Blog Series: Biofilm Part 2

BIOFILMS IN THE FOOD INDUSTRY

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In part 1 An Introduction To Understanding Biofilm we looked at the background to biofilms and briefly described their formation and the reasons why they are of prime concern in the food and medical industries. This time we will look at the main pathogens of concern in the food industry.

Biofilms are complex microbial ecosystems formed by one or more species immersed in an extracellular polymeric matrix (EPS) of different compositions depending on the type of pathogen, environment and colonizing species.
The presence of more than one bacterial species in a biofilm has important ecological advantages because it can facilitate the biofilm's attachment to a surface and contribute to its increased resistance to sanitisers and disinfectants.

In the food industry the EPS can attach to hard surfaces or biological structures (vegetables, meat, bones, fruits, etc). Once formed the biofilm confers many advantages to the microbial cells encased in it:

- Physical resistance (against desiccation)
- Mechanical resistance (against liquid streams in pipelines)
- Chemical protection (against chemicals, antimicrobials and disinfectants used in the industry.

Of particular importance to the food industry is that some biofilms in food factory environments are human pathogens and they are able to develop on different artificial substrates such as stainless steel, polyethylene, wood, glass, polypropylene, rubber and concrete.
The associated effects of these biofilms (pathogenicity and corrosion of metal surfaces etc) are of critical importance in some industries, such as dairy factories, where numerous processes and structures (raw milk tanks, pipelines, butter centrifuges, cheese tanks, pasteurizers, and packing tools) act as surface substrates for biofilm formation at different temperatures and with different colonizing species.

HEALTH ASPECTS ASSOCIATED WITH FOOD INDUSTRY BIOFILM

Food-borne diseases associated with pathogenic biofilms on food surfaces or factory equipment can arise via intoxications or infections. As an example, toxins can be secreted by biofilm found within food processing plants. From there, they can contaminate a food surface causing individual or multiple (in the case of an outbreak) intoxications. Either way the presence of biofilms in a food factory puts human health at risk.
The main locations for biofilm development depend on the factory type, but may include water, milk and other liquid pipelines, pasteurizer plates, reverse osmosis membranes, tables, employee gloves, animal carcasses, contact surfaces, storage silos for raw materials and additives, dispensing tubing, packing material, etc.

Listed below are five of the most important food borne bacterial pathogens in NZ (apart from campylobacter) and their effects on human health and their capability to form biofilms on different substrates.

Pictured above: Stock imagery of dairy beverage production line

Bacillus cereus

Bacillus cereus is an anaerobic gram positive and spore-forming bacterium that has the ability to grow in different environments and over a wide temperature range (4–50°C). It is resistant to heat, chemical treatments, radiation and industrial pasteurization processes. This complicates the removal of biofilm with cleaning procedures and can affect biofilm persistence in dairy factories, reducing pasteurized milk and cream shelf-life.

Various strains of this bacteria cause a wide range of health issues including diarrhea, vomiting, extreme dehydration and other symptoms of food poisoning and may even lead to death.
B. cereus biofilms are found mainly at the air-liquid interface attached to the deposit wall from which the bacterial biofilm matrix protrudes onto the liquid surface. Some strains are able to form biofilms on submerged surfaces, for example, on stainless steel tanks and pipes. From these biofilms, bacteria can easily migrate long distances along the food factory pipeline, posing serious health risks if they reach the food batches distributed to consumers.

Enterohemorrhagic Escherichia coli

Most E. coli strains are part of human intestinal microbiota, where they do not represent a health problem. Unfortunately, some strains do pose a health risk and are noxