# Surfactants versus Biosurfactants

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Based on their origin and composition, surfactants can be divided into three different categories: (i) synthetic surfactants; (ii) bio-based surfactants; and (iii) microbial biosurfactants. The first group is the most widespread and cost-effective. It is composed of surfactants, which are synthetically produced, using non-renewable sources, with a final structure that is different from the natural components of living cells. The second category comprises surfactants of intermediate biocompatibility, usually produced by chemical synthesis but integrating fats, sugars or amino acids obtained from renewable sources into their structure. Finally, the third group of surfactants, designated as microbial biosurfactants, are considered the most biocompatible and eco-friendly, as they are produced by living cells, mostly bacteria and yeasts, without the intermediation of organic synthesis.

petroleum-based surfactants | bio-based surfactants | microbial surfactants | cosmetics

## 1. Introduction

Surfactants are amphiphilic compounds that contain a tail, which is insoluble in water, presenting hydrophobic groups and a water-soluble head with hydrophilic groups [1][2]. Due to this structure, these substances have the ability to diffuse in water and to place themselves between air/water or oil/water interfaces [3][4], solubilizing hydrophobic compounds in water and giving stable emulsions with many applications in different industrial sectors including the agrochemical [5][6][7], agriculture [8], food [9][10][11], pharmaceutical [12] and cosmetic industries [13][14] as well as therapeutic [15], medicine [16] and oral-health related [17] applications.

The synthesis of surfactants usually involves chemical reactions to combine a hydrophobic chain with a hydrophilic group. Surfactants can be classified from different points of view [2], as there is currently no official categorization. Usually, they are classified depending on their ionic charge, although this classification can only be applied to synthetic and bio-based surfactants since the charge of most surfactants produced by living cells is still unknown. At the moment, only a few researchers have paid attention to the ionic charge or to the hydrophilic–lipophilic balance (HLB) of microbial biosurfactants [18]. Both parameters, together with the critical micellar concentration (CMC), are the important features of microbial biosurfactants and also important properties for cosmetic applications [19][20]. For instance, skin and eye irritation, absorption by hair and antibacterial properties can be associated with the ionic charge of microbial biosurfactants [21][22]; while the HLB value influences the ability of microbial biosurfactants to act as wetting, anti-foaming or emulsifier agents, among others purposes [14][22].

Other classifications divide surfactants into synthetic surfactants and bio-based surfactants, including also as bio-based surfactants produced by living cells, called microbial biosurfactants. Bio-based surfactants are usually produced by chemical synthesis but integrating fats, sugars or amino acids obtained from renewable sources, whereas microbial surfactants are obtained from living cells, typically bacteria and yeasts, without the intermediation of organic synthesis. However, the synthesis and composition of bio-based surfactants produced by organic synthesis differ from the surfactants directly produced from living cells and, therefore, they should be classified separately [2][23].

Microbial biosurfactants are secondary metabolites produced by different microorganisms, including bacteria, fungus and yeast [24]. They can be associated with different stages of microbial growth [25] and most of them are produced extracellularly, although there are some microorganisms that are able to produce microbial biosurfactants linked to the plasmatic membrane, called cell-bound microbial biosurfactants. Usually, lipopeptides and glycolipids compose extracellular microbial biosurfactants [26][27][28][29][30], whereas cell-bound microbial biosurfactants are composed of glycolipids and glycolipopeptides [31][32][33][34][35].

Another group of substances with surfactant capacity that can be considered biosurfactants, as they are extracted from vegetable or animal cells, are phospholipids [36]. However, it is important to remark that the main function of phospholipids at an industrial scale is emulsifiers. Moreover, some microorganisms also produce polymeric and particulate substances (named viscosin or emulsan) with surfactant capacity, although their main property is also as an emulsifier [24]. These groups of substances have similar properties to phospholipids and, therefore, they should be included in the same group.

