Liposome of textile auxiliary agent, method of its preparation and application results

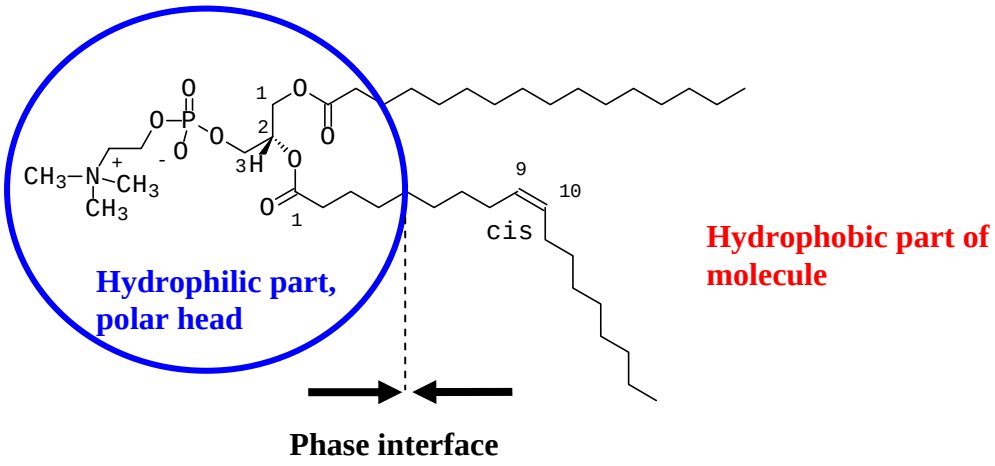
Radim Hrdina, Ladislav Burgert, Marcela Hrdinová, Libor Dušek, Petr Přichystal, Nasanjargal Purev, Jitka Kunstová, Costas Boutris*, Christos Koukiotis*, Eleni Loutsopoulou*, Nena Malliou*, Kyriakos Loufakis+

University of Pardubice, Faculty of Chemical Technology, Czech Republic
* Clothing Textile and Fibre Technological Development S.A., Greece
+ Loufakis Chemicals S.A.

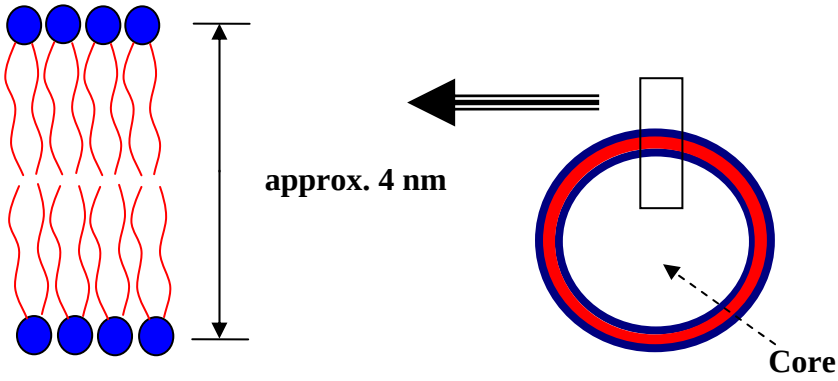
1 INTRODUCTION

The **micro-encapsulation technology**, i.e. preparation of micro-capsules (vesicles, cells) is extensively utilised in a number of industrial branches, especially in agriculture, medicine, cosmetics and also in textile industry. The micro-encapsulation is a process in which very small droplets or solid particles are coated with a continuous film. A special category is **encapsulation into liposome systems**. In this case the encapsulation material is a natural product called lecithin, i.e. a substance used in foodstuff, cosmetics and pharmaceutical industries, which is harmless for health, environmentally friendly and cheap. The encapsulation into liposome systems is applicable to both liquids and solids, and is universal, i.e. it encapsulates both water soluble substances and water insoluble ones. In biochemical literature, the term lecithin is used as trivial name for 3-*sn*-phosphatidylcholines. American Oil Chemists Society gives the following definition: lecithin is a mixture of glycerophospholipids obtained from plant, animal or microbial sources and containing a number of substances, such as sphingosylphospholipids, triglycerides, fatty acids and glycolipids.

