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Review on bacterial biofilm: An universal cause of contamination

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ABSTRACT

Biofilms contain cluster of microorganisms that are found to be associated with the biotic and abiotic surfaces. Biofilm formation is a dynamic process and different mechanisms are involved in their attachment and growth. The formation of microbial biofilms is an important reason for failure of antimicrobial therapy. Biofilm-associated infections represent one of the major threats of modern medicine. Consequently, various preventive and control strategies like mechanical, physical and chemical methods can be appropriately applied for controlling biofilm formation or eradicate mature biofilm. The present review will focus on describing the effective bio control and removal of biofilms. These newer bio control strategies are considered as ecofriendly and cost effective method in terms of therapeutic.

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1. Introduction

Biofilms can be either single or multilayered. Biofilms contain either homogenous or heterogeneous populations of bacteria which remain in the matrix made up of extracellular polymeric substances secreted by component population of the biofilm. Costerton, one of the founding fathers of biofilm research, described a biofilm as a structured community of bacterial cells enclosed in a self-produced polymeric matrix and adherent to an inert or living surface (Costerton et al., 1999). Bacterial biofilms are widely distributed and play important roles in many industrial activities. In dairy industry biofilm formation can lead to serious hygiene problems and economic losses due to food spoilage and equipment impairment (Gram et al., 2007). A huge significant number of reports have appeared on the persistence of some

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foodborne pathogens on food contact surfaces and biofilms, affecting the quality, quantity and safety of the food products. From a medical perspective, biofilms can form on different medical implants such as catheters, artificial hips and contact lenses, these infections can often only be treated by removal of the implant, thus increasing the trauma to the patient and the cost of treatment. It has been estimated that biofilms are associated with 65% of nosocomial infections and that treatment of these biofilm-based infections costs $>$ $1 billion annually (Licking, 1999; Potera, 1999). Microorganisms in biofilms catalyze chemical and biological reactions causing metal corrosion in pipelines and tanks, and they can reduce the heat transfer efficacy if biofilms become sufficiently thick at plate heat exchangers and pipelines (Mittelman, 1998; Vieira et al., 1993). Some populations of biofilm-associated bacteria exhibit antibiotic resistance (Vasudevan, 2014). Biofilm also enables gene transfer among bacteria which can lead to increase in the number of virulent strains (Lewis, 2001). After more than 70 years of the first report on biofilms (Zobell, 1943), still an alarm in a broad range of areas, like food, environmental and biomedical fields (Flint et al., 1997; Maukonen et al., 2003; Sihorkar and Vyas, 2001). In this current review, we have tried to put light upon the biofilms, its structure and formation, pathogenesis and green strategy for biofilm control.

2. Biofilm development

In most biofilms formation, unicellular organisms come together to form a community that is attached to a solid surface and covered in an exo-polysaccharide matrix. The microorganisms account for less than 10% of the dry mass, whereas the matrix can account for over 90%. There are a variety of mechanisms by which different microbial species are able to come into closer contact with a surface, attach firmly to it, promote cell–cell interactions and grow as a complex structure (Breyers and Ratner, 2004; Verstraeten et al., 2008). Presently five simple generalized stages are shown for formation of biofilm (Fig. 1). Step-1 planktonic cell attaches with the substrate by adhesion mechanism, Step-ll cell starts adsorption and multiplication, Step-lll early development of biofilm architecture, production of cell-cell signaling molecule and finally produce firmly mature biofilm architecture with extracellular polymeric substances (EPS) and Step-V dispersion of single cell from the biofilm. Literature review showed that both genetic and environmental factors contribute towards the microbial biofilm formation (Maric and Vranes, 2007). EPS have been called 'the dark matter of biofilms' because of the large range of matrix biopolymers and the difficult to analyzed (Flemming et al., 2007). EPS mainly consist of polysaccharides and other biomolecules like proteins, lipids and nucleic acids etc. (Cortes et al., 2011). Polymers like glycopeptides, lipids and lipopolysaccharides form a scaffold and hold the biofilm together (Flemming and Wingender, 2010). The complexity of biofilm structure and metabolism has led to the analogy of biofilms to tissues of higher organisms (Costerton et al., 1995). The comparison between planktonic and sessile biofilm interaction represents in Fig. 2.

3. Molecular basis of biofilm formation

The development of a biofilm and the release of cells (either individually or in clusters) can be regulated by population density-dependent gene expression controlled by cell-to-cell signaling molecules such as acylated homoserine lactones (AHLs) for Gram-negative bacteria (Davies et al., 1998) and specific peptides for Gram-positive bacteria (Yarwood et al., 2004). There is evidence that during this attachment phase of biofilm development, perhaps after micro colony formation, the transcription of specific genes is activated. In particular, studies with *Pseudomonas aeruginosa* algC, algD, and algU::lacZ reporter constructs show that the transcription of these genes, which are required for synthesis of the extracellular polysaccharide (alginate in this case), is activated after attachment to a solid surface (Davies and Geesey, 1995). However, in *Escherichia coli* does produce a receptor-like protein (SdiA), similar to the LuxR-type transcriptional activator in AHL-dependent quorum-sensing (Ahmer, 2004). Secondary messengers like c-di-GMP (cyclic guanosine monophosphate) are also involved in triggering biofilm formation (Jonas et al., 2009). Extra cytoplasmic function (ECF) signaling pathway and quorum sensing (QS) events play a pivotal role in biofilm formation. Two component systems of GacS (HK)/GacA (RR) are generally involved in the formation of *Pseudomonas aeruginosa* biofilm (Rasamiravaka et al., 2015). Two-component system of GraS (HK)/GraR (RR) has been found to be active in biofilms formed by *Staphylococcus aureus* (Boles et al., 2010), PIA is polysaccharide intercellular adhesin that helps in biofilm formation and is encoded by Ica operon (Cramton et al., 1999; Archer et al., 2011). The IcaR (regulatory) and Ica ADBC (biosynthetic) genes are important for the formation of biofilms and impart virulence to the bacteria (Archer et al., 2011).

4. Biofilm challenge

It has now been established that most biofilm growing bacteria

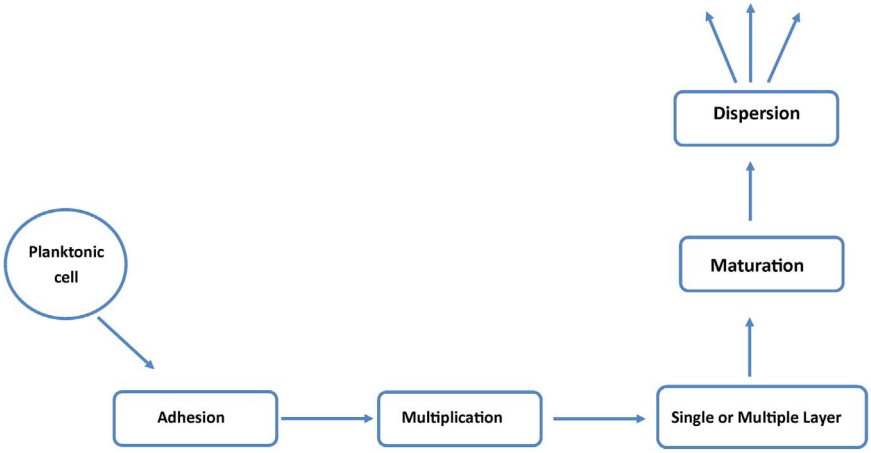

Fig. 1. Schematic diagram of stage wise formation.