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Note

Stability of multiple emulsions I. Determination of factors influencing multiple drop breakdown

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Abstract

The paper describes a method to study the stability of w/o/w (water/oil/water) multiple drops by means of an ion-selective membrane-electrode, using a marker compound, ephedrine HCl. The effect of the 1st emulsifier concentration and the influence of the w/o emulsion ratio on the stability were investigated. An exponential equation and a power-function relationship were found to characterize the multiple drop breakdown during storage. The less the w/o emulsion ratio and the higher the 1st emulsifier concentration, the slower the multiple drop number decrease rate. © 1997 Elsevier Science B.V.

Keywords: Multiple phase emulsion; Stability of droplets; Surfactant; Ratio of w/o emulsion; Ion-selective membrane electrode; Ephedrine HCl

1. Introduction

Detailed investigation on multiple emulsions were started at the end of the 1970s. Several reviews can be found on this topic originating mainly from three research groups (Florence and Whitehill, 1981, 1982, 1985, Matsumoto et al., 1980, 1985 and also Frenkel et al., 1983).

These systems are promising from the pharmaceutical point of view in the area of controlled drug release (Florence et al., 1989).

Multiple emulsions are unstable, and sooner or later they invert to simple emulsions (Matsumoto et al., 1976; Matsumoto, 1986). Two processes have to be taken into account in the case of multiple emulsion breakdown: (i) coagulation of the multiple drops; and (ii) multiple drop breakdown. The aim of these stability investigations

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was mainly to clarify the second process and to determine the influencing factors.

There are several theories to explain this phenomenon. The most accepted one declares an osmotic gradient exists between the two sides of the oil layer. This causes the swelling of the internal water drops, which leads to oil layer breakdown resulting in the unification of the internal and external water phases.

There are still several important questions to clarify. There are no defined quantitative relations between the most important components (e.g. 1st emulsifier concentration) and the stability of these systems.

The aim of our research was to characterize the relation between the composition and the breakdown of multiple emulsion. Our previous research (Balázs et al., 1988; Erõs et al., 1990) confirmed that formation and stability of w/o/w emulsions are mainly influenced by two factors: (i) the structure of internal water/oil interface and its saturation by the emulsifier; and (ii) the number of the multiple drops and the possible interactions between them.

2. Materials, methods

The oil phase of w/o/w emulsions was liquid petrolatum (Ph.Hg.VII.). Sorbitanhydridmonooleate (Span 80) and izo-stearinic acid-partial glyceride (Imwitor 780 K) were applied as 1st emulsifiers; these were chosen from several previously studied low HLB emulsifiers as by means of these surfactants the w/o/w formation percentage almost reached 100% (Fig. 1). These emulsifiers were used in a concentration range of 10–20%. In order to produce the w/o/w emulsion 1.0% Polysorbate 80 was used. Multiple emulsions were prepared using the two-step procedure.

The amount of multiple emulsion formed after preparation and also its change during storage were determined as follows: Ephedrine hydrochloride was dissolved in the internal water phase, and the presence of this marker compound in the external water was determined with a chloride selective membrane electrode (Radellkis OP-208/1-OP-Cl-07 11P). The values measured after preparation gave the multiple drop formation percentage and the multiple drop number decrease rate was followed from the data measured during storage. (A calibration curve was used for calculations).

3. Results

3.1. Formation of multiple emulsions

The model emulsion systems prepared for stability investigations had a formation efficiency close to 100%. (There was no marker compound in the external water after preparation). The w/o emulsion ratios in the multiple ones were 0.40 g/g in these compositions. Fig. 1. shows that with increasing 1st emulsifier concentration from 10–20% there was no increase in formation percentage, as the 10% emulsifier concentration gave maximal multiple formation.

3.2. Effect of emulsifier concentration on the stability of w/o/w emulsions

Although the 10% 1st emulsifier concentration (Span 80) was enough for 100% formation, this was not able to stabilize the multiple drops.