Liposomes are particles in which a certain volume—the core—is surrounded by a membrane consisting of molecules of a lipid, usually phospholipid (constituents are held together by means of hydrogen bonds and van der Waals forces). After dispersing the lipid in aqueous medium, the liposomes are formed spontaneously and have diameters from nanometers to micrometers (*Liposomes, A Practical Approach,* Edited by R. R. C. New, Oxford University Press, 1997). Molecules of phospholipids contain a hydrophilic part and a hydrophobic one. An example is 1-palmitoyl-2-oleyl-*sn*-glycero-3-phosphocholine (POPC). The polar group can be phosphocholine, ethanolamine, serine, glycerol etc., and the exact composition depends upon the source of the respective phospholipids. The hydrophobic moiety is formed by fatty acids such as palmitic, stearic, oleic, linolenic acid etc. The compounds of this type are called **amphiphilic compounds**, and following picture is schematic representation. The double bonds in phospholipids bring with them slightly anti-oxidising effects. However, their easy oxidation results in their colour turning yellow and finally in their destruction. That is why hydrogen-saturated (hydrogenated) phospholipids (e.g., hydrogenated lecithin) are manufactured; these derivatives are white and also more stable (in chemical context this means that they do not undergo oxidative destruction so easily). Liposomes are formed in water thanks to the tendency of amphiphilic molecules to create aggregates in which the hydrophobic moiety has a minimum contact with polar solvent, i.e. water.



Membrane



The phospholipids (probably due to the presence of two hydrocarbon chains in their molecule) can create a number of structures depending on “water concentration”: lamellar and non-lamellar ones. Liposomes can form one layer (one double layer) or several layers (several double layers) depending on the method of their preparation.

Generally, in principle the preparation of liposomes does not much depend upon the chemical structure of amphiphilic molecules. Very important is correct temperature of the preparation, which must be 5-10 °C higher than the main phase transition temperature (T_m). Below this temperature the hydrocarbon chains assume a rigid conformation similar to crystal state (gel). Above the T_m temperature, the hydrocarbon chains are “loosened” (liquid crystal), which makes it possible to mechanically prepare (dispersing by stirring, ultrasound etc.) the lipid double layer (membrane). As a rule, the longer and the more saturated (i.e. with the double bonds hydrogenated) the hydrocarbon chains are, the higher is the T_m temperature. For instance, 1-palmitoyl-2-oleyl-*sn*-glycero-3-phosphocholine (POPC) has the T_m temperature about –2.5 ± 2.4 °C.

The type o liposome formed depends upon **the preparation method** adopted. A survey of preparation methods is presented in a review article (P. Walde, S. Ichikawa, *Enzyme inside lipid vesicles: preparation, reactivity and applications*, Biomolecular Engineering **18** (2001), 143-177) or encyclopaedia (P. Walde: *Preparation of Vesicles (Liposomes),* Encyclopaedia of Nanoscience and Nanotechnology (2004), **9**, 43-79).

Lecithins, i.e. generally amphiphilic compounds (lipids) can encapsulate both water-soluble and water-insoluble compounds.

The simplest case is **encapsulation of hydrophobic water-insoluble substances,** such as fats, oils, disperse dyes, etc. The hydrophobic compound is inside of the capsule (core) and also incorporated in the membrane (double layer), either as a lens between the two layers or directly between the hydrocarbon chains of individual molecule (cholesterol in natural cells is incorporated similarly). Large unilamellar vesicles (LUV) are prepared by the following technique: e.g., first, purified egg lecithin (eluent chloroform/methanol = 2:1) is placed on the wall of rotary evaporator by evaporation of the solvent in nitrogen atmosphere, which results in formation of a thin film. Then ethyl ether is added to obtain a solution, and the aqueous dispersion of the substance to be encapsulated is added to it with stirring and application of ultrasound. Then the organic solvent is removed by evaporation with stirring in vacuum. The suspension of liposomes can be extruded, e.g., through a 400 nm polycarbonate membrane.

Substantially more complex is the **encapsulation of hydrophilic water-soluble compounds** (both of anionic and of cationic nature). In this case, only a part of the compound is encapsulated, while the rest remains in the solution outside of the liposomes. Formation of ionic bond between polar group of lecithin and the substance encapsulated has the result that the “concentration” of encapsulated substance in the liposome is higher than that of the free substance in “outer” solution. The preparation of LUV in this case is similar to the procedure described above (Gomes J.I.N.R, Genovez M.C., Hrdina R., Textile Res. J 67(7), 537-541 (1997)). The procedure is very suitable, e.g., for dyeing animal substrates (wool, leather) with dyestuffs that exhibit a too high affinity for the substrate dyed, and the dyeing process has to be retarded to achieve diffusion of dyestuff into the fibre.

