Available online at www.sciencedirect.com
SCIENCE DIRECT
Journal of Membrane Science 269 (2006) 109–117
journal of MEMBRANE SCIENCE
www.elsevier.com/locate/memsci

Cholesterol removal by nanofiltration: Applications in nutraceutics and nutritional supplements

C. Allègre [a], P. Moulin [a,*], B. Gleize [b], G. Pieroni [b], F. Charbit [a]

[a] *Université Paul Cézanne, Laboratoire en Procédés Propres et Environnement (LPPE-UMR 6181), Europole de l'Arbois, BP 80, Bâtiment Laennec, Hall C, 13545 Aix en Provence Cedex 04, France*
[b] *INSERM Unité 476, Faculté de Médecine, 27, boulevard Jean Moulin, 13385 Marseille Cedex 05, France*

Received 16 July 2004; received in revised form 14 June 2005; accepted 16 June 2005
Available online 22 July 2005

Abstract

The extraction process applied on egg yolk by the Laboratoire de Micronutrition Appliquée (LMA laboratory) allows recovery of three lipidic compounds in an ethanolic solution: triacylglycerides, phospholipids and cholesterol. Our work consists in separating these three lipidic compounds. First cholesterol is separated from the other two lipids by nanofiltration, as this technique is generally able to separate compounds whose molecular weights range between 200 and 2000 g mol^{-1}. A feasibility study performed on a variety of nanofiltration membranes with different characteristics shows that for this membrane range the separation is poorly influenced by the membrane cut-off but greatly influenced by the membrane chemistry. Then the most appropriate membrane is selected and the best experimental procedure determined. The relationship between cholesterol levels in foods and the development of coronary diseases is a very controversial issue, and therefore the possibility of separating cholesterol by using the appropriate nanofiltration membrane would be a breakthrough in the domain of nutraceutics and nutritional supplements.

Keywords: Cholesterol; Triacylglycerides; Phospholipids; Nanofiltration; Nutraceutic

1. Introduction

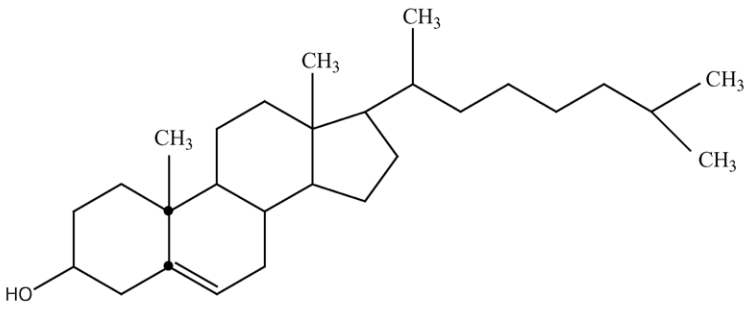
The lipids contained in egg yolk are principally triacylglycerides (65%, w/w), glycerophospholipids (28%, w/w) and cholesterol (5%, w/w) (Fig. 1). A more or less selective extraction of these lipids can be performed using various organic solvents such as diethyl ether, methyl chloride, ethyl acetate, propane/butane, hexane, benzene, ethanol [1] or supercritical CO_2 in the presence or the absence of ethanol [2]. In our case, after extraction, these products were recovered in 95% ethanol. The lipid concentration in ethanol ranged from 3 to 15% (w/w). The lipids present in the ethanol were glycerophospholipids (760 g mol^{-1}), 80%, and a mixture of cholesterol (386.7 g mol^{-1}) and triacylglycerides (860 g mol^{-1}), 20%.

