RESERCH ARTICLE

PROSPECTIVE BIOSURFACTANT APPLICATIONS IN FOOD INDUSTRY – OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Biosurfactant are surface active compounds released by microorganisms. They are biodegradable non-toxic and ecofriendly materials. Biosurfactant have paying attention by many scientists because of their low toxicity, ecological acceptability. The increasing environmental concern about chemical surfactants triggers attention to microbial derived surface-active compounds essentially due to the low and biodegradable nature. At present, biosurfactants are predominantly used in remediation of pollutants; however, they show potential applications in many sectors of Food Industry. Associated with emulsion farming and stabilization, antiadhensive and antimicrobial activities are some properties of biosurfactant, which could be explored in food processing and formulation. Potential applications of microbial surfactants in food area and the use of agroindustrial wastes as alternative substrates for their production are discussed.

Key words: Biosurfactant, Ecofriendly, Low toxicity, Antiadhensive, Antimicrobial

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INTRODUCTION

Surfactants are amphiphilic compounds containing both hydrophilic and lipophilic moietys. Surfactants can be derived from both chemically based (“chemical surfactants” or “synthetic surfactants”) and biologically based (“biosurfactants”) sources [Urum et al., 2004]. Biosurfactant is a surfactant directly derived from a natural source (i.e., from a plant, animal or microorganism), but this term is often used in a broader sense to include surfactants synthesized from natural raw materials. They possess the characteristic property of reducing the surface and interfacial tension using the same mechanisms as chemicals surfactants (Singh et al., 2007). Microorganisms showed a high capacity of synthesizing a wide range of surface-active compounds, generally called biosurfactants. Biosurfactant reduce surface tension, Critical Micelle Concentration (CMC) and interfacial tension in both aqueous solutions and hydrocarbon mixtures (Rahman et al., 2002; Banat, 1995). Non-toxic nature, excellent biodegradability, high surface/interfacial activity, low toxicity, high thermal/chemical stability, production from renewable resources and the ability to form micro emulsions (Long et al., 2013; Nguyen et al., 2011). These compounds are mainly classified according to their Surfactants are widely used for industrial, agricultural, food, cosmetics and pharmaceutical molecular weight, physico-chemical properties and mode of action (Radhika et al., 2014; Banat et al., 2014). Application however most of these compounds are synthesized chemically and potentially cause environmental and toxicology problem due to the recalcitrant and persistent nature of these substances (Makkar et al., 2003). Biosurfactant are biocompatibility and digestibility which allows their application in cosmetic, pharmaceuticals and as functional food additives (Kosaric et al., 2001). Their properties and potential application, have encouraged many researchers to improve their production and have become the most investigated biosurfactants (Zgola-Grzeskowski et al., 2011). Surfactants are widely used for industrial, agricultural, food, cosmetics and pharmaceutical application however most of these compounds are synthesized chemically and potentially cause environmental and toxicology problem due to the recalcitrant and persistent nature of these substances (Makkar et al., 2003). Rhamnolipids from Pseudomonas aeruginosa, surfactin from Bacillus subtilis, emulsan from Acinetobacter calcoaceticus and sophorolipids from Candida bombicola are some examples of microbial-derived surfactants. Nowadays, the applications of biosurfactants mostly focused on bioremediation of pollutants (Mulligan, 2005). Currently, according to the literature no research works have been focused on applications of biosurfactants in foods. Researchers also stated that, these microbial compounds (biosurfactants) exhibit a variety of useful properties for the food industry specially as emulsifiers, foaming, wetting, solubilizers (Banat et al., 2000), antiadhensive
and antimicrobial agents (Singh and Cameotra, 2004). The major goal for the food processing industries is to provide safe, wholesome and acceptable food to the consumer and control of microorganisms (Baggen-Ravn et al., 2003; Karthik et al., 2013). Moreover, an increasing consciousness among consumers demands for reducing the use of artificial or chemically synthesized compounds by replacing it for more natural food ingredients and additives (Shepherd et al., 1995). The use of artificial and/or chemically synthesized compounds changes the natural flavor, texture and nature of the food (Rasooli, 2007). Despite the advantages demonstrated by biosurfactants, few reports are available regarding their use on food products and food processing. To manufacture commercial products with long shelf lives and resistances to environmental stresses, stabilizers are therefore required (McClements 2015). Numerous types of stabilizers are available to improve emulsion stability, including emulsifiers, thickeners, weighting agents, and ripening inhibitors. In this article, we primarily focus on emulsifiers because these ingredients are critical to the proper performance of any emulsion-based product. The demand for the use of natural and sustainable ingredients in food products is growing because of increasing awareness of the importance of healthy eating and environmental sustainability (Karaca et al. 2015; Lam and Nickerson 2013). For this reason, many food manufacturers are trying to replace synthetic emulsifiers with natural alternatives, as well as trying to replace animal-based ingredients with plant-based ingredients (Baines and Seal 2012).

Review of Literature

Biosurfactant as food additives

The particular combination of characteristics such as emulsifying, anti adhesive and antimicrobial activities presented by biosurfactants suggests their application as multipurpose ingredients or additives. The development of these biomolecules should represent, in the near future, an increasing significant part of the market for food additives.

Applications of Biosurfactant in dairy industry

Surfactin are biodegradable and non-toxic compounds so they can be used in dairy industry (Krishnaswamy, 2008) for the following properties.

It increases quality, improves overrun and organoleptic attributes. Huang et al. (2009) demonstrated that Salmonella enteritidis strain sensitive to 6.25 μg/mL of surfactin. This was done by Agar well diffusion test method 6.25 μg of surfactin added to wells it shows clear zone to Salmonella enteritidis. Then demonstrated that when surfactin was added in milk in the amount 6.25 μg/mL containing 7 log counts of Salmonella enteritidis, counts reduced by 6 logs. Meena and Kanwar (2015) showed surfactin gives anti adhesive activity by inhibiting the biofilm formation by two selected pathogenic strains of Salmonella aureus and E.coli by 97% and 90% dairy cans and vats. Biosurfactants have been used for various food processing application but they usually play a role as food formulation ingredient and anti-adhesive agents, as food formulation ingredient they promote the formation and stabilization of emulsion due to their ability to decrease the surface and interfacial tension. It is also used to control the agglomeration of fat globules, stabilize aerated systems, improve texture and shelf -life of starch-containing products, modify rheological properties of wheat dough and improve consistency and texture of fat based products (Krishnaswamy et al., 2008).

Emulsifiers

Food makers use emulsifiers to reduce the surface tension between two immiscible phases at their interface allowing them to mix (Shepherd et al., 1995). Biosurfactants exhibit surface active and emulsifier action, there is a great potential market for effective biosurfactants in the food industry not only due to their surface activity, but also for their environmental friendly nature (Mohan et al., 2006), low toxicity (Flasz et al., 1998).

Antimicrobial Agent

A wide range of biosurfactants has shown antimicrobial activity against bacteria, yeast, fungi, algae, and viruses (Nitschke and Costa 2007). Among biosurfactants, lipopeptide from the widely reported class having antimicrobial action. The genus Bacillus is responsible for producing the most well-known lipopeptides biosurfactants. B. subtilis produces the first biosurfactant presenting this antimicrobial property, that is, surfactin (Das et al., 2008). It also produces other lipopeptides with the same property: fengycin, iturin, bacillomycins, and mycosubtilins (Das et al., 2008).