Generally, the rate of release of dyestuff from capsule into outer solution (dyeing bath) can be controlled by means of temperature—a temperature increase accelerates the release—or also by addition of, e.g., a non-ionic surfactant, such as Triton X100 (oxyethylated alkylphenol). As a rule, on reaching a certain concentration of the surfactant all the liposomes are destroyed. Multilamellar vesicles (MLV) are generally prepared by dissolving the lipid in organic solvent, evaporation of the latter, formation of a thin film on the wall of vessel and, finally, addition of aqueous solution of the substance to be encapsulated. The obtained liposomes are 30 microns in diameter and the amount of encapsulated substance is low (below 20 %). The liposomes can be submitted to action of ultrasound, which decreases their diameter but does not increase the amount of encapsulated substance. Intensive action of ultrasound upon MLV can even produce small unilamellar vesicles (SUV) with a diameter of 20-50 nm. They are obtained by fast injecting ethanolic solution of lipid (the maximum concentration of lipid is 3 %) into aqueous phase. However, the encapsulated amount is so small (about 1 %) that the method is virtually useless in industry. In this respect, other techniques are similar. Company Lucas Meyer (EP 0 158 441 A2) introduced a procedure in which the encapsulated substance is first mixed with the so-called “pro-liposome” (lecithin in lamellar structures) and then the obtained mixture is diluted with water using vigorous stirring. The dilution produces multilamellar vesicles (MLV) in which, however, the amount of encapsulated substance is much higher.

Affinity of liposomes for various materials is controlled by electrostatic charge at the outer surface of membrane, i.e. **ZETA potential** that is established in the given medium. The liposomes formed from phosphatidylcholines should be electrically neutral (have zero electrostatic charge at their surface). Negatively charged liposomes can be prepared by addition of negatively charged amphiphilic compounds

(dicetyl phosphate is a typical example), while positively charged liposomes can be prepared by addition of positively charged amphiphilic compounds (octadecylamin is an example, and dioctadecyldimethylammonium bromide is an even better example). The magnitude of ZETA potential also affects the stability of dispersion. It is claimed that liposomes with ZETA potentials above ca +30 mV or below ca –30 mV tend rather to mutual repulsion than to aggregation, and dispersions of liposomes having such charges are stable.

Mechanical properties of membrane are usually affected by addition of cholesterol, which influences the organisation of the lipid double layer (McMullen T.P.W., McElhaney R.N., Biochim. Biophys. Acta, 1234(1995), 90-98).

In dyestuff chemistry, or to be more precise, in **textile applications**, lecithins were predominantly applied to encapsulation of disperse dyes for dyeing polyester and wool. Barni et al. reported dyeing of polyester in which he had achieved a faster migration of dyestuff and good uniformity of dyeing (E. Barni et. al., J. Dispersion Sci. Technol., 9(1), (1988), 75-97).

Liposomes were also investigated in applications to wool dyeing. In this respect pioneering work was done by Maza et al. (Maza et al., JSDC Vol.108, December 1992), as well as by Genovez et al. (Genovez et al., Colorchem 94, 1994; J. I. N. R. Gomes, M. C. Genovez, R. Hrdina: Controlling Exhaustion of Reactive Dyes on Wool by Micro-Encapsulation with Liposomes, Textile Res. J. 67(7) (1997) 537-541), who proved that liposome systems can be adopted in wool dyeing not only with acid dyes (because phospholipids increase the adsorption forces and are, therefore, excellent carriers of dyestuffs) but also with disperse dyes. Wool dyeing with disperse dyes usually suffers from either bad migration of dyestuff to the surface or, on the other hand, uneven dyeing. Encapsulation of disperse dye into phospholipids enabled easy and uniform dyeing of wool. Preparation of liposome capsules for use in dyeing with acid dyestuffs was described by Bangham (A. D. Bangham, M.M. Standish and J. C. Watkins, J. Mol. Biol., 13 (1965) 238). A method of preparation of monolayer-type micro-capsules was described by Paternostre and Rigaud (J. L. Rigaud, A. Bluzar and S. Buschlen, Biochem. Biophys. Res. Commun., 111 (1983) 373; M. T. Paternostre, M. Roux and J. L. Rigaud, Biochem., 27 (1988) 2668), who started from the general method of preparation described by Szoka and Papahadjopoulos (F. Szoka and D. Papahadjopoulos, Proc. Nat. Acad. Sci. USA, 75 (1978) 4194).

