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Agriculture and Food

AIMS Agriculture and Food, 9(1): 237–253.
DOI: 10.3934/agrfood.2024014
Received: 09 November 2023
Revised: 10 January 2024
Accepted: 29 January 2024
Published: 04 February 2024

http://www.aimspress.com/journal/agriculture

Review

Potential applications of biosurfactants in animal production and meat research

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Abstract: Muscle foods are perishable products that are subject to several contaminations such as microbial and/or chemical (lipid and protein oxidation) alterations, which result in their deterioration and quality loss. Several processing strategies are used to preserve and improve the stability, shelf-life and quality of meat and meat products, from which natural preservative agents are gaining interest from both industrials and consumers as green and eco-friendly strategies. Among these natural preservatives, biosurfactants are emerging molecules. Their natural origin and biodegradability make them appealing for use in the food industry. In meat research, biosurfactants are of great interest as antimicrobial and antioxidant agents to reduce meat spoilage and wastage as well as for improving the shelf-life of the products. We aimed to discuss the potential applications of biosurfactants with a focus on their antimicrobial and antioxidant activity within the objectives of reducing meat quality deterioration and improving the image quality (acceptability by consumers) of meat and meat products. Additionally, further perspectives under the context of practical applications of biosurfactants in meat emulsification have been discussed, serving as a reference to feed knowledge gaps in this emerging topic of research. Further studies and evaluations of biosurfactants in meat research are needed to establish more evidence of their potential benefits, applicability and feasibility at a larger scale.

Keywords: meat quality; meat preservation; biosurfactants; amphiphilic agents; biological activities; antimicrobial and antioxidant agents

1. Introduction

Animal-derived foods, particularly meat and meat products, have a diverse array of nutrient compositions, characterized by significant contents of high-quality proteins, essential amino acids, B-group vitamins, minerals, and various other nutrients [1,2], making them important constituents of human nutrition worldwide. However, muscle foods (proteins of animal origin) are perishable products that are subject to several microbial contaminations (growth of pathogens and several microorganisms), resulting in their deterioration and quality loss [3–5]. In fact, meat quality deterioration can be driven by multiple mechanisms, namely microbial proliferation and lipid and protein oxidation, which all together impact the different properties of meat and meat products such color, flavor, texture, and nutritional value [4,6–11]. Besides the internal factors impacting the rate and extent of meat quality deterioration, numerous external factors such as oxygen, temperature, light exposition, preservative compounds, and processing techniques are key in the stability and final quality preservation [4,8]. Lipid and protein oxidation are the major non-microbial issues causing meat deterioration [4]. For example, oxidative reactions occurring during the manufacturing, distribution and storage of meat and meat products induce multiple physicochemical transformations and/or alterations, which consequently generate undesirable aromas that have detrimental impacts on the final quality, leading to consumer dissatisfaction and economic losses [12]. Several strategies are used to preserve and improve the stability, shelf-life, and quality of meat and meat products, namely, cold chain logistics, heat treatments, packaging innovations, and chemical preservatives [2]. However, the increasing concerns on food safety and the potential risks associated with the application of chemical and synthetic preservative agents/molecules [13,14], have resulted in a notable shift towards natural preservatives that seemed to have interesting properties to maintain or improve the stability of muscle foods. Overall, these natural molecules aim to inhibit or delay microbial growth, oxidative reactions, and enzymatic degradation, thereby extending the shelf-life of meat products and ensuring their safer consumption, resulting in consumer satisfaction [15]. For this purpose, numerous bio-preservatives have been explored, among which certain studies demonstrated antioxidant and antimicrobial effects of biosurfactants to preserve and extend the shelf-life of meat and meat-based products (Table 1). We aimed to review the applications of biosurfactants, a class of microorganism-formed compounds, in animal production and meat research, with specific emphasis on their antimicrobial and antioxidant activities, as compounds enabling extended shelf-life of meat products.

2. Biosurfactants

Surface-active agents, commonly named surfactants, have versatile properties and occupy a significant position in the field of colloid and interfacial science due to their inherent amphiphilic nature. This characteristic facilitates the reduction of interfacial tension between disparate phases, including air-water, liquid-liquid (oil-water or water-oil), and liquid-solid interfaces [16]. For their production, two approaches can be distinguished. In the chemical approach, the organic chemistry serves as a founder of the covalent linkage of the amphiphilic (hydrophilic and hydrophobic) molecules, and ensures their structural integrity and functionality. In the biological approach, the biosurfactants may be produced by two primary pathways, either through direct extraction from plants or synthesized by an enzymatic or microbial process. It is worthy to mention that the scientific community refer to the term "biosurfactants" to the amphiphilic surface active agents that are obtained *via* fermentation process (microbial biosurfactants) [17]. Biosurfactants possess a hydrophilic moiety that can include carbohydrates, amino acids, cyclic peptides, phosphates, carboxylic acids, or alcohols, and a hydrophobic moiety that is mostly composed of long-chain fatty acids, hydroxyl fatty acids, or α-alkyl β-hydroxy fatty acids. This combination of hydrophilic and hydrophobic moieties provides to biosurfactants their amphiphilic property and contributes to their surfactant and antimicrobial activities [18].

2.1. Biosurfactants sources

The production of biosurfactants depends on some factors that play a crucial role in the efficiency of the production yield, mostly the source of carbon and nitrogen, the carbon/nitrogen ratio, the content of salts and trace elements, and fermentation conditions [19]. The valorization of renewable wastes generated by food industry can be used to produce biosurfactants including bagasse, press mud, vegetables and fruits wastes, oil processing wastes, spent coffee ground, dairy products, fat, tallow, and lard [20,21]. Since the production of biosurfactants depends on carbon presence in the growth medium; lignocellulosic molecules (cellulose, lignin, hemicellulose) are selected for this purpose [20]. Accordingly, recent studies that used different renewable substrates for the production of microbial biosurfactants reported interesting yields (40.5 g/L) using *Pseudomonas* sp. Cultivated, for example, in canola waste frying oil [20,22]. Furthermore, rhamnolipid was produced by *Burkholderia kururiensis* KP23T isolated from an aquifer and glycolipoprotein by *Lactobacillus paracasei* subsp. *tolerans* N2 using sugar cane molasses as substrate [23]. However, the pathogenicity of strains and safety of produced biosurfactants should be assessed before any application.

2.2. Production of biosurfactants from microorganisms

With the growing demand for surface-active agents to mitigate the environmental concerns associated with the use of chemical surfactants, microbial-derived surfactants are receiving increasing attention. In fact, they are regarded as eco-friendly alternatives because of their low toxicity, better biodegradability, high selectivity, and versatile activity/use under extreme conditions [19]. Moreover, microbial-derived surfactants, from both bacteria and yeast [24], present important advantage due to the ability of their production using agri-food wastes and/or renewable sources [21].

