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# Assessment of Biofilm Advantages and Disadvantages

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**Abstract** Problematic Biofilms in several food industry branches, in industrial water systems and in medical process industries contain many microbial species. Its microstructure and mechanical characteristics are responsible for cleaners' response, and its capacity to adhere to the biotic or abiotic surface. Biofilmsdiffer from those of planktonic bacteria regarding resistance to biocides. The effects of charge, topography, and stiffness of substratum material control its resistance to some chemical sanitizers and antibiotics. Also, liquids flow conditions vary within biofilm internal and external mass transfer. The quorum sensing response has been shown to play a role in biofilm formation in food borne pathogens.

**Keywords** Biofilm matrix, quorum sensing, synergism, mass transfer, microbiome

## Introduction

The microbial interactions include commensalism, mutualism, antagonism, parasitism, symbiosis and competition. Some of these interactions act in an inhibitory way, while other lead to stimulating microbial growth. Multispecies biofilms affect directly each other in synergistic or antagonistic ways. The biofilm ability to affect human health, water quality and industrial power generation systems result in heavy costs. The unwanted aspects include a collapse of dental surfaces, imperfection of surfaces in the food processing industry, and the drop of air quality in ventilation -conditioning systems. However, biofilms can also serve very beneficial purposes, such as in the treatment of drinking water [1], wastewater, and hazardous waste, contaminated soil and groundwater bioremediation.

A polysaccharide protecting matrix above the different strains of fungi, algae, and yeasts which come together in multilayered clusters of cells in the biofilm community and constitute the initial adhesion is formed [2-3]. This biofilm matrix which is composed of fibrous cellulose filaments are extremely difficult to break down and in many situations, the applied chemicals can even result in a defensive reply by the biofilm which makes it much stronger phenotypically and physiologically, and leaving the microbiome masked to multiply.

Biofilm is a known virulence character of *staphylococci*, pathogen and peaceful coexistence commensal [4]. Some of the strains become intrusive under favorable conditions while others didn't. Early detection and management of potentially pathogenic *staphylococci* is the essential step to prevent device- combined infections by biofilm.

## Effects of substratum on bacterial adhesion

Engineers and material scientists attempted to invent surfaces that prevent microbial attachment. The type of surface material quality and, hydrophobicity affects microbe-surface interactions and resistance to antibiotics. All the type of surface stainless steel, polyester, or polyester backed with polyurethane had limited effect on the cell attachment procedures but affected the property of different sanitizers and cleaners. Also microorganisms surface charge influences their ability to attach and is the aim of antimicrobial therapy in colonies propagation reduction [5].

Biofilms abiotic surfaces comprised also glass, rubber, stainless steel, cast iron, buna-n rubbers, low-density polyethylene and polycarbonate and many types of plastics surfaces. While sanitizer had limited inactivation effect on bacterial biofilms of Listeria monocytogenes and Salmonella typhimurium developed on stainless steel, planktonic bacteria were reduced by these sanitizers [6-8].

Biofilm maturation was affected by microorganism species, growth conditions, and polysaccharide production. Strains expressing curli fimbriae were found to produce significantly greater biofilms as the cell appendages (fimbriae, pili, and flagella) move the cells closer to the substrate and help the bacteria adhere to the surface [9-11]. Growth conditions such as the medium, pH, salt concentration, contact time, temperature, agitation and substrate micro-topography play an important role in bacterial adherence [12-13]. Another factor is the ability of the microorganisms to produce extracellular adhesive material that helps the cells to anchor to surface [14-15].

Biofilm undergo dynamic changes during their transition from free-living organisms to sessile biofilm cells activity including the specific production of chemotaxis, secondary metabolites and a significant increase in the resistivity to biological, chemical, and physical treatments, and then cells lose their flagella-driven motility [16]. After maturation and depending on the conditions, biofilms can further develop into complex and differentiated communities or single motile cells scattered from the micro colonies. Different microscopic techniques such as optical, epifluorescence, phase contrast, scanning electron, transmission electron and force atomic microscopy can be applied to evaluate cell adherence in biofilm surfaces.

