Formulation and Characterization of IPM/Water/Nonionic-Ionic Surfactant Microemulsions

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Abstract: Microemulsions of both O/W and W/O types were formulated by using Brij76, Brij97 and Tween80 as nonionic surfactant and propanol or butanol as cosurfactant with isopropyl myristate oil and water. Low concentrations of sodium salts of hexanoic, decanoic, palmitic and stearic acids were added to the prepared microemulsions to assess their ability to enhance microemulsion stability. Solubilization capacity of microemulsions was estimated and compared with their conductivities at the same water content. Solubilization capacity for Tween80-containing microemulsions was found to be lower than that of Brij containing microemulsions. Different effects of the ionic surfactants at the maximum solubilization capacity were observed in both O/W and W/O microemulsions. Microemulsion conductivity results showed that different ionic surfactants exerted minor and comparable effects regardless to the implemented nonionic surfactant. Analysis of solubilization conductivity revealed that the presence of ionic surfactant can improve microemulsion solubilization capacity and provided that optimum physicochemical properties for both surfactants are fulfilled. These properties have direct impact at the goodness of the interfacial film.

Key words: Microemulsion, solubilization capacity, conductivity, sodium salts of fatty acids.

1. Introduction

Microemulsions (MEs) are homogenous, transparent, isotropic, thermodynamically stable dispersions of water and oil [1]. Microemulsions are of three types: water-in-oil (W/O), oil-in-water (O/W) or bicontinuous [2]. They might be stabilized either by single surfactant (nonionic or anionic), mixture of surfactants, or by cosurfactant/surfactant combination [3-4]. Cosurfactants have essential role in stabilization of microemulsions as they act as cosurfactants and cosolvents [5]. It is believed that cosurfactants fine-tune the surfactant hydrophile-lipophile balance HLB [6] which is also the small volume of the cosurfactant molecule to enable its fitting at the interface providing more coherent interfacial film and decreasing the interfacial tension [7]. The partitioning of the cosurfactant between the interface, the oily phase and a lesser extent of the aqueous phase will change the structure and the solubilization capacities of these phases [8]. For a stable microemulsion formulation, the selected surfactant and cosurfactant should have optimum physicochemical properties and they should be added at optimum ratio, which is known as the *km* value. Quantitative structure-property relationship (QSPR) models were developed in order to cut down the trial time required in the selection of the suitable surfactant-cosurfactant combination [9].

Microemulsions are graphically represented as stability areas in triangular phase diagrams [10], where each triangular corner designates certain component; the *km* value is estimated from the triangle area of microemulsion and used in the ME formulation. MEs have high solubilizing capacity for drugs of various polarities, which attracted the attention of many researchers to develop MEs based drug delivery systems [11-13]. One of the major obstacles in

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adopting MEs as pharmaceutical vehicles is their high surfactants content [14]. Presence of certain additives in the ME formula might improve the solubilization capacity of the ME at lower total surfactants concentrations [15]. Low concentrations of ionic surfactants when added to ME stabilized by nonionic surfactant are expected to modify the interfacial film and consequently the solubilization capacity [16-17]. ME microstructure and the mechanism of additives effect can be examined by several techniques like conductivity, surface tension [18-19], viscosity [20-21] electron microscopy and NMR [20] among other techniques. Conductivity is one of the simplest and most informative methods used to follow changes in the ME microstructure upon the addition of the internal phase and in the prediction of ME stability. Sharp increase in conductivity of W/O microemulsion over orders of magnitude might indicate phase transition from a reverse micellar to a bicontinuous microemulsion or/and a percolation process [22]. The percolation phenomenon has been linked to physical changes within the interface, such as increased interfacial flexibility and decreased chain packing order leading to ME coalescence [23-25].

In the present work, the existence areas of MEs prepared from three nonionic surfactants, namely Brij76, Brij97 and Tween80 by employing optimum *km* values are assessed. For each ME, two composition points within the ME existence area namely the oil corner (OC) and the water corner (WC) were selected for conductivity and maximum solubilization measurements. Effect of sodium salts of fatty acids as ionic surfactants at the maximum solubilization capacity and conductivity was also examined.

2. Materials and Methods

Brij97 (polyoxyethylene 10 oleoyl ether), Brij76 (polyoxyethylene 10 stearyl ether), and sodium stearate (SS, assay > 98%) were purchased from Fluka in Switzerland; Tween80 (Polyoxyethylene 20 sorbitan monooleate) was purchased from MERCK-Schuchardtr in Germany; Sodium decanoate (SD), sodium hexanoate (SH) and sodium palmitate (SP) were purchased from Sigma in USA; Propanol (assay $\geq$ 99.5%) was purchased from Lab-scan in Ireland; Butanol (assay 99%) was obtained from Riedel-de Haën in Germany; Isopropyl myristate (IPM, assay 98%) was purchased from Scharlau in Spain. All compounds were used as received without further purification. Double distilled water was used in the preparation of all observed systems. Table 1 lists some physicochemical properties of surfactants related to the present investigation.

2.1 Microemulsion Formulation

The investigated solubilized systems are composed of nonionic surfactant (Brij76, Brij97 or Tween80), cosurfactant (propanol or butanol), ionic surfactant (sodium salts of fatty acids), IPM oil and water. The first step in microemulsion formulation is to find suitable surfactant-cosurfactant combination and to expect to produce stable microemulsion; the next step is to determine the optimal surfactant-to-cosurfactant ratio (*km*) to produce the largest microemulsion existence area, this step was performed by adding the internal phase (oil or water) to a fixed external phase (water or oil)-nonionic surfactant mixture at variable ratios. The two-phase mixture was then titrated with the

Table 1   Physicochemical properties of the tested surfactants.