## 2. Comparison of Microbial Biosurfactants with Synthetic and Bio-Based Surfactants in the Cosmetic Industry

Due to the huge operational costs to obtain microbial biosurfactants compared to synthetic or bio-based surfactants [3], their uses have to be limited to the personal care and pharmaceutical industries, with the exception of those obtained directly from fermented agro-industrial streams, with a reduced cost, like the case of the microbial biosurfactants extracted from corn steep water [37][38]. This type of microbial biosurfactant extract is directly obtained from corn wet-milling waste streams, thus its production costs are as competitive as the synthetic ones. In fact, this finding was internationally patented, since the corn steep liquor stream involves a new source of microbial biosurfactants [39]. Recently, López-Prieto et al. [40] isolated and characterized the microorganism responsible for the production of microbial biosurfactants in this corn residue, noticing that it is a *Bacillus* strain with the capacity to generate both extracellular and cell-bound microbial biosurfactants. On the other hand, this microbial biosurfactant has already been tested in hair care [21][41][42] as well as skincare [43][44][45][46] formulations.

Microbial biosurfactants were applied to cosmetic, personal care and pharmaceutical formulations, achieving interesting results with fewer side effects than those produced by synthetic surfactants. Table 1 summarizes some studies that show different applications of microbial biosurfactants among these fields.

**Table 1.** Uses of microbial biosurfactants among cosmetic, personal care and pharmaceutical industries.

| Type of Microbial Biosurfactant | Application | Ref. |
|---|---|---|
| Rhamnolipid | Anti-ageing product | [47] |
| | Cleanser in shampoos | [48] |
| | Anti-adhesive activity | [49] |
| Rhamnolipid/Sophorolipid | Cleanser for antidandruff shampoo<br>Moisturizing skin cleanser<br>Body cleanser | [50] |
| Sophorolipid | Cleanser in shower gel and shampoo | [51] |
| | Body washer | [52] |
| | Anti-inflammatory agent | [53] |
| Glycolipid | Cleanser in shampoo formulation | [54] |
| | Antifungal activity | [55] |
| | Hair-care conditioning polymers | [56] |
| Lipopeptide | Hair care formulation | [21] |
| | Rosemary oil/water emulsions | [57] |
| | Dyed hair care formulation | [41] |
| | Stabilizing agent for antidandruff formulations based on Zn pyrithione powder | [42] |
| | Sunscreen formulations based on mica powder | [43] |
| | Pickering emulsions containing Vitamin E | [44] |
| | Stabilizing agent of vitamin C | [45] |
| | Antiacne formulation | [46] |
| | Antiviral agent | [58] |
| | Antimicrobial agent in silver plasmonic nanoparticles | [59] |
| | Nanoemulsions and nanocrystals for dermal application | [60] |

| Type of Microbial Biosurfactant | Application | Ref. |
| --- | --- | --- |
| | Permeation of pharmaceutical compounds by silicone membranes | [61] |
| | Antimicrobial agent | [62] |
| Glycolipopeptide | Rosemary oil/water emulsions | [34] [35] |
| | Cosmetic formulation with antioxidants | [63] |
| | Bioactivity against skin pathogens (antimicrobial and anti-adhesive agent) | [64] |
| Glycolipopeptide/Lipopeptide | Rosemary oil/water emulsions | [57] |
| | Preservative and irritant agent | [65] |
| MELs | Anti-ageing product | [66] |
| | Prevent skin roughness | [67] |
| | Makeup product | [68] |
| | Antimicrobial agent | [69] |
| Oligomeric biosurfactant | Conditioning agent for hair products | [70] |

Table 1 shows that microbial biosurfactants have a wide variety of applications in the cosmetic and personal care industry, acting as anti-ageing agents or cleansers, as well as in the pharmaceutical field, where they can be applied to different products owing to their antimicrobial capacity, which means they are regarded as substances with huge potential.

Among all microbial biosurfactants used in the cosmetic industry, lipopeptides and glycolipids are the ones selected due to their multifunctional profile, especially based on their physiochemical properties and biological activities [71][72].

