BIOSURFACTANTS AN ECOFRIENDLY TOOL, A REVIEW

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ABSTRACT

Biosurfactants are the surfactants obtained from microbes and can be synthesized in the lab by several microorganisms including bacteria, yeast and fungi and are produced extracellular or as part of the cell membrane. Examples include *Pseudomonas aeruginosa* which produces rhamnolipids, *Candida* (formerly *Torulopsis*) *bombicola*, one of the few types of yeast to produce biosurfactants, which produces high yields of sophorolipids from vegetable oils and sugars and *Bacillus subtilis* which produces a lipopeptide called surfactin. Biosurfactants find there application in today's world due to is easy operation in the environmental, Ecofriendly, biodegradable, less toxic and effectiveness in enhancing biodegradation and solubilization of low solubility composites. This review includes environmental application of these biosurfactants for soil and water treatment. Biosurfactants find application in Bioremediation process.

Key words: Biosurfactants, microorganisms, emulsification, toxicity, biodegradability

INTRODUCTION

Surfactants are a versatile group of chemicals with various applications as household detergents, personal care products, pharmaceutical agent agricultural chemicals, oilfield chemicals, food processing agents, industrial additives, environmental remediation agents and so on [1]. Surfactants are chemical substances composed of hydrophilic and hydrophobic parts that partition at physical interfaces that make them amphipathic in natures. The hydrocarbon chains forms the non-polar part, while the polar part can be a cationic, anionic, nonionic, or amphoteric. This combination of hydrophobic and hydrophilic enables surfactants to reduce surface tension and helps on the formation of microemulsion. This helps in solubilization of hydrocarbons in water or vice-versa[2]. The effectiveness of surfactant can be analysed by measuring its capacity to reduce the surface and interfacial tension.[3]. Critical Micelle concentration is that strength of surfactant at which it starts to form clusters and starts micilliezation. Surfactants are widely used in industrial, Agricultural, food, cosmetic and medicinal application However majority of these chemicals are synthetically synthesised and because of their biodegradable and persistent character they may pose environmental and toxicological risks [4] Recent developments in biotechnology have drawn attention to an alternative, method for producing several kinds of biosurfactants from microorganisms [5].

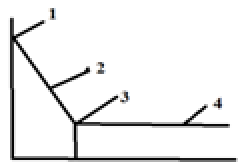


Fig 1Graph showing the relationship between surface tension and concentration of surfactant

1. Plain sample –no reduction in surface tension
2. Reduction in surface tension due to addition of surfactants
3. Criticle micelle concentration
4. Micelle formation of surfactants

CLASSIFICATION

Surfactants are materials that lower the surface tension (or interfacial tension) between two liquids or between a liquid and a solid. The four general grouping of surfactants are based upon the polarity of the molecules head group, these are: anionic, cationic, nonionic, and zwitterionic. Anionic surfactants carry a negative charge and these are the most commonly available surfactants of those both synthetically and naturally produced. Anionic surfactants have applications in personal care products and soaps as they are very effective in cleansing systems.

On the basis of molecular mass it is of 2 types

The average molecular mass of a biosurfactant ranges from 500 Da to 1500 Da

1. low molecular weight biosurfactants: Low molecular weight biosurfactants are more effective in reducing the surface tension at the air-water interface and the interfacial tension at the oil-water interface,
2. High molecular weight biosurfactants are most effectively used in stabilizing oil-in-water emulsions

On the basis of origin they are classified as

1 Natural /3 Biosurfactants

Biosurfactants exist naturally in the environment and play some roles in the ecosystem even without human interferences. Based upon the composition of the polarity of the head group, there are 4 types of surfactants, nonionic, anionic, cationic, amphoteric. A natural surfactant has to have both the head and tail groups to come from truly natural sources. Natural surfactants can be derived from many types of plants. Common sources are coconut or palm, but they can also be derived from other types of fruits and vegetables. 5 plant-derived non-ionic surfactants are as follows:

Coco Glucoside: Coco glycoside is a non-ionic natural surfactant with an alkaline pH around 12. It is a gentle foamy cleanser derived from coconut oil and fruit sugars and is completely biodegradable.