Several studies on biosurfactants used lactic acid bacteria (LAB) for their production [25]. The use of LAB is mostly related to their GRAS status, their ability to promote human health, and strengthening the immune system. Thus, they have been proposed and evaluated for food preservation, food fermentation, improvement of the nutritional and sensory properties of food products. LAB have also interesting abilities to produce numerous functional metabolites that possess biopreservative potentials, such as enzymes, bacteriocins, biosurfactants, etc… [26]. The production of biosurfactants (glycolipoproteins biosurfactant) from LAB have been reported from several strains such as *Lactobacillus paracasei* subsp. *tolerans* N2 isolated from fermented cow milk [27]. Another study successfully isolated low-cost glycolipoprotein biosurfactant that is produced by *Lactobacillus plantarum* 60 FHE from cheese samples using food wastes [28]. Likewise, Kachrimanidou *et al*. [29] investigated the production of proteinaceous-based biosurfactants by several LAB strains, namely *Lactobacillus rhamnosus, Lactobacillus casei, Lactobacillus pentosus, Lactobacillus coryniformis, Lactobacillus paracasei,* and *Lactobacillus plantarum* using Cheese whey permeate as a low-cost fermentation feedstock for biosurfactant production. Our findings presented in this study indicate promising results for reducing the expenses related to biosurfactant production. Moreover, they support the advancement of refining food industry by-products to bolster the circularity and sustainability of food systems. Other types of biosurfactants were further produced by LAB strains: Cell-bound biosurfactants Phosphoglycoprotein (*Lactobacillus rhamnosus* CCM 1825), cell-bound lipoprotein biosurfactants (*Lactobacillus pentosus* CECT-4023T and cell-bound glycoprotein (*Lactococcus lactis* 53, *Pediococcus acidilactici* F70 [30]. Glycolipid and cell-bound glycolipid biosurfactants have been further produced by several other strains such as *Weissella cibaria* PN3 and *Streptococcus thermophilus* [30]. LAB and many other mesophilic species are positive amphiphilic agents' producers, likely *Brukholederia kururiensis* KP23 that produces rhamnolipid [27].

Different recent studies evidenced the potential of extremophilic bacteria such as thermophilic microorganisms, to produce microbial surface tension agents [31]. For example, *Bacillus subtilis*, a thermophilic strain, was found as a good producer of surfactin that is a cyclic lipopeptide group of biosurfactants, possessing promoting properties such as high surface tension activity, high foaming capacity and stability, and antimicrobial activity [32]. Several other thermophilic bacteria strains are of interest: *Bacillus licheniformis* F2.2 [33], *Bacillus safensis* YKS2 [34] and *Bacillus tequilensis* [35].

Biosurfactants compounds have also been produced from yeasts. For example, *Candida bombicola* produces acidic sophorolipid, acidic glucolipid and alcoholic glucoside [36]. The marine yeast *Cyberlindnera saturnus* SBPN-27 produces the glycolipid cybersan (trigalactomargarate) biosurfactant [37]. Furthermore, anionic biosurfactants with possible glycolipid structure were isolated from *Geotrichum candidum*, *Galactomyces pseudocandidum* and *Candida tropicalis* [38], glycolipid bio-emulsifiers were produced by high-salt-tolerant halophilic *Cryptococcus* sp. YLF [39], and a high-titer liamocin was produced by yeast-like fungus *Aureobasidium pullulans* [40]. Several fungal species have also been identified as promising sources, such as *Mucor circinelloides* UBOCC-A-109190, *Mucor plumbeus* UBOCC-A-111133, and *Mucor mucedo* UBOCC-A-101353 as glycolipid producers [41].

3. Use of biosurfactants in the processing of meat and meat products

Owing to their multiple functional characteristics, mostly emulsifying capacity, stabilization, and antimicrobial and antioxidant activities, biosurfactants are widely used in food industry, however, their utilization in meat research is very limited.

3.1. Antimicrobial activity of biosurfactants

The spoilage of meat products depends on the presence of various bacteria, mostly *Salmonella* spp., *Campylobacter jejuni*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Clostridium* spp., *Pseudomonas*, *Acinetobacter*, *Brochothrix thermosphacta*, *Lactobacillus* spp., *Enterobacter*, molds, and yeasts. These spoilage microorganisms have the potential to cause outbreaks that can severely impact both public health and economy [2,42]. Therefore, effective preservation methods and strict quality control measures are crucial to mitigate meat spoilage and ensure food safety. For this purpose, some studies have focused on the use of biosurfactants as antimicrobial, fungicidal, fungistatic, and antibiofilm using different compounds produced from myriad microorganism [25,43–45]. Table 1 represents a few studies that evaluated the potential of biosurfactants as antimicrobial agents against microorganisms commonly present in meat and meat products. In Table 2 are summarized the available studies on the different applications of biosurfactants in meat research to preserve the quality or extend the shelf-life of meat and meat products.

