 85°C and 60°C) is performed three times. At the final cooling, an quenching at 70°C is carried out by adding 12.5 ml of distilled water at 2°C ± 1°C. The system is then maintained under magnetic stirring for 5 minutes. The

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final concentration, ie after quenching, that is to say dilution, is 0.50 mg/ml.

Example 5: Influence of the nature of the fatty substance on the phase inversion temperature

Labrafac®, an oil composed of capric and caprylic acid triglycerides, is compared with fatty acid esters. It was possible to reveal the influence of the size of their end groups on the phase inversion temperature. An increase in the phase inversion temperature with increasing size of the groups is observed. Thus, in the myristate series, the change in appearance is visible at 69.5°C for the ethyl ester, at 71.5°C for the isopropyl ester and at 86.5°C for the octyldodecyl ester. This increase means that an oil-in-water emulsion is more readily obtained when the oil has a lower HLB value (more lipophilic). Specifically, this more pronounced lipophilic nature brings about an accentuation of the hydrophobic bonds between the surfactant and the oil, and more energy is thus required to invert this system. Moreover, the carbon chain length of the fatty acid does not influence the particle size, or the phase inversion temperature (between C_{14} and C_{18}). It appears, however, that the double bond present in ethyl oleate substantially increases the phase inversion temperature.

The results are given in the table below.

Oils	Number of carbons (fatty acid)	Double bonds	°T change in appearance (°C)	Particle size (nm)
Labrafac® lipophile	8/10	0	77.0	43 ± 7
Ethyl palmitate	16	0	69.0	37 ± 15
Ethyl oleate	18	1	71.5	41 ± 5
Ethyl myristate	14	0	69.5	35 ± 13
Isopropyl myristate	14	0	71.5	44 ± 23
Octyldodecyl myristate	14	0	86.5	42 ± 16

TABLE IV

The HLB value of the fatty substance does not appear to affect the particle size significantly.

Example 6: Influence of the nature of the lipophilic surfactant on the size of the nanocapsules

Various types of lecithin whose phosphatidylcholine proportions range from 40% to 90% were used. The mean particle size increases as the phosphatidylcholine content in the lecithin increases (Table V below). Specifically, for 40% phosphatidylcholine, the size of the nanocapsules is 35 ± 8 nm, whereas it is, respectively, 43 ± 7 nm and 78 ± 12 nm for a proportion of 75% and 90% phosphatidylcholine in the lecithin. On the other hand, the use of charged molecules did not allow nanocapsules to be obtained.

Type of lipoid	% of phosphatidyl-choline	Mean particle size (nm)
Lipoid® S45	40	35 ± 8
Lipoid® S75-3	69	43 ± 7
Lipoid® S100	90	78 ± 12
Lipoid® EPC	98	61 ± 12
Lipoid® E80	80	72 ± 18

TABLE V

Example 7: Lipid nanocapsules with a water-soluble active principle attached to their surface

500 mg of a dispersion of lipid nanocapsules not containing active principle, as described in Example 1, are prepared using the following formulation:

- Lipoid® S 75-3 : 1.51 mass%
- Labrafac® W1.1349 : 10.08 mass%
- Solutol® HS 15 : 10.08 mass%
- Water : 76.6 mass%
- NaCl : 1.76 mass%

The lipid nanocapsules obtained have a size of 43 ± 7 nm. 50 mg of the dispersion of lipid nanocapsules obtained are diluted in 1 ml of water and incubated with gentle stirring with an aqueous solution containing 50 µg of DNA (pSV β-galactosidase, Promega, France) for one hour in the presence of a mixture of histones obtained from calf thymus (Boehringer Mannheim, Germany). Lipid nanocapsules containing DNA molecules condensed with the proteins, adsorbed onto their surface, are obtained.

CLAIMS

1. Nanocapsules with an average size of less than 150 nm, preferably less than 100 nm and more preferably less than 50 nm, consisting of an essentially lipid core that is liquid or semiliquid at room temperature, coated with an essentially lipid film that is solid at room temperature.

2. The lipid nanocapsules as claimed in claim 1, characterized in that their polydispersity index is between 5% and 15%.

3. The lipid nanocapsules as claimed in claim 1 or 2, characterized in that the thickness of the solid film is between 2 and 10 nm.

