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Phase Behaviour of Ternary System: Soybean Oil/Non-Ionic Surfactants/Deionized Water

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Ternary phase diagrams of soybean oil with different types of non-ionic surfactants and deionized water were constructed in order to determine their phase behaviours. The five ternary phase diagrams constructed were: soybean oil/Tween 80/deionized water; soybean oil/Span 20/deionized water; soybean oil/Cremophor EL/deionized water; soybean oil/Cremophor EL-Tween 80/deionized water and soybean oil/Cremophor EL-Span 20/deionized water. The regions observed from the diagrams were isotropic, homogenous, liquid crystalline, two-phase and multiphase. The area of isotropic and homogenous region increased with the increasing of hydrophilic-lipophilic balance value and also with the presence of co-surfactant. Among those five ternary phase diagrams obtained, the largest one-phase region can be found at the formulation of soybean oil/Cremophor EL-Span 20/deionized water. Cremophor EL has the highest hydrophilic-lipophilic balance value, followed by Tween 80 and Span 20. Larger one-phase region is beneficial because the stability of the components in the mixture is higher if compared to two and multiphase regions.

Key Words: Ternary phase diagram, Phase behaviour, Non-ionic surfactant.

INTRODUCTION

Emulsions are mixtures of oil and water with the addition of surfactant to assist the combination between hydrophobicity of oil and hydrophilicity of water molecules[1,2]. Surfactant which consists of both water-loving (hydrophilic) and oil-loving (lipophilic) properties allows two different phases of polarity between oil-water to mix[3]. When surfactant is added in an oil-water system, the polar and non-polar ends of the surfactant will be oriented towards water and oil molecules respectively[4]. Gosh *et al.*[5] has claimed that emulsions are homogenous, transparent and thermodynamically stable dispersion between water and oil because of the existence of surfactant as the stabilizer. In certain formulations, co-surfactants are also used to assist the aggregates formed by the primary surfactant[6].

Nowadays, emulsions are widely used in cosmeceuticals and pharmaceuticals products. Emulsions are the alternative drug carriers especially for poor-water-soluble drugs[7,8]. Non-ionic surfactant is well recognized for its good biological acceptance which is the main reason why it is suitable to be used in cosmeceuticals and pharmaceuticals[9]. Span 20 (sorbitan monolaurate) and Tween 80 (sorbitan mono-oleate) are fatty acid esters of sorbitan, the examples of non-ionic surfactants. Cremophor EL is a nonionic surfactant that is made by reacting castor oil with ethylene oxide. The main component of Cremophor EL is glycerol polyethylene glycol ricinoleate. The fatty acid esters of polyethylene glycol form the hydrophobic part which eventually will be oriented towards oil molecules. In this research, phase behaviour of soybean oil with these two non-ionic surfactants is being studied and we hereby report the results obtained in which are featured in ternary phase diagrams.

EXPERIMENTAL

Soybean oil (product code: S7381) and surfactant Cremophor EL (product code: C5135) were bought from Sigma-Aldrich, St. Louis, USA. The surfactants, Tween 80 (product No: 8170611000) and Span 20 (product No: 8401190500) were bought from Merck Schuchardt OHG, Hohenbrunn, Germany. The HLB values of Tween 80, Span 20 and Cremophor EL are 11.0, 8.6 and 12.0, respectively. Deionized water was freshly prepared in the laboratory prior to formulation.

Construction of ternary phase diagram: Three ternary phase diagrams between soybean oil-water system and single non-ionic surfactant of: (1) soybean oil/Tween 80/deionized water; (2) soybean oil/Span 20/deionized water and (3) soybean oil/Cremophor EL/deionized water systems were first constructed. Another two ternary phase diagrams were between soybean oil-water system and mixture of two non-ionic

surfactants of: (4) soybean oil/Tween 80-Cremophor EL/deionized water and (5) soybean oil/Span 20-Cremophor EL/deionized water. Samples of mixtures of surfactant and soybean oil were prepared in the ratio of 0/100 with increment of 5 % of surfactant for each sample. The total weight of the mixture was 0.5 g for each sample. Deionized water was added in stepwise ranging from 5 to 95 %. The mixture was mixed evenly using vortex mixer and centrifuged at 4000 rpm for 15 min after every 5 % of deionized water addition. The samples were examined through cross-polarized light for the determination of phase behaviours. All the ternary phase diagrams were prepared through low-emulsification method under room temperature. The compositions are expressed in wt. % ratio between the components.

RESULTS AND DISCUSSION

Tween 80, Span 20 and Cremophor EL were used as the surfactants in these formulations with the hydrophilic-lipophilic balance values of 11.0, 8.6 and 12.0. The higher value of hydrophilic-lipophilic balance was claimed to be more water loving if compared to surfactants with lower hydrophilic-lipophilic balance value. High hydrophilic-lipophilic balance values tend to form oil-in-water emulsion.

