# BIOSURFACTANTS FOR SUSTAINABLE SOIL MANAGEMENT

**Abstract**

Biosurfactants, a diverse group of biologically-derived surface-active molecules, have garnered significant attention due wide applications and special properties. Produced by microorganisms, biosurfactants exhibit exceptional surface tension reduction, emulsification, and foaming abilities, surpassing their synthetic counterparts in several aspects. This abstract provides an overview of biosurfactants, their production and their diverse applications.

**Keywords:** Biosurfactants, Microorganism

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## I. INTRODUCTION

Biosurfactants are amphiphilic chemicals obtained mostly from plants and microbes. In that microbially obtained biosurfactants are best over plant obtained ones because of fast production, more capability and more functionally active while plant obtained biosurfactants are good emulsifiers but their production cost is more on large scale. Furthermore, they have challenges with solubility and hydrophobicity. Kinetics and bioavailability of hydrophobic substances are influenced by biosurfactants (Ahmad *et al*., 2016).

Surfactants, or surface-active agents, are compounds that can reduce the surface tension between two immiscible phases, such as oil and water. They consist of a hydrophobic (water-repellent) tail and a hydrophilic (water-attracting) head group. This structure allows surfactants to lower the interfacial tension between different phases, facilitating the mixing and dispersion of substances that would otherwise not readily interact.

Water repellence is decreased to increase availability of hydrophobic substances. Chemical properties of biosurfactants are responsible for both stimulating and inhibiting effects of bio surfactants. These biosurfactants has role in enhancing the solubility and availability of hydrophobic substances, as well as in stimulating micro-organism swarming motility and cellular signalling and differentiation processes. These biosurfactants play role in biofilm formation and interact with variety of microbial proteins. They effect the enzyme structure in this way, altering enzyme selectivity and functions. It helps ensure agriculture sustenance by serving as antimicrobial agents to combat illness (Ahmad *et al*., 2016).

## II. HISTORY

The history of biosurfactants dates back several decades and has evolved through various stages of discovery, development, and application. Here's a brief overview of the key milestones in the history of biosurfactants

1. **Early Observations (Early to Mid-20th Century):** Biosurfactants were initially observed in natural sources like plants and animals, such as soapwort (a plant) and bird feathers. Indigenous communities in different parts of the world have long utilized plant-based saponins as natural cleansers.

2. **Emergence of Microbial Biosurfactants (1950s-1960s):** The discovery of microbial biosurfactants began in earnest in the 1950s and 1960s when scientists started to identify and characterize the surface-active compounds produced by various microorganisms. This era marked the beginning of more systematic research into biosurfactants.

3. **Early Commercial Applications (1980s):** By the 1980s, certain biosurfactants, like rhamnolipids produced by Pseudomonas aeruginosa, were being studied for their potential in various industries. Rhamnolipids, for example, were explored for their use in enhanced oil recovery.

4. **Advancements in Biotechnology (1990s-2000s):** Advancements in biotechnology and genetic engineering led to improved methods for the production of biosurfactants. This

era witnessed the development of more efficient and cost-effective biosurfactant production processes using a range of microorganisms.

5. **Environmental and Bioremediation Applications (Late 20th Century):** The 1990s and 2000s saw increased interest in biosurfactants for environmental applications, particularly in bioremediation efforts to clean up oil spills and contaminated sites. Biosurfactants were recognized for their ability to enhance the removal of hydrophobic contaminants from soil and water.

6. **Diversification of Biosurfactant Types (2000s-Present):** Ongoing research has led to the discovery and characterization of various types of biosurfactants, including glycolipids, lipopeptides, and sophorolipids, each with distinct properties and applications.

7. **Expanding Industrial and Commercial Use (Present):** Biosurfactants have found a place in a variety of industries, including biotechnology, pharmaceuticals, cosmetics, food, and agriculture. They are employed in processes such as emulsification, foaming, and as food additives.

8. **Ongoing Research and Development (Present and Future):** The research and development of biosurfactants continue to advance, with scientists exploring new applications and ways to optimize their production. Biosurfactants are being studied for their antimicrobial properties, in biofuels, and as potential tools for addressing various global challenges.

