University of Rome "La Sapienza"
Department of Chemical Materials Environmental Engineering
Email: marco.stoller@uniroma1.it

Low energy production of nanoliposomes by means of a spinning disk reactor

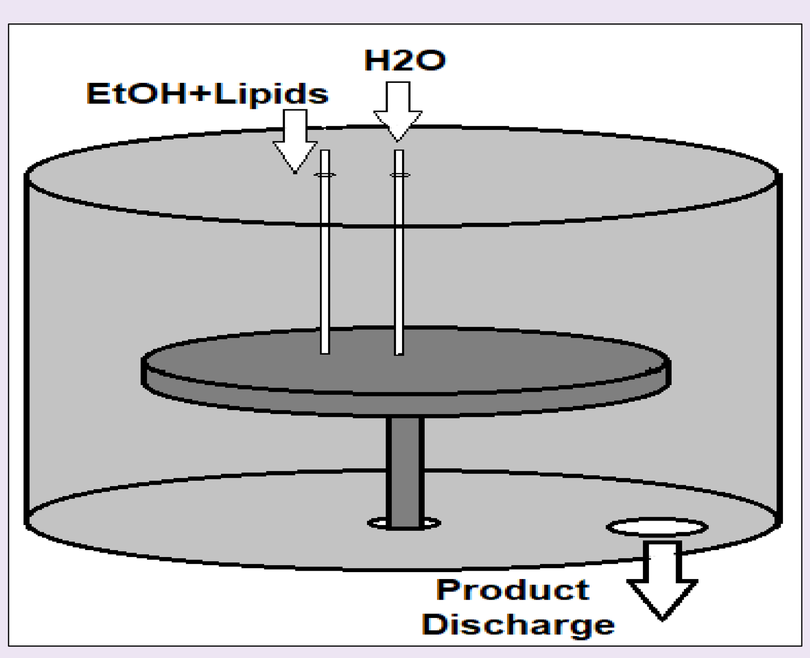
Lorenzo Iezzi, Giorgio Vilardi, Xinghua Gao, Ruiqun Qi, Li Zhang, Marco Stoller
marco.stoller@uniroma1.it

ABSTRACT

In recent years the interest in the production of liposomes as carriers for a wide range of different substances is increasing. ULs are classified on the basis of their size, ranging from some nanometres (SUVs) up to hundreds of micrometres (LUVs). There are several methods to prepare unilamellar liposomes, some of which are based on the use of toxic organic solvents, complex multistage processes and high energy requirements to obtain a product showing poor stability and wide broad particle size distribution (PSD). In this work, spinning disk reactor (SDR) technology was used to produce ULs with a narrow size distribution (PSD) by adopting a green solvent-antisolvent protocol, that are ethanol and water respectively. This reactor is introduced in the context of Process Intensification (PI). Compared to other common reactors, it shows high heat and mass transfer as well as other features such as versatility, low energy requirement and easy to scale up to produce commercial quantities. Relevant operational parameters such as the rotational velocity of the disk (ω), the position of the injector from the disk center (r) as well as the molar ratio (MR) between the reactants were investigated. The PSD of the produced ULs was checked by means of a particle size analyzer based on the dynamic light scattering technology (DLS). By adopting a similar protocol, the encapsulation efficiency (EE) of an organic dye (betacarotene) by the produced ULs was checked.

