Surfactants of microbial origin and its application in foods

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Received 11 November, 2019; Accepted 9 January, 2020

Surfactants are petroleum-derived compounds widely used globally in industrial areas such as pharmaceuticals, cosmetics, textile, among others. The synthesis and use of these compounds has generated environmental pollution, putting public health at risk. For several years, the synthesis of surfactants has been reported by various microorganisms called biosurfactants. Biosurfactants have been shown to reduce surface tension using emulsifying agents, in addition to presenting biodegradability and low toxicity. The objective of this mini review document is to deal with aspects related to the classification, producing microorganisms, physicochemical and biological properties of biosurfactants that have placed them as a potential biotechnological alternative regarding chemical counterparts in various industrial areas, including food production.

Key words: Amphiphilic, antimicrobials, biotechnology, biosurfactant, food safety, glycolipids.

INTRODUCTION

Surfactants are versatile chemical agents, which exert their effect on the contact surface between two immiscible phases (interface), through the reduction of surface tension (Cabanes, 2014). Because of their ability to reduce surface tension, these compounds are commonly used as detergents, foaming agents, emulsifiers, plasticizers, solubilizers, dispersants or humectants in various areas ranging from home to industrial areas such as textile, food, agriculture, mining, pharmaceutical, petroleum, cosmetics, paint, paper, among others, and its demand in recent years has had a considerable increase (Cruz and Del Valle, 1987; Cabanes, 2014; Martinez et al., 2015; Varjani and Upasani, 2017; Akbari et al., 2018).

Surfactants are amphiphilic molecules made up of hydrophilic and hydrophobic fractions that divide at the interface between fluid phases with different polarity and hydrogen bonds (oil / water or air / water interfaces); this allows reducing surface and interfacial tension and forming micro emulsions, favoring the solubility of hydrophobic compounds in water (Varjani and Upasani, 2017).

Most of the production and availability of surfactants are derived from the petrochemical industry, estimating that these compounds represent between 70% and 75% of active tensions used in industrialized nations (Campos et al., 2013; Akbari et al., 2018); this has contributed to greater environmental pollution with possible effects...
on public health, which is why there is currently the
human and environmental challenge of developing
strategies to replace petroleum, coal and natural gas-
based products with renewable, biodegradable and
sustainable energies (Akbari et al., 2018).

In the search for alternatives that favor the reduction of
environmental pollution in the field of surfactants, the
biosurfactants (BS) are found (Nitschke and Silva, 2018).
BSs are compounds that have broad advantages
compared to their chemical counterparts, such as:
biodegradability, low toxicity, specificity, selectivity,
stability under adverse conditions (pH and salinity), low
critical micellar concentration (CMC), detergent capacity,
emulsifier, solubilizer, foaming, biological activity,
biocompatibility and digestibility, in addition to being
synthesized from relatively inexpensive carbon sources
or industrial waste (Cortés et al., 2013; Sobrinho et al.,
2013; Nitschke and Costa, 2014; Chavez et al., 2016;
Martinez et al., 2015; Santos et al., 2016; Varjani and
Upasani, 2017; Bustos et al., 2018; Das et al., 2018).
This has catapulted them as potential alternatives to
surfactants of synthetic origin and its use in various
industrial areas such as oil recovery, pharmaceutical,
food, cosmetics, agricultural and livestock sectors
(Martinez et al., 2015; Chavez et al., 2016; Bustos et al.,
2018).

The objective of this mini review document is to
address a brief and general description of surfactants of
microbial origin covering aspects such as their
classification, producing organisms, as well as
physicochemical and biological properties that have
made them to be considered for their potential
biotechnological alternative application in the food
industry.

Biosurfactants

Biosurfactants (BS) are molecules with surface activity
capable of reducing the surface tension of water; it is
considered a good biosurfactant when it is capable of
reducing the surface tension of water from 72 mN / m to
35 mN / m and the interfacial tension of water / n-
hexadecane from 40 mN / m to 1 mN / m (Sourav et al.,
2015; Chavez et al., 2016).