Property	Brij76	Brij97	Tween80	SH[a]	SD[a]	SP[a]	SS[a]
CMC (mM)	$3.0 \times 10^{-3\,b}$	$9.4 \times 10^{-1\,b}$	$1.0 \times 10^{-2\,b}$	$1.5 \times 10^{3\,c}$	$1.0 \times 10^{2\,c}$	$1.7^{\,c}$	$4.0 \times 10^{-2\,c}$
HLB	12.4^{b}	12.4^{b}	15^{b}	-	-	-	-
Molecular weight	710	711	1309	138.1	194.2	278.4	306.5

[a] SH: sodium hexanoate; SD: sodium decanoate; SP: sodium palmitate and SS: sodium stearate;

[b] Data collected from Ref. [26];

[c] Data collected from Ref. [27].

cosurfactant; the end point was indicated by the formation of homogenous, clear O/W or W/O microemulsion. Microemulsion existence area is then presented by pseudo-ternary phase diagram, as shown in Fig. 1a. The *km* value is calculated from the composition of the central point of the microemulsion existence area. For each surfactant-cosurfactant combination, a fixed *km* value will be used to prepare the "surfactant mixture". Two types of microemulsions were investigated in this work: O/W and W/O microemulsions. In the preparation of these microemulsions, the initial composition of the external

phase/surfactant mixture was determined as follows: to a fixed surfactant mixture of predetermined *km* values (1.14:1 for Tween80:Butanol; 0.7:1 for Brij97:Propanol; and 0.5:1 for Brij76:Propanol), the external phase was added at different ratios. The one phase mixture was then titrated with the internal phase; the end point was indicated by the formation of two phase system. Pseudo-ternary phase diagrams showing the areas of microemulsion existence were constructed as shown in Fig. 1b. The microemulsion existence area was roughly divided to water corner (WC, O/W) and oil corner (OC, W/O). Microemulsions from both oil
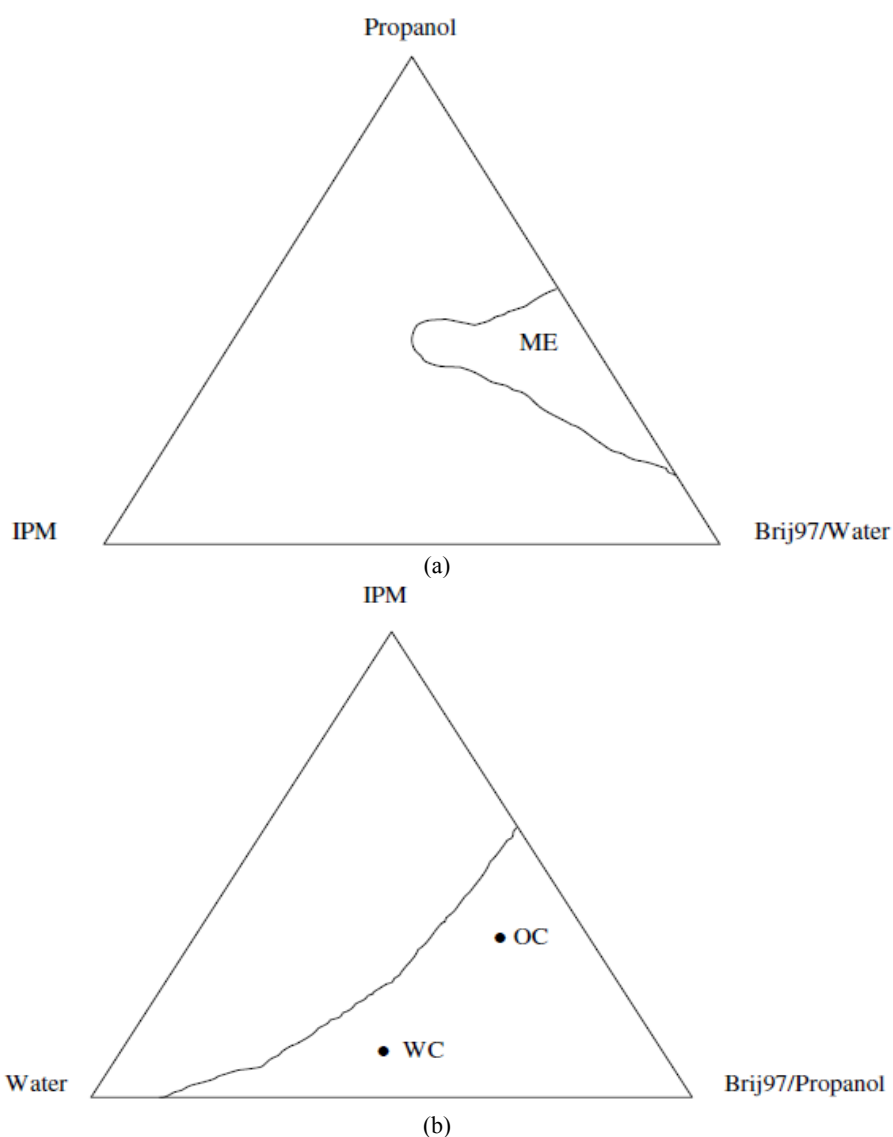

(a)

(b)

Fig. 1 Pseudo-ternary phase diagram showing (a) microemulsion existence area and (b) position of the tested microemulsions taken either from the oil corner, OC, or from the water corner, WC.

and water corners were investigated because they are expected to be sensitive to additives more than the central area which is assumed to be highly stable. Ionic surfactants were prepared at 0.01 M concentration by dissolving the sodium salt either in double distilled water (SD and SH) or in the surfactant mixture (SP and SS) at the predetermined km values. The value of 0.01 M was dictated by the low solubility of SP and SS. Microemulsions were respectively characterized in the presence and absence of the ionic surfactants. The initial composition of the investigated systems was 40% of either IPM (W/O) or water (O/W) together with 50% (or 60%) non ionic surfactant mixture and 10% (or 0%) of the 0.01 M ionic surfactant solution. Control systems contain no ionic surfactants. All systems were prepared by weight. Table 2 lists the systems observed in this work.

2.2 Maximum Solubilization Measurements

Maximum solubilzation of the internal phase of either O/W or W/O microemulsions was determined at 25 °C, 30 °C and 35 °C. In a scanning step, the internal phase was added in small volumes to the initial mixtures described above until the appearance of permanent turbidity. The turbid mixture was then left

to equilibrate at room temperature for at least 24 hours before the estimation of the volume of the separated phase (normally ≤ 10% of the total added volume). Based on the results of this step, microemulsions containing the estimated maximum amount of the solubilzed internal phase were prepared and subjected to centrifugation for 30 minutes at 14,000 rpm (SIGMA 1-15, Germany), when no phase separation took place, the microemulsion was described as being stable and its internal phase content is represented later as the maximum solubilzed value. Stable microemulsions were kept in tightly capped bottles and stored in dark place at room temperature and checked periodically for about one year with no signs of phase separation.

2.3 Conductivity Measurements

Conductivity measurements were carried out by InoLab condLevel1 conductometer (TetraCon®325, WTW, Germany) having a cell constant of 0.474 cm^{-1} at 25 °C and reported accuracy of ± 0.5%. The equipment was calibrated weekly with KCl standard calibration solution. During the course of measurement, the conductivity of double distilled water did not exceed 2.2 µS/cm. Conductivity was measured at 25 °C,

Table 2 Tested systems.

System number	System abbreviation	System composition[a]
1	Tween80	Tween80/butanol (1.14:1) + IPM + water
2	Tween80-SH	Tween80/butanol (1.14:1) + IPM + water + SH
3	Tween80-SD	Tween80/butanol (1.14:1) + IPM + water + SD
4	Tween80-SP	Tween80/butanol (1.14:1) + IPM + water + SP
5	Tween80-SS	Tween80/butanol (1.14:1) + IPM + water + SS
6	Brij97	Brij97/Propanol (0.7:1) + IPM + water
7	Brij97-SH	Brij97/Propanol (0.7:1) + IPM + water + SH
8	Brij97-SD	Brij97/Propanol (0.7:1) + IPM + water + SD
9	Brij97-SP	Brij97/Propanol (0.7:1) + IPM + water + SP
10	Brij97-SS	Brij97/Propanol (0.7:1) + IPM + water + SS
11	Brij76	Brij76/Propanol (0.5:1) + IPM + water
12	Brij76-SH	Brij76/Propanol (0.5:1) + IPM + water + SH
13	Brij76-SD	Brij76/Propanol (0.5:1) + IPM + water + SD
14	Brij76-SP	Brij76/Propanol (0.5:1) + IPM + water + SP
15	Brij76-SS	Brij76/Propanol (0.5:1) + IPM + water + SS

[a] SH: sodium hexanoate; SD: sodium decanoate; SP: sodium palmitate and SS: sodium stearate.

30 °C and 35 °C. The measurement was carried out by a drop-wise addition of the internal phase to the earlier described initial mixtures. After each addition, the components were mixed and left for 30 seconds to equilibrate before recording the conductivity reading. Titration was stopped when permanent turbidity was observed. Conductivity was respectively measured for O/W and W/O microemulsions in the presence and absence of the ionic surfactants.

3. Results and Discussions

3.1 Maximum Solubilization Capacity

Figs. 2 and 3 show the effects of both ionic and nonionic surfactants on the solubilization capacity of W/O and O/W MEs, respectively. Solubilization capacities of Tween80 containing systems were lower than those of Brij76 and Brij97. Moreover, the percentage of solubilized oil was larger than the percentage of solubilized water for all tested nonionic surfactants. However, ionic surfactants seem to produce variable effects on the maximum solubilization capacities of O/W and W/O MEs. Rodriguez et al. [16] studied the effect of ionic surfactants at MEs formed using nonionic surfactant and found that oil in water solubility was not changed while water in oil solubility was improved. These findings agree partially with the results of this work.

Considering W/O solubility results as shown in Fig. 2 in the absence of ionic surfactants, Brij76 and Brij97 were able to form stable ME with up to 16.0% and 19.0% w/w of solubilized water respectively. On the other hand, MEs formed using the more hydrophilic Tween80 could not solubilize more than 4% water. In a pilot study, Tween40 (HLB 15.6) and Brij35 (HLB 16.9) failed to form stable MEs with IPM. Apparently, the type and stability of the formed ME is function of both HLB value and structure of the surfactant. Tween80 HLB is higher than Brij76 and Brij97, moreover, the hydrophilic chains in Tween80 make the interfacial film less coherent even in the presence of the cosurfactant, which is also expected to lower the

surfactant HLB [6]. Attempts to improve the solubilization efficiency of the nonionic surfactant MEs by the addition of low concentration of the ionic surfactants were not all successful. As shown in Fig. 2, although sodium palmitate (SP) and sodium stearate (SS) improved the solubilization capacity, sodium decanoate (SD) produced negative effect, while sodium hexanoate (SH) produced minor and variable effects. These results suggest the necessity of certain optimal physicochemical requirements for the incorporated ionic surfactant to achieve maximum water solubilization in W/O microemulsions.

