Vol.2 Issue-5, JAN 2022 (e-ISSN: 2582-8223)

JUST AGRICULTURE
multidisciplinary e-Newsletter

Siderophore: Role in Plant Disease Management

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ARTICLE ID: 044

Introduction

Mycobactin was found as a growth factor for *Mycobacterium johnei* in the 1950s, which led to the discovery of siderophores. The relevance of siderophores was initially established by Kloepper *et al.* (1980). Siderophores are tiny compounds with strong affinity for ferric iron, typically between 500 and 1500 daltons in molecular weight. The Greek term siderophores means "iron carrier." Siderophores are among the most powerful Fe3+ binders known, with enterobactin being the most powerful. In diverse surroundings, pathogenic and non-pathogenic bacteria create siderophores.

Types of Siderophores

(A) Based on Chemical Properties and Structure

I. Hydroxamate Siderophore

Hydrophilic siderophores of bacteria are made up of acylated and hydroxylated alkylamines, whereas those of fungus are made up of hydroxylated and alkylated containing N5-acyl-N5-Hydroxyornithine or N6-acyl-N6-Hydroxylysine are the components. All other hydroxamates possess peptide linkage, with the exception of fusarinine C generated by *Aspergillus nidulans* (e.g., TAFC), which contains ester bonds. Between two oxygen molecules from each hydroxamate group and iron, a bidentate ligand formed. Each hydroxamate may form a hexadentate octahedral complex with ferric ion that has a binding constant between 1022-1032 M1.

II. Catecholate Siderophore

It's solely found in bacteria. Catecholate and hydroxyl groups make up this molecule, which binds Fe3+ to neighbouring hydroxyls or catechol endings. It's made up of dihydroxybenzoic acid (DHBA) and an amino acid. Lipophilicity, complex stability and pH resistance are its unique characteristics. By supplying two oxygen atoms for iron chelation forming a hexadentate octahedral complex.

III. Carboxylate siderophore

Few bacteria, such as *Rhizobium meliloti's* rhizobactin, and fungus such as members of the Mucorales family of Zygomycota possesses carboxyl and hydroxyl groups for iron uptake. It is made up of citric acid or β -hydroxyaspartic acid that binds to iron, like staphyloferrin A, which is made up of one D- ornithine and two citric acid residues joined by two amide bonds and excreted by *Staphylococcus aureus*.

IV. Mixed Siderophores

Some species, such as *Rhosococcus erythropolis*, create mixed siderophores that include both catecholate and hydroxamate groups, such as heterobactin.

(B) Based On Producing Organism

I. Bacterial Siderophore

Enterobactin is a catechol siderophore produced by *E. coli* that has the greatest affinity for the Fe (III) ion of any known siderophore. *Streptomyces*, a Gram-positive spore-producing member of the *Streptomycacetaceae* family, generates desferrioxamine siderophores such as desferrioxamine G, Band E.

II. Fungal Siderophore

Aspergillus fumigatus and *A. nidulans* generate 55 siderophores that are quite similar. *A. fumigatus* uses the hydroxamate siderophores fusarinine C and triacetyl fusarinine Cto capture extracellular iron, ferricrocin, a hyphal siderophore, for intracellular iron distribution and storage and hydroxyferricrocin, a conidial siderophore, for conidial iron storage, germination and oxidative stress resistance. Linear fusigen, an ester-containing siderophore, is found in large numbers in two ectomycorrhizal basidiomycetes, *Laccaria laccata* and *Laccaria bicolor*, as well as coprogen, ferricrocin, and triacetylfusarinine C. The brown-rot fungus *Wolfiporia cocos*, a basidiomycota member used in Chinese medicine, also produces catecholate siderophore.

III. Cyanobacterial Siderophore

Dihydroxymate type siderophores, such as schizokinen and anachelin H, are known to be produced by cyanobacterial species. *Anabaena oryza* produces a siderophore that functions as

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a biological sequestering agent for cadmium metal ions, with promising outcomes for agricultural productivity increase.

IV. Plant Siderophores

The mugineic acid family includes phytosiderophore (PS) forming a hexadentate Fe-PS complex in members of the poaceae family. Two amine-N, two carboxylate-O and one a-hydroxycarboxylate site create a compact octahedron in which the core Fe (III) atom remains bound in these siderophores.

V. Mammalian Siderophore

According to research done on FL5.12/ EC-24p3 murine interleukin-3 (IL-3) dependent pro-B lymphocytic cell lines, mammalian cells may contain certain siderophores that are structurally and functionally comparable to bacterial siderophores. Lipocalin 24p3 binds enterobactin, which binds iron in cells in mammals.

Mechanism of Siderophore

A transport protein or a pump performs the mechanism that allows siderophores to be secreted or exported outside the cell. The main facilitator superfamily (MFS), the resistance, nodulation and cell division (RND) superfamilyand the ABC superfamily have all been identified as being involved in this process.Enterobactin export is carried out in *E. coli* by an MFS protein called EntS, which is encoded by the ybda gene. Bacillibactin secretion in *B. subtilis* has recently been discovered to be carried out by a comparable MFS-type transporter called YmfE. The efflux system MexA-MexB-OprM, which is a typical RND superfamily transport protein, was considered to be responsible for pyoverdine secretion in *P. aeruginosa*. *S. aureus*, *Mycobactetium* TB, and *Mycobactetium smegmatis* all have ABC type transporters implicated in siderophore export.The ferric-pyoverdine complex is dissociated in the periplasm of *P. aeruginosa*, iron is liberated via reduction and pyoverdine is subsequently recycled from the periplasm to the external media by the efflux pump PvdRT-OpmQ, according to recent investigations. The FiuA and FoxB receptors, on the other hand, transport the ferrichrome siderophore through the outer membrane.

Bacterial typing tool

Siderophore (pyoverdine) might be utilized as a taxonomic identifier in fluorescent pseudomonads to distinguish between closely related strains. Siderotyping techniques like as mass spectrometry and isoelectrophoresis have been employed successfully

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Role of Siderophores in Controlling Plant Pathogens

The siderophores trap Fe near the roots and limit the iron necessary for diseases like *Fusarium oxysporum, Pythium ultimum*and others that cause wilt and root rot disease in crops. *P. fluorescens* CHA0, *P. putida* WCS strains and *P. syringae pv. syringae* strain 22d/93 are siderophore-producing pseudomonads that have been recommended as biocontrol agents against soil-borne plant diseases. Under experimental conditions, coinoculation of *Pseudomonas* strains with *Bradyrhizobium* and *Ralstonia solani* strains significantly increased legume growth and completely controlled root rot disease.Xanthoferrinsiderophore of *Xanthomonas campestris pv. campestris*, is required for optimum virulence and growth inside cabbagewhich helps to promotes plant growth by the sequestration.Thus, chemical inhibition of pyoverdine production may be an effective strategy to control *Pseudomonas* virulence. In *Pseudomonas cichorii* SPC9018, pyoverdine production is required for virulence on eggplant.

Conclusion

The siderophore are ecofriendly option without hazardous effect like chemicals and enhance the yield with controlling the diseases.