Antiadhesive Agent

It is important to review some concepts to understand why one would use the antiadhesive properties of biosurfactants in the food industry. Usually, in nature, bacteria do not stand as alone cells, but they organize themselves as communities, which may be more or less structuralized. (Rodrigues et al., 2004) studied the influence of two biosurfactants produced by probiotic bacteria (Lactococcus lactis and Streptococcus thermophilus) biofilms development by Streptococcus epidermidis. salvarius, Streptococcus aureus, Rothia dentocariosa, Calbicans, and C.tropicalis in voice prostheses. Both biosurfactants showed antimicrobial activity but, depending on the microorganism, they presented different concentrations. Surfactants provide multifunctional properties for food additives as emulsifiers, dispersants, wetting agents and solubilizers in foods which contain fats and oils such as baked goods, dairy foods, salad dressings, shortenings and margarine. Researchers also stated that, these microbial compounds (biosurfactants) exhibit a variety of

Yeh et al. (2005) demonstrated biosurfactant has the best emulsion stability and concentration of 0.16g/L when added to ice cream mix over lecithin (1g/L).
useful properties for the food industry especially as emulsifiers, foaming, wetting, solubilizers (Banat et al., 2000), antiadhesive and antimicrobial agents (Singh and Cameotra, 2004). The major goal for the food processing industries is to provide safe, wholesome and acceptable food to the consumer and control of microorganisms (Baggren-Ravn et al., 2003; Karthik et al., 2013). Moreover, an increasing consciousness among consumers demands for reducing the use of artificial or chemically synthesized compounds by replacing it for more natural food ingredients and additives (Shepherd et al., 1995).

The use of artificial and/or chemically synthesized compounds changes the natural flavor, texture and nature of the food (Rasooli et al., 2007). The present study aimed to determine antimicrobial activity of biosurfactants derived from bacterial strains such as Saccharomyces cerevisiae and Pseudomonas aeruginosa and its applications on fruit salads. The maximum antimicrobial effect of biosurfactant produced by Pseudomonas aeruginosa may be due to the presence of Rhamnolipids (Toribio et al., 2010). Generally, the Rhamnolipids molecules of rhamnose are linked to β-hydroxy-decanoic acid and they have many industrial applications. Da rosa et al. (2010) also reported that the biosurfactant production by P. aeruginosa DS10-129 and P. aeruginosa LBM10 have rhamnolipid type biosurfactant. Abalos et al. 2001 reported that, the rhamnolipid mixture obtained from P. aeruginosa showed inhibitory activity against the bacteria (Escherichia coli, Micrococcus luteus and Alcaligenes faecalis, Serratia marcescens, Mycobacterium phlei and Staphylococcus epidermidii) and fungi (Aspergillus niger, Chaetomium globosum, Penicillium crysogenum, Aureobasidium pullulans, Botrytis cinerea and Rhizoctonia solani) in various concentrations. (Bodour et al., 2004) have recently described a new class of biosurfactants named flavolipids produced by a soil isolated Flavobacterium sp. The new surfactant showed strong surface activity and emulsifying ability, and exhibits a polar moiety that features citric acid. In dairy products (soft cheese and ice creams) the addition of emulsifiers improves the texture and creaminess. This quality is of special value for low-fat products (Rosenberg and Ron., 1999). A lipopeptide obtained from Bacillus subtilis able to form stable emulsions with soybean oil and coconut fat, suggesting its potential as emulsifying agent in foods (Nitschke and Pastore,., 2006). A large variety of Bacillus subtilis strains produces lipopeptide biosurfactants which possess a high surfactant activity such as surface active properties and antibacterial activity (Rashedi et al., 2005). They possess the characteristic property of reducing the surface and interfacial tension using the same mechanisms as chemicals surfactants (Singh et al., 2007).

Biosurfactant and Bioemulsifier

A number of small surface-active molecules can be isolated from natural sources, e.g., glycolipids, lipoproteins, and lipopeptides (De et al., 2015, Varvaresou and Iakovou 2015). These molecules are typically either extracted from plant materials or produced by fermentation using specific microorganisms (bacteria, yeasts, or fungi) (De et al. 2015, Uzoigwe et al., 2015). In both cases, the biosurfactants typically have to be isolated from a complex mixture of other molecules and then purified before they can be used as food ingredients.