Apparently, the differences in the effect of the ionic surfactants can be explained by differences in their structures. Although the four ionic surfactants were incorporated in their corresponding MEs at same concentrations, i.e., 1.0×10^{-3} M, the fact that they have different structures means they have significantly different critical micellar concentrations (CMCs), as shown in Table 1. Accordingly, SH and SD are present in their corresponding MEs at concentrations lower than their CMCs, on the other hand, SP and SS concentrations are around their CMC values. At concentrations below CMC, ionic surfactant molecules are expected to concentrate mainly in the water core rather than the interface. Consequently, they are expected to exert less effect at the interfacial film, which explains the minor effects exerted by SH on the stability of corresponding MEs. However, as the molecular sizes of ionic surfactants become larger, in particular their alkyl chains, i.e., in SP and SS cases, their water solubilities and CMC values become lesser, and therefore, they tend to saturate the interface at lesser concentrations, i.e., lower than 1.0×10^{-3} M, hence improving the coherence of the interfacial film and leading to better ME stability and water solubilization, as can be seen in SP and SS cases. As shown in Fig. 2, SP seems to have the optimum molecular properties to be accommodated at the interfacial film formed by the three nonionic surfactants, while SS has no effect at both Brij76 and Brij97 MEs.
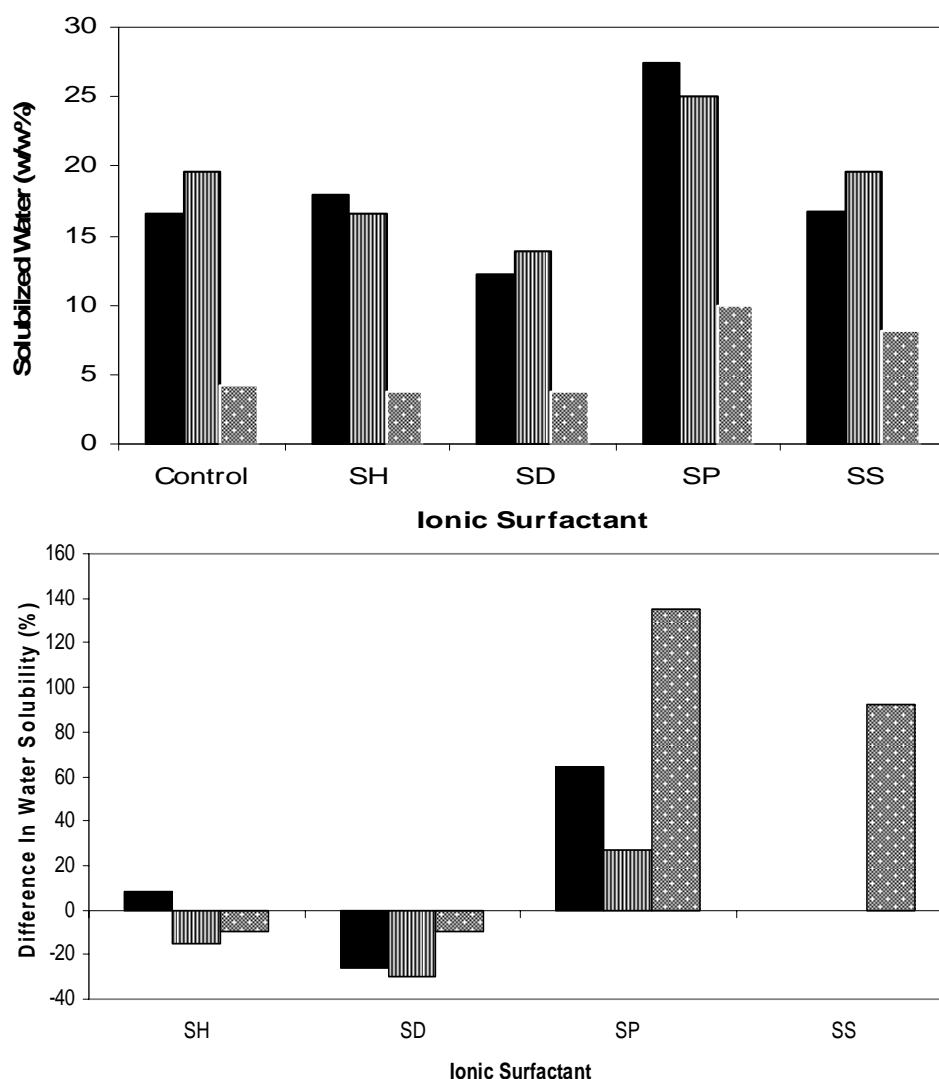
Fig. 2   Effect of ionic and non-ionic surfactant type at the maximum solubilized water in W/O ME systems at 25 °C, Tween80 ( ), Brij97 ( ) and Brij76 ( ). Upper: as solubilized volume; lower: as % difference in solubilized volume compared with the control. *SH: sodium hexanoate; SD: sodium decanoate; SP: sodium palmitate and SS: sodium stearate*

Another probable reason for the observed poor ME-stabilizing performances of SH and SD is related to their excellent water solubilities that render them excellent competitors for water molecules. This effect should promote dehydration of nonionic surfactant molecules at the interface, and therefore, undermines the continuity and coherence of the interfacial film, and consequently the stabilities of the corresponding MEs. This effect is probably more pronounced in cases of Brij76 and Brij97 compared to the more hydrophilic Tween80, which explain the apparent trends in Fig. 2, particularly in SD case.