BS are secondary metabolites synthesized, in the
stationary phase of microbial growth, by a variety of
bacteria, filamentous fungi and yeasts in various
substrates, mainly in those immiscible in water such as
oils, alkanes, sugars and water, being secreted
extracellularly or remain bound to cellular components
(Cortés et al., 2013; Sourav et al., 2015; Chavez et al.,
2016; Becerra and Horna, 2016; Varjani and Upasani,
2017). These biomolecules are compounds of
amphiphilic nature because they are formed from a polar
or hydrophilic part, consisting of mono-, oligo- or
polysaccharides, amino acids, peptides or proteins, and
another non-polar or hydrophobic, which are commonly
saturated, unsaturated, hydroxylated fatty acids, or fatty
alcohols (Chavez et al., 2016; Nitschke and Silva, 2018;
Bustos et al., 2018; Kubicki et al., 2019).

BS are compounds of structural diversity classified
according to: 1. Their chemical structure in: glycolipids,
lipoproteins or lipopeptides, phospholipids, fatty acids or
natural lipids, polymeric surfactants and surfactant
particles (Santos et al., 2016; Varjani and Upasani,
2017), and 2. Based on its molecular weight: (a) low
molecular weight compounds such as: glycolipids,
lipopeptides, short chain grade acids and phospholipids,
and (b) high molecular weight compounds such as:
polymeric surfactants, lipopolysaccharide surfactant
particles or lipoproteins considered bioemulsifiers
(Sourav et al., 2015; Varjani and Upasani, 2017; Kubicki
et al., 2019; Fenibo et al., 2019). Stressing that BS reduces
surface and interfacial tension while bioemulsifiers are
more effective in stabilizing oil-in-water emulsions
(Varjani and Upasani, 2017).

Glycolipids are the largest class of biosurfactants
widely known and studied; these compounds contain in
their structure carbohydrates (hydrophilic fraction) linked
to long chains of aliphatic or hydroxyaliphatic acids
(hydrophobic fraction) by an ester group. Within the
group of glycolipids there are rhamnolipids, trehalolipids
and sophorolipids (Vijayakumar and Saravanan, 2015;
Santos et al., 2016).

The physiological function of the BS in the producing
cell is not fully understood yet, but it is believed that these
compounds are synthesized and released to facilitate the
transportation, absorption and metabolism of hydrophobic
compounds by solubilization and emulsification
processes, as well as acting as biocidal agents in the
survival and competition in ecological niches (Dhanarajan
and Sen, 2014; Chavez et al., 2016; Santos et al., 2016;
Fenibo et al., 2019).

On the other hand, the synthesis of BS can be affected
in quality and quantity by factors such as the nature of
the carbon source (lipophilic or hydrophilic), nitrogen
source, pH, temperature, aeration, agitation, metal ion
concentration, incubation time, culture strategy (batch,
fed-batch, continuous), dilution rate and cell stress
conditions like low concentration of the nitrogen source
(Saharan et al., 2011; Sourav et al., 2015; Usman et al.,
2016; Santos et al., 2016; Fenibo et al., 2019).

Some methods have been developed for the search
and detection of BS-producing microorganisms in nature
such as phenotypic tests that is, hemolytic activity,
emulsification index, blue agar plate method, hydrocarbon
agar plate, drop collapse, or oil spreading; also, there are
molecular techniques through the polymerase chain
reaction (PCR); while, on the other hand, physicochemical
and instrumental methods have been developed focused
on the recovery, purification and characterization of these
compounds that involve the use of organic solvents, acid
precipitation, alkaline precipitation, crystallization, filtration,
ultrafiltration, lyophilization, centrifugation, layer chromatography fine, ion exchange chromatography, high pressure liquid, gas chromatography coupled to mass spectrometry, infrared, nuclear magnetic resonance, matrix assisted laser desorption / ionization with ion detector, and mass spectrometry (MALDI-TOF MS) (Satpute et al., 2010; Saharan et al., 2011; Sachdev and Cameotra, 2013; Sourav et al., 2015; Mnif and Ghribi, 2016; Santos et al., 2016; Varjani and Upasani, 2017; Fenibo et al., 2019).