In the course of **dyeing process**, the micro-capsules are gradually opened by heat, which in principle means displacing the equilibrium between the encapsulated dyestuff and the free one. This technique of opening is applied in dyeing processes with disperse dyes. It is also possible a non ionic surfactant added to destroy all the capsules or a part o them (F. Szoka et al., Biochim. Biophys. Acta, 601 (1980) 559).

A special paragraph will be dedicated here to the already mentioned work by Genoveze et al., who used liposome system for encapsulation of reactive dyes Lanasol (reactive dyestuffs of α-bromoacrylamide type) for the use in wool dyeing.

A review article on applications of liposomes to wool dyeing was published by Sekar (N. Sekar, Colourage (1999), 46(4), 37-38). Also Coderch et al. reported applications of liposomes to wool dyeing and in particular dyeing of wool/polyester mixtures. (L. Coderch et al., Recent Research Developments in Oil Chemistry (1997), 1, 17-29).

Textile auxiliaries are used in dyeing of textile fibres and textiles. The textile auxiliary added to dye bath is an electrolyte (salt) in the cases of dyeing of fibres made from native and regenerated cellulose with direct dyes, reactive dyes, vat dyes,

sulphur dyes and insoluble azo dyes, in dyeing of wool with acid and metal-complex dyes of all classes, mordant dyes and reactive dyes, in dyeing of synthetic polyamides with acid dyes, reactive dyes and metal-complex dyes of all classes, and in dyeing of anion-modified poly(acrylonitriles) with cationic dyestuffs. The textile auxiliary added to dye bath is a dispersing agent in the case of dyeing of hydrophobic fibres, e.g., synthetic polyesters, with disperse dyes.

The basic disadvantage of the present procedures of encapsulation of dyestuffs into liposome system lies in the fact that the encapsulation of dyestuff must be carried out by its manufacturer; if it is carried out by the dyer of particular goods, it must be taken into account that the process is extremely demanding and basically impracticable in ordinary dye works. This drawback is eliminated by the present invention.

2 ESSENCE OF INVENTION

The subject of this invention is a **liposome of textile auxiliary agent** composed of a **solid nucleus containing the textile auxiliary agent** and a **membrane containing phospholipids** and optionally cholesterol, a surfactant and/or water-soluble polymer of cationic type, wherein the content of textile auxiliary agent referenced to the total mass of liposome is 80-99.5 % wt., the content of the phospholipid is 0.5-20 % wt., the content of cholesterol is up to 19.5 % wt., the content of surfactant is up to 19.5 % wt., the content of water-soluble polymer of cationic type is up to 19.5 % wt., whereas the liposome is a solid particle (R. Hrdina at al., PCT/CZ2008/000003).

The invention is distinguished by the fact that the textile auxiliary agent has been selected from among the group including salts and dispersants.

Application a spray drier allows preparation of encapsulated inorganic salt, organic salt or dispersant, i.e. liposomes of textile auxiliary agent with lipid membrane and with a narrow distribution curve of their sizes, and **without using organic solvents**.

The salts present in dye bath affect not only the ionic strength but also pH of dye bath (depending on their sort). The diameter of resulting liposomes depends upon the concentration of the compounds in water and the size of drops formed at the top of the spray drier.

The invention is distinguished by the fact that the phospholipid is lecithin. It is advantageous to select the lecithin from among the group including rapeseed, egg or soya lecithin. The lecithin can also be hydrogenated. It is also possible to adopt synthetic lecithins, e.g., dipalmitoylphosphatidylcholine.

The surfactants are possibly added to phospholipid because during drying in spray drier the surfactant is incorporated into the membrane and thus affects the properties of this membrane, first of all its surface potential and electrokinetic ZETA potential.

The water-soluble polymers of cationic type without surface activity are possibly added to phospholipids because they shift the surface potential and electrokinetic ZETA potential of the membrane towards positive values.

Depending upon the required application, anionic, cationic, amphoteric or non-ionic surfactants can be used as the surfactants.