Application of quantitative structure-property relationship (QSPR) models to MEs structure elucidations support the above explanations [9]. In fact these studies suggested that the quality of the complex interfacial film is determined by the physical descriptors of ME components and their interactions with each other [15].

As shown in Fig. 3, in O/W systems, oil solubilization in Tween80-based ME systems improved in the presence of any of the tested ionic surfactants, with maximum solubilzation achieved using SD. On the other hand, ionic surfactants exerted
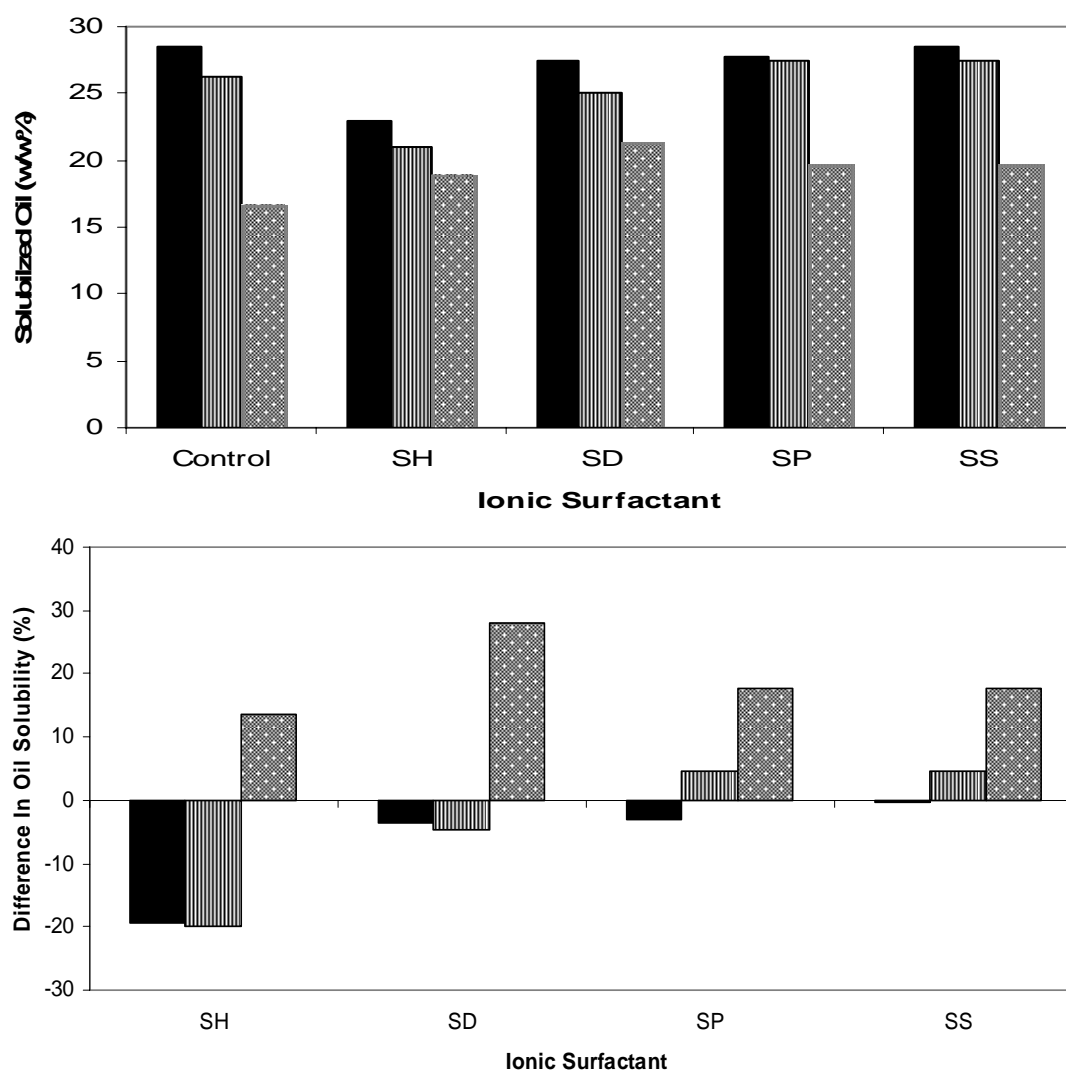
Fig. 3 Effect of ionic and non-ionic surfactant type at the maximum solubilized oil in O/W ME systems at 25 °C, Tween80 (▦),**Brij97 (▥)and Brij76 (■). Upper: as solubilized volume; lower: as % difference in the solubilized volume compared with the control.** *SH: sodium hexanoate; SD: sodium decanoate; SP: sodium palmitate and SS: sodium stearate*

either negative or marginal positive effects on oil solubilization in Brij76- and Brij97-based ME systems. Interestingly, SH gave the most negative effects on the solubilization capacities of both Brij systems.

The contradicting effects of ionic surfactants on oil solubilization capacities of O/W ME systems can be explained based on their effects on the partition behavior of associated cosurfactant molecules, i.e., between water, oil and interfacial phase. Changing cosurfactant concentration in any bulk phases will influence its effect as cosolvent [17], while disturbing its distribution at the interface might affect the quality

of the interfacial film. Both effects will result in changes in the solubilization capacity.