**BIOSURFACTANTS IN FOOD**

At the level of primary food production, the yield of agricultural land is negatively affected by the presence of organic and inorganic pollutants that give abiotic stress in crop plants. For this reason, and in order to increase the quality of soils contaminated by hydrocarbons and heavy metals, it is necessary to implement bioremediation processes to improve the soils dedicated to agriculture. Thus, microorganisms producing biosurfactants, or biosurfactants only, can be used to eliminate of hydrocarbons, pesticides and heavy metals in contaminated soils (Sachdev and Cameotra, 2013; Usman et al., 2016; Rangarajan and Narayanan, 2018).

Glycolipid-type BS such as sophorolipids, cellobiose lipids, mannosylerythritol lipids and rhamnolipids has reported agricultural utility through their growth-inhibiting effects of phytopathogenic fungi (Sclerotinia sclerotiorum, Phomopsis helianthi, Botrytis cinerea, Alternaria tomatophila, Alternaria solani, among others). It has also been observed that they are involved in the stimulation of plant signaling and immunity processes, while rhamnolipids synthesized by Pseudomonas sp., in studies on insects have shown a pesticidal effect, being therefore considered as biocontrol agents for pests (Mnif and Ghribi, 2016). Meanwhile, lipopeptide type BS produced by species of the genus Bacillus presented growth inhibition of phytopathogens, such as Fusarium spp., Aspergillus spp., Trichoderma spp., and Biopolaris sorokiniana, opening the alternative for using thus in biocontrol activities (Sachdev and Cameotra, 2013; Hafeez et al., 2019).

In food processing, one of the main goals is to provide safety and good sensory characteristics (Nitschke and Silva, 2018). Any substance that modifies the distinctive property of food when added is considered a food additive. The purpose of incorporating additives is to improve and maintain the nutritional value, texture, safety, taste and appearance of food. However, during some years there has been a change in the tendency of consumers towards natural additives over synthetics, along with the growing concerns about environmental and health contamination, it has created demand for natural or green additives in food, opening the door for BS due to their different shown properties (Nitschke and Silva, 2018).

Within the applications in the processing and food industry, the BS intervene as detergents, thickeners, foaming agents, thickeners, and emulsifying agents, with the latter being possible by reducing the surface and interfacial tension, facilitating the formation and stabilization of emulsions (Nitschke and Costa, 2007; Shoeb et al., 2013; Sourav et al., 2015; Vijayakumar and Saravanavan, 2015; Santos et al., 2016). Thus, in the food industry, BS is used in two main ways: (a) In the treatment/cleaning of surfaces in contact with food, and (b) food additives/ingredients (Nitschke and Silva, 2018).

BSs have been considered for potential uses as formulation ingredients to control the aggregation of fat globules, stabilization of aerated systems, improvement of the texture and shelf life of products containing starch, modification of the rheological properties of wheat mass and improving the consistency and texture of fat-based products; while in bakery and ice cream formulations, these compounds act by controlling consistency, slowing aging and solubilizing oil flavoring and flavoring (Nitschke and Costa, 2007, Vijayakumar and Saravanavan, 2015). It has been reported that Candida utilis produces a bioemulsifier used in processed salad dressings and Saccharomyces cerevisiae produces a mannanprotein capable of stabilizing water / oil emulsions in biscuits, mayonnaise and ice cream (Santos et al., 2016). Other yeasts such as Hansenula anomala, Rhodotorula graminis, Rhodosporidium diobovatum, red algae such as Porphiridium cruentum, and species of bacteria of the genus Klebsiella sp., and Acinetobacter calcoaceticus have been reported to produce extracellular bioemulsifiers with a better stabilizing activity than the Arabic gum and carboxycellulose (Campos et al., 2013).