**Water channels in biofilm**

Biofilm growth depends on nutrients and wastes diffusion transport as a main source of transport. However, diffusion is insufficient for transport over long distances and thus growth decreased. Biofilms grow to be very large with an exceptional, network of well-defined channels that form in wild-type Bacillus subtilis biofilms and provide a mean for upgrade transport. These channels have high permeability to liquid flow and ease, its transport through the biofilm. Moreover, spatial dissimilarity, in the evaporative drift from the surface of these biofilms deliver a driving force for the flow of liquid in the channels [17]. These channels finding provides understanding the physiology and growth of biofilms.

**Internal and external mass transfer**

Biofilm is composed of the substratum, the adsorbing biofilm surface, the boundary layer, and the bulk fluid phase surrounds the biofilm. It is complex structure includes transport from the bulk liquid to the external community surface (external mass transfer), diffusion within the microbiome matrix (internal mass transfer), and nutrients consumption by the microorganisms. The flow velocity enhances biofilms to handle their internal architecture regarding the internal mass transfer rate and microbial activity [18-20].

Biofilms arrange their internal structure to control the nutrient transport rate and the mechanical flexibility needed to resist the shear stress of the water flowing past them. Biofilms attempt to increase their mechanical strength, and that they do so neglect the nutrient transfer rate to deeper layers. This increased strength is related to an increase in biofilm density, which slows down the internal mass transport rate. Biofilms grown at low flow velocities manifest low density and high operative diffusivity but cannot resist higher shear stress, whereas biofilms grown at excessive flow velocities are denser and can resist greater shear stress but have a lower fruitful diffusivity.

**Synergism in heterogeneous biofilm**

Species league increases biofilm resistance to chemical and mechanical treatments due to genetic and physiological heterogeneity that includes adaptation to local environmental conditions, gene expression and the genotypic variation occurs through mutation and selection. Binary biofilm formation by *Stenotrophomonas maltophilia* and *Fusarium oxysporum* developed cross-feeding mode between interacting species and expression of specific genes upon contact with cells. Understanding bacterial biofilm formation on fungi leads to comprehend economically important interactions as those involved in the bacterial biocontrol of fungal plant pathogens. Bacterial colonization on a fungal surface may enable the bacteria, to abuse the fungus as a source of nutrients [21], collecting nutrients from the fungal cell wall, consume fungi-secreted by-product, or induce lysis

of the fungal cells and as result of that liberating the intracellular contents for utilization by the local bacterial population. Also, in communities where bacteria and fungi compete for nutrients, biofilm formation on fungal cells may enhance bacterial antagonism of fungi by concentrating bacterially derived antifungal compounds. Also, these biofilms enable bacteria to accompany fungi as they reached new areas searching for nutrients and enhance breakdown combined effect. The attachment of the second colonizer was not affected remarkably by the preceding attachment of the first [22-23].

**Quorum sensing**

The idea of quorum sensing as a communication mechanism for microorganisms to regulate population growth was found in both gram-positive and gram-negative bacteria [24-25]. When the population has reached a certain sill density, high enough to overpower the immune system; bacteria increase infecting their host opportunity by delaying virulence factors then they change their behavior and progress to a full- ruined disease state. Quorum sensing (QS) or cell to cell signaling systems are also administered in Vibrio species and necessitate population density-dependent synthesis, release, and detection of signaling molecules; auto inducer. At high auto inducer set up concentrations in the medium, it will bind to a transcription regulator, LuxR in *V. fischeri*, which will then alter the gene expression [26-28].