The potential at the surface of membrane is affected by the kind of lecithin used and is always negative; ZETA potential ranges ca from –30 mV to –70 mV. The

lecithin used is not purified; it is a crude material as obtained from individual manufacturers. For instance, a liposome of sodium chloride, whose membrane was prepared from fresh soya lecithin, had a negative ZETA potential about –30 mV. A liposome of sodium chloride whose membrane was prepared from rapeseed lecithin (one year old) had a ZETA potential about –62 mV. This is due to the fact that ageing of lecithin results in hydrolysis of its ester bonds and formation of phosphatidyl acid, which increases the absolute value of the negative charge. As already mentioned, the value of charge can be affected by addition of surfactants. **When using non-purified lecithin, a positive potential at the surface of liposome can only be achieved by addition of compounds carrying a permanent positive charge**.

In the procedure carried out according to the present invention, the value of potential can be affected by addition of cholesterol, which is incorporated into the membrane, too, this shift being from the limiting value towards zero. This fact offers a possibility to adjust the value of potential at a required value within certain limits. This phenomenon is perhaps due to a change in organisation and mechanical properties of membrane. Very suitable is the addition of cholesterol when employing crude non-purified lecithin, since cholesterol shifts ZETA potential to zero value, which is highly advantageous in its applications to dyeing of hydrophobic fibres.

Another subject of the present invention is the **method of preparation** of liposomes of textile auxiliary agent: according to this invention the principle of the method consists in using 100 mass units of water (advantageous is distilled or deionised water), in which first 2-40 mass units of textile auxiliary agent is dissolved, and then phospholipid is added with stirring to the solution of the compound encapsulated, whereupon the milky dispersion formed is dried in spray drier, where the temperature at the top is 140-170 °C and at the bottom (at the outlet of liposomes) is 70-110 °C. In an advantageous arrangement, the phospholipid (before being added to the solution of the compound encapsulated) is mixed in another vessel with a surfactant and cholesterol, as the case may be, and water-soluble polymer of cationic type, as the case may be, and the mixture is homogenised.

Another subject of this present invention is a preparation based on liposomes, in particular for addition to dye baths, containing liposomes of textile auxiliary agent, the final preparation being in the form of powder.

Hence, the **encapsulated textile auxiliary agent** is used for encapsulation of water-soluble or water-insoluble compound, e.g., dyestuff or pigment, in such a way that first the dye is dissolved in water (or disperse dye or pigment is dispersed in water), whereupon the liposome of textile auxiliary agent (e.g., salt or dispersant) is added. Since the textile auxiliary agent rapidly diffuses through the membrane, it is gradually dissolved in water. On the other hand, the dyestuff or pigment, having a large molecule and much lower solubility in water, is expelled from this solution (in the case of water-soluble compounds this process is called salting-out) and subsequently **"re-encapsulated"** by molecules forming the membrane. The encapsulated textile auxiliary agent can also be used for increasing wet fastness properties of dyed textile fibres or textiles, or for removing residual dyestuff from residual dye bath containing **residual dyestuff.**

Liposomes of dyestuffs or pigments containing substances that affect the surface potential and electrokinetic ZETA potential of membrane possess affinity for the substrates dyed or, on the contrary, repulsive properties against these substrates, depending on the kind of electrostatic charge. Moreover, these substances affect the rate of release of dyestuff from liposome into the substrate dyed or into the surrounding dye baths.