BSs are also considered in the foods area as antiadhesive and antimicrobial agents (Nitschke and Costa, 2007; Cortés et al., 2013; Akbari et al., 2018). Biofilms are heterogeneous communities of microorganisms that adhere and colonize a biotic or abiotic surface, where extracellular material produced is included. These biofilms are also considered as a form of resistance against antimicrobials and adverse conditions by the microorganisms that constitute them (Nitschke and Costa, 2007, 2014; Nitschke and Silva, 2018). The biofilms present in the food processing and production surfaces are of relevance, because when they are established they can cause the obstruction of pipes, corrosion of equipment, and the reduction of the efficiency of the temperature transfer systems; besides, they are also a source of contamination that can lead to food spoilage and disease transmission (Nitschke and Costa, 2007, 2014). Therefore, the BSs contribute to the breakdown and prevent the formation of biofilms, making it impossible for the microorganisms to adhere and colonize food contact surfaces, thus improving the quality and safety of food products (Nitschke and Costa, 2007; Cortés et al., 2013; Akbari et al., 2018).
Table 1. Types of biosurfactants and producing microorganisms.

<table>
<thead>
<tr>
<th>Type of biosurfactant</th>
<th>Producer microorganism</th>
</tr>
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<tbody>
<tr>
<td><strong>Glycolipids</strong></td>
<td></td>
</tr>
<tr>
<td>Rhamnolipids</td>
<td>Pseudomonas sp.</td>
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<tr>
<td></td>
<td>Acinetobacter calcoaceticus</td>
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<tr>
<td></td>
<td>Serratia rubidea</td>
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<tr>
<td>Trehalose lipids</td>
<td>Rhodococcus erythropolis</td>
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<td></td>
<td>Arthrobacter sp.</td>
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<tr>
<td></td>
<td>Nocardia sp.</td>
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<td></td>
<td>Corynebacterium sp.</td>
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<td></td>
<td>Tsukamurella spumae</td>
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<td></td>
<td>Tsukamurella pseudospumae</td>
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<tr>
<td>Sophorolipids</td>
<td>Candida apícola</td>
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<td></td>
<td>Candida bombicola</td>
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<tr>
<td>Mannosylethritol lipids</td>
<td>Ustilago maydis</td>
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<tr>
<td>Celobiose lipids</td>
<td>Ustilago zeae</td>
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<tr>
<td></td>
<td>Ustilago maydis</td>
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<tr>
<td>Xylolipids</td>
<td>Lactobacillus helveticus</td>
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<tr>
<td></td>
<td>Lactococcus lactis</td>
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<td></td>
<td>Enterococcus faecium</td>
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<tr>
<td>Lipopeptides and lipoproteins</td>
<td></td>
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<tr>
<td>Subtilisin/surfactin/iturin/fengycin</td>
<td>Bacillus subtilis</td>
</tr>
<tr>
<td>Lichenysin</td>
<td>Bacillus licheniformis</td>
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<tr>
<td>Viscosin</td>
<td>Pseudomonas fluorescens</td>
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<tr>
<td>Serrawettin</td>
<td>Serratia marcescens</td>
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<tr>
<td>Polymyxin</td>
<td>Bacillus polymyxa</td>
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<tr>
<td>Fatty acids</td>
<td>Nocardia erythropolis</td>
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<tr>
<td></td>
<td>Arthrobacter paraffincus</td>
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<td></td>
<td>Corynebacterium lepus</td>
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<td></td>
<td>Penicillium spiculisporum</td>
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<tr>
<td>Fosfolipids</td>
<td>Acinetobacter sp.</td>
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<tr>
<td></td>
<td>Corynebacterium lepus</td>
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<td></td>
<td>Thiobacillus thiooxidans</td>
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<tr>
<td>Polimeric surfactants</td>
<td></td>
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<tr>
<td>Emulsan/biodispersan</td>
<td>Acinetobacter calcoaceticus</td>
</tr>
<tr>
<td>Liposan</td>
<td>Candida lipolytica</td>
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<tr>
<td>Yasan</td>
<td>Yarrowia lipolytica</td>
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<tr>
<td>Alasan</td>
<td>Acinetobacter radioresistens</td>
</tr>
<tr>
<td>Mannoproteins</td>
<td>Saccharomyces cerevisiae, Klyveromyces marxianus</td>
</tr>
<tr>
<td>Carbohydrate-lipid-protein</td>
<td>Pseudomonas fluorescens</td>
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</tbody>
</table>
The antimicrobial activity of the BSs is potentially useful in food production as conservative agents. Studies show the utility in the control of microbial growth including that of human pathogens (Cortés et al., 2013; Shoeb et al., 2013; Nitschke and Costa, 2014; Nitschke and Silva, 2018).

