

# Microemulsions in food industry uses and applications



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Abstract: Microemulsions are a class of microheterogeneous systems having unique features of stability, solubilization capacity, structural morphology, physical property and applicability. Depending on the types of oil and amphiphile, and environmental conditions, microemulsion systems of varied categories, consistencies and internal structures may result. The essentials of microemulsion systems are thus controlled by external factors and internal chemistry. The underlying physicochemical principles controlling their formation, phase behaviour and related properties supplemented with experimental observations need time to time assessment and appraisal to scientists and technologists. This review aims at such a purpose and makes a concise presentation of the physicochemistry and applications of microemulsions in food industry to bring the readers up-to-date with the present state of knowledge on the subject. The features that will be presented in some details are the theory of microemulsion formation, general procedure for their preparation, phase forming behaviour of mixed water, amphiphile and oil systems. Important uses and applications of microemulsions in food industry will also be discussed.

Keywords: Microemulsion, theory, preparation, phase behaviour, structure, properties, application.

## Introduction

Microemulsions are amphiphile aided thermodynamically stable oil in water (o/w) or water in oil (w/o) dispersions. They have stability for long duration. Normally, an oil-water interface has high interfacial energy (or tension) so that the free energy of formation of the interface is highly positive. The

addition of amphiphilic compounds can bring the interfacial tension to a very low value, leading to spontaneous formation of one dispersion into the other, i. e., forming a microemulsion. The difference between emulsions (some times called macroemulsions) and microemulsions is in terms of stability. The former has comparatively higher interfacial tension and is kinetically stable (requiring occasional stirring or agitation), whereas the latter is thermodynamically stable. Thus, emulsions are moderately stable systems and with time separate into water and oil. The droplet sizes of the dispersions in microemulsions range between 10-100 nm; for emulsions the size may be greater than 105 nm. Systems with sizes ranging between 102 to 105 nm are termed as miniemulsions. They also are not thermodynamically stable.

In the presence of water, surfactants can form reverse micelles in non polar organic media. A completely dry organic medium does not allow reverse micelle formation. A w/o microemulsion droplet is also a reverse micelle. In the reverse micelle, the amount of water present is low and is limited to the maximum capacity of hydration of the hydrophilic head group of the surfactants; hence, the pool water is rigid. In a w/o microemulsion, when the amount of water exceeds the hydration requirement of the surfactant headgroups, both bound and free water prevail in the pool. The rigidity and the bend of the interfacially bound water layer affect the structure and physicochemical behaviour of the microemulsion. A term  $w$  defined as  $\frac{[\text{water}]}{[\text{surfactant}]}$  has been taken as a criterion as to whether a reverse micelle or a microemulsion has been formed. It has been suggested that when  $w < 10$  it is a reverse micellar system and when  $w > 10$  it is a

microemulsion. However, some evidence exists that the cut-off point may be  $w = 15$ .

Though historically microemulsions have been studied for a long time, their importance was not acknowledged until the work of Schulman in 1943 with his definition of the system. Physicochemically speaking, a microemulsion is an amphiphile stabilized low viscous, isotropic, and thermodynamically stable dispersion of either w/o or o/w. The importance of microemulsions lies in the varied formulation possibilities and numerous applications. The characteristics of microemulsions have been ascertained by different physical methods. It has been found that microemulsions generally have low viscosity and are conveniently formed in the presence of short chain alcohols or amines (called cosurfactants), which help to reduce the interfacial tension to a very low value. But surfactants like Aerosol OT (AOT) can conveniently form microemulsions without employing a cosurfactant (Moulik, S. P., 2006).