Table 1. Biosurfactants as antimicrobial agents against pathogens commonly tested in food industry with emphasis on meat and meat products.

Source (origin)	Biosurfactant tested	Targeted microorganisms	Refs.
Pseudomonas fragi NMC25	Undefined	Psychrophilic bacteria: *Acinetobacter* *Shewanella* *Serratia*	[46]
Bacillus subtilis	Lipopeptides: surfactin, fengycin, mycosubtilin and their mixtures	*Paecilomyces variotti* *Byssochlamys fulv* *Candida krusei*	[43]
Aneurinibacillus aneurinilyticus	Lipopeptides	*Pseudomonas aeruginosa* *Escherichia coli* *Aspergillus brasiliensis* *Candida albicans*	[47–49]
Commercial Rhamnolipid	Rhamnolipid	*Bacillus cereus*	[50]
S. bombicola	Sophorolipid	*Staphylococcus aureus* *Listeria monocytogenes* *Salmonella enterica* *Escherichia coli*	[51]
Rhodococcus fascians	Trehalose lipid (glycolipid)	*Candida albican* *Escherichia coli*	[52]
Pediococcus pentosaceus	Lipoprotein	*Bacillus subtilis* *Pseudomonas aeruginosa* *Staphylococcus aureus* *Escherichia coli*	[53]
Bacillus cereus	Lipopeptide	*Aspergillus niger* *Penicillium fellutanum* *Cladosporium cladosporioides*	[54]
Lactobacillus rhamnosus	Glycolipid	*Bacillus subtilis* *Pseudomonas aeruginosa* *Staphylococcus aureus* *Escherichia coli*	[55]
Lactobacillus paracasei subsp. tolerans N2	Glycolipoprotein	*Pseudomonas aeruginosa* *Pseudomonas putida* *Salmonella enteritidis* *Yersinia enterolitica* *Escherichia coli* *Bacillus sp.* *Staphylococcus aureus* *Proteus mirabilis* *Klebsiella pneumoniae*	[27,56]
Commercial Rhamnolipid	Rhamnolipid	*Escherichia coli* *Bacillus cereus*	[57]

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Source (origin)	Biosurfactant tested	Targeted microorganisms	Refs.
Pseudozyma aphidis DSM 70,725	Mannosylerythritol Lipids-A	*Listeria monocytogenes*	[57]
Wickerhamomyces anomalus	Glycolipid	*Escherichia coli* *Staphylococcus aureus* *Salmonella*	[58]
Candida parapsilosis	13-Docosenamide	*Escherichia coli* *Staphylococcus aureus*	[59]

The antimicrobial action of biosurfactants is widely explored for food safety purposes, which can act through several mechanisms: i) Modification of the surface charge, wettability and reduction of the interaction of bacterial population with the surface [60,61]; ii) interaction with intracellular constituents and perturbation of the normal functioning of microorganisms, thereby hindering crucial cellular processes, consequently, inhibiting the microbial growth, survival, and proliferation [61,62]; iii) induction at high concentration of necrosis and at low concentration fungal apoptosis [61,63]; and iv) binding to the phospholipid surface of the microbial cytoplasmic membrane through electrostatic forces, which can lead to the diffusion into the inner hydrophobic part of the membrane, consequently, weakening its lipid structure (Figure 1) and leaking its essential molecules [64].

