Applications of Surfactants in Diverse Areas

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Abstract

Surfactants represent a class of amphiphilic compounds having a hydrophilic head (polar) and hydrophobic tail (non-polar) group. Owing to their amphiphilic nature and capability of reducing the interfacial tension, the surfactants are used in diverse areas like skin care products, cleaners, pharmaceutical formulations, novel drug delivery systems and many more. This article explains the classification, mechanism of action, advantages & limitations and the applications of surfactants in pharmaceutical formulations development and other allied fields.

Keywords

Amphiphile, Pharmaceuticals, Cosmetics,

INTRODUCTION

Surfactants are becoming an essential ingredient next to an active pharmaceutical ingredient in the formulations. These surfactants involve the surface chemistry, which relates to the surrounding forces acting on the surface. The forces may occur due to the interactions between the particles of similar state or different states of solid, liquid and gas by forming an interface. Every surface bearing interaction can be considered as an interface, and the behaviors at the interface are referred to as interfacial phenomena. The interface also manages by opposite forces to counter the two different forces exerted on the interface and prevent them from getting inward, which is known as surface tension. The surfactants or surface-active agents work on the motto to reduce the surface tension and increase the area of contact. These agents act by wetting the substance, which minimizes the surface tension and creates easy means to spread over the surface. Antara Products coined the term surfactant in 1950. They are measured in the units of dyne/ cm. These surfactants are amphiphilic, which have hydrophobic head and a hydrophilic tail and can be soluble into polar and non-polar environments. When surfactants under suitable conditions added to the biphasic solution of oil and water, it results in a microemulsion. Most of the times, in emulsion preparations, these surfactants are mentioned as emulsifiers or emulsifying agents. These microemulsions are very small in their structures and appear to be transparent.

In some types of emulsion, surfactants form an intermediate layer between the oil and water. In the process of separating the oil phase and water phase, they form cylindrical micelles, which may occur as oil in the aqueous medium or as a watery structure in oil medium. The different mediums attached to an interface at an angle known

as the contact angle, which reflects the quality of the emulsion. The surfactants like cationic or anionic type induce an electrostatic stabilization by producing either a cationic charge or anionic charge that develops an electrostatic force which stops the droplet from developing coalescence. In the case of nonionic surfactants, they tend to build a spring-type structure, which prevents further hitting of droplets and thereby minimizing the chance of coalescence. It is also used as a foaming agent, wetting agent, in phase separation and even in altering the viscosity of a formulation. These agents are used as an essential ingredient and also as the active ingredient in many preparations of soap, detergents, cleansers etc. They are available from the natural sources and also synthetically prepared [1-4].

ADVANTAGES

Biodegradability

By having a simple chemical structure, they can be easily degraded and may create a minimum level of toxicity [5].

Biocompatibility

Having simple form and origin through biological sources, make the surfactants more flexible and mould according to the formulation. They often present good compatibility with different formulations of cosmetics, pharmaceuticals and even the food preparations [6].

Minimum toxic levels

Surfactants are chemically uncomplicated having no toxicity inducing chemical groups. So, they are easily tuned and does not create harmful reactions.

Efficient surface activity

The fine quality of surfactant can reduce the surface tension at the maximum extent and improve the surface area at a higher level.

Easily available

They are naturally abundant materials and available at cheap. They are also easy to prepare even synthetically, mostly built by hydrocarbon groups.

Tolerance to physical conditions

Surfactants can survive and tolerate the changes in physical conditions like temperature, humidity, pH etc.

High foaming capacity

Surfactants are known for producing large amounts of foam using minimum sources, which helps in saving production costs and yield a high range of business [7-10].

DISADVANTAGES

Despite having several advantages, it has few concerns which are needed to be rectified for betterment.

Toxicity

In most of the cases, surfactants are friendly to the environment, but in a few extreme situations, it has reported having toxic levels. Due to the drastic change in physical conditions, it may reverse the system and produce unintended effects.