## 3. Concluding Remarks and Future Perspectives

The increasing demand for surfactants by the cosmetic and personal care and pharmaceutical industries has generated huge consumption of petroleum-based synthetic surfactants, which are often toxic, irritant and non-biodegradable. Bio-based surfactants have come along as an alternative to synthetic surfactants, obtained from the petrochemical industry. Bio-based surfactants are compounds obtained using renewable sources and biomass. Hence, these kinds of surface-active compounds prevent the use of petrochemical sources; however, although vegetable and animal oils are used in their production, they are obtained through a chemical reaction that involves the consumption also of non-renewable sources. Nevertheless, microbial biosurfactants, which are produced by microorganisms, using biological reactions, as secondary metabolites, could represent a promising alternative since they are composed of lipids, carbohydrates or proteins, which makes them more biocompatible and biodegradable than their synthetic and bio-based counterparts. Additionally, they present low toxicity, stability in extreme conditions and several bioactivities.

Therefore, if microbial biosurfactants are less toxic and more biodegradable than chemical surfactants, what is wrong with microbial biosurfactants? Why are they not being included in cosmetic, personal care and pharmaceutical formulations? The main problem is related to the biotechnological production of microbial biosurfactants, which means a higher production cost, as they are secondary metabolites. Moreover, the biotechnological production of microbial biosurfactants involves an important cost regarding not only the nutritional medium but also the extraction and purification steps. Therefore, it is necessary to seek an increase in the overall productivity of microbial biosurfactants by obtaining higher producer microorganisms and by exploring the use of cost-competitive nutritional media, including the use of fermented residual streams (like corn steep liquor) where microbial biosurfactants can be produced spontaneously. Lastly, due to the current trend towards green consumption, it is expected there will be a significant effort to develop cosmetic, personal care and pharmaceutical formulations in which synthetic surfactants are replaced by renewable and environmentally friendly microbial biosurfactants. Therefore, international cosmetic regulations are required to incorporate microbial biosurfactants as a separate group of surfactants in order to obtain more biocompatible and greener formulations.

## References

1. Desai, J.D.; Banat, I.M. Microbial Production of Surfactants and Their Commercial Potential. Microbiol. Mol. Biol. Rev. 1997, 61, 47–64.
2. Tadros, T.F. An Introduction to Surfactants; Walter de Gruyter GmbH: Berlin/Heidelberg, Germany, 2014; ISBN 9789896540821.
3. Banat, I.M.; Cameotra, S.S.; Makkar, R. Potential Commercial Application of Biosurfactants. Appl. Microbiol. Biotechnol. 2000, 53, 495–508.
4. Soberón-Chávez, G.; Maier, R.M. Biosurfactants: A General Overview. Microbiol. Monogr. 2011, 20, 1–11.
5. Singh, A.K.; Cameotra, S.S. Microbial surface active agents as agrochemicals. In Bioremediation: Biotechnology, Engineering and Environmental Management; Nova Science Pub Inc: Hauppauge, NY, USA, 2011; pp. 267–293. ISBN 9781611227307.
6. Fukuoka, T.; Yoshida, S.; Nakamura, J.; Koitabashi, M.; Sakai, H.; Abe, M.; Kitamoto, D.; Kitamoto, H. Application of Yeast Glycolipid Biosurfactant, Mannosylerythritol Lipid, as Agrospreaders. J. Oleo Sci. 2015, 64, 689–695.

7. López-Prieto, A.; Vecino, X.; Rodríguez-López, L.; Moldes, A.B.; Cruz, J.M. A Multifunctional Biosurfactant Extract Obtained from Corn Steep Water as Bactericide for Agrifood Industry. Foods 2019, 8, 410.
8. Sachdev, D.P.; Cameotra, S.S. Biosurfactants in Agriculture. Appl. Microbiol. Biotechnol. 2013, 97, 1005–1016.
9. Nitschke, M.; Costa, S.G.V.A.O. Biosurfactants in Food Industry. Trends Food Sci. Technol. 2007, 18, 252–259.
10. Nitschke, M.; Sousa e Silva, S. Recent Food Applications of Microbial Surfactants. Crit. Rev. Food Sci. Nutr. 2018, 58, 631–638.
11. López-Prieto, A.; Rodríguez-López, L.; Rincón-Fontán, M.; Moldes, A.B.; Cruz, J.M. Effect of Biosurfactant Extract Obtained from the Corn-Milling Industry on Probiotic Bacteria in Drinkable Yogurt. J. Sci. Food Agric. 2019, 99, 824–830.
12. Gharaei-Fa, E. Biosurfactants in Pharmaceutical Industry (A Mini-Review). Am. J. Drug Discov. Dev. 2011, 1, 58–69.
13. Varvaresou, A.; Iakovou, K. Biosurfactants in Cosmetics and Biopharmaceuticals. Lett. Appl. Microbiol. 2015, 61, 214–223.
14. Vecino, X.; Cruz, J.M.; Moldes, A.B.; Rodrigues, L.R. Biosurfactants in Cosmetic Formulations: Trends and Challenges. Crit. Rev. Biotechnol. 2017, 37, 911–923.
15. Gudiña, E.J.; Rangarajan, V.; Sen, R.; Rodrigues, L.R. Potential Therapeutic Applications of Biosurfactants. Trends Pharmacol. Sci. 2013, 34, 667–675.
16. Rodrigues, L.; Banat, I.M.; Teixeira, J.; Oliveira, R. Biosurfactants: Potential Applications in Medicine. J. Antimicrob. Chemother. 2006, 57, 609–618.
17. Elshikh, M.; Marchant, R.; Banat, I.M. Biosurfactants: Promising Bioactive Molecules for Oral-Related Health Applications. FEMS Microbiol. Lett. 2016, 363, 1–7.
18. Moldes, A.B.; Vecino, X.; Rodríguez-López, L.; Rincón-Fontán, M.; Cruz, J.M. Microbial Glycoprotein and Lipopeptide Biosurfactants Production, Properties and Applications. In Microbial Biosurfactants and their Environmental and Industrial Applications; Banat, I.M., Thavasi, R., Eds.; Taylor & Francis Group: Milton Park, Abingdon, Oxfordshire, UK, 2019; pp. 106–128.
19. Satpute, S.K.; Banpurkar, A.G.; Dhakephalkar, P.K.; Banat, I.M.; Chopade, B.A. Methods for Investigating Biosurfactants and Bioemulsifiers: A Review. Crit. Rev. Biotechnol. 2010, 30, 127–144.
20. Satpute, S.K.; Płaza, G.A.; Banpurkar, A.G. Biosurfactants’ Production from Renewable Natural Resources: Example of Innovativeand Smart Technology in Circular Bioeconomy. Manag. Syst. Prod. Eng. 2017, 25, 46–54.

21. Rincón-Fontán, M.; Rodríguez-López, L.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Adsorption of Natural Surface Active Compounds Obtained from Corn on Human Hair. RSC Adv. 2016, 6, 63064–63070.

22. Bezerra, K.G.O.; Rufino, R.D.; Luna, J.M.; Sarubbo, L.A. Saponins and Microbial Biosurfactants: Potential Raw Materials for the Formulation of Cosmetics. Biotechnol. Prog. 2018, 34, 1482–1493.

23. Hayes, D.G. Biobased Surfactants: Overview and Industrial State-of- the-Art. In Biobased surfactants and detergents Synthesis, Properties, and Applications; Hayes, D.G., Kitamoto, D., Solaiman, D.K., Ashby, R.D., Eds.; AOCS Press: Urbana, IL, USA, 2009; pp. 3–25. ISBN 978-1-893997-67-7.

24. Shekhar, S.; Sundaramanickam, A.; Balasubramanian, T. Biosurfactant Producing Microbes and Their Potential Applications: A Review. Crit. Rev. Environ. Sci. Technol. 2015, 45, 1522–1554.

25. Patowary, K.; Das, M.; Patowary, R.; Kalita, M.C.; Deka, S. Recycling of Bakery Waste as an Alternative Carbon Source for Rhamnolipid Biosurfactant Production. J. Surfactants Deterg. 2019, 22, 373–384.

26. Williams, B.H.; Hathout, Y.; Fenselau, C. Structural Characterization of Lipopeptide Biomarkers Isolated from Bacillus Globigii. J. Mass Spectrom. 2002, 37, 259–264.

27. Vanittanakom, N.; Loeffler, W.; Koch, U.; Jung, G. Fengycin-A Novel Antifungal Lipopeptide Antibiotic Produced by Bacillus Subtilis F-29-3. J. Antibiot. (Tokyo) 1986, 39, 888–901.