4. The lipid nanocapsules as claimed in one of claims 1 to 3, characterized in that the core of the nanocapsules consists essentially of a fatty substance, such as a triglyceride or a fatty acid ester, representing 20% to 60% and preferably 25% to 50% by weight of the nanocapsules.

5. The lipid nanocapsules as claimed in claim 4, characterized in that the triglyceride constituting the core of the nanocapsules is chosen from C_8 to C_{12} triglycerides, for example capric and caprylic acid triglycerides, and mixtures thereof.

6. The lipid nanocapsules as claimed in claim 4, characterized in that the fatty acid ester constituting the core of the nanocapsules is chosen from C_8 to C_{18} fatty acid esters, for example ethyl palmitate, ethyl oleate, ethyl

myristate, isopropyl myristate and octyldodecyl myristate, and mixtures thereof.

7. The lipid nanocapsules as claimed in claim 6, characterized in that the fatty acid ester is C_8 to C_{12}.

8. The lipid nanocapsules as claimed in one of claims 1 to 7, characterized in that the solid film consists essentially of a lipophilic surfactant.

9. The nanocapsules as claimed in claim 8, characterized in that the fatty substance/lipophilic surfactant compound ratio is chosen between 1 and 15, preferably between 1.5 and 13 and more preferably between 3 and 8.

10. The lipid nanocapsules as claimed in claim 8 or 9, characterized in that the lipophilic surfactant is a lecithin whose phosphatidylcholine proportion is between 40% and 90%.

11. The lipid nanocapsules as claimed in one of claims 1 to 10, characterized in that the solid film also contains a nonionic hydrophilic surfactant, for example Solutol® HS 15, representing 2% to 10% by weight of the nanocapsules.

12. The lipid nanocapsules as claimed in one of claims 1 to 11, characterized in that they contain a pharmaceutically active principle.

13. A process for preparing the nanocapsules according to any one of claims 1 to 12, which involves the operations consisting in:

a) - preparing an oil/water emulsion containing an oily fatty phase, a nonionic hydrophilic surfactant, a lipophilic surfactant that is solid at 20°C and optionally a pharmaceutically

active principle that is soluble or dispersible in the oily fatty phase, or a pharmaceutically active principle that is soluble or dispersible in the aqueous phase,

- bringing about the phase inversion of said oil/water emulsion by increasing the temperature up to a temperature T_2 above the phase inversion temperature (PIT) to obtain a water/oil emulsion, followed by a reduction in the temperature down to a temperature T_1, $T_1 < PIT < T_2$,
- carrying out at least one or more temperature cycles around the phase inversion zone between T_1 and T_2, until a translucent suspension is observed,

b) quenching the oil/water emulsion at a temperature in the region of T_1, preferably greater than T_1, to obtain stable nanocapsules.

14. The process as claimed in claim 13, characterized in that the oily fatty phase is a C_8 to C_{12} triglyceride, for example capric and caprylic acid triglycerides and mixtures thereof or a C_8 to C_{18} fatty acid ester, for example ethyl palmitate, ethyl oleate, ethyl myristate, isopropyl myristate or octyldodecyl myristate, and mixtures thereof.

15. The process as claimed in claim 13 or 14, characterized in that the nonionic hydrophilic surfactant is Solutol® HS 15.

16. The process as claimed in one of claims 13 to 15, characterized in that the lipophilic surfactant is a lecithin whose phosphatidylcholine proportion is between 40% and 90%, for example Labrafac® WL 1349.

17. The process as claimed in one of claims 13 to 16, characterized in that the oil/water emulsion contains:
1% to 3% of lipophilic surfactant,
5% to 15% of hydrophilic surfactant,
5% to 15% of oily fatty substance,
64% to 89% of water,
the percentages being expressed on a weight basis.

18. The process as claimed in one of claims 13 to 17, characterized in that the oil/water emulsion also contains from 1% to 4% of a salt, such as sodium chloride.

19. The process as claimed in one of claims 13 to 18, characterized in that the lipophilic surfactant is solid at 37°C.

20. A process for preparing nanocapsules as claimed in one of claims 13 to 19, characterized in that a water-soluble pharmaceutically active principle is adsorbed onto the free surface of the stable nanocapsules obtained after step b).

21. The use of the nanocapsules as claimed in one of claims 1 to 12, for the manufacture of a medicament administered by injection, especially by intravenous injection, orally or nasally.