The small molecular size of SH promotes its water solubility, and therefore, SH is expected to exist mainly in the aqueous phase causing decreased solubility of the lower HLB surfactants, namely Brij76 and Brij97, leading to the observed lowering in their solubilization capacity. This effect is expected to be less for SD, SP and SS. On the other hand, the less coherent interfacial film formed by the hydrophilic Tween80 made it more sensitive to the co-adsorption of ionic surfactants that form better interfacial film.

Conductivity results (see the following section) showed that microemulsions containing Brij76 are the most stable MEs which might explain the least effect of the ionic surfactants at the solubilization capacity of Brij76 containing systems. The phase behavior of Brij56/1-butanol/*n*-heptane/water was investigated in presence of ionic surfactant, sodiumdodecyl benzene sulfonate [17] and the addition of ionic surfactant was thought to make the nonionic surfactant more hydrophobic. This might be the case in the present study where the most hydrophilic surfactant, Tween80 was more sensitive to the added ionic surfactants which shifted its HLB down to the best for solubilization effect. Water solubilization capacity was measured at 25 ^{o}C, 30 ^{o}C and 35 ^{o}C and the effect of temperature was found to be minor within the studied temperature range (data not shown).

3.2 Conductivity Measurements

Conductivity was measured at 35 ^{o}C for W/O MEs with or without ionic surfactants; both water corner (titrant is oil) and oil corner (titrant is water) were investigated, the results are shown in Figs. 4 and 5. The oil corner was further investigated at 25 ^{o}C and 30 ^{o}C. All tested W/O MEs illustrated the same trend: The conductivity increased with increasing water content in presence and absence of ionic surfactants. For the same nonionic surfactant, all ionic surfactants exerted almost the same effect at the ME conductivity suggesting that at the investigated level of ionic surfactants, nonionic surfactants exert the major effect on ME conductivity. These results agree with previous investigations carried out by Bumajdad et al. [28] who measured the electrical conductivity of D_2O-in-*n*-heptane MEs stabilized by cationic/nonionic surfactant mixtures and found that at constant, relatively high nonionic surfactant content, the conductivity depends strongly on nonionic head-group size.

Examination of Fig. 4 shows three regions in the conductivity curve. These regions are labeled as A, B and C. Region A corresponds to low water content

where the hydration of the polar/ionic heads of the surfactants is accompanied by increase in the conductivity [29]. This increase in conductivity was sharp in the case of Tween80 containing systems and moderate in the case of Brij76 and Brij97 containing systems. The second region B indicates reverse micellar solution followed by O/W microemulsion formation at higher water content [20]. This region shows the smallest changes in conductivity with increasing in water content, indicating minimum interdroplet interaction and low water/charge exchange which reflects microemulsion stability [13]. Brij76 shows the largest range of region B, while Tween80 shows the smallest one. Region C might indicate the beginning of phase transition. Addition of the internal phase beyond this region might lead either to formation of O/W ME or to phase separation, which was the case in the present work. The volume threshold for the phase transition was estimated as intersection of the linear parts of regions B and C. The volume threshold was almost the same nonionic surfactant irrespective to the type of the ionic surfactant or the measurement temperature. The estimated volumes threshold, as water content w/w%, were 16-18 for systems containing Brij76 and Brij97, and 8-12 for Tween80 containing systems. The slope of region C for Tween80 is larger than that for Brij76 and Brij97. There is a good agreement between the maximum solubilization capacity and the interpretation of the conductivity data.

