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Bacterial Biopolymers

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Abstract

A vast range of extracellular and intracellular biopolymers, including polyamides, polysaccharides, polyphosphates, polyesters, proteinaceous compounds, and extracellular DNA, may be produced by bacteria, which are regarded as the primary cell manufacturers. Bacterial biopolymers are employed in pathogenicity and are appropriate for use in the pharmaceutical industry due to their wide range of physical and chemical characteristics. When these biopolymer compounds are created by non-pathogenic bacteria, they function as food additives or biomaterials, however when they are derived from pathogenic bacteria, they serve as significant virulence factors. Using synthetic biology to create novel biomaterials, there have been multidisciplinary researches looking at the molecular processes involved in the synthesis of bacterial biopolymers and the discovery of new antimicrobial drug targets.

Keywords: Bacterial biopolymers, pathogenicity, antimicrobial drug, polysaccharides

Introduction

A wide variety of intracellular and extracellular biopolymers, including polysaccharides, polyamides, polyesters, polyphosphates, extracellular DNA, and proteinaceous components, may be produced by bacteria, which are excellent cell factories capable of converting carbon and nitrogen sources. Bacterial polymers play significant roles in pathogenicity, and they are suited for use in both medicinal and industrial settings due to their wide range of chemical and material characteristics. When created by pathogenic bacteria, the same biopolymers serve as important virulence factors, but when produced by non-pathogenic bacteria, they are transformed into food components or biomaterials. Interdisciplinary research has uncovered new antibacterial medication targets, given information on the molecular principles of bacterial polymer production, and provided guidance for synthetic biology approaches to the development of novel materials.

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In bacteria, regulatory networks that process environmental inputs and regulate responses through transcriptional and post-translational regulation govern polymer biosynthesis. Transcription factors activate promoters that manage the expression of genes with similar functions at the transcriptional level. Sigma factors, which are RNA polymerase subunits, and regulatory proteins, which bind to DNA areas upstream of biosynthetic genes, are examples of these transcription factors. Anti-sigma factors bind to some sigma factors, which are then released when exposed to outside stimuli. For instance, the sigma factor AlgU facilitates binding to a particular promoter region upstream of the alginate biosynthetic gene cluster by attaching to the core RNA polymerase. When circumstances are not favourable for the synthesis of alginate, P. aeruginosa85 and probably other pseudomonads sequester AlgU through the membrane-bound anti-sigma factor MucA. AlgU is released and triggers transcription of the alginate biosynthesis gene cluster upon environmental destabilisation of this complex, such as in response to cell envelope stress or on mutation of the mucA gene (for

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example, adaptive mutation during persistent infection). A designed MucA-inactivated strain86 generated significant quantities of alginate constitutively, which suggests a potential route for improved bacterial alginate synthesis. Furthermore, signal processing and intricate regulatory networks that regulate polymer production in bacteria are regulated by short non-coding RNAs, two-component systems, regulatory RNA-binding proteins, and second messengers (such c-di-GMP and c-di-AMP). Synthetic biology methods for effective polymeric material manufacturing will be informed by improved knowledge of these regulatory complexities through systems biology. Bacteria have the ability to produce polyaminoacids or polyamides, such as secreted poly-L-lysine and poly-D-glutamic acid or the intracellularly produced cyanophycin (copolymer of L-arginine and L-aspartic acid), which can be used as a storage substance as well as a component of biofilm matrix or capsular polymer. Similar to the polysaccharides in the biofilm matrix, polyamide biofilm or capsule is less immunogenic, preventing the human immune system from attacking bacteria like Bacillus anthracis. Numerous non-pathogenic bacteria, including Bacillus megaterium, Bacillus licheniformis, and several cyanobacteria, also manufacture polyamide-based polymers. Polyamides can be polycationic or polyanionic and contain large charges. They are thought to be renewable, biodegradable, and non-toxic. The manufacture of polyamides with increased biological properties is aided by metabolic engineering [6-10]. Chemically manufactured polymers may be replaced by polyamides in industry. For instance, poly-D-glutamic acid can be used to treat wastewater instead of synthetic flocculants like polyacrylamide or polyaluminum chloride. Since it can damage the cross links and compromise the integrity of the membrane, poly-L-lysine, which is employed in antimicrobial coatings, has antibacterial capabilities.

Bacteria can even create a variety of biopolymers that can function as extracellular DNA and proteinaceous components. These biopolymers can be utilised to make biomaterials in addition to being involved in bacterial disease. When a cell is lysed, the intracellular DNA is released, and extracellular DNA is created. In the case of biofilms, a cellular subpopulation lyses to create extracellular DNA, as seen, for instance, in the stalks of P. aeruginosa's mushroom-like microcolonies. Extracellular DNA plays a variety of roles in the adherence and stability of the biofilm matrix by interacting with cationic polysaccharides (like Pel) and other cations, and it can also act as a source of nutrients during times of starvation, conferring antibiotic resistance. This is due to the extracellular DNA's high negative charge.

Conclusion

Major virulence factors generated by bacterial pathogens include extracellular polymers. Thus, a technique for the therapy of bacterial infections involves inhibiting their production processes. New approaches to combat bacterial infections are urgently needed due to the increased rates of antibiotic resistance. Understanding the production, secretion, and control of biopolymers will provide novel and precise drug development targets, such as those that compromise bacterial defences against host immunological defences or antimicrobial therapy. Non-pathogenic bacterial polymers are regarded as safe materials for a variety of uses. Challenges persist despite significant advancements in the design of cell factories for improved biopolymer synthesis as well as manufacture of custom biopolymers. It is difficult to rationally develop new GRAS-certified cell factories and biopolymers because complex biological systems have so many interconnected parts and feedback loops. In order to better inform genome-scale metabolic models, metabolic network modelling, and computer simulations of massive data sets that feed into synthetic biology methodologies, it is crucial to minimise this complexity through systems biology. This effort will lay the groundwork for effective bioengineering tactics and precise projections of the evolution of cell factories and bioprocesses.

In addition to producing a large number of biopolymers, non-pathogenic bacteria are also employed in a wide range of biotechnological products for both commercial and medical purposes. Despite making considerable strides in the planning and construction of cell factories for a higher output of natural and custom biopolymers, there are still certain obstacles to overcome, such as their high cost and the need to validate their safety profiles, among other things. Some viable bioengineering solutions for novel GRAS-guaranteed microbial cell factories and biopolymers are still not well investigated since complex bio-systems include a broad range of interplaying components and many feedback loops. To develop metabolic models for genome-scaling and metabolic modelling of networks, coupled with computer simulations incorporating vast sets of databases feeding into synthetic biology methodologies, it is required to reduce the complexity through systems biology.

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