Cells cannot exchange macromolecules such as DNA or protein, but they can exchange small diffusible auto inducer molecules. The auto inducer is produced and subsequently sensed by the bacterial cells. The difference between the genetically encoded macromolecules and enzymatically produced small auto inducer molecules is that auto inducer can more frequently cross membranes and thus affect the phenotype of neighboring cell subsequently used to complement the genetic defect in the original mutant strains. Auto inducers can be thought of as pheromones; chemicals produced by an individual that can be sensed, and interpreted as a specific code of information, by other individuals within a population. In many of the gram-negative bacteria, N-Acyl-L-homoserine lactones (AHLs) produced by the bacteria bind to transcriptional regulators resulting in activation or repression of target genes [29]. However, certain bacteria including *Escherichia coli* and *Salmonella enterica* are incapable of synthesizing AHLs but possess the AHL receptor known as SdiA. It has been shown that SdiA in *E. coli* and S. enterica binds to AHLs produced by other bacterial species and regulates gene expression. The sdiA gene in *Salmonella* regulates the rck gene, which mediates adhesion and invasion of epithelial cells and the resistance of the pathogen to the host complement. In *E. coli*, SdiA regulates genes involved in acid resistance, virulence, motility, biofilm formation, and autoinducer-2 transport and processing. Though the involvement of AHL-receptor, SdiA in biofilm formation of *E. coli* and *Salmonella* have been investigated, yet the role of the signaling molecules in cell attachment and surface colonization needs more investigation [30]. Many members of the *Vibrionaceae*are known to regulate activities such as biofilm formation, virulence, and luminescence by the mechanism of quorum sensing, e.g *V. fisheri*. The pathogen *V. parahaemolyticus* with AHL mediated quorum sensing signaling molecules in the biofilms is a worldwide cause of food-borne gastroenteritis which is usually self-limited and lasts for several days [31]. However, there is a lack of information concerning the role of acyl homoserine lactones in regulating biofilm formation in the enteric pathogens *E. coli*, *Vibrio and Salmonell*a in food environments. The budding yeast *Saccharomyces cerevisiae* exhibits this regulation and the signals are aromatic alcohols as extracellular signals to transmit information about population density and environmental conditions. The mechanism by which quorum sensing can be inhibited is called quorum quenching [32]. Nonbiocidal molecules provide a competitive interaction within biofilms that could lead to ant biofilm strategies of potential biomedical interest.

**Strategies for community-based diseases**

Biofilms are consortia of micro-organisms that formed on various surfaces including, household, mucosal membranes, teeth medical devices [33]. Besides surfaces, some pathogen constructs form slimy 'streamers' that clogged up medical devices. In the medical industry, the biofilm is referred to as glycocalyx when diseases of the lungs or the gastrointestinal or urinary tract are involved.

Compared with their planktonic complement, the compact microbial aggregates present in biofilms show extraordinary resistance to traditional biocides, antimicrobial treatments and most important, responses to the

host immune defense. Biofilms pose a double threat to the patient as a persistent source of infection, they may also result in the deterioration of the surface, leading to a loss of its functionality and a need for the substitution of the device. Antimicrobial treatment gets rid of most of the microbial cells, as a result of that minimize the symptoms [34]. However, a significant portion of sessile cells may last, regrow, and leads to biofilm stability or homeostasis cause appearance of the symptoms.

Under normal healthy conditions, biofilms live in the gut and large bowel protecting the host by aiding the digesting luminal contents and defending against pathogenic attack. However, the nature of biofilms on medical devices including hospital-acquired infections and biofouling dental hand pieces come in contact with oral microorganisms during use play a role in the chronic nature of chronic harm. Also, undesirable bacterial adherence on inert food surfaces could lead to food contamination, resulting in food spoilage and disease widespread [35-36]. The difference between the occurrence of *P. acnes* as a skin commensal in healthy hosts or as a pathogen in acne ulcer could be related to phenotypical differences associated with biofilm formation quorum sensing.