Both reflected the poor interfacial film formed using Tween80 and lower ME stability compared with Brij76 and Brij97. Mitra et al. [25] interpreted the changes in conductivity of AOT/IPM/water ME upon the addition of nonionic surfactants Brij56 and Brij58 by the difference in the physicochemical properties of water molecules localized in the interior of reverse micelles from those of bulk water which indicates changing states of solubilized water in reverse micelles at the changing water content. Also they found that the bound water exists below a threshold value regardless of cationic and anionic surfactants and they concluded that
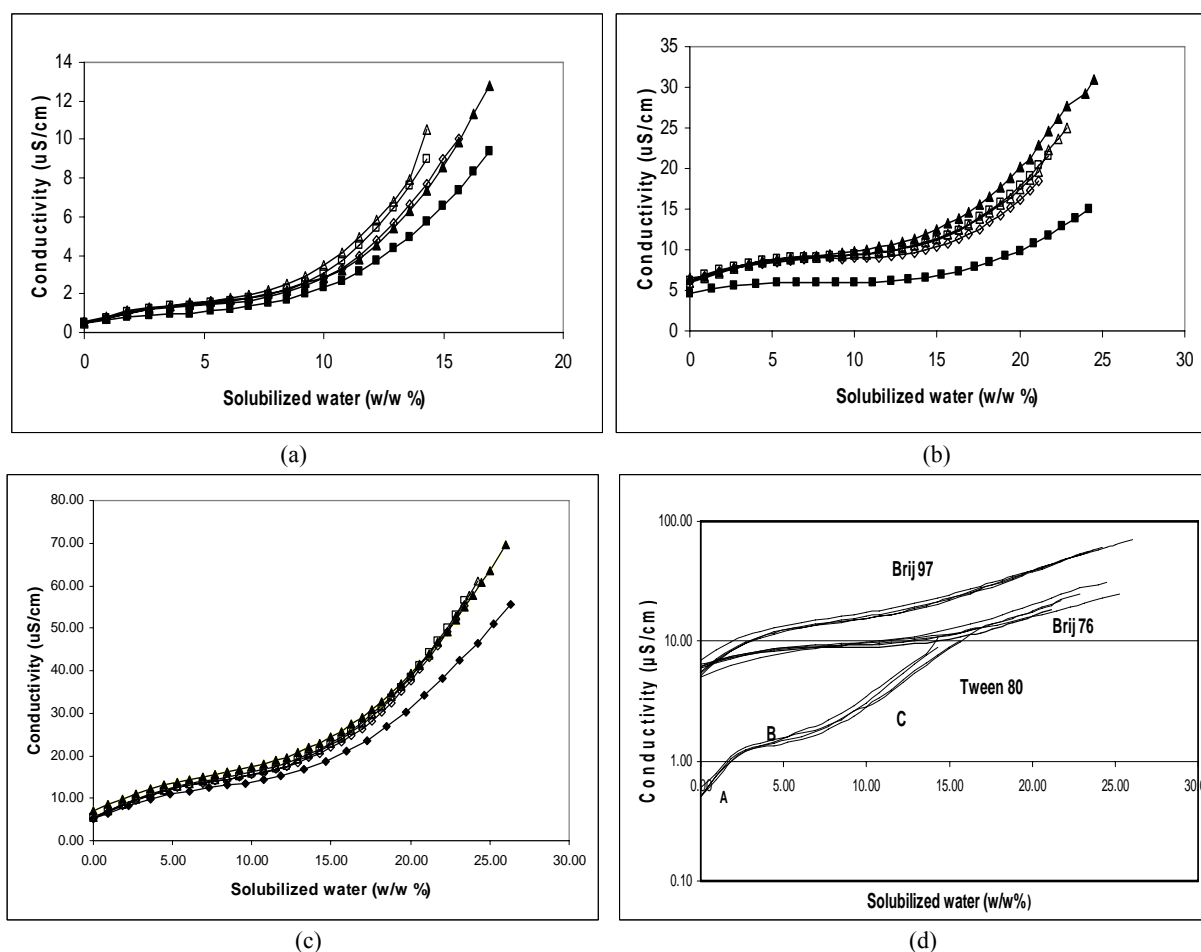
Fig. 4   Conductivity of W/O MEs based on nonionic surfactants: (a) Tween80, (b) Brij76 or (c) Brij97 measured at 35 ^{o}C either in the absence of ionic surfactants (control) (■) or in the presence of SH (□), SD (◊), SP(▲) or SS(∆); (d) comparing between the conductivities of the three nonionic surfactants and showing the different regions in the conductivity-solubilized water profiles.
SH: sodium hexanoate; SD: sodium decanoate; SP: sodium palmitate and SS: sodium stearate

the state of the interface between the water core and surfactant monolayer depends strongly on the hydrophilic group of the surfactant. This conclusion is in agreement with the findings in the present work where the hydrophilic groups of the nonionic surfactants determined the ME conductivity behavior.

In the conductivity measurements of W/O MEs, percolation process takes place when sharp, 100-1000 times, increase in conductivity is observed. Percolation is considered as sign of ME instability. In this work no such sudden and sharp increase in conductivity was observed, consequently it might be assumed that MEs observed in this work were stable within the studied conditions [22-25].

Formation of a bicontinuous ME which is followed

by phase inversion was indicated by some researchers by the sharp increase in the conductivity [25], while others assumed transition to bicontinuous ME structure if the measured conductivity exceeds 1 μS/cm [21].

In this work, formation of bicontinuous MEs cannot be excluded but it can be stated that there was no phase inversion from stable W/O to stable O/W ME in all tested systems. The moderate increase in conductivity, as observed in region C, upon water addition was followed by phase separation. Alternative to the bicontinuous phase formation, the increase in the conductivity upon the water addition was explained by the formation of a solution type system where the continuous phase can accommodate more water molecules [21]. This argument seems logical if absence
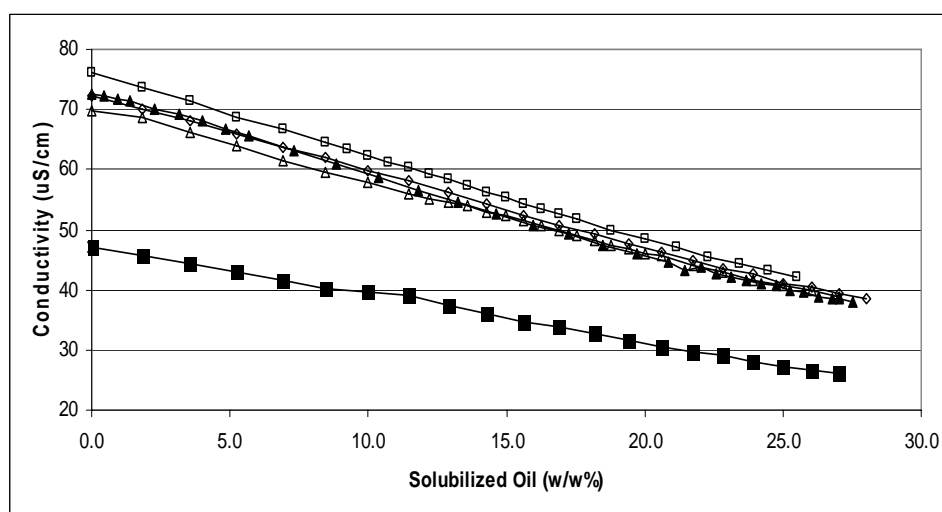
(a)
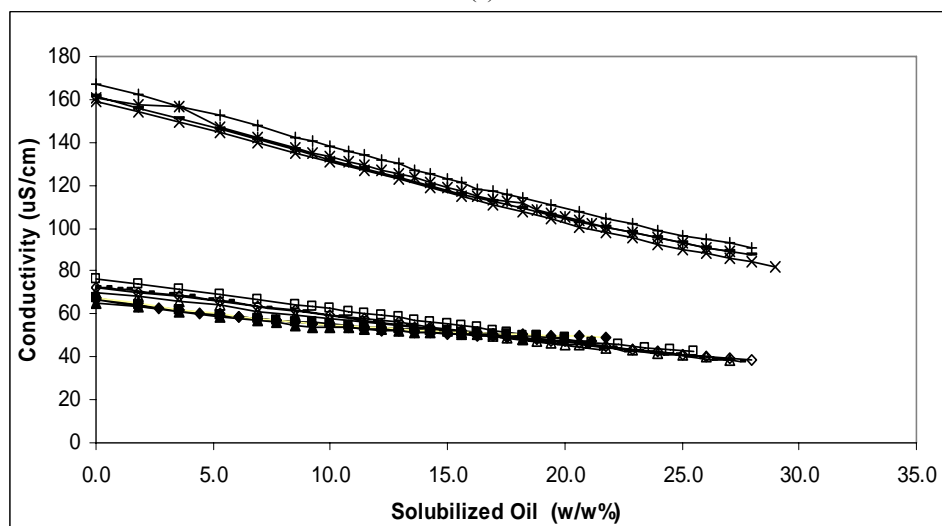
(b)