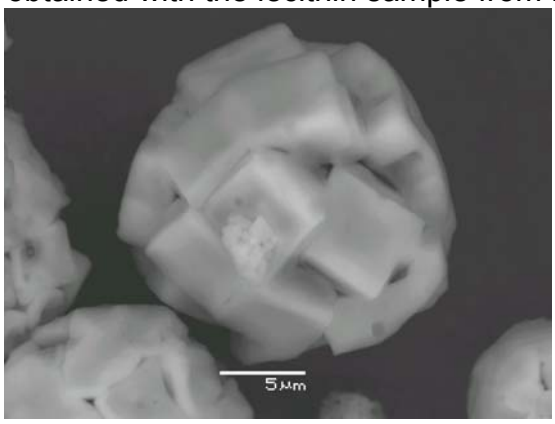
3 EXAMPLES OF RESULTS

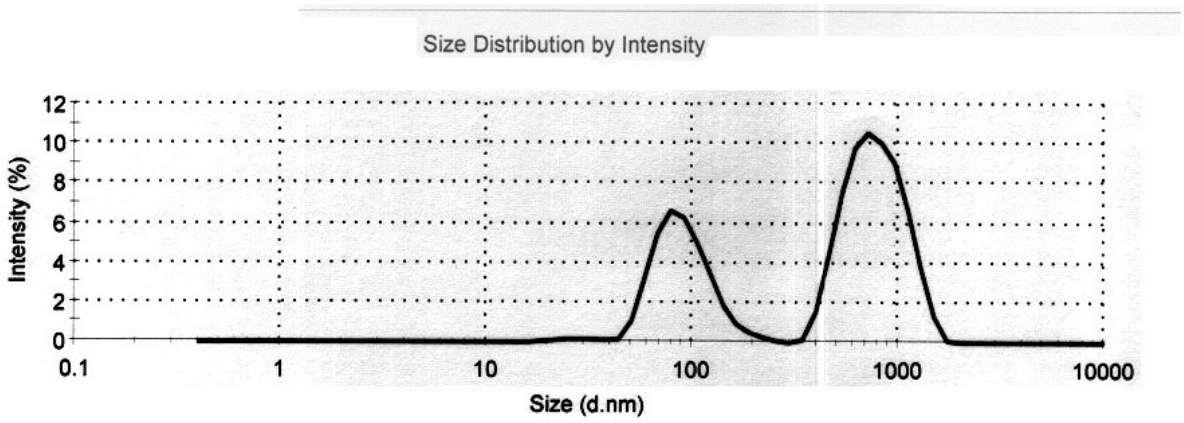
ZETA potential of liposome samples was measured in CPN Ltd. Dolní Dobrouč (Zetasizer Nano ZS, model 3600, Malvern Instruments Ltd.) and the distribution curve of size of particles was measured in the disperse medium of water at the liposome concentration of 0.1 g.dm^{-3}.

The photograph from electron microscope was obtained with a JEOL JSM-5500LV apparatus (the University of Pardubice). The parameters of measurement: accelerating voltage of primary electron beam 20 kV, pressure in the chamber 20 Pa, representation regime – back-reflected electrons.

I. Liposome of sodium chloride, lecithin membrane (LP-1)

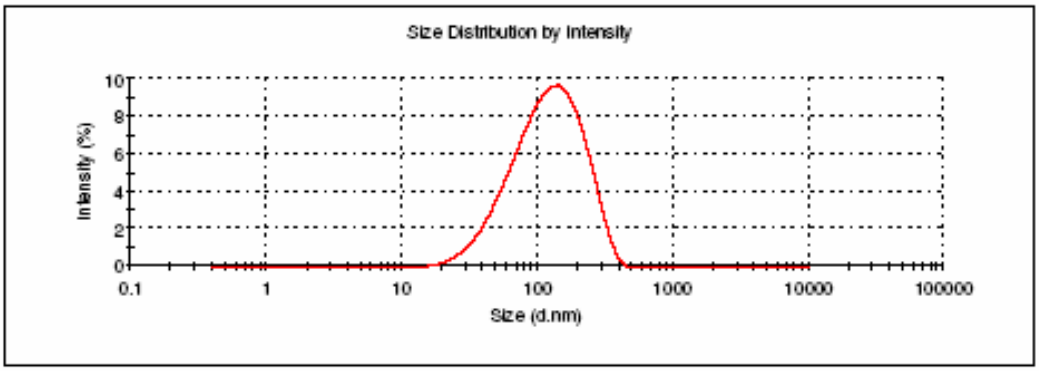
Sodium chloride p.a. (190 g) is dissolved in 1000 cm^3 distilled water. The solution is stirred, and 10 g lecithin is added (Lecithin RM-50, Milo PLC Olomouc; or Lecigran 5750, Riceland Foods, Inc., Stuttgart, Germany; or Soya lecithin, Ekoprodukt Ltd., Jinačovice, the Czech Republic), and the milky dispersion is dried in a spray drier Büchi 190 (input 2900 W), equipped with a 1.3 mm jet. Conditions in drier: temperature at the top 165-170 °C, temperature at the bottom (at the outlet) 104-107 °C, flow rate in jet inlet 5 g.min^{-1}. The yield is 200 g liposome of sodium chloride LP-1. ZETA potential depends upon the provenience of lecithin used: –29.5 mV (soya lecithin from Ekoprodukt Ltd.), –36.7 mV (lecithin RM-50 from Milo PLC, Olomouc), and –61.7 mV (Lecigran 5750 from Riceland Foods, Inc., Stuttgart, Germany). For illustration, the distribution curve of particle sizes and photograph from electron microscope obtained with the lecithin sample from Ekoprodukt Ltd. are shown.