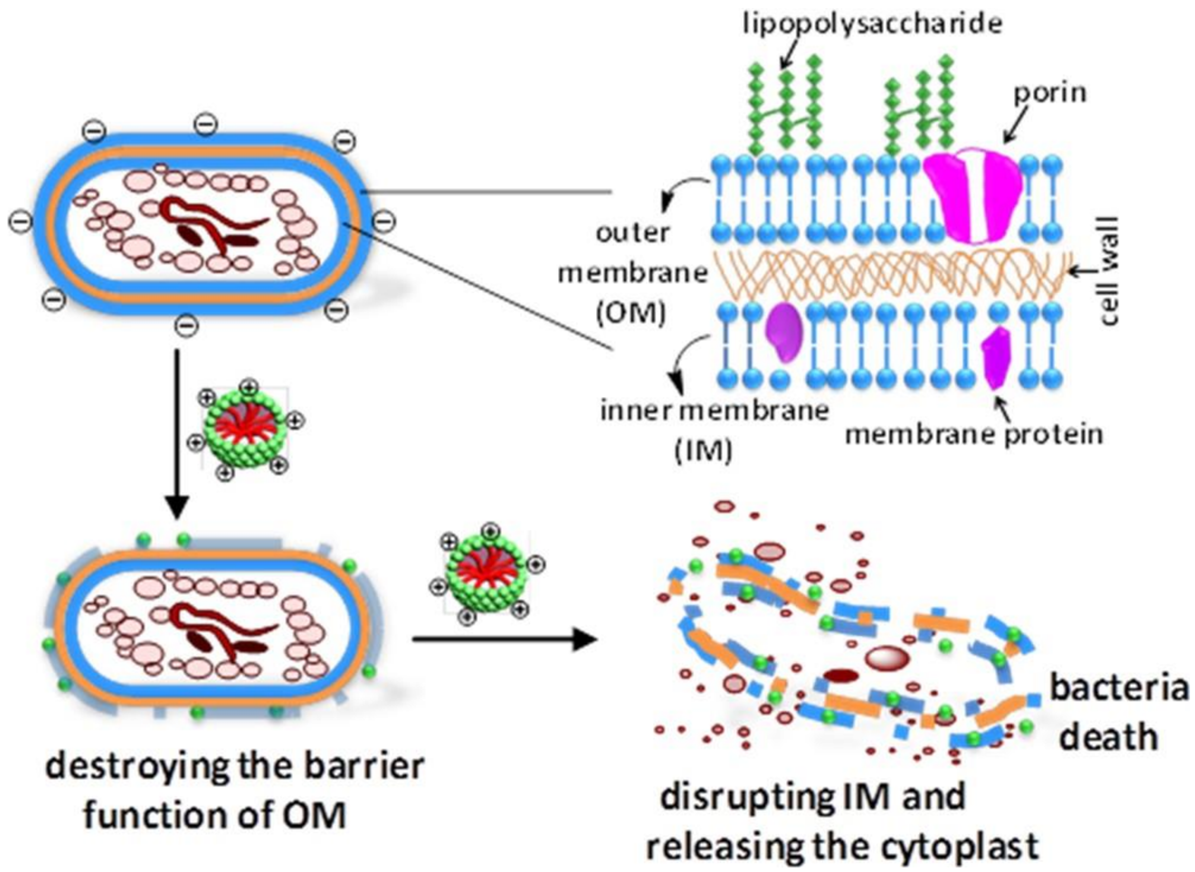

Figure 1. Schematic antibacterial mechanism of surfactant micelles against *E. coli.* (Reprinted with permission from [65]).

Table 2. A non-exhaustive list of the various applications of biosurfactants in meat research.