In Fig. 1(i), which is the ternary phase diagram of soybean oil/Tween 80/deionized water, the isotropic region was formed along the apex line of Tween 80. Isotropic region is a one-phase region which is transparent. The decreasing percentage of Tween 80 caused the isotropic region to become two-phase and multiphase solution. The multiphase region was found at soybean oil-rich corner with ± 10 % of Tween 80.

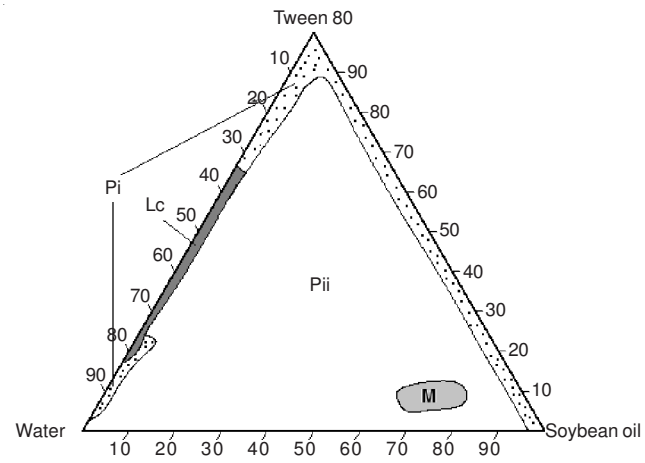

Fig. 1. (i) Ternary phase diagram of soybean oil/Tween 80/deionized water. Pi- isotropic region, Pii- two-phase region, M- multiphase region and Lc- liquid crystalline region

In Fig. 1(ii), less phase behaviour can be observed through the ternary phase diagram. This soybean oil/Span 20/deionized water system formed only isotropic, two-phase and homogenous regions. Homogenous region is a one-phase region but in the form of milky/cloudy solution. As the percentage of deionized water was increased to 60% with percentage of Span 20 is less than 20 %, the homogenous region was formed. More than 95 % of the phase diagram showed the formation of two-phase region.

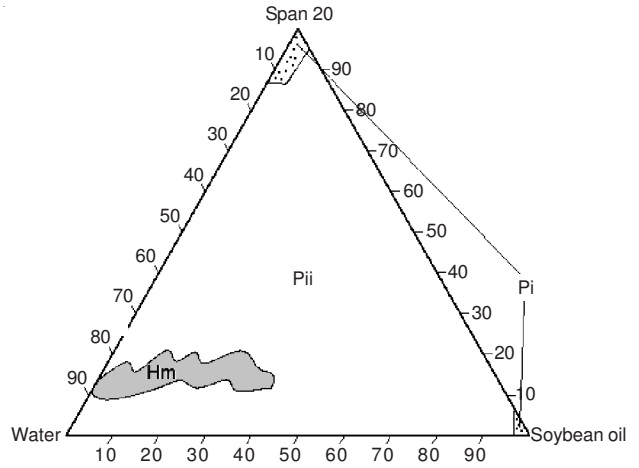

Fig. 1. (ii) Ternary phase diagram of soybean oil/Span 20/deionized water. Pi- isotropic region, Pii- two-phase region and Hm- homogenous milky region

The ternary phase diagram of soybean oil/Cremophor EL/deionized water in Fig. 1(iii) showed formation of larger area of isotropic region if compared to Fig. 1(i) and 1(ii). The large area of the isotropic region can be found at ± 10 % of soybean oil with higher percentage of deionized water. This means that this formulation which might be due to the higher hydrophilic-lipophilic balance value of Cremophor EL of 12.0 is suitable for producing oil-in-water emulsion.

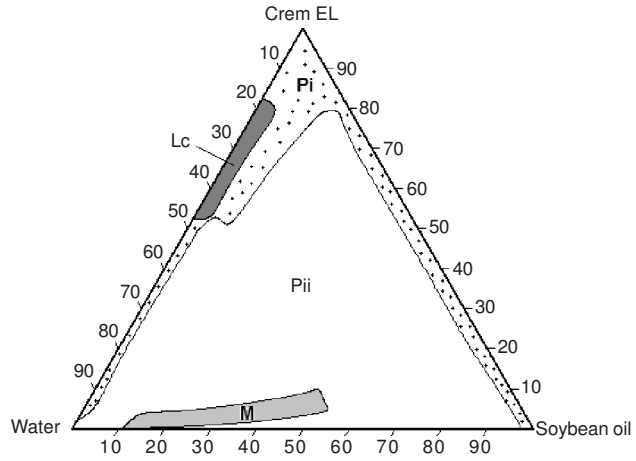

Fig. 1. (iii) Ternary phase diagram of soybean oil/Cremophor EL/deionized water. Pi- isotropic region, Pii- two-phase region, M- multiphase region and Lc- liquid crystalline region

From Fig. 1, it is proven that the formulation with Cremophor EL formed larger area of one-phase region. It is suitable for cosmeceutical and pharmaceutical purposes because one-phase solution can contribute to the stability of a formulation.