Fig. 5 Conductivity of O/W MEs measured at 35 °C. (a) MEs contain Brij76 in the absence of ionic surfactants (control) (■) or in the presence of SH (□), SD (◊), SP (▲) or SS (Δ); (b) MEs contain Brij76, Brij97 or Tween80 with the different ionic surfactants. Brij97-SH (+), Brij97-SD (×), Brij97-SP (–), Brij97-SS (*), Brij76-SH (■), Tween80-SH (□), Brij76-SD (◊), Tween80-SD (♦), Brij76-SP (○), Tween80-SP (●), Brij76-SS (Δ) and Tween80-SS (▲). *SH: sodium hexanoate; SD: sodium decanoate; SP: sodium palmitate and SS: sodium stearate*

of the sharp and sudden change in the conductivity is considered in addition to the high surfactants and cosurfactant concentrations which might change solvents structure allowing miscibility up to certain volume fraction after which phase separation takes place.

Conductivity of O/W MEs was measured for Brij76, Brij97 and Tween80 in presence of the ionic surfactants. The mixture conductivity at zero oil percent was almost the same for Brij76 and Tween80

and both were lower than Brij97. Linear decrease in the conductivity was observed in response to oil solubilization in ME based on the three nonionic surfactants. Fig. 5a shows the conductivity of Brij76 MEs in presence of the ionic surfactants compared with the control ME while Fig. 5b compares between the conductivity of the three nonionic surfactants in the presence of the ionic surfactants. As mentioned above, the conductivity behavior is dictated by the nonionic surfactants with minor effect of the ionic surfactants.

3.3 Effect of Temperature

Microemulsions conductivity was measured at 25 °C, 30 °C and 35 °C. Relatively small change in conductivity with increasing temperature was observed (data not shown) which might indicate stability of the observed MEs at this temperature range.

Bearing in mind that ionic surfactants reduce the temperature sensitivity of nonionic surfactant [17], the minor effect of temperature at both solubilization and conductivity in presence of the ionic surfactants might be attributed to the low observed temperature range, 25 °C-35 °C, comparing the relatively high cloud point values of the nonionic surfactants.

Surface tension was measured for serial dilutions of nonionic surfactant-cosurfactant-ionic surfactant in the absence of the oil phase (data not shown). It was found that both the apparent CMC and surface tension at the CMC are dictated by the nonionic surfactant irrespective to the ionic surfactant components. Similar results were obtained by Zakharova et al. [30] who measured the CMC for Brij97 in presence of different concentration of a cationic surfactant and found that the CMC is determined by the nonionic surfactant. For each nonionic surfactant, the average surface tension in the presence of the different ionic surfactants was estimated at the apparent CMC and the obtained values were: 45, 38 and 31 dyne/cm for Tween80, Brij76 and Brij97 containing mixtures, respectively. In the case of Tween80 containing systems, the high surface tension value at the CMC might indicate the less coherent packing at the interface, which agrees with the solubilization and conductivity results.

4. Conclusion

Several microemulsion systems were formulated by nonionic surfactant-cosurfactant mixtures and their ternary diagrams were employed for the estimation of suitable *km* value for each surfactant mixture. The formulated microemulsions were based on either Brij76, Brij97 or Tween80 as nonionic surfactant, IPM as oil and propanol or butanol as cosurfactants.

Homologous series of sodium salts of fatty acids were added to the microemulsions at low concentrations. Microemulsions were investigated for their maximum solubilization, electrical conductivity and surface tension. The solubilization capacity of Tween80-based microemulsions was the lowest but it showed best improvements by addition of ionic surfactants. Sodium palmitate improved water solubilization in the three observed microemulsions. It was found that the solubility and CMC of the ionic surfactant and the HLB value of the nonionic surfactant in addition to the structure of both surfactants are important factors that should be taken in consideration in any attempts to improve the solubilzation capacity using ionic surfactants. A correlation was found between maximum solubilization capacities and the conductivity profile.

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