Molecular and physicochemical characteristics

Biosurfactants are that they are natural, biodegradable, and sustainable and often have low toxicity (Kralova and Sjoblom 2009, Uzoigwe et al. 2015). Some examples of biosurfactants include glycolipids (sophorolipids, rhamnolipids, and trehalose lipids) and lipopeptides (surfactin, iturin, and fengycin) (Uzoigwe et al., 2015). A few studies have investigated the potential use of bioemulsifiers in food systems, e.g., mannoproteins (da Silva Araujo et al. 2014, Torabizadeh et al. 1996) and hydrophobins (Lumsdon et al. 2005, Tchuenbou-Magaia et al. 2009).

Emulsion formation

In this section, only the properties of a select number of biosurfactants and bioemulsifiers that may have potential application within the food industry are discussed: saponins, sophorolipids, rhamnolipids, and mannoproteins.

Saponin

They are a broad class of natural surface-active molecules that have hydrophilic regions (e.g., sugar groups) and hydrophobic regions (e.g., phenolic structures) on the same molecule (Mitra and Dungan 1997, Sidhu and Oakenfull 1986). Although they can be isolated from different natural sources, the most commonly used saponins in the food industry are extracted from the bark of the Quillaja saponaria tree. Indeed, a food emulsifier based on the quillaja saponin extract is already sold under the trade name Q-Naturale R for utilization in food and beverage products (Ingredion, Bridge water, NJ). This ingredient is provided in both powdered and liquid forms that can be conveniently incorporated into food. Quillajas saponin absorb to water interfaces and reduce the interfacial tension, and are capable of forming and stabilizing oil-in-water emulsions (Yang et al., 2013). Saponin based emulsifiers (Q-NaturaleR) are commercially available and are already being used in many commercial food applications. Sophorolipids have been used to encapsulate structured lipids (interesterified soybean and rice bran oils) in oil-in-water emulsions (Xue et al., 2013).

Sophorolipids

Sophorolipids are glucolipids produced by some species of microorganisms, particularly yeasts (de Oliveira et al., 2015, Rosenberg and Ron 1999). They can be produced on an industrial scale using microbial fermentation processes utilizing suitable yeast strains (such as Candida batistae and Candida bombicola) and substrates (such as carbon and nitrogen sources) (de Oliveira et al., 2015, De et al., 2015). These molecules consist of a hydrophilic sophorose group (a disaccharide) attached to a hydrophobic hydrocarbon tail (a fatty acid chain) (de Oliveira et al., 2015). The nature of the sophorose head group and hydrocarbon tails depends on the
microbial strain, fermentation conditions, and substrates used, which leads to biosurfactants with different physicochemical and functional properties (Lang 2002, Ribeiro et al., 2013). In 2013, the production costs associated with synthesizing sophorolipids by industrial fermentation processes were estimated to be approximately $2.54/kg (Ashby et al., 2013).

Rhamnolipids

Rhamnolipids are another type of glycolipid that can be obtained from certain microorganisms (e.g., *Pseudomonas aeruginosa*) using fermentation processes (Henkel et al., 2012, Jirku et al., 2015, Muller et al., 2012). As with other biosurfactants, the microbial strain, fermentation conditions, and substrates must be optimized.

**Conclusion**

Biosurfactant are non-toxic, non-polluting, eco friendly and biodegradable in nature. The major goal for the food processing industries to provide safe, wholesome and acceptable food to the consumer and control microorganisms. An increasing consciousness among consumer’s demands for reducing the use of chemically or artificial synthesized compounds changes the natural flavor, texture and nature of the food. The uses of chemical or synthesized compounds change the natural flavor, texture and nature of the food. Biosurfactant should be emphasized in order to certify the sale of these compounds for food utilization.

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