The mechanism involved in antimicrobial activity by BSs is not well clarified yet; however, it is estimated that these compounds act by altering the permeability of the cytoplasmic membrane causing cellular damage, derived from their amphipathic nature that allows interaction with constituent phospholipids of microbial cell membrane (Shoeb et al., 2013; Cortés et al., 2013; Nitschke and Costa, 2014). In related studies, Sambanthamoorthy et al. (2014) determined that BS produced by lactic bacteria, such as Lactobacillus jensenii and Lactobacillus rhamnosus presented anti-adhesive and antimicrobial effect at concentrations between 25 and 50 mg/ml against multi-resistant pathogenic strains such as Acinetobacter baumannii, Escherichia coli, and Staphylococcus aureus. Meanwhile, Mani et al. (2016) reported that the glycolipid-type BS produced Staphylococcus saprophyticus and showed antimicrobial activity against bacteria and pathogenic fungi in humans such as Klebsiella pneumoniae (4 µg/mL), E. coli (12 µg / mL), Pseudomonas aeruginosa (32 µg/mL), Vibrio cholerae (64 µg/mL), Cryptococcus neoformans (32 µg/mL) and Candida albicans (32 µg/mL); in addition, this BS was evaluated at a range of pH (3-9) and temperature (30 - 80°C), highlighting the promising use of these compounds in different industrial areas.

On the other hand, BSs favor the activity of probiotic strains (Cortés et al., 2013; Fariq and Saeed, 2016). Probiotics are defined as living microorganisms that when administered in adequate amount confer different benefits for the health of the consumer by preventing and treating different gastrointestinal disorders, allergies, reducing lactose intolerance, in addition to having modulation effects on the immune response and cholesterol (Cortés et al., 2013; Fariq and Saeed, 2016; Saha et al., 2018). Lactic acid bacteria (LAB) are widely distributed in nature and are an important part in the production of various foods in addition to being considered probiotics, some species of the genera that are part of this group are: Lactobacillus, Bifidobacteria, Enterococcus, Pediococcus, Leuconostoc and Streptococcus (Parra, 2010; Ramírez et al., 2011; Cortés et al., 2013; Sharma et al., 2015; Fariq and Saeed, 2016; Cortés and Barrón, 2017; Hajfarajollah et al., 2018). Probiotics can release various metabolites (free fatty acids, hydrogen peroxide, peptides, biosurfactants, diacetylated compounds, lactic acid, and bacteriocins) that may affect specific pathogenic microorganisms, thus benefiting the host and maintaining the balance of native microbial communities (Cortés et al., 2013; Sharma and Singh, 2014; Fariq and Saeed, 2016; Cortés and Barrón, 2017; Hajfarajollah et al., 2018).

