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Production of vegetable oil in milk emulsions using membrane emulsification

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Abstract

The production of emulsions using milk as the continuous phase has a number of applications of interest from the food industry's point of view. In addition, producing an emulsion with a narrow drop size distribution is interesting since their increased stability could avoid Oswald ripening and creaming.

Membrane emulsification is a novel technique which helps to obtain a narrower distribution compared to other emulsification techniques such as homogenizers or ultrasound. Moreover the use of membrane emulsification may reduce the energy cost.

The food industry is interested in reducing the use of food additives, both to save money and increase consumer acceptance. Therefore the aim of this work was to investigate the use of the intrinsic emulsifying capacity of milk proteins to act as stabilizers for oil droplets produced by membrane emulsification.

Using tubular SPG membrane (4.8 μm pore diameter) in recirculation mode, at dispersed phase fluxes of either 5 L/hm^2 or 50 L/hm^2, a stable final emulsion of 30% w/w oil was obtained. The fat globule size distribution was more bimodal at higher oil concentrations and at the higher flux.

Keywords: Membrane emulsification; Milk; Drop size; Operating parameters; Milk proteins

1. Introduction

Emulsions are commonly used in several industries such as the cosmetic, pharmaceutical, food, and paint industries. The stability of the emulsions formulated is important, since, the more stable the emulsion is, longer is their life. Emulsion stability is closely related to the drop size distribution, since wider drop size distributions may enhance the Oswald ripening effect, increasing the size of the larger drops which in turn favours drop coalesce and creaming. The

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required emulsion stability depends on the application, it can be years in the case of cosmetic applications or just days in some food applications, but in all cases should be stable during the time the components present in the emulsions keep their properties and thus fit for its intended use.

Milk is a liquid that contains water, minerals, lactose, fat and proteins. The proteins present in milk could be divided into three groups:, the whey proteins, proteins of milk fat globule membrane (MFGM), and the caseins in aggregates known as casein micelles, which represent 80% of the total milk proteins [1]. The main casein proteins are α_{S1}-casein, α_{S2}-casein, β-casein, and κ-casein, all of them are responsible of the formation of complex micelles. The α-caseins and β-caseins form the main micelle structure while the κ-caseins are present around the micelle structure and give more stability to the structure [1,2]. In native milk the whey proteins and casein are not associated with fat; the MFGM proteins have only recently been well characterized [3,4].

During homogenization of milk, as the size of fat globules is decreased and their number and total surface area increased, caseins are incorporated into the newly created fat surface and provide stability against coalescence. Homogenization is also used for the production of recombined milk from skim milk powder and butter fat, and of filled milk, with fat of non-dairy origin such as vegetable oils.

Dairy emulsification processes need to control the drop size and distribution drop size, since a change in these factors may alter rheological and organoleptic properties of the final product [5]. For larger droplet sizes, there are several techniques used to make emulsions, as for example high speed mixers or ultrasound techniques. During the last 20 years, an alternative emulsification technique has been studied, "membrane emulsification" or "microchannel emulsification" [6,7]. These techniques produce a narrower drop size distribution than conventional techniques [7], and much lower energy consumption [8].

Membrane emulsification technique had been developed in two different designs—direct emulsification and premix emulsification. (i) In direct membrane emulsification, the continuous phase flows tangentially to the membrane surface while the dispersed phase is pressed through the membrane's pores, the drops of the dispersed phase grow at the openings of pores in the membrane and when they reach a certain size, detach. (ii) Premix emulsification is based on the formation of a pre-emulsion by a traditional mechanical technique, which is then passed through the membrane in order to obtain a narrow drop size distribution.

During membrane emulsification process several forces act in order to detach the droplets found at the membrane surface (Fig. 1). These forces are described extensively elsewhere [9,10]. In order to produce drops of dispersed phase, the pressure should be enough to allow the dispersed phase to overcome the interfacial tension and pass through the membrane pores.

The minimum pressure required is the critical pressure (P_c), P_c which is calculated from equation 1.

$$P_c = \frac{4\gamma \cos\theta}{d_p} \quad (1)$$

where γ is the oil/water interface tension, θ is the contact angle between the dispersed phase and the membrane surface and d_p is the pore diameter.

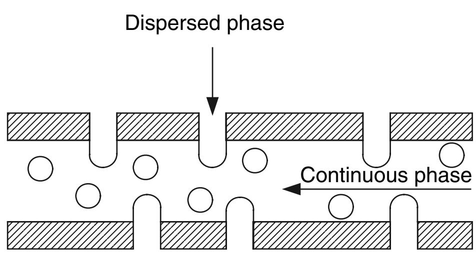

Fig. 1. Schematic diagram of membrane emulsification.