PRODUCTION METHOD

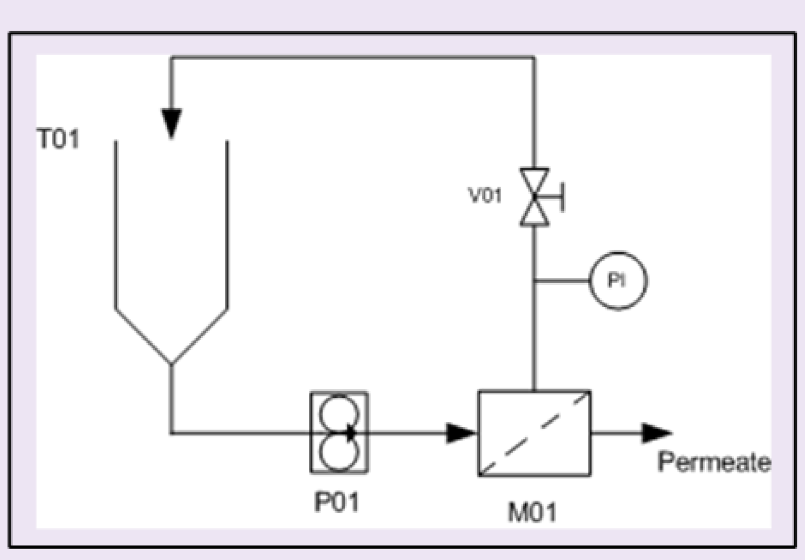
ULs were prepared based on the procedure adopted batch-wise by the ethanol injection method. The involved reactants for this synthesis are egg yolk L-α-Phosphatidylcholine (60% purity), β-Carotene (93 % synthetic powder) and ethanol (98% v/v); all reactants were of analytical grade supplied by Sigma Aldrich. Used water was of double distilled grade. A schematic representation of the adopted SDR for ULs preparation is showed in Figure 1. The apparatus consists of a stainless-steel disk with a radius of 0.015 m (rb) that can be set in motion at controlled rotational velocity angular speed, with a maximum equal to 136 rad s-1. Two or more reagent streams may be injected on the surface of the rotating disk. Injectors were of 3 mm in diameter and positioned at a heigh equal to 2 cm from the disk surface. The thin liquid film formed on the surface of the disk is pushed outwards by the resulting centrifugal forces obtained as a result of the rotation of the same. A vessel surrounding the system collects the liquid droplets which are conveyed to the bottom and to the outlet of the reactor, where the reaction product is continuously discharged and collected.



	Φ = 0.2				Φ = 0.5				Φ = 1			
ω [rad s^{-1}]	D [nm]	ε [W kg^{-1}]	τ [s]	δ [μm]	D [nm]	ε [W kg^{-1}]	τ [s]	δ [μm]	D [nm]	ε [W kg^{-1}]	τ [s]	δ [μm]
42	235	20	0.9	106	332	19	1	97	606	16	1.2	83
63	136	60	0.7	81	363	57	0.7	74	481	46	0.9	61
84	124	128	0.6	66	251	124	0.6	61	475	100	0.7	50
104	113	232	0.5	57	288	220	0.5	52	421	182	0.6	43
136	95	580	0.4	45	195	552	0.4	41	213	446	0.5	34

RESULTS AND DISCUSSION

From Table 1 it is possible to observe that smaller ULs are produced by operating the SDR at higher ω values and adopting lower φ values. It appears that it is possible to control the size of the produced ULs with ease by fixing and manipulating the φ and ω value, respectively. Both SUV and LUV can be produced by this technique.



Sample ID	Abs [-]	c [mg l^{-1}]	R [%]	EE_{min} [%]
Feed	1.066	28.57	-	-
PnoUL	0.908	24.33	14.8%	-
PUL	0.046	1.23	95.7%	80.9%

After ULs production, the product was sent to UF to separate the ULs including the β-carotene as a concentrate stream from the aqueous permeate stream.
It might be observed that the adopted membrane has a very low rejection value towards the dissolved organic pigment, equal to 14.8%. During ULs production, most of the β-carotene is encapsulated in the vesicle membrane, at a ratio between 80.9% and 95.7%.

Concerning energy requirements, by adopting the same operating conditions used to produce the PUL sample, a total operating time and energy of 47.6 h and 157.5 MJ/kg of produced ULs are required, respectively. Comparing this result to other techniques the energy requirements of the SDR resulted to be less of some order of magnitude.