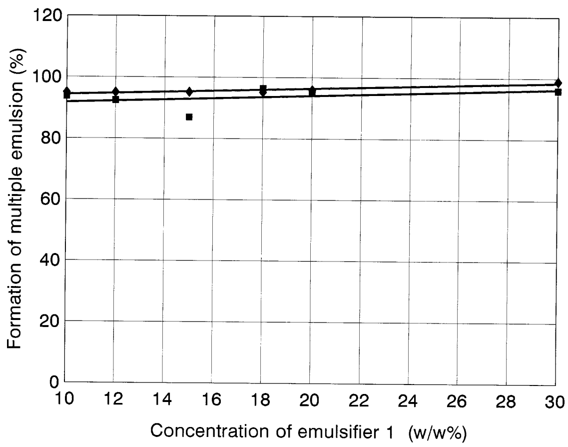

Fig. 1. Effect of concentration of emulsifier 1 on the formation of multiple droplets. Mass ratio of w/o emulsion in w/o/w emulsion is 0.40 g/g. (■) Span 80, (◆) Imwitor 780 K.

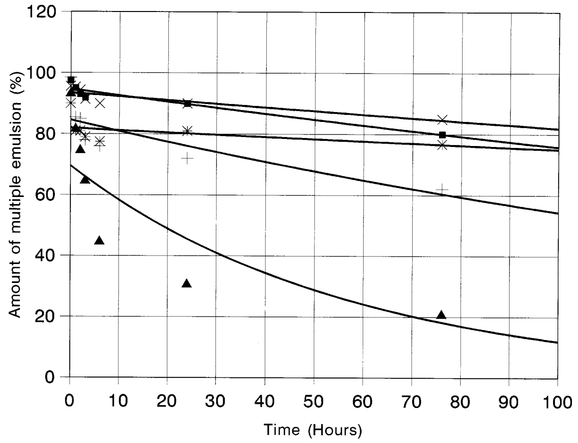

Fig. 2. Multiple emulsion breakdown during storage. Mass ratio of w/o emulsion in w/o/w emulsion is 0.40 g/g, 1st emulsifier is Span 80. (▲) 10%, (+) 12%, (*) 15%, (■) 18%, (x) 20% Span 80.

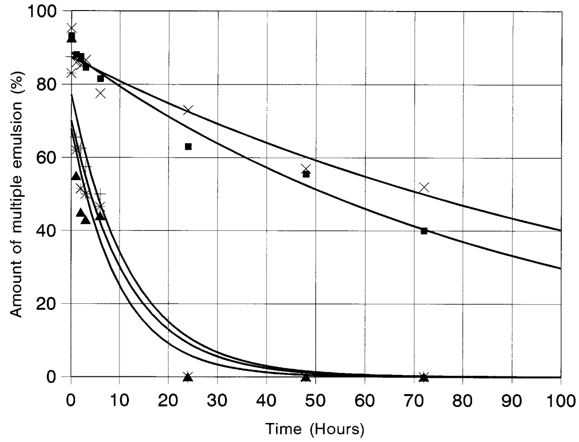

Fig. 4. Multiple emulsion breakdown during storage. Mass ratio of w/o emulsion in w/o/w emulsion is 0.60 g/g, 1st emulsifier is Span 80. (▲) 10%, (+) 12%, (*) 15%, (■) 18%, (x) 20% Span 80.

Figs. 2–4 illustrate the multiple character decrease during storage providing the following conclusions:

The amount of multiple drops decreased in the case of all systems investigated during a given period of time. The rate of this decrease was determined mainly by two factors: the concentration of the low HLB emulsifier stabilizing the primary interface and the amount of w/o emulsion in the multiple one. We found a slower decrease rate in multiple character in the case of increasing emulsifier concentration. The amount of w/o emulsion had an opposite effect on the stability: with increasing w/o ratio the instability increased, the multiple drop breakdown became faster.

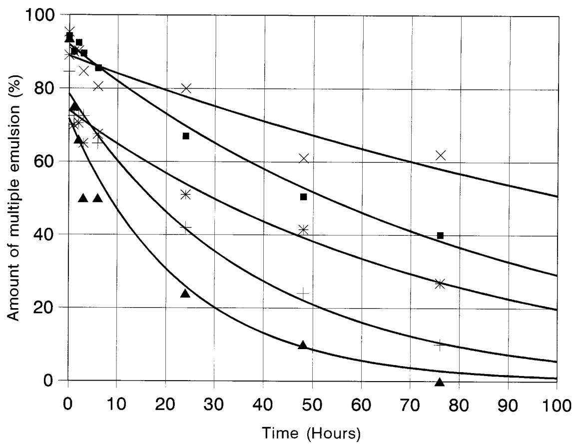

Fig. 3. Multiple emulsion breakdown durind storage. Mass ratio of w/o emulsion in w/o/w emulsion is 0.50 g/g, 1st emulsifier is Span 80. (▲) 10%, (+) 12%, (*) 15%, (■) 18%, (x) 20% Span 80.