**Biofilm formation by industrial bacteria**

Although the biofilm forming capacity has been associated with the pathogeny or spoilage in medicine and food industry including dairy, poultry and meat processing [37]. Biofilm forming is sometimes a desired feature especially, in the food industry as in using yeast strains. Some yeast species are biotechnological appropriate such as *Saccharomyces cerevisiae* might exhibit the QS type. The yeast integration has an importance for the food industry in fermentation and brewing industry and also cheese ripening (38). In the QS mechanism of the yeast strains, aromatic alcohols are the most observed signal molecules and the regulation of the QS mechanism can result in adaptation and development of industrial processes that performed by yeast species. The signaling network could be controlled by tryptophol and phenyl ethyl alcohol in *S. cerevisiae*. Dimorphic fungal pathogen *Candida albicans* has been shown to produce tryptophol and phenyl ethyl alcohol [39-40]. *Bacillus subtilis* is an industrially important bacterium exhibiting developmental stages. It forms rough biofilms at the air-liquid interface rather than on the surface of a solid phase in a liquid, due to the aerotaxis of the cells. Biofilm formation by B. subtilis and related species permits the control of infection caused by plant pathogens, the reduction of mild steel corrosion, and the exploration of novel compounds. Although it is obviously important to control harmful biofilm formation, the exploitation of beneficial biofilms formed by such industrial bacteria may lead to a new biotechnology.

Different biofilms are used in pulp and paper industry, ethanol [41], 2,3-butanediol, polysaccharides, and butanol production, in organic acid production, for gas and odor treatment. Immobilized biofilm of *Citrobacter* sp. for the removal of uranium and lead from the industrial flowing water system [42].

Corrosion resulted in the severe economic loss and the applied corrosion control methods are expensive, sometimes have environmental restrictions and may be inefficient. The microbial corrosion inhibition is an alternative technique by using beneficial bacteria biofilms [43]. This technique involves removal of corrosive agents; oxygen by aerobic respiration in bacterial physiological activities, and inhibiting corrosion-causing bacteria by antimicrobials substances originated, within biofilms and generation of protective layer by biofilms as it is the case in by inhibiting sulfate-reducing bacteria causing corrosion by gramicidin S-producing *Bacillus brevis* biofilm, and *Bacillus licheniformis* biofilm produces a protective layer on aluminum surface of gamma-polyglutamate. The application of this strategy depends on the study of corrosion engineering and biofilm formation. There are also anaerobes that can produce corrosive biofilms [44].

On the contrary, densely packed multicellular communities of microorganisms or biofilm formation cause problems in many branches of industry, as the biofilm is a "disease" in the equipment such as in industrial water systems and the medical process industries [45]. Besides causing problems in cleaning and hygiene, the biofilm may cause energy losses and blockages in condenser tubes, cooling fill materials, water and wastewater circuits, heat exchange tubes, and on ship hulls. Sometimes, biofilmcan also present microbial risks due to the release of pathogens from cooling towers or by reducing water quality in drinking water distribution systems.

**Elimination of Biofilms**

Traditionally, detergents, biocides, enzymes, and mechanical or physical methods of cleaning bio fouled surfaces cleaning have been used in the elimination of biofilm [46-47]. Biofilms are formed on critical locations in the food and beverage processing plants industries, with available nutrients and inadequate cleaning and disinfection, lead to a number of problems such as food spoilage, production efficiency problems. These microorganisms may survive for prolonged periods after application, depending on the medium temperature, and relative humidity. Agents used in the pulp and paper industry for the elimination of biofilm are divided into three groups: oxidizing agents: chlorine, chlorine dioxide, hydrogen peroxide, ozone, nonoxidizing agents (methylene bisthiocyanate), and enzymes. Sodium dichloroisocyanurate, hypochlorite, iodophors, hydrogen peroxide and per acetic acid are used efficiently against *Staphylococcus aureus a*dhered cells [48],. Per acetic acid was the most efficient in removing adhered Large numbers of *L. monocytogenes* cells that remained on stainless steel chips after sanitizer treatment [49-50]. Scanning electron microscopy revealed that biofilm cells and extracellular matrices remained on chlorine and anionic acid-treated surfaces better than iodine and quaternary ammonium detergent sanitizers, from which no viable cells were released.

Oxidative and nonoxidative biocides have been used for a long time [51], whereas the use of enzymes is currently on a trial basis. Tanks, pipelines, pasteurizers, coolers, membrane filtration unit and fillers in various industries must be inspected to establish a quality control program me because it helps prevent microbiological hazards and significant financial losses.

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