## III. PLANT-BASED BIO-SURFACTANTS

Plant-based biosurfactants, as the name suggests, are biosurfactants derived from various parts of plants, such as leaves, seeds, and roots. They are a subset of biosurfactants and are notable for their renewable and sustainable nature. Some examples are listed in Table 1.

**Table 1: Plant based Biosurfactants**

| Biosurfactant | Source | References |
|---|---|---|
| Lecithin | Soybean oil seed, root mucilage of maize, lupin and wheat | Read *et al.* (2003) |
| Saponin | Tea seed | Wang *et al.* (2016) |
| | Soybeans, broad beans, | Xu *et al.* (2011) |
| | Chinese soapberry | Zhou *et al.* (2013) |
| Phospholipid | Maize roots and lupin | Read *et al.* (2003) |
| Humic acid-like substance | Soapnut plant | Mukhopadhyay *et al.* (2013) |
| Polymeric | Chicory | Stevens *et al.* (2001) |

Vecino et al. (2014) investigated the surface tension of maize steep liquor derived from the maize milling industry and isolated the bio-surfactant present in this residue using organic solvents.

**1. Types of Plant-Based Biosurfactants**

- **Saponins:** Saponins are natural compounds found in various plants, including soapwort (Saponaria officinalis) and the soapberry tree (*Sapindus* spp.). They have been traditionally used for their soap-like properties and are used in the cosmetics and cleaning industries.

- **Lectins:** Certain plant lectins can also exhibit surfactant properties. Lectins are proteins or glycoproteins found in many plants and can have emulsifying and foaming abilities.

- **Starch-Based Surfactants**: Some starch-derived materials, like certain modified corn starches, can act as biosurfactants and are used in food and industrial applications.

**2. Advantages of Plant-Based Biosurfactants**

- **Renewable Source**: The use of plant-based materials for biosurfactant production is sustainable and reduces the dependence on non-renewable resources.

- **Biodegradability:** Plant-based biosurfactants are generally biodegradable, making them environmentally friendly and suitable for applications where biodegradability is essential.

- **Low Toxicity:** Many plant-based biosurfactants are non-toxic and safe for use in various consumer and industrial products.

- **Versatile Applications**: Plant-based biosurfactants find applications in a variety of sectors, including food, cosmetics, agriculture, and bioremediation.

**3. Applications**

- **Food Industry:** Plant-based biosurfactants can be used in the food industry for emulsifying, foaming, and stabilizing properties. They are used in the production of products like salad dressings and ice cream.

- **Cosmetics and Personal Care:** Many plant-based biosurfactants are gentle on the skin and are used in cosmetic formulations, such as shampoos, soaps, and skincare products.

- **Agriculture:** In agriculture, plant-based biosurfactants are used in pesticide formulations to improve the spreading and adherence of pesticides to plant surfaces.

- **Bioremediation:** They can also be employed in bioremediation efforts to enhance the removal of hydrophobic contaminants from soil and water.

## IV. MICROBIALLY PRODUCED BIO-SURFACTANTS

Microbially produced biosurfactants are a subgroup of biosurfactants that are synthesized by various microorganisms, including bacteria, yeasts, and fungi. These naturally derived surface-active compounds have gained significant attention due to their eco-friendly and sustainable properties. Some examples are listed in table 2, 3, 4.

### 1. Types of Microbially Produced Biosurfactants

- **Rhamnolipids:** Produced by Pseudomonas species, rhamnolipids are one of the most well-known and extensively studied microbial biosurfactants. They have applications in enhanced oil recovery, bioremediation, and more.

- **Glycolipids:** Glycolipids, like sophorolipids and trehalolipids, are produced by yeasts, including Candida and Rhodotorula species. They have applications in cosmetics, food, and pharmaceuticals.

- **Lipopeptides:** Lipopeptides are biosurfactants produced by several bacterial strains, such as Bacillus subtilis and Pseudomonas fluorescens. They have applications in agriculture, as biopesticides, and in the pharmaceutical industry.

- **Production Processes:** The production of microbially produced biosurfactants typically involves fermentation processes. Microorganisms are cultivated in bioreactors under controlled conditions, and biosurfactants are secreted into the culture medium. After fermentation, the biosurfactants can be extracted and purified for various applications.

### 2. Applications

- **Enhanced Oil Recovery:** Microbially produced biosurfactants are used in the petroleum industry to improve the recovery of oil from reservoirs by reducing the interfacial tension between oil and water.

- **Bioremediation:** They are valuable in bioremediation processes for the removal of hydrophobic contaminants from soil and water, such as in the cleanup of oil spills.

- **Food and Cosmetics:** Some microbially produced biosurfactants are used in the food and cosmetics industries for emulsification, foaming, and as food additives.

- **Pharmaceuticals:** Lipopeptides, in particular, have applications as potential antimicrobial agents and drug delivery systems.

**Table 2: Bio-Surfactant Producing Bacteria**

| Sl. No. | Microorganism | Biosurfactant |
|---|---|---|
| 1. | *Pseudomonas sp* | Ornithine lipids |
| 2. | *Pseudomonas fluorescens* | Viscosin |
| 3. | *Pseudomonas aeruginosa* | Rhamnolipids |

**Table 3: Bio-Surfactant producing Fungi**

| Sl. No. | Microorganism | Biosurfactant |
|---|---|---|
| 1. | *Candida antarctica* | Mannoserthritol lipid |
| 2. | *Candida bombicola* | Sophorous lipids |
| 3. | *Penicillium chrysogenum* | Polyketide derivative |
| 4. | *Yarrowia lipolytica* | Carbohydrate complex |

**Table 4: Bio-Surfactant producing Yeast**

| SL. No. | Microorganism | Biosurfactant |
|---|---|---|
| 1 | *Debaryomyces polymorphus* | Carbohydrate complex |
| 2. | *Saccharomyces cerevisiae* | Mannanoprotein |
| 3. | *Pseudozyma aphidis* | Mannoserthritol lipids |

## V. CLASSIFICATION OF BIO-SURFACTANTS

Biosurfactants can be classified into several categories based on their chemical structure, microbial origin, and properties. Here are some common classifications of biosurfactants

### 1. Based on Chemical Structure

- **Rhamnolipids:** Rhamnolipids are glycolipid biosurfactants produced by various Pseudomonas species. They are composed of a hydrophilic rhamnose head group and one or two hydrophobic fatty acid tails. Rhamnolipids are known for their emulsification and foaming properties and have applications in enhanced oil recovery and bioremediation.

- **Glycolipids:** Glycolipids include compounds like sophorolipids and trehalolipids. These biosurfactants are produced by yeasts, particularly Candida and Rhodotorula species. They have applications in cosmetics, food, and pharmaceuticals.

- **Lipopeptides:** Lipopeptides are biosurfactants that contain a cyclic or linear peptide linked to a hydrophobic fatty acid chain. They are produced by various bacterial strains, such as Bacillus subtilis and Pseudomonas fluorescens. Lipopeptides have applications in agriculture (as biopesticides), pharmaceuticals, and as antimicrobial agents.

- **Phospholipids:** Phospholipids are a class of biosurfactants that contain a phosphate group in their structure. They are produced by some bacterial strains and have applications in the pharmaceutical and food industries.

2. **Based on Microbial Origin**

- **Bacterial Biosurfactants:** Many biosurfactants are produced by bacteria. This category includes rhamnolipids, lipopeptides, and other types produced by various bacterial species.

- **Yeast Biosurfactants:** Yeasts, such as Candida and Rhodotorula, are known for producing glycolipids like sophorolipids.

- **Fungal Biosurfactants:** Some fungi also produce biosurfactants, though they are less commonly studied than bacterial and yeast biosurfactants.

3. **Based on Properties**

- **Anionic Biosurfactants:** These biosurfactants have a negatively charged hydrophilic head group. Rhamnolipids are an example of anionic biosurfactants.

- **Cationic Biosurfactants:** Cationic biosurfactants have a positively charged head group. They are less common but have antimicrobial properties.

- **Nonionic Biosurfactants:** Nonionic biosurfactants have a hydrophilic head group with no charge. They are often used in applications where charge interactions need to be minimized.

- **Amphoteric Biosurfactants:** These biosurfactants have both positive and negative charges and can function under a wide range of pH conditions.

4. **Based on Applications**

- **Emulsifying Biosurfactants:** Some biosurfactants are excellent at emulsifying immiscible substances, making them valuable in industries like food, cosmetics, and pharmaceuticals.

- **Foaming Biosurfactants:** Biosurfactants that generate stable foams are used in the food and beverage industry, as well as in fire-fighting foams.