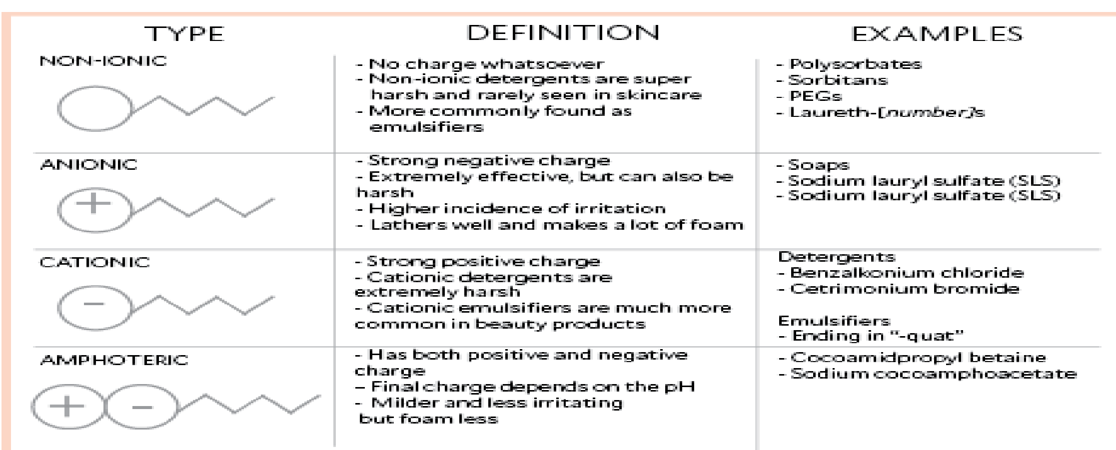
Decyl Glucoside: Decyl glycoside is also obtained from coconut oil and glucose and is completely biodegradable. It is similar to Coco Glucoside except that it has a shorter chain length and creates less foam. The foam that is created is less stable.

Lauryl Glucoside: Lauryl glycoside is similar to Coco glycoside and Decyl glycoside but with a longer chain. It is also more viscous. Lauryl Glucoside takes the longest to foam but the form that is created is also the most stable.

Coco Betaine: Coco betaine is a mild, coconut-based amphoteric surfactant with a pH around 6-8. It is completely biodegradable and increases the form and viscosity of products to which it is added.

Disodium Laureth Sulfosuccinate: Disodium laureth sulfosuccinate is a gentle anionic surfactant. Its larger molecules are unable to penetrate and irritate the skin, making it the preferred choice for use in products formulated for sensitive skin

2. **Synthetic surfactants**:-Most synthetic surfactants are derived from the petrochemical industry and can therefore be produced at a low cost and high yield.



TYPE	DEFINITION	EXAMPLES
NON-IONIC	- No charge whatsoever - Non-ionic detergents are super harsh and rarely seen in skincare - More commonly found as emulsifiers	- Polysorbates - Sorbitans - PEGs - Laureth-[*number*]s
ANIONIC	- Strong negative charge - Extremely effective, but can also be harsh - Higher incidence of irritation - Lathers well and makes a lot of foam	- Soaps - Sodium lauryl sulfate (SLS) - Sodium lauryl sulfate (SLS)
CATIONIC	- Strong positive charge - Cationic detergents are extremely harsh - Cationic emulsifiers are much more common in beauty products	Detergents - Benzalkonium chloride - Cetrimonium bromide Emulsifiers - Ending in "-quat"
AMPHOTERIC	- Has both positive and negative charge - Final charge depends on the pH - Milder and less irritating but foam less	- Cocoamidpropyl betaine - Sodium cocoamphoacetate

PRODUCTION.

The four components involved in a biosurfactant production process are

(1) Feedstock, (2) microorganism, (3) fermentation conditions, and (4) downstream processing. Out of the four the microorganism used is the main and important part of the process. It determines the maximum yield, functionality and the potential of a biosurfactant product[6]. The recovery and purification of biosurfactants also plays an important role in production process.