Lipid oxidation tends to reduce the quality and safety of food through the development of toxic compounds resulting in rancidity and perception of unpleasant tastes and odors; therefore, antioxidants are relevant food additives focused on preventing lipid oxidation, and improving the shelf life of food (Nitschke and Silva, 2018). Some BS have exhibited antioxidant properties, as observed in the case of glycolipids called mannosylethritol lipids synthesized by yeasts of the genus Pseudozyma and its free radical neutralizing effect analyzed through the method of 1,1-diphenyl-2-picrylhydrazine (DPPH) (Takahashi et al., 2012). On the other hand, an emulsifying polysaccharide of Klebsiella shows inhibition of the self-oxidation of soybean oil by encapsulation processes (Campos et al., 2013). B. subtilis produces a lipopeptide capable of neutralizing free radicals and that can be used as a natural antioxidant in foods by protecting cells from oxidative stress (Yağcın and Çavuşoğlu, 2010). Meanwhile, Bacillus methylotrophicus produces a lipopeptide with chelating activity for iron ions and antioxidant activity above commercial products such as Ethylene Diamine Tetra-Acetate (EDTA), and hydroxybutylanisole (BHA) that makes it an alternative potential as an antioxidant agent (Jemil et al., 2017).

## Table 1. Contd.

<table>
<thead>
<tr>
<th>Surfactant particles</th>
<th>Acinetobacter calcoaceticus</th>
<th>Phormidium J-1</th>
</tr>
</thead>
</table>


**Production of Biosurfactants from Agroindustrial Waste**

Despite the advantages of the BS with respect to their counterparts derived from the petrochemical industry, some drawbacks of these biomolecules are: 1) Acquisition of products with a high degree of purity is difficult due to
the need for steps of consecutive purification on the culture; 2) Superproductive species are rare in such a way that the known producing species are not capable of producing high surfactant yields, and they require a complex culture medium; 3) Biosynthesis regulation is not fully understood as well; hence these biomolecules can be produced as secondary metabolites or in association with microbial growth; 4) Increased productivity is often affected by foaming, which requires the use of a diluted medium, and 5) Large-scale production is of high economic costs (Sobrinho et al., 2013; Fenibo et al., 2019).

Commonly, a large part of biotechnological processes requires high cost inputs, so it is necessary to ensure optimum product performance at the lowest cost through economical materials. On the other hand, microorganisms produce very low amounts of active tense and the subsequent processing of biotechnological products costs between 60 and 80% of the total production expenditure; therefore, in most cases, marketable BS products are economically high and it is important to reduce production costs through the use of economic and renewable substrates (Banat et al., 2014; Banat and Thavasi, 2018).

The relationship between BS and food is that different agroindustrial wastes, due to their high sugar and lipid content, can be used as a substrate by microorganisms producing these compounds. In this way, they are considered economic processes and cultivation conditions (impediment to the production of large scales), in addition to environmental care, recycling and recovery of this waste; being wastes from the oil, dairy, distiller, food-processing by-products, and carbohydrate-rich wastes mainly intended for the production of BS (Gautam and Tyagi, 2006; Nitschke and Costa, 2007; Saharan et al., 2011; Campos et al., 2013; Banat et al., 2014; Das et al., 2018; Singh et al., 2019).

Conclusion

The biosurfactants are compounds of biological origin synthesized by bacteria, fungi and yeasts during their growth mainly in hydrophobic carbon sources with the ability to reduce surface tension between immiscible liquids. The BS have shown a variety of physicochemical and biological properties (antimicrobial, anti-adhesive, biodegradability, low toxicity, among others) that make them potential alternatives for use regarding their chemical-type counterparts (toxic and contaminating) for using in various industrial areas including in food. The BS due to their different physicochemical and biological properties, are promising alternatives to synthetic surfactants. However, there are still disadvantages for its use at large scales, and it is such that the synthesis of BS is at low yields and high production costs, so research should focus on the search for producing and hyper-producing strains, improve and optimize conditions of microbial biosynthesis, as well as extraction and purification techniques through the best knowledge of biochemical and genetic processes (Chavez et al., 2016; Akbari et al., 2018). For the application of BS in the production, processing and preservation of food, further studies should be generated regarding the physicochemical and biological properties presented in addition to its safety, an essential quality that an additive must have for its use in food.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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