Biosurfactant(s)	Sources	Objective of the trials	Type of meat matrix and procedure	Main results	Refs.
Glycolipoprotein	-*Lactobacillus paracasei* subsp. Tolerans N2 -*Lactobacillus casei* subsp. casei TM1B	*In-situ* effects of biosurfactants on the microbiological and physicochemical stabilities of raw ground goat meat stored at 4 °C	Raw ground goat meat mixed with the glycolipid biosurfactant in sterile polyethylene bags	• Decrease of the total aerobic counts, *E. coli* and *Pseudomonas aeruginosa*, leading to increased shelf-life (up to 15 days) • Better color stability • Inhibition of lipid oxidation • Inhibition of the production of basic volatile nitrogen	[25,56]
-Acetylated starch -Octenyl succinic -Anhydride starch -Ethyl (hydroxyethyl) cellulose -Dodecenyl succinylated inulin	Commercial	Formulation and development of a low-fat, printable, acceptable texture and fibrous sensation of plant-based meat analogue ink for potential utilization in 3D printing technology, focusing on exploring the biosurfactants and their functional properties	Oil partially or entirely replaced with hydrophobically modified biosurfactants in a soy protein-based emulsion, in order to develop a reduced-fat meat analogue	• Improvements of the pseudoplastic behavior with viscoelastic properties due to reduced-fat inks • Increase of consistency index recovery, frequency crossover point, and storage modulus	[66,67]
Undefined	*Bacillus subtilis* DS03	Evaluate the biological activity of the biosurfactants against pathogenic strains and its potential sanitizer in open cleaning systems in the meat processing laboratory	Designing an open cleaning system in the meat processing (after sausage production) where 3 products of the cleaning out-of-place system were formulated using biosurfactants	• The cleaning of the equipment and utensils with biosurfactants led to a significant decrease of *E. coli*, *S. aureus* and *L. monocytogenes*	[68]
Sophorolipid	*Starmerella bombicola*	Develop a green packaging for the control of foodborne pathogens against poultry spoilage	Formulated bioactive film incorporating polylactic acid and sophorolipid biosurfactant	• Total inhibition of *L. monocytogenes, S. aureus* and reduction of 50% of *Salmonella*. spp bacterial population	[69]
Lipopeptide	*Enterobacter cloacae*	Investigate the antioxidant activity, emulsion stability and the conservation stability of raw beef patties using a biosurfactant	Determination of the antioxidant activity of the lipopeptide biosurfactant	• Significant oxidative stability of raw beef patties in the presence of the lipopeptide	[70]

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Biosurfactant(s)	Sources	Objective of the trials	Type of meat matrix and procedure	Main results	Refs.
Undefined	*Pseudomonas fragi*	Evaluate the effect of the biosurfactant on the spoilage ability and community dynamics of bacteria on the surface of chilled meat	The biosurfactant was spread onto the surface of chicken breast. Several meat quality parameters have been evacuated including the microbiological counts, TVB-N, pH and meat color	• Significant changes of the microbial diversity of the meat matrix, with a dominance of *Pseudomonas* in the population and effective reduction of spoilage state of meat	[46]
Lipopeptides	*Bacillus methylotrophicus*	Determine the antioxidant properties of the biosurfactant in raw beef patties during conservation; develop a novel type of beef patties coating: biosurfactant-gelatin-film for lipid oxidation prevention and shelf-life extension	Ground beef meat used for patty formulations was treated with lipopeptide biosurfactant through two ways: patty formulation including the biosurfactant, and standard beef patty covered with the biosurfactant coating	• Inhibition of lipid oxidation • Significant efficiency of the direct use of biosurfactant in lipid oxidation than coating	[71]
Sophorolipids	*Starmerella bombicola*	Develop chicken sausage with biosurfactant and exploring their antimicrobial, antioxidant and emulsifying properties.	Formulation of the sausage prepared by mixing chicken ground meat, non-meat ingredients and additives, enriched with different concentrations of sophorolipid biosurfactants	• Improvement of the sausage structural integrity: less porous mass, low cracks and better emulsion stability • Impact on color • Antimicrobial activity against *C. perfringens* and better antioxidant activity	[72]
Quillaja Saponin	Commercial purchased	Develop a natural and edible antioxidant agent via a formulation of a thymol nanoemulsion applied on raw chicken breast meat using biosurfactant.	Formulation of a nanoemulsion using Quillaja Saponin biosurfactant in addition to other green solvents, where the meat samples were dipped during 14 days of storage in 4 °C	• Effective green nanoemulsion • Antioxidant capability against lipid oxidation	[73]