Complexity in preparing pure forms

Due to the high chance of microbial contamination, the purity in the preparation is missing. Especially in the case of preparations associated with food and pharmaceuticals, a lot of care is required.

Loss due to high-intensity foams

The high-intensity foams give quality but something excess than what is needed counts as a loss. So, a more significant amount of foam may bring loss to the production line; hence dilutions are needed to be carried on for minimal usage of resources [12-14].

CLASSIFICATION

Surfactants can be classified on the basis of a charge on their structures. Some surfactants have a positive charge on them, few have negative, and some do not have it at all. The surfactant having a positive charge are considered as cationic surfactants. The surfactants which have a negative charge, are called anionic surfactants. Those having neither positive nor negative are nonionic surfactants. Those equipped with dual charges at terminals are called amphoteric surfactants.

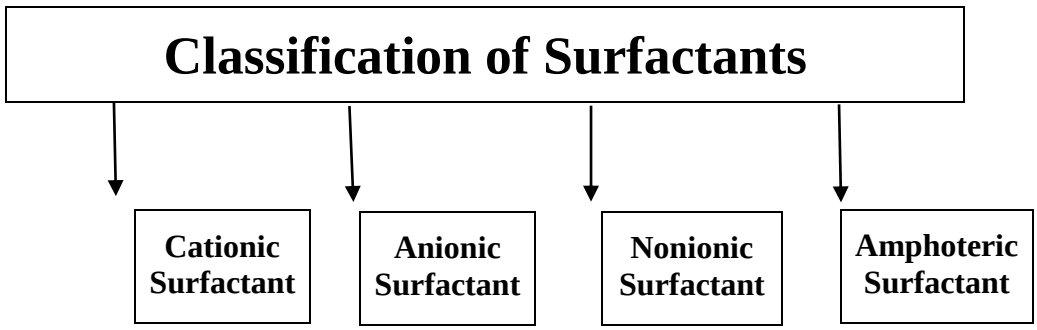

Fig. 1. Classification of surfactants.

Cationic Surfactants

The cationic surfactants are positively charged, which are generally quaternary ammonium compounds. They are majorly used in the preparation of bactericidal drug formulations. They are used as a disinfectant and also for clearing the wounds. They are also applied as preservatives in some food preparations. Cetrimide, Benzalkonium chloride are some of the examples of cationic surfactants.

Anionic Surfactants

The anionic surfactants are negatively charged, which is frequently favored for several formulations. They are always preferred in shampoo formulations for their excellent cleansing and conditioning properties, even in the case of oily, hard hair textures. There are different types of anionic surfactants like Divalent and trivalent, Alkali metal and ammonium, Alkyl sulphates and Amine group of anionic surfactants.

Anionic surfactants are very susceptible to acidic medium and are stable at pH higher than 10. Sodium lauryl sulphate is one of the popular agents used as an anionic surfactant in preparation of shampoos and soaps.

Nonionic Surfactants

Nonionic surfactants do not carry any charges, which is considerably less irritant than the remaining type of surfactants. These surfactants are tolerant of hard water and help the formulations become sensitive. They are also applied for removing grease stains. The hydrophobic moiety constitutes fatty acids, and hydrophilic moiety has polyol derivatives. These are further classified into poloxamers, Polyol esters, polyoxymethylene. The fatty alcohols are one of the popular nonionic surfactants.

Amphoteric Surfactants

Amphoteric surfactants may carry positive or negative charges or no charge. These are mild substances, specifically intended for sensitive applications like for sensitive skin. Depending on the pH, they behave like cationic forms or anionic forms or nonionic forms or may carry both. The surfactants which are having both the charges are good for dermal applications. These are also into other formulations like cleaning liquids, shampoos etc. [15-17].

MECHANISM OF ACTION

Surfactants work mainly by three different mechanisms, i.e., solubilization, emulsification and roll-up mechanism.