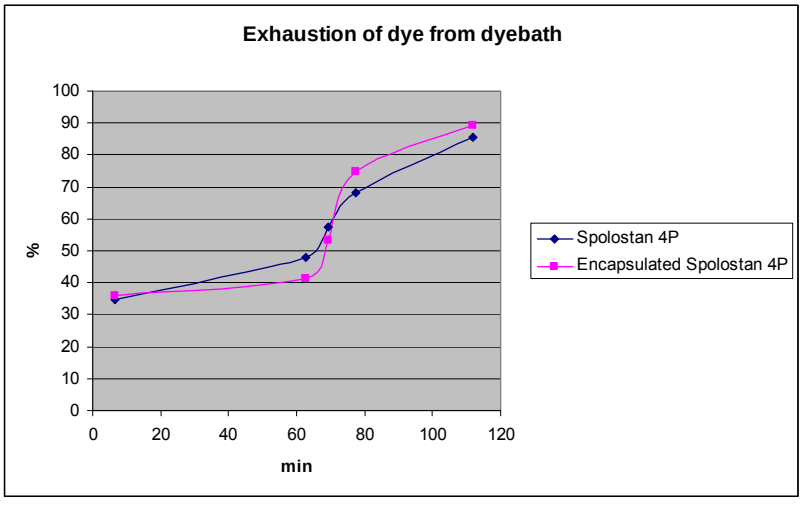
II. Liposome of sodium naphthalenesulphonate (Spolostan 4P), lecithin membrane, addition of Slovasol 359 (LP-2)

Spolostan 4P (SPOLECHEMIE Ústí nad Labem, Czech Republic) in an amount of 100 g is mixed with 200 cm^3 water during 1 hour. The non-ionic surfactant Slovasol 359 (6.66 g) is also dissolved in 200 cm^3 water, and after its dissolution, 3.33 g soya lecithin (Ekoprodukt Ltd., Jinačovice, the Czech Republic) is added and a fine emulsion is prepared by stirring, whereupon vigorous stirring is continued for about 1 hour. The emulsion thus obtained is slowly poured into the above-mentioned solution of Spolostan 4P with continuous stirring. Finally, the newly formed dispersion is dried in a spray drier Büchi 190 (input 2900 W) equipped with a 1.3 mm jet at the following conditions: temperature at the top of drier 165-170 °C, at the bottom outlet 104-107 °C, flow rate at the jet inlet 5.0 $g.min^{-1}$. The yield is 110 g liposome of Spolostan 4P LP-2, which exhibits the ZETA potential of -67.3 mV (ZETA deviation 8.8 mV).



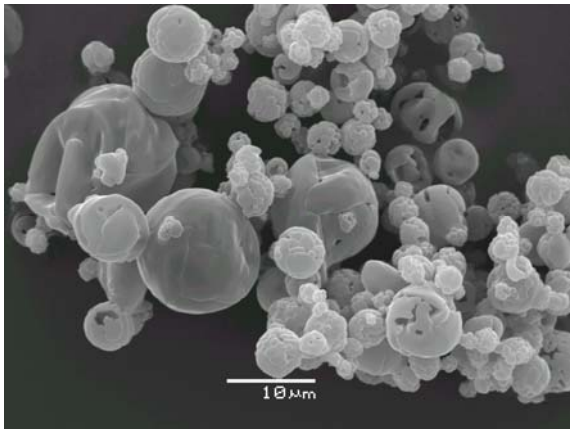
Example of high-temperature dyeing of polyester with disperse dyes

The bath kept at a temperature of 50-60 °C contains 1 $g.dm^{-3}$ liposome LP-2, 2 $g.dm^{-3}$ ammonium sulphate, and formic acid to adjust pH 5-5.5. After 10 min, the well-dispersed disperse dye is added and the temperature is raised to 125-130 °C within 30 min. The material is dyed for a period of 60 min. The resulting shade is uniform and deep in contrast to that obtained with application of non-encapsulated dispersant. Dyeing of polyester fibre with **Ostacet Blue ELG** is shown in the next figure.



