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Microbial Siderophore and its Importance in Agriculture

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***Abstract*: Under iron restricted condition many bacteria produced iron chealating molecules called siderophore. Siderophore chealate iron and supply to bacterial cell by outer membrane receptors. A great variation is seen in siderophore structure produced by many bacteria. There are three main kinds of siderophores known as hydroxamate, catecholate and carboxylate. Siderophore production can be obtained under iron restrict media and many researcher have produced siderophore from bacteria on succinate media. Siderophore and their derivative have large application in agriculture as to increase soil fertility and biocontrol for fungal pathogen. In medicine the most important application is selective drug delivery, a Trojan horse strategy, to defeat drug resistant bacteria. Siderophore also used to reduce the level of metal contamination in environment specifically from soil and water.**

***Keywords*: siderophore, chelating agent, hydroxamates, catecholate, carboxylate, biocontrol agent.**

1. Introduction

Iron is the fourth most abundant element in the Earth's crust and is also one of the most important element for microbial growth. It is a transition metal that can exist in two oxidation state, Fe(III) and Fe (II). The variable valence of iron allows it to play a key role in the oxidation-reduction reactions (Taylor and Konhauser, 2011). Iron is required in several metabolic process including TCA, electron transport chain and photosynthesis.

In recent year's iron deficiency is known to occur in many region of the world, the reason is low solubility of Fe^{2+} an Fe^{3+} under toxic condition. Therefore, Fe deficiency impairs chlorophyll biosynthesis, thylakoid synthesis and chloroplast development (Jin et al., 2014). In order to survive under such iron-depleted environment, microorganisms produce certain organic compounds with low molecular mass called siderophores (Ahmed and Holmstrom, 2014). It is a Greek word (sideros meaning iron and phores meaning bearer) are the metal-chelating agent that helps to capture the insoluble irons. Iron is known to be very important microelement influencing metabolic process of bacteria, fungi and plants.

A. Types of Siderophores

Siderophores are classified into three main categories, namely hydroxamate, catecholate and carboxylates. Microorganisms use different siderophore-mediated Fe transport systems. For bacteria, the transport systems vary between gram-positive bacteria and gram-negative bacteria. More than 500 different type of siderophores are known, of which 270 have been structurally characterized (Boukhalfa et al., 2003).

B. Hydroxamate

Hydroxamate have a 1:1 stability constant with Fe(III) that nears that of the Fe(III)- EDTA complex whereas catecholates and carboxylates can form 1:1 complexes stability near that of Fe(III) EDTA (Robert et al., 1992). The formation of the siderophore complex are affected by the pH because of the competition for the free siderophore ligand between free protons and Fe. These types of siderophore comprised the most common group of siderophore found in nature. These siderophore produced by both fungi and bacteria.

C. Catecholate

It is mostly produced by certain type of bacteria (Dave et al., 2000). Each catecholate group supplies two oxygen atom for chelation with iron in order to form hexadentate octahedral complex. Siderophore are the part of multi component that actively transports the iron siderophore catecholate complex into the cytoplasm.

D. Carboxylate

Carboxylate type of siderophore is produced mostly by bacteria and fungi. This type of siderophore binds to iron through carboxyl and hydroxyl goup (Dave et al., 2000). Rhizobacterin produced by Rhizobium meliloti strain DM4 is the best characterized carboxylate siderophore having an aminopolycarboxylic acid conisting of ethylene diamine dicarboxyl and hydroxyl carboxyl moieties that act as iron-chelating group.

Certain report showed that both gram negative and gram positive bacteria synthesised siderophore under iron-deprived condition. There are also found in human pathogens like entric sp, spore formers and also found in various soil bacteria in plants and animals. Siderophore act as solublizing agents for iron from minerals or organic compounds under condition of iron limitation (Gandhi et al.,2008).

E. Mechanism of Siderophores

Siderophore first binds with iron(Fe^{+3}) tightly and then the siderophore iron complex moves into the cell through the cell membrane using the specific sidertophore receptors. The membrane network of gram-negative bacteria markedly different from that of gram- positive bacteria. In case of gram positive bacteria, siderophore –binding protein, enzymes are involved in the transport of siderophore iron(Fe^{+3}) complex in the cell membrane (Ahmed and Holmstrom. 2014). Once sidetrophore bound to ferric iron moves to cytosol, the ferric iron get reduced to ferrous and the ferrous form of iron becomes free from the siderophore. After release of irons siderophores either get degraded are recycled by excretion through efflux pump system.

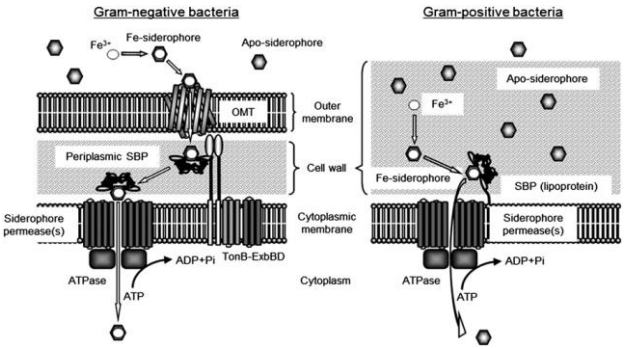

Fig. 1. Mechanism of siderophore in gram positive and gram negative bacteria

F. Application of Siderophores

Siderophores will be used in many fields such as Agriculture- to promote plant growth, it is used used as bio-control agent, it is used as bio-innoculant, it is used as biosensor, siderophore is used as medicine etc., It provide iron as a nutrition for the plant to enhance the growth when the iron level is less in the environment. This siderophore will reduce the Fe(III) in the apoplast region of the plant root, in that region reduction reaction will take place, in that reaction the insoluble form will be converted into soluble form, so that plant will uptake more amount of iron for their growth, sometimes plant also synthesise phyto-siderophore which helps to chelates the irons directly. It is used as bio-control agent and it is non-hazardous to the environment, nowadays this siderophores are used instead of synthetic pesticides. Many bacterial and fungal siderophores are act as bio-control agent for pest in plant so the bacterial and fungal disease werw treated. Some siderophore had a high affinity to chelate Fe(III) form soil and its negatively affects the growth of pathogens.

2. Conclusion

Iron is a vital element required by every living organism for numerous cellular processes. Under iron-deficient conditions, the growth of microorganisms becomes impaired. The microorganisms survive under such iron-limited conditions by secreting siderophores. The wide applications of siderophores reveal that it holds the promise to be implemented as a potential agent in different areas including ecology, agriculture, bioremediation, biosensor, from different habitats for the benefit of living beings and the environment.

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