The process of multiple drop breakdown during storage can be characterized by the following equation:

$$A = A_0 \exp(-vc) \tag{1}$$

where A_0 is the amount of w/o/w emulsion formed after preparation; c is the concentration of the 1st emulsifier; and v is the constant rate of the process. The values of the constants used in the Eq. (1) and the correlation coefficients are summarized in Table 1.

3.3. Effect of w/o emulsion ratio on the stability of w/o/w emulsions

The stability of the emulsions decreased with increasing w/o emulsion ratio as shown in the previous figures. This relation was confirmed in the case of another emulsifier also.

There is a characteristic relationship between the w/o emulsion ratio and the stability as shown

Table 1
Constants of Eq. (1) and correlation coefficients

Concentration of emulsifier(%)	Mass ratio (g/g)							
	0.40		0.45		0.50		0.60	
	v	r	v	r	v	r	v	r
10	−0.020	−0.84	−0.027	−0.93	−0.05	−0.89	−0.10	−0.77
12	−0.006	−0.89	−0.011	−0.89	−0.03	−0.97	−0.08	−0.84
15	−0.007	−0.89	−0.008	−0.84	−0.011	−0.93	−0.08	−0.82
18	−0.002	−0.96	−0.006	−0.98	−0.011	−0.99	−0.01	−0.97
20	−0.001	−0.89	−0.006	−0.97	−0.006	−0.93	−0.007	−0.94

in Fig. 5. A power function relates to the linearized curves as follows:

$$A = A_0 t^v \qquad (2)$$

The constants used in Eq. (2) and the correlation coefficient values can be found in Table 2.

4. Discussion

Our investigations closely followed Florence and Whitehill's (Florence and Whitehill, 1981, 1982, 1985) and Magdassi's (Magdassi et al., 1984) research work. Our conclusions, that the relationship between the amount of w/o/w emulsion vs. storage time is an exponential one, mirrors their findings.

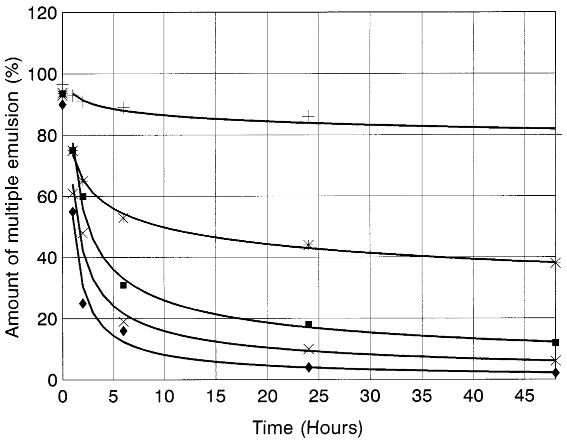

Fig. 5. Multiple emulsion breakdown during storage. 1st emulsifier is 20% Imwitor 780 K, the mass ratio of w/o emulsion in w/o/w emulsion was changed. (+) 0.40, (*) 0.45, (■) 0.50, (x) 0.55, (◆) 0.60 g/g mass ratio.

The fact that with increasing 1st emulsifier concentration the stability increases, confirms the solubilization theory (Matsumoto et al., 1976; Frenkel et al., 1983). On this basis the 2nd emulsifier which produces the w/o/w emulsion is able to solubilize the first one. As a result of this process the amount of adsorbed emulsifier on the w/o interface decreases, which leads to the rupture of the oil layer and to the inversion of the w/o/w emulsion. The number of the multiple drops and their specific surface area increase with increasing w/o emulsion ratio. Therefore there is a relationship between the specific surface area and the swelling of the oil drops (Matsumoto, 1985). The connection between the w/o emulsion ratio and the stability is another experimental confirmation of osmotic theory, mentioned in the introduction. The practical application of our research is that with the knowledge of the constant rate the most suitable emulsifier can be chosen in the optimal concentration for adequate stabilization.

Table 2
Constants of Eq. (2) and correlation coefficients

Mass ratio (g/g)	v	r
0.40	−0.034	−0.94
0.45	−0.0169	−0.89
0.50	−0.475	−0.79
0.55	−0.603	−0.73
0.60	−0.816	−0.66

Acknowledgements

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