## **Preparation of Microemulsion and Phase Behaviour**

Microemulsions are spontaneously formed dispersions of either water-in-oil or oil-in-water. Generally, water (1), surfactants and cosurfactants (2) are placed together in a container and the mixture is then titrated with an oil (3) until turbidity is visually observed. Alternatively, a mixture of water and oil can be titrated with a surfactant until turbidity disappears. Also, a mixture of surfactants and oil can be titrated with water. The weight percent compositions at the end points of all these titrations (which are either appearance or disappearance of turbidity) are then plotted on a triangular coordinate to create a pseudo-ternary phase diagram, which illustrates

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different regions in it representing microemulsions and other types of entities as shown in Fig. 1. When a cosurfactant is used as more often than not, for a particular pseudo-ternary phase diagram, the surfactant and the cosurfactant are taken in a definite ratio considering the mixture as a single component.

It should be noted that the phase diagrams might be more complicated than shown in the figure. Viscous solution, lamellar liquid crystals, thin or thick gels, single phase, two phase and three phase regions are observed depending upon the surfactant, the co-surfactant, the oil, and their concentrations as well as the temperature. The structures of microemulsions can be very complex and different. Four different types of situation may arise by mixing water, oil and amphiphiles as shown by Winsor ( Winsor, 1954). In the first, the spherical oil droplets are dispersed in water continuum and such a phase is in equilibrium with oil (Winsor I or W I). Similarly, spherical water droplets dispersed in oil and in equilibrium with water is the second possibility (Winsor II or W II). In these cases the concentrations of dispersed oil and water are low. In W II system, the requirement of surfactant is low. As it increases, it distorts the droplets. At a ratio of 1: 1(v/v) oil/water, the distorted droplets get attached to one another leading to a state of continuous water and oil phases and form a bicontinuous structure that remains in equilibrium with both the oil and water phases. This is referred to as (the Winsor III or W III) system. It has been suggested that the bicontinuous microemulsion structures have the physical appearance of a ' fractal' though is not yet conclusively proven. Besides these three types, a final type of totally homogeneous single phase may arise. Such a system is

known as Winsor IV or W IV. A schematic representation of all these four types is shown in Fig. 2.

The mixed water-oil-amphiphile systems have complex phase variations and it can be difficult to identify these various forms. The nature of the surfactant and the cosurfactant influence the phase diagram. In Fig. 3, a collaged comparison of four different pseudo phase diagrams with water, chloroform (as oil) and various different surfactants are presented. As seen, that the diagrams differ from one another in respect of type and size.

These surfactants have different characteristics e. g., cetyltrimethylammonium bromide (CTAB) is a cationic surfactant, whereas Triton X-100 (TX100) is a nonionic surfactant. Besides the type of surfactant, the diagrams also vary in their hydrophilic lipophilic balance (HLB) number. A lower HLB number indicates a lower hydrophilicity of the molecule. Systems with a low HLB generally forms w/o microemulsions. Systems with high HLB form o/w microemulsions. This criterion is also true for emulsion formation.

In addition to HLB, phase inversion temperature (PIT) and cohesive energy ratio (CER) have been used to predict the possibility of microemulsion formation.

The surfactant hydrophobic group should match the oil structure: the better the match, the higher the possibility of a microemulsion formation. The phase inversion temperature (PIT) can be used to determine the type of oil, nature of microemulsion.

etc. The HLB number of surfactant is a function of temperature, and at a particular temperature o/w microemulsion may change over to w/o microemulsion. This transition temperature, called the PIT provides an idea about the chemical type of emulsifier needed to match a given oil. The HLB and PIT values correlate with each other and an increase in HLB means an increase in PIT though the relation is not linear. The cohesive energy ratio (CER) is another criterion, which may determine the type of microemulsion formed. If the interaction parameters between the lipophilic group and oil, and the hydrophilic group and water are represented by  $CL_0$  and  $CHW$  respectively, then when  $CL_0/CHW > 1$ , a w/o microemulsion is formed. For an o/w microemulsion, the ratio is less than 1. (Moulik, S. P., 2006).