Glycerophospholipids contain fatty acids that can be highly polyunsaturated. They can thus be considered as a source of essential fatty acids in C18 or conditionally essential fatty acids in C20 or C22 for the families of ω6 (molecules composed of a polyunsaturated carbon chain with two or more double bonds, the first double bond being located on the 6th carbon atom from the terminal methyl) and ω3 (the first double bond is located on the 3rd carbon atom). Thanks to their surface-active properties, glycerophospholipids, once completely purified, can be used in the preparation of emulsions of lipids in water used in the fabrication of food additives or even pharmaceuticals. For these applications, the amount of cholesterol in egg yolk is a problem. Cholesterol ingestion can increase cholesterol concentration in the blood, which is a marker linked to the risk of arteriosclerosis and coronary diseases. It is therefore of interest to eliminate the

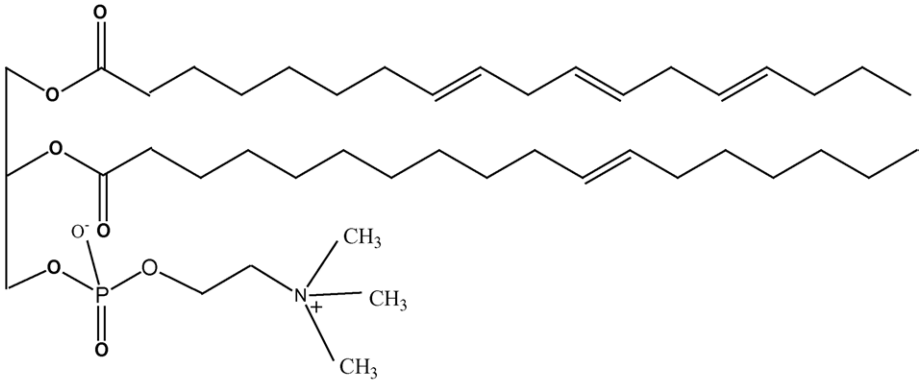
Abbreviations: MWCO, molecular weight cut-off (g mol^{-1}); TMP, transmembrane pressure (Pa); RF, retention factor; *C*, concentration

* Corresponding author. Tel.: +33 4 42 90 85 05; fax: +33 4 42 90 85 15.
E-mail address: philippe.moulin@univ.u-3mrs.fr (P. Moulin).

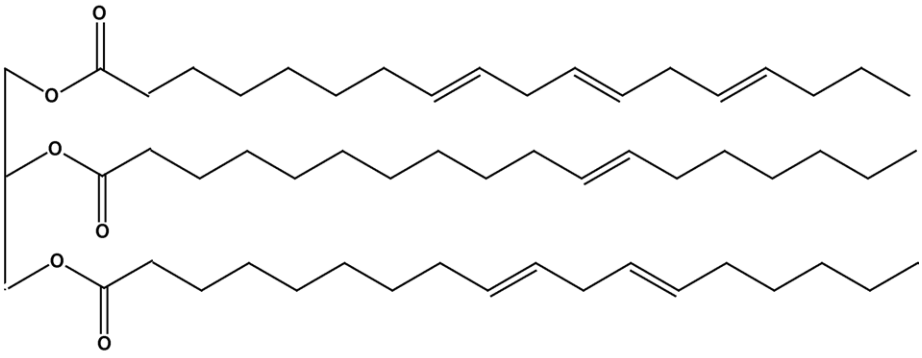
0376-7388/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.memsci.2005.06.025



CHOLESTEROL



PHOSPHOLIPIDS



TRIACYLGLYCERIDES

Fig. 1. Compound structure.

cholesterol from the lipids extracted from egg yolk. No information was found in the literature that would help estimate the performances of filtration or even of membrane processes for the separation of this type of mixture. In view of the size of the compounds, we decided to use a process of nanofiltration. However, the initial mixture was complex and the treatment was made difficult by the following:

(i) The molecular weights of the compounds were quite similar: 386.7 g mol^{-1} for cholesterol, between 850 and 1020 g mol^{-1} for triacylglycerides and between 760 and 878 g mol^{-1} for phospholipids.
(ii) The solution was ethanolic. The stability of a membrane in an organic solvent such as ethanol depends on the physicochemical characteristics of the solvent and of the membrane. The membrane–solvent interaction may result in swelling, plasticization or dissolution of the membrane material and subsequent loosening of the membrane structure, leading to modified separation properties and/or loss of mechanical strength under pres-