In the mechanism if solubilization, the micellar form of surfactant undergoes a spontaneous dissolution in the solvent medium and form stabilized solutions.

In the emulsification mechanism, surfactants reduce the interfacial tension in a biphasic system and emulsifies the system.

The roll-up mechanism is commonly carried to remove stains on the fabric. They act by lowering the interfacial tension between the phases, which lifts the stain from the fabric and solubilize [1,4].

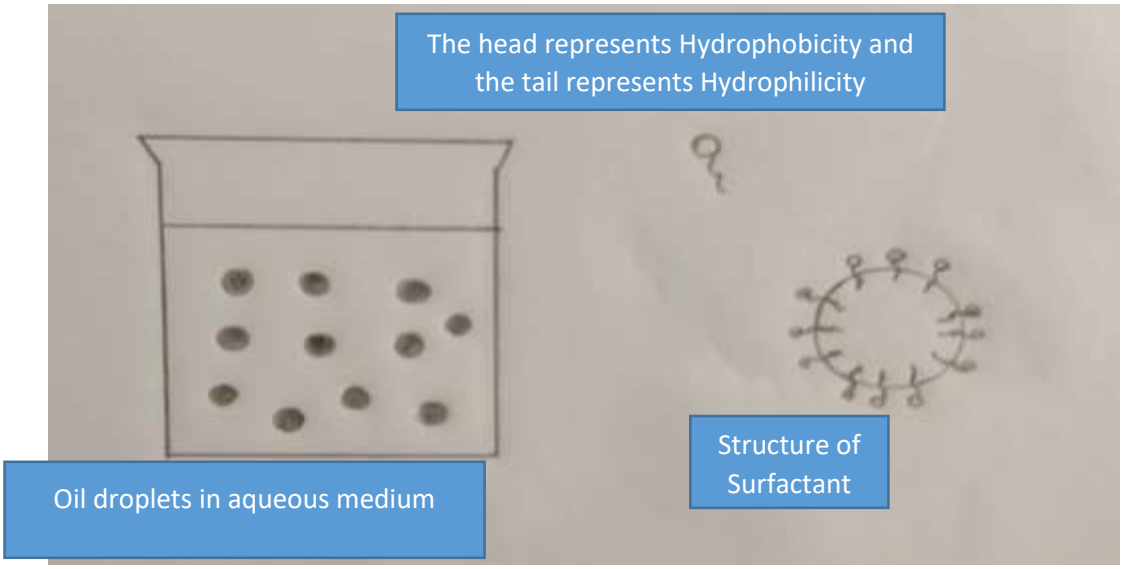

Fig. 2. Structure and nature of surfactant.

FACTORS AFFECTING THE SURFACTANTS

For forming an efficient, stable, surfactant environmental factors play a crucial role. Surfactants requires some optimum conditions of temperature, pH and aeration facilities to get successful results. From the reports, the temperature should be maintained at 25-30 degrees Celsius and pH should be above 8 to obtain a fine preparation. A proper aeration facility should be provided for a positive influence on the preparation.

Critical Micellar concentration (CMC) is an important phase where the micellar formation takes place at some particular concentration of surfactants. It may be affected by solubilization, temperature, pH and chain length etc.

Solubilization is another essential factor, which results in the poor formulation if the solubility is low or high than expected. So, to prevent the undesired conditions, dimers are applied to enhance solubility in the required rate.

Kraft temperature is the temperature at which the condition of micellar formation is attained.

Foaming rate is the ability of a surfactant to develop an acceptable amount of foam. Foaming is associated with many formulations of pharmaceuticals, cosmetics and toiletries. Usually chosen surfactants are capable of developing the required foam, but due to few issues caused by altering conditions of surface elasticity, surface viscosity and surface tension, results in less foam formation. In order to develop the foam at a wanted rate, foam enhancers are involved [18-20].