III. Liposome of ammonium sulphate, lecithin membrane, addition of Slovasol 359 (LP-3)

Ammonium sulphate p.a. (Sigma-Aldrich Co., 100 g) is dissolved in 300 cm^3 distilled water. Then a solution is prepared from **6.6 g non-ionic surfactant** Slovasol 359 and 300 cm^3 water. After dissolution of the surfactant, **3.3 g soya lecithin** (Ekoprodukt Ltd., Jinačovice, the Czech Republic) is added with stirring to produce an emulsion of lecithin in the tenside solution. The fine emulsion produced is stirred with a magnetic stirrer at room temperature for 1 hour and then for another 15 min in ultrasonic bath. The obtained emulsion is slowly mixed with the above-mentioned solution of ammonium sulphate, and while being stirred, it is pumped to the spray drier Büchi 190 (input 2900 W) equipped with a 1.3 mm jet at the following conditions of drying: temperature at the top of drier 165-170 °C, at the bottom outlet 104-107 °C, flow rate at the jet inlet 5.0 $g.min^{-1}$. The yield is 110 g liposome of ammonium sulphate LP-3, which exhibits the ZETA potential of –67.3 mV in water (ZETA deviation 8.8 mV).



Example of polyamide dyeing with acid dyestuffs

Polyamide fibre was dyed at different processes for the determination of efficiency of encapsulated $(NH_4)_2SO_4$. Firstly, polyamide was dyed under “usual conditions”. In other experiments was dyed with the addition of LP-3 or with encapsulated dyes (the procedure of encapsulation is similar to encapsulation of inorganic salts).
Polyamide substrate was dyed (dyeing system – textile dye + $(NH_4)_2SO_4$) in dyeing machine Ahiba Nuance for 60 minutes at 100 ^oC. Depth of shade: 0.5%, ratio of bath: 1:20, weight ratio dye : ammonium sulphate – 1:1. In the following table are combinations of microencapsulated and no-capsulated forms of textile dye and textile auxiliary product $(NH_4)_2SO_4$ (dyeing systems 1-5) used for experiments.

Dyeing system	**Dye**	**$(NH_4)_2SO_4$**
	microencapsulated with	
1	-	-
2	-	10 w % lecithin
3	-	10 w % (lecithin : Slovasol 358,1:2)
4	10 w % (lecithin : Slovasol 358,1:2)	-
5	10 w % (lecithin : Slovasol 358,1:2)	10 w % (lecithin : Slovasol 358,1:2)

Dyeing system 3: The polyamide material is treated in a bath containing 2-3 % liposome LP-3 for a period of 30 min. The starting temperature of bath is about 30 °C and up to 50 °C for dyeing pale and deep shades, respectively. After addition of well-dissolved dyestuff, the bath is brought to a simmer within 45 min, and the dyeing process is continued for another 60 min. The resulting shade is even and deep in contrast to that obtained with non-encapsulated preparation.

Dye / Dyeing system		Acid Khaki*	Acid Green 43	Acid Blue 193	Acid Violet 90
1	a	0.67	0.54	0.66	0.11
	b	80.79	76.08	77.85	92.84
2	a	0.57	0.02	0.82	0.30
	b	82.82	100.10	75.16	93.54
3	a	0.14	0.07	0.08	0.07
	b	100.63	93.63	99.76	97.77
4	a	1.29	0.42	0.20	0.13
	b	80.24	83.01	108.86	92.68
5	a	0.13	0.33	0.13	0.03
	b	99.44	79.98	97.86	101.52

a - value of total colour difference ΔE^*_{ab}
b – value of colour difference – indicate by depth of shade (%).
* - Acid Khaki (mixture of Acid Yellow 116, Acid Black 107, Acid Red 213)

The following table shows the results, where lecithin and Slovasol 358 were added directly into dye-bath together with dyestuff. The mass proportions of compounds were the same as in the case of dyeing system 3.

Dye / Addition of		Acid Khaki*	Acid Green 43	Acid Blue 193	Acid Violet 90
lecithin	a	1.50	0.41	0.36	0.26
	b	74.91	78.97	82.38	85.10
lecithin + Slovasol 358	a	1.35	0.35	0.65	0.25
	b	85.80	77.74	136.90	89.12
Slovasol 358	a	1.60	0.09	0.80	0.01
	b	87.14	102.64	72.68	93.91

From the obtained results can be seen, that encapsulated ammonium sulphate is very efficient in the dyeing of polyamide fibres, and (surprisingly) gives better results in the comparison with encapsulated dyes.

Acknowledgement

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