Extraction: Extraction technologies such as adsorption to wood-activated carbon or polystyrene resins, centrifugation, ion exchange chromatography, foam fractionation, and ultrafiltration are being investigations as viable alternative to liquid phase solvent extraction that are more environmentally benign. Another advantage achieved using these extraction technologies are that one can obtain highly pure biosurfactants at lower cost, faster, and the extraction materials can be reused

PROPERTIES OF SURFACTANTS WITH REFERENCE TO BIOSURFACTANTS

In recent studies, it was revealed that biosurfactants have a more mosaic distribution of polar and a polar regions, due to the complex structural properties, as compared to chemically synthesized surfactants [7]. With the help of this mosaic distribution biosurfactants control the biofilm formation. This unique ability leads to mild interaction of biosurfactants with proteins/enzymes, which makes them active participant in detergents, pharmatheutical and bioremediation agents [7]. These features of Biosurfactants make them multifunctional bio molecules [3].The important properties of biosurfactants are Wetting ,emulsification, Foaming , dispersion, dissolution, reduction in viscosity, and Solubilization, which result in a broad spectrum of potential applications in oil contaminate control[8].

Wetting:- This refers to how a liquid deposits onto a solid or liquid surface and how it spreads out. An example of this is how shampoo and conditioner spreads out onto the hair in order to carry out its function.,

Emulsification:- Emulsification is the formation of a dispersed system made of two immiscible liquids *(eg oil and water)*, where one is dispersed within the other in the form of small droplets.The surfactant is positioned at the oil and water interface, lowering interfacial tension and preventing separation. This is how an emulsifier normally works to allow both oil and water phases to mix.

Foaming:- Surfactants are used to create foam in products such as shampoo, and body, face and hand washes. Foam forms when gas is trapped inside so-called 'cells' with liquid film walls.

Dispersion:- this is normally a powder *(solid)* dispersed in a liquid. A surfactant reduces interfacial tension and helps effective dispersion.

Reduction in viscosity :-Surfactants have the ability to remove dirt and grime from a surface. The hydrophilic *(water-loving)* head is attracted to the water and the lipophilic *(oil-loving)* tail is attracted to the oil in the dirt and grime. These opposing forces loosen the dirt and grime on the surface, eventually suspending it in the water that washes it away. This mechanism is used when we wash our clothes with detergent and when we use shampoo on our hair. Detergency is the function of surfactants that plays a key role in the cleansing action of face and body washes.

Solubilization:-It is the process by which insoluble materials are made water soluble by their encapsulation within micelles. Solubilization is required when you want a clear formula but still want to blend oil in a mostly water formula. There are surfactants, fortunately, that can create particles so small that light can pass through them. This allows the solutions to remain clear. Use of solubilising surfactants is required when adding essential oils or fragrance oils to a water-based product. For solubilization to occur, oil and surfactant ratios must be at the optimum level.

EXAMPLES OF BIOSURFACTANTS

Common biosurfactants include:

- Bile salts are mixtures of micelle-forming compounds that encapsulate food, enabling absorption through the small intestine.
- Lecithin, which can be obtained either from soybean or from egg yolk, is a common food ingredient.
- Rhamnolipids, which can be produced by some species of *Pseudomonas*, e.g., *Pseudomonas aeruginosa*.
- Sophorolipids are produced by various nonpathogenic yeasts.
- Emulsan produced by *Acinetobacter calcoaceticus*

Microbial biosurfactants are obtained by including immiscible liquids in the growth medium.

Factors affection the functioning of Biosurfactants

Environmental factors such as pH, salinity and temperature also affect biosurfactant activity.

Factors affecting biosurfactant production

The composition and emulsifying activity of the biosurfactants not only depends on the producer strain but also on the culture conditions, thus, the nature of the carbon source, the nitrogen source as well as the C:N ratio, nutritional limitations, chemical and physical parameters such as temperature, aeration, divalent cations and pH influence not only the amount of biosurfactant produced but also the type of polymer produced [9].

Carbon sources: The quality and quantity of biosurfactant production are affected and influenced by the nature of the carbon substrate [10]. Diesel, crude oil, glucose, sucrose, glycerol have been reported to be a good source of carbon substrate for biosurfactant production [11].