Fig. 2(i) and 2(ii) show the ternary phase diagrams of soybean oil/Cremophor EL-Tween 80/deionized water and soybean oil/Cremophor EL-Span 20/deionized water respectively. Both Fig. 2(i) and 2(ii) formed large area of isotopic and homogenous regions. In Fig. 2(i), isotropic region can be found mainly at surfactant-rich area and along the apex line of the surfactant (Cremophor EL-Tween 80). As the percentage of deionized water was increased to 20 %, homogenous-phase was formed. Only a small area of liquid-crystalline was observed.

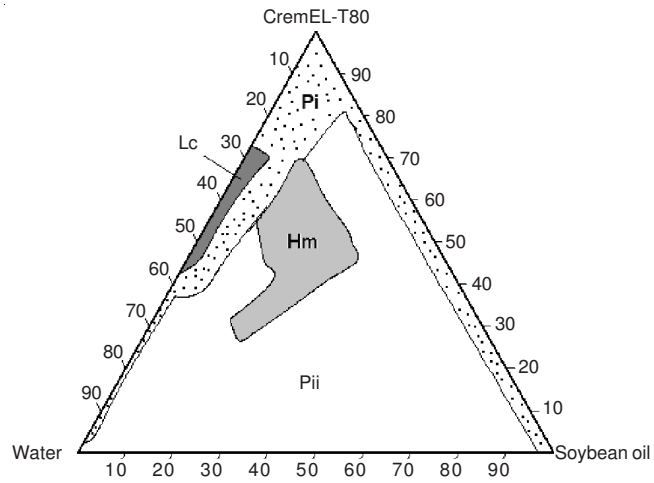

Fig. 2. (i) Ternary phase diagram of soybean oil/Cremophor EL-Tween 80/deionized water. Pi- isotropic region, Pii- two-phase region, Hm- homogenous region and Lc- liquid crystalline region

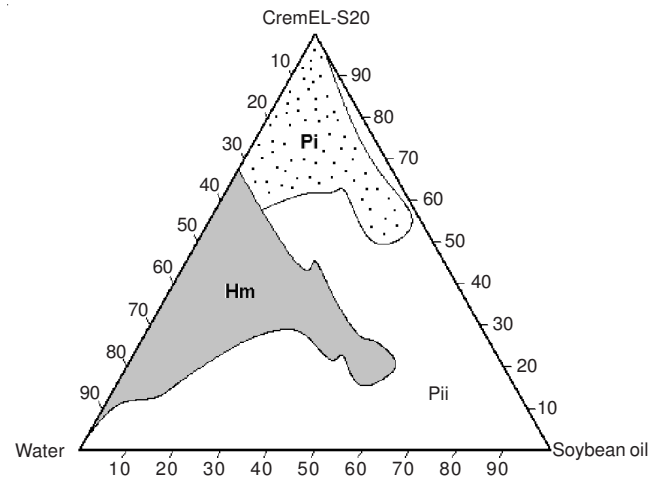

Fig. 2. (ii) Ternary phase diagram of soybean oil/Cremophor EL-Span 20/ deionized water. Pi- isotropic region, Pii- two-phase region and Hm- homogenous region

The largest isotropic and homogenous regions between the five formulations in this study can be found from the formulation of soybean oil/Cremophor EL-Span 20/deionized water system as shown in Fig. 2(ii). Both isotropic and homogenous regions were mainly found near the apex line of deionized water. Homogenous region emerged as the percentage of deionized water was increased to 35 %. The appearance of this region continued until *ca.* 90 % of deionized water content. In these two formulations, Tween 80 and Span 20 acted as co-surfactants to Cremophor EL. From the diagrams in Fig. 2, it can be concluded that the one-phase region of the formulations were enlarged with the presence of co-surfactants.

Conclusion

The ternary phase diagrams of soybean oil with non-ionic surfactants were successfully constructed. The formulation of soybean oil/Cremophor EL-Span 20/deionized water gave the largest homogenous and isotropic regions. This might be due to the increasing value of hydrophilic-lipophilic balance value of surfactants which gave the increment of one-phase regions areas. In contrast, the formulation of soybean oil/Span 20/ deionized water gave the smallest of both regions.

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