3.2. Antibiofilm activity

Biosurfactants were evidenced in several studies as a sustainable alternative to chemical compounds thanks to their antiadhesive and antibiofilm properties. Studies demonstrated that biosurfactants from two *L. casei* strains exhibited antibiofilm activities against *S. aureus* [74]. Other studies confirmed the biofilm inhibition of *S. aureus* by rhamnolipid produced by *Enterobacter* sp. UJS-RC [75] and others observed a reduction of 60% of *Salmonella* biofilm cells [76]. A study conducted by Mouafo and co-workers [56] reported that the glycolipoprotein biosurfactant from *Lactobacillus paracasei* was able to inhibit biofilm formation of six pathogen strains isolated from braised fish, namely *Escherichia coli, Staphylococcus aureus, Salmonella enteritidis, Pseudomonas aeruginosa, Yersinia enterolitica, Proteus mirabilis,* and *Klebsiella pneumonia*. It has been shown that biosurfactants are capable of modifying the physio-chemical properties of surfaces, subsequently reducing adhesion and biofilm formation [77].

3.3. Antioxidant activity

In order to mitigate the oxidation of proteins and lipids in muscle foods, natural compounds with antioxidant activity are widely used [1], from which biosurfactants are good candidates [25]. Some, as evidenced in Table 2, have demonstrated significant effects, such as the application of glycoprotein biosurfactant in inhibiting both lipid oxidation and the production of total volatile basic nitrogen in fresh ground goat meat [25]. Antioxidant activity of a lipopeptide biosurfactant was investigated by several mechanisms using several lipid oxidation tests, and it showed a significant impact on the inhibition of lipid oxidation in beef samples [70]. Furthermore, another earlier study confirmed the effective antioxidant activity of lipopeptides in ground beef patties up to 14 days, suggesting that the direct use of biosurfactants is more effective than using gelatin-based antioxidant packaging[71]. Kaiser *et al.* [72] carried out research to investigate the inhibition of lipid peroxidation of chicken sausages, and their findings revealed promising results using sophorolipid biosurfactant as a potential natural preservative. Quillaja Saponin biosurfactant also seemed to have a significant antioxidant activity on raw chicken breast meat through thymol nanoemulsion formulation [73]. Authors have explained the mechanisms behind this potency via ferric reducing antioxidant power of surfactin and rhamnolipid and further demonstrated that this might be due to hydroxyl groups in the lipopeptide molecular structure, hydrophobic amino acids (valine and leucine), acidic amino acids (aspartic acid and glutamic acid), and sulfur-containing amino acids such as methionine acids [78]. Moreover, biosurfactants exhibit a DPPH scavenging activity in which free radicals are neutralized by transferring either protons to electrons [78] or a hydrogen atom [77]. The results demonstrated the unsaturated lipids' ability to scavenge the reactive oxygen species and to prevent lipid peroxidation. Thus, this scavenging effect might be attributed to the presence of several active residues and to the hydrocarbon fatty acid chain in the peptide ring of the lipopeptide biosurfactant, which can react with the free radicals of DPPH. However, the lipid peroxidation inhibition could be attributed to the presence of both hydrophobic amino acids in the peptide ring and the acyl chain of beta-hydroxy fatty acids, thus improving the solubility of the peptide in the hydrophobic medium [77,78].