Nitrogen sources: Nitrogen is important in the biosurfactant production medium because it is essential for microbial growth as protein and enzyme syntheses depend on it. Different nitrogen compounds have been used for the production of biosurfactants such as urea peptone, yeast extract, ammonium sulphate, ammonium nitrate, sodium nitrate, meat extract and malt extracts. Though yeast extract is the most used nitrogen source for biosurfactant production, its usage with respect to concentration is organism and culture medium dependent. Ammonium salts and urea are preferred nitrogen sources for biosurfactant production by *Arthrobacter paraffineus* whereas nitrate supports maximum surfactant production in *P. aeruginosa* [12].

Environmental factors: These are extremely important in the yield and characteristics of the biosurfactant produced. To obtain large quantities of biosurfactants, it is always necessary to optimize the bioprocess as the product may be affected by changes in temperature, pH, aeration or agitation speed. Most biosurfactant productions are reported to be performed in a temperature range of 25-300C [11]. The effect of pH on biosurfactant produced was studied by Zinjarde and Pant[[13] who reported that the best production occurred when the pH was 8.0 which is the natural pH of sea water.

Aeration and Agitation: Aeration and agitation are important factors that influence the production of biosurfactants as both facilitate the oxygen transfer from the gas phase to the aqueous phase. It may also be linked to the physiological function of microbial emulsifier, it has been suggested that the production of bio emulsifiers can enhance the solubilization of water insoluble substrates and consequently facilitate nutrient transport to microorganisms. Adamczak and Bednarski[12] observed that the best production value of the surfactant (45.5g/l) was obtained when the air flow rate was 1vvm and the dissolved oxygen concentration was maintained at 50% of saturation.

Salt concentration: Salt concentration of a particular medium also had a corresponding effect on the biosurfactant production as the cellular activities of microorganisms are affected by salt concentration. Nevertheless, contrary observations were noticed for some biosurfactant products which were not affected by concentrations up to 10% (weight/ volume) although slight reductions in the CMC were detected [11].

APPLICATION OF BIOSURFACTANTS

Industry	Biosurfactant types	Application	Role of Biosurfactants
Petroleum	Rhamnolipids,sophorolipids and lipopeptides	Enhanced oil recovery Crude oil pipelines/transport	Emulsification of oils, lowering of interfacial tension, de-emulsification of oil emulsions, solubilisation of oils, viscosity reduction, dispersion of oils, wetting of solid surfaces, spreading, detergency, foaming, corrosion inhibition in fuel oils and equipment
Environment	Rhamnolipids,sophorolipids and lipopeptides	BioremediationOil spill cleanup operationsSoil remediation and flushingTreatment of	Emulsification and de-emulsification of oils, lowering of

		wastewaterHeavy metal remediationBiofouling	interfacial tension, dispersion of oils, solubilisation of oils, wetting, mobilization, spreading, detergency, foaming, corrosion inhibition in fuel oils and equipment; binding, desorption, and mobilization of heavy metals
Agriculture	Rhamnolipids,sophorolipids and lipopeptides	BiocontrolFertilisersPlant protection	Wetting, dispersion, suspension of powdered pesticides and fertilisers, emulsification of pesticide solutions, facilitation of biocontrol mechanisms of microbes, plant pathogen elimination and

			increased bioavailability of nutrients for beneficial plant-associated microbes
Food	Glycolipids, lipeptides and polymeric surfactants	EmulsificationFunctional ingredient	Solubilisation of flavoured oils, control of consistency, emulsification, wetting agent, spreading, detergency, foaming, thickener.
Medicine	Rhamnolipids,sophorolipids and lipopeptides	MicrobiologicalPharmaceuticals and therapeutics	Anti-adhesive agents, antifungal agents, antibacterial agents, antiviral agents, vaccines, gene therapy, immunomodulatory molecules.

LIMITATIONS

the two most specific disadvantages are their production cost and purification. Biotechnological processes involved in the synthesis of biosurfactants are quite expensive, and purification of surfactants is tricky.

CONCLUSION

In spite of many laboratory based success in biosurfactants production and its immense commercial applications, the production of biosurfactant at a plant scale remains a challenging issue as the composition of final product is affected by the nutrient, and environmental factors. Guideline and regulation should be formulated for use of biosurfactants in different areas sectors. It is expected that in future, super-active microbial strains will be developed using genetic engineering for production of biosurfactants at industrial level using renewable substrates as raw material.

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