APPLICATIONS

Food sector

The poor preparation and long-lasting stability are the major problems dealing with many food preparations. Surfactant is the aid to solve all those problems by affecting the food ingredients to a palatable form. These surfactants are added as an additive in the food preparation and enrich the taste, essence and quality for a longer

duration. It is applied in many drinks, soups, oils, starch preparations etc. Ethylene glycol, sorbitan, fatty acid esters having glycerol are few surfactants which enhance food properties [21].

Cosmetics

Surfactants are almost occupied in the majority of cosmetic preparations, without which the chief activity remain in dormancy. They perform different activities of wetting agent, foaming enhancer, cleanser, solubilizing agent, a preservative in many formulations. The preparations like toothpaste, hair care products, foundation products, mascara, lipsticks, creams etc. have surfactant as an ingredient [22].

Toiletries

It is used in the preparation of soaps, shaving creams, disinfectants, toilet cleaners for favoring the effective use of formulation [22].

Biomedical Sciences

The surfactants have also medicinal benefits, which can be used in treating many medically associated problems. From the reports, it is observed that surfactants can perform anti-microbial activity and cure the disease. The adhesive properties present in the surfactants can trap the disease-causing agents and survive the host cells [23].

Pharmaceutical preparations

The surfactants are being used in different formulations with different roles. They are used in a wide range of preparations like tablets, capsules, suspensions, emulsions, aerosols, suppository bases and in many other dosage forms to facilitate the drug delivery. It is used as flocculant, emulsifier, stabilizer, thickener, wetting agent, suspending agent, coating agent etc. It is also used in enhancing the drug absorption rate, drug permeation rate in transdermal delivery, release profiles, spray phenomenon in aerosols.

The surfactants have also found a significant role in the field of biochemistry, which is involved in different enzymatic and catalytic reactions of biological processes.

They are involved in various analytical processes, which helps to obtain the effective results in determining the sample, separation and recognizing the concentration of the sample [24-25].

In nanotechnology, the nano delivery systems like liposomes, niosomes, polysomes etc. use surfactant for targeted delivery. The amphiphilic nature of the surfactant and the special characteristic feature of forming self assembles structure is used as a tool for synthesizing nanoparticles. Additionally, it can act as a wetting agent and capable of creating microemulsions [26].

In Genetic applications

During the gene therapy, DNA may face challenges of permeability while entering into a cell. Surfactants by its structural components, induce permeability in the cell wall and facilitate the transfection [27].

In Microbiology

The surfactants are employed in testing many antimicrobials for a cultured medium in suitable conditions. For instance, the quaternary ammonium compound is used in the antibiotic application as a surfactant. These surfactants can also be developed from various microbial sources and utilized in many biotechnical applications [7].

Popular Surfactants in trending formulations:

Table 1. Popular surfactants and their application [2,6].

Sr. No.	Surfactant name	Surfactant type	Application
1	Alkylbenzene sulfonates	Anionic	Detergents
2	Lauryl sulfate	Anionic	Foaming agent
3	Di-alkyl sulfosuccinate	Anionic	Wetting agent
4	Lignosulfonates	Anionic	Dispersant
5	Quaternary ammonium salts	Cationic	Softener
6	Fatty acids esters	Cationic	Food and cosmetic sectors
7	Betaine	Amphoteric	Foam booster
8	Polyoxymethylene surfactant	Nonionic	Chemical analysis
9	Span	Nonionic	Emulsifier
10	Tween	Nonionic	Food industry

Conclusion

In present times, surfactants are considered as leading excipients, which are almost a part of every formulation which we regularly use in our life. Due to its multiple benefits, they have brought beneficial outcomes and made the intended application more effective. Currently, the developing multi-functional formulations or products are practically becoming possible by the involvement of surfactants. However, there are few concerns like high productivity, and unexpected outcomes have affected the quality of the product. For minimizing the issues, many research activities like developing approaches associated with genetic recombination, microbe mediated synthesis, new techniques with minimal expenditures are being implemented. Furthermore, investigations are being processed on these surfactants, aiming to find new functional areas and potential advantages.

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