## **Microemulsions in food industry**

There has been a revolution in the last two decades in the utilization of microemulsion systems in a variety of chemical and industrial processes. Microemulsions have found numerous applications in different fields, such as: enhanced oil recovery, fuels, lubricants, cutting oils and corrosion inhibitors, coatings and textile finishing, detergency, cosmetics, agrochemicals, pharmaceuticals, environmental remediation and detoxification, media synthesis, analytical applications, liquid membranes, biotechnology, food.

Certain foods contain natural microemulsions. Microemulsions as a functional state of lipids have been, therefore, used in the preparation of foods.

Microemulsions form in the intestine during the digestion and absorption of fat. The possibility of producing microemulsion on purpose and using them as tools in food production is, however, a neglected field in food technology. <https://assignbuster.com/microemulsions-in-food-industry-uses-and-applications/>

Excellent component solubilization, enriched reaction efficiency and extraction techniques have considerable potential in the area of food technology. The major differences between food and other microemulsions are in the composition of the oil component and food grade surfactants. In foods, the oil is a triglyceride, whereas in other microemulsions the oil is a hydrocarbon, often a mineral oil. The triglyceride molecule is itself surface active, which in turn implies that triglycerides are not capable of forming separate oil domain in an amphiphile-water system in the same way as mineral oils. Therefore, the composition range in the oil-water-surfactant systems that allows microemulsions to form when the oil is a triglyceride is much smaller than the range allowing microemulsion formation when the oil is a hydrocarbon. Food grade surfactants, viz. phosphatidycholine (lecithin), AOT and sorbatin monostearate/monolaurate (Tweens) have been extensively studied with regard to the formation of o/w and w/o microemulsions. Recently, Dungan (1997) reviewed current information on o/w and w/o microemulsion formed using food-grade materials, complex food mixture (liquid crystal, gels), possibilities of incorporating food ingredients (such as flavour, preservatives and vitamins) within microemulsions, reactions carried out in microemulsions media and potential of microemulsions for extracting food components from a complex mixture. Larsson et al. (1991) have focused on the cereal and edible lipid systems that form microemulsions and their potentialities. Recent research has shown that microemulsions of carnauba wax form better protective coatings on citrus fruit than shellac, wood resin, oxidized polyoxyethylene or mixtures of these substances with caranuba wax. The protective coatings minimize weight loss as well as internal oxidation. The fruit coated with the

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microemulsions of caranauba wax maintains a better appearance than other coatings after washing and drying. Microemulsions have also been used to produce glycerides for application in food products. An important application of microemulsion is to provide improved antioxidation effectiveness because of the possibility of a synergistic effect between hydrophilic and lipophilic antioxidants. It is known that soybean oil is effectively protected when contained within an L2-phase produced by the addition of monoglycerides (sunflower oil monoglycerides) to water. An approximately 1 : 5 ratio of monoglycerides to triglycerides is needed to get enough water into the L2-phase (about 5 wt%). In such a system, 200 ppm of tocopherol in the oil and 5% ascorbic acid in the reverse micelles give a dramatic antioxidant effect compared to conventional methods of dissolving or dispersing antioxidants in oils. In fish oils, the same microemulsion-based method to achieve an antioxidant protective effect has also been used. Glycerol has been used instead of water for further improvement of the protectivity. The effect of adding various lipids and propylene glycol to monoolein (a common food emulsifier)-water system and the cubic liquid crystal thus formed undergoing a transition to a sponge or L3-phase have been reported. The structure of the spongy cubic phase has been described as a 'melted' bicontinuous cubic phase. Although considerable research has been conducted to show the usefulness of microemulsions in foods, the application and technology require further work (Moulik, S. P., 2001).

## **Conclusion**

Because of their high degree of dispersion (and their very low size), microemulsions are a unique class of colloidal systems having novel

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properties. Both traditional and emerging techniques are required for their characterization and property elucidation. The numerous applications of microemulsions mean that these microheterogeneous systems will continue to be a rich field for exploration for scientists and will continue to create interest among industrial technologists.