3.4. Potential use of biosurfactants in meat emulsification

Several meat products, such as sausages, frankfurters, bologna, and mortadella under the name of emulsion-type meat products, are produced [79]. These emulsion-type products are prepared by finely chopping meat from various sources (pork, beef, mutton, etc.), creating a stable mixture that effectively binds water and entraps fat. This unique emulsion imparts the textural properties to the product when cooked [80], which are considered as oil-in-water emulsions [81]. The quantity of fat plays a crucial role of the enhancement of flavor, texture, hardness, juiciness, mouth feel, moisture, and technological properties of these products such as pork backfat in sausages, meat batters, frankfurters, beef fat in beef burgers, and so on. However, the current concerns of consumers about various aspects of food quality and health is getting significant attention. Consequently, the reformulation of meat derivatives and especially emulsion based ones to enhance their health profile has become a vital strategy, particularly because consumers often perceive them as unhealthy because of the considerable quantity of fat that they contain [80]. Therefore, several studies have been performed to address the reduction of fat content, enhancement of fat profile, and transformation of liquid oil into a semi-solid system through various approaches such as hydrogenation, interesterification, oil bulking systems, and structured emulsions [82]. Accordingly, numerous emulsifying agents have been investigated, encompassing proteins, amphiphilic polysaccharides, protein-polysaccharide complexes, and low molecular weight surfactants. These agents play a crucial role in stabilizing emulsions, leading to improve product quality and functionality in various meat emulsion [83]. In the context of evaluating surfactants and among the very few studies, Serdaroğlu and co-workers [84] investigated the effect of partial beef fat replacement with gelled emulsion on functional and quality properties of model system meat emulsion supplemented with polyglyserol polyricinoleate surfactant. The findings indicated that partial replacement of beef fat with gelled emulsion could enhance cooking yield. Although the inclusion of gelled emulsion significantly influenced the textural properties of the samples, it did not have any adverse effects on water holding capacity and emulsion stability, concluding the potential benefits of using gelled emulsion in meat product formulations for the development of healthier meat products.

The preparation of meat emulsion gels typically involves the production of a protein-stabilized emulsion, but it can be further supplemented with a hydrocolloid stabilizer or other ingredients, such as proteins, polysaccharides, and surfactants, after the formation of the emulsion [85]. This approach ensures the stability and functionality of the resulting emulsion gel [83,86]. For example, soybean protein serves as a source of surfactant molecules, effectively reducing the interfacial tension between oil and water in emulsion gels, which enhances the stability of the emulsion gels and contributes to their overall quality and functionality [83]. However, these surfactants are considered toxic agents causing environmental damage due to their chemical production process [87]. Therefore, as discussed earlier, biosurfactants gained recently a significant interest, including their use as emulsifying agents [88]. Even though many researchers investigated the use of biosurfactants as a green alternative of chemical surfactants in many fields globally and in the food industry, there is a lack of studies exploring biosurfactants in emulsion-based meat products. Thus, we believe that exploring the use of biosurfactants in fat meat replacers and emulsion-based meat formulations could yield noteworthy and valuable outcomes. Such investigations may open up new avenues for developing healthier and more sustainable meat products as well as satisfying the consumers’ expectations.

4. Conclusions

Green biopreservatives are receiving a huge interest worldwide due to their low toxicity and ecological purposes. In this sense, biosurfactants, which are amphiphilic molecules, are showing advantageous features that can be considered sustainable and biological alternatives to chemical and harmful surfactants, owing to their multiple and functional properties such has emulsification, stabilization, and bacterial and fungal inhibition, consequently enhancing food quality and extending the shelf-life of the products. These characteristics are widely demanded in the meat industry to reduce waste and prevent the perishability of meat products. In this article, we discussed the utilization of biosurfactants in food science with an emphasis on meat and meat products. We highlighted the multiple potential applications of biosurfactants as antimicrobial, antibiofilm, and/or antioxidant agents to tackle the problem of different types of meat products' spoilage and their stability. The effectiveness of the biosurfactants is not confirmed, but all the available data are promising, especially in extending the shelf-life of the products. Notwithstanding, they seemed to have interesting properties to be applied as stabilizers in meat-based emulsions. Further studies and evaluations of biosurfactants in meat research are needed to establish more evidence of their applications' potential and feasibility of use at larger scale.

Use of AI tools declaration

The authors declare that they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflict of interest

All the authors declare that they have no conflicts of interest with the work presented here.

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