- **Oil Recovery Biosurfactants**: Biosurfactants are used to enhance oil recovery from reservoirs by reducing the interfacial tension between oil and water.

- **Bioremediation Biosurfactants:** Biosurfactants are employed in bioremediation processes to facilitate the removal of hydrophobic contaminants from soil and water.

## VI. BIOSURFACTANT PRODUCTION

The production of biosurfactants involves the cultivation of microorganisms (typically bacteria, yeasts, or fungi) in a controlled environment to encourage the secretion of biosurfactants into the culture medium. There are various methods for biosurfactant production, and the choice of method depends on the specific microorganism, the desired biosurfactant, and the scale of production. Here are some common methods used for biosurfactant production

1. **Batch Fermentation:** Batch fermentation is a straightforward method where microorganisms are cultivated in a closed bioreactor for a specific period. The growth medium, which contains nutrients and a carbon source, is inoculated with the selected microorganism. The microorganisms grow and produce biosurfactants as they consume nutrients. The biosurfactants accumulate in the culture medium. Once the fermentation period is complete, the culture medium is harvested, and the biosurfactants are extracted.

2. **Continuous Fermentation:** Continuous fermentation is a more advanced method where fresh growth medium is continuously added to the bioreactor while the culture medium is simultaneously removed. This process maintains a steady-state condition and can lead to higher yields and longer production times.

3. **Fed-Batch Fermentation:** Fed-batch fermentation is a combination of batch and continuous fermentation. Nutrients are added intermittently to the bioreactor to maintain optimal growth conditions. This method can enhance biosurfactant production by controlling nutrient availability while preventing nutrient depletion.

4. **Solid-State Fermentation:** Solid-state fermentation (SSF) is a method used for certain microorganisms, particularly filamentous fungi. In SSF, a solid substrate, such as agricultural waste or a lignocellulosic material, is inoculated with the microorganism and kept at the appropriate moisture level. This method is often used for the production of certain glycolipid biosurfactants.

5. **Submerged Fermentation:** In submerged fermentation, microorganisms are cultivated in a liquid medium (as opposed to solid-state fermentation). The submerged method is commonly used for the production of rhamnolipids, lipopeptides, and glycolipids.

6. **Optimization and Control:** In all of the above methods, it is crucial to optimize various factors such as pH, temperature, aeration, and agitation to maximize biosurfactant production. Microbial strains can be genetically modified to improve biosurfactant production yields.

7. **Downstream Processing:** After the fermentation process, the biosurfactants must be extracted and purified. Common methods include solvent extraction, precipitation, and chromatography. Downstream processing is essential to remove impurities and concentrate the biosurfactants for various applications.

 

## VII. APPLICATIONS OF BIO-SURFACTANTS

- Bioremediation of contaminated agricultural soil.
- Plant growth promotion by elimination of phytopathogens (Ayele *et al.,* 2021).
- Application in pesticide industries.

## VIII. ADVANTAGES OF BIO-SURFACTANTS

- Biodegradability, Low Toxicity
- Biocompatibility
- They can be produced from cheap raw materials that are easily available in large quantities
- It exhibits emulsification capacity
- Specificity
- Tolerance to temperature, pH and ionic strength
- They are ecologically accepted due to their property of maintaining sustainability (Shadia, 2017)
- Low critical micelle concentration

## IX. DISADVANTAGES OF BIO-SURFACTANTS

- High-cost, extensive production
- Obtaining pure chemicals is difficult
- creation of dense foam

## X. CONCLUSION

In conclusion, biosurfactants represent a remarkable class of natural molecules with immense potential and versatility. These biologically-derived surface-active compounds offer a wide array of benefits over their synthetic counterparts, making them attractive for various industrial applications.

One of the most significant advantages of biosurfactants is their eco-friendly nature and low toxicity, which aligns with the growing global focus on sustainability and environmental protection. Their production by microorganisms, such as bacteria and fungi, offers a sustainable alternative to chemical surfactants, reducing the environmental burden associated with conventional surfactant manufacturing. In agriculture, biosurfactants can enhance nutrient availability and soil remediation, promoting sustainable and efficient farming practices. Their potential to support microbial interactions and biofilm formation enhances biodegradation processes, contributing to environmental cleanup and pollution mitigation.

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