28. Morikawa, M.; Hirata, Y.; Imanaka, T. A Study on the Structure-Function Relationship of Lipopeptide Biosurfactants. Biochim. Biophys. Acta 2000, 1488, 211–218.

29. Mnif, I.; Ghribi, D. Glycolipid Biosurfactants: Main Properties and Potential Applications in Agriculture and Food Industry. J. Sci. Food Agric. 2016, 96, 4310–4320.

30. Paulino, B.N.; Pessôa, M.G.; Mano, M.C.R.; Molina, G.; Neri-Numa, I.A.; Pastore, G.M. Current Status in Biotechnological Production and Applications of Glycolipid Biosurfactants. Appl. Microbiol. Biotechnol. 2016, 100, 10265–10293.

31. Garcés, M.E.; Sequeiros, C.; Olivera, N.L. Marine Lactobacillus Pentosus H16 Protects Artemia Franciscana from Vibrio Alginolyticus Pathogenic Effects. Dis. Aquat. Organ. 2015, 113, 41–50.

32. Moldes, A.B.; Paradelo, R.; Vecino, X.; Cruz, J.M.; Gudiña, E.; Rodrigues, L.; Teixeira, J.A.; Domínguez, J.M.; Barral, M.T. Partial Characterization of Biosurfactant from Lactobacillus Pentosus and Comparison with Sodium Dodecyl Sulphate for the Bioremediation of Hydrocarbon Contaminated Soil. BioMed Res. Int. 2013, 2013.

33. Gudiña, E.J.; Fernandes, E.C.; Teixeira, J.A.; Rodrigues, L.R. Antimicrobial and Anti-Adhesive Activities of Cell-Bound Biosurfactant from Lactobacillus Agilis CCUG31450. RSC Adv. 2015, 5,

90960–90968.

34. Vecino, X.; Barbosa-Pereira, L.; Devesa-Rey, R.; Cruz, J.M.; Moldes, A.B. Optimization of Extraction Conditions and Fatty Acid Characterization of Lactobacillus Pentosus Cell-Bound Biosurfactant/Bioemulsifier. J. Sci. Food Agric. 2015, 95, 313–320.
35. Vecino, X.; Rodríguez-López, L.; Gudiña, E.J.; Cruz, J.M.; Moldes, A.B.; Rodrigues, L.R. Vineyard Pruning Waste as an Alternative Carbon Source to Produce Novel Biosurfactants by Lactobacillus Paracasei. J. Ind. Eng. Chem. 2017, 55.
36. Weschayanwiwat, P.; Scamehorn, J.F.; Reilly, P.J. Surfactant Properties of Low Molecular Weight Phospholipids. J. Surfactants Deterg. 2005, 8, 65–72.
37. Vecino, X.; Barbosa-Pereira, L.; Devesa-Rey, R.; Cruz, J.M.; Moldes, A.B. Optimization of Liquid–Liquid Extraction of Biosurfactants from Corn Steep Liquor. Bioprocess. Biosyst. Eng. 2015, 38, 1629–1637.
38. Vecino, X.; Barbosa-Pereira, L.; Devesa-Rey, R.; Cruz, J.M.; Moldes, A.B. Study of the Surfactant Properties of Aqueous Stream from the Corn Milling Industry. J. Agric. Food Chem. 2014, 62, 5451–5457.
39. Moldes, A.B.; Cruz, J.M.; Devesa, R.; Vecino, X. Method for Separating the Surfactants Present in the Washing Liquors of Corn, and Uses. WO2014044876A1, 27 March 2014.
40. López-Prieto, A.; Martínez-Padrón, H.; Rodríguez-López, L.; Moldes, A.B.; Cruz, J.M. Isolation and Characterization of a Microorganism That Produces Biosurfactants in Corn Steep Water. CYTA J. Food 2019, 17, 509–516.
41. Rincón-Fontán, M.; Rodríguez-López, L.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Influence of Micelle Formation on the Adsorption Capacity of a Biosurfactant Extracted from Corn on Dyed Hair. RSC Adv. 2017, 7, 16444–16452.
42. Rincón-Fontán, M.; Rodríguez-López, L.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Novel Multifunctional Biosurfactant Obtained from Corn as a Stabilizing Agent for Antidandruff Formulations Based on Zn Pyrithione Powder. ACS Omega 2020, 5, 5704–5712.
43. Rincón-Fontán, M.; Rodríguez-López, L.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Design and Characterization of Greener Sunscreen Formulations Based on Mica Powder and a Biosurfactant Extract. Powder Technol. 2018, 327, 442–448.
44. Rincón-Fontán, M.; Rodríguez-López, L.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Study of the Synergic Effect between Mica and Biosurfactant to Stabilize Pickering Emulsions Containing Vitamin E Using a Triangular Design. J. Colloid Interface Sci. 2019, 537, 34–42.
45. Rincón-Fontán, M.; Rodríguez-López, L.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Potential Application of a Multifunctional Biosurfactant Extract Obtained from Corn as Stabilizing Agent of

Vitamin C in Cosmetic Formulations. Sustain. Chem. Pharm. 2020, 16, 100248.

46. Lorena, R.-L.; Rincón-Fontán, M.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Study of Biosurfactant Extract from Corn Steep Water as a Potential Ingredient in Antiacne Formulations. J. Dermatolog. Treat. 2020, 1–8.
47. Piljac, T.; Piljac, G. Use of Rhamnolipids in Wound Healing, Treating Burn Shock, Atherosclerosis, Organ Transplants, Depression, Schizophrenia and Cosmetics. Patent EP 1,889,623A3, 8 April 2009.
48. Desanto, K. Rhamnolipid-Based Formulations. Patent US 7,985,722B2, 26 July 2011.
49. Nickzad, A.; Déziel, E. The Involvement of Rhamnolipids in Microbial Cell Adhesion and Biofilm Development—An Approach for Control? Lett. Appl. Microbiol. 2014, 58, 447–453.
50. Allef, P.; Hartung, C.; Schilling, M. Aqueous Hair and Skin Cleaning Compositions Comprising Biosurfactants. Patent US 9,271,908B2, 1 March 2016.
51. Cox, T.F.; Crawford, R.J.; Gregory, L.G.; Hosking, S.L.; Kotsakis, P. Mild to the Skin, Foaming Detergent Composition. Patent US 8,563,490B2, 22 October 2013.
52. Kulkarni, S.; Choudhary, P. Production and Isolation of Biosurfactant-Sophorolipid and Its Application in Body Wash Formulation. Asian J. Microb. Biotechnol. Environ. Sci. 2011, 13, 217–221.
53. Hagler, M.; Smith-Norowitz, T.A.; Chice, S.; Wallner, S.R.; Viterbo, D.; Mueller, C.M.; Gross, R.; Nowakowski, M.; Schulze, R.; Zenilman, M.E.; et al. Sophorolipids Decrease IgE Production in U266 Cells by Downregulation of BSAP (Pax5), TLR-2, STAT3 and IL-6. J. Allergy Clin. Immunol. 2007, 119, S263.
54. Parry, N.J.; Stevenson, P.S. Personal Care Compositions. Patent EP 2,931,237B1, 4 April 2018.
55. Mimee, B.; Labbé, C.; Pelletier, R.; Bélanger, R.R. Antifungal Activity of Flocculosin, a Novel Glycolipid Isolated from Pseudozyma Flocculosa. Antimicrob. Agents Chemother. 2005, 49, 1597–1599.
56. Fernández-Peña, L.; Guzmán, E.; Leonforte, F.; Serrano-Pueyo, A.; Regulski, K.; Tournier-Couturier, L.; Ortega, F.; Rubio, R.G.; Luengo, G.S. Effect of Molecular Structure of Eco-Friendly Glycolipid Biosurfactants on the Adsorption of Hair-Care Conditioning Polymers. Colloids Surf. B Biointerfaces 2020, 185, 110578.
57. Rodríguez-López, L.; Rincón-Fontán, M.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Biological Surfactants vs. Polysorbates: Comparison of Their Emulsifier and Surfactant Properties. Tenside Surfactants Deterg. 2018, 55, 273–280.
58. Wu, W.; Wang, J.; Lin, D.; Chen, L.; Xie, X.; Shen, X.; Yang, Q.; Wu, Q.; Yang, J.; He, J.; et al. Super Short Membrane-Active Lipopeptides Inhibiting the Entry of Influenza A Virus. Biochim.

Biophys. Acta Biomembr. 2015, 1848, 2344–2350.

59. Gómez-Graña, S.; Perez-Ameneiro, M.; Vecino, X.; Pastoriza-Santos, I.; Perez-Juste, J.; Cruz, J.M.; Moldes, A.B. Biogenic Synthesis of Metal Nanoparticles Using a Biosurfactant Extracted from Corn and Their Antimicrobial Properties. Nanomaterials 2017, 7, 139.
60. Knoth, D.; Rincón-Fontán, M.; Stahr, P.L.; Pelikh, O.; Eckert, R.W.; Dietrich, H.; Cruz, J.M.; Moldes, A.B.; Keck, C.M. Evaluation of a Biosurfactant Extract Obtained from Corn for Dermal Application. Int. J. Pharm. 2019, 564, 225–236.
61. Rodríguez-López, L.; Shokry, D.S.; Cruz, J.M.; Moldes, A.B.; Waters, L.J. The Effect of the Presence of Biosurfactant on the Permeation of Pharmaceutical Compounds through Silicone Membrane. Colloids Surf. B Biointerfaces 2019, 176, 456–461.
62. Das, P.; Mukherjee, S.; Sen, R. Antimicrobial Potential of a Lipopeptide Biosurfactant Derived from a Marine Bacillus Circulans. J. Appl. Microbiol. 2008, 104, 1675–1684.
63. Ferreira, A.; Vecino, X.; Ferreira, D.; Cruz, J.M.M.; Moldes, A.B.B.; Rodrigues, L.R.R. Novel Cosmetic Formulations Containing a Biosurfactant from Lactobacillus Paracasei. Colloids Surf. B Biointerfaces 2017, 155, 522–529.
64. Vecino, X.; Rodríguez-López, L.; Ferreira, D.; Cruz, J.M.; Moldes, A.B.; Rodrigues, L.R. Bioactivity of Glycolipopeptide Cell-Bound Biosurfactants against Skin Pathogens. Int. J. Biol. Macromol. 2018, 109.
65. Rodríguez-López, L.; Rincón-Fontán, M.; Vecino, X.; Cruz, J.M.; Moldes, A.B. Preservative and Irritant Capacity of Biosurfactants From Different Sources: A Comparative Study. J. Pharm. Sci. 2019, 108, 2296–2304.
66. Takahashi, M.; Morita, T.; Fukuoka, T.; Imura, T.; Kitamoto, D. Glycolipid Biosurfactants, Mannosylerythritol Lipids, Show Antioxidant and Protective Effects against H(2)O(2)-Induced Oxidative Stress in Cultured Human Skin Fibroblasts. J. Oleo Sci. 2012, 61, 457–464.
67. Kitagawa, M.; Suzuki, M.; Yamamoto, S.; Sogabe, A.; Kitamoto, D.; Imura, T.; Fukuoka, T.; Morita, T. Biosurfactant-Containing Skin Care Cosmetic and Skin Roughness-Improving Agent. Patent US 20,100,004,472, 7 January 2010.
68. Kitagawa, M.; Nishimoto, K.; Tanaka, T. Cosmetic Pigments, Their Production Method, and Cosmetics Containing the Cosmetic Pigments. Patent US 9,181,436B2, 10 November 2015.
69. Kitamoto, D.; Yanagishita, H.; Shinbo, T.; Nakane, T.; Kamisawa, C.; Nakahara, T. Surface Active Properties and Antimicrobial Activities of Mannosylerythritol Lipids as Biosurfactants Produced by Candida Antarctica. J. Biotechnol. 1993, 29, 91–96.
70. Owen, D.; Fan, L. Oligomeric Biosurfactants in Dermatocosmetic Compositions. U.S. Patent No. 8,431,523, 30 April 2013.

71. Kanlayavattanakul, M.; Lourith, N. Lipopeptides in Cosmetics. Int. J. Cosmet. Sci. 2010, 32, 1–8.
72. Lourith, N.; Kanlayavattanakul, M. Natural Surfactants Used in Cosmetics: Glycolipids. Int. J. Cosmet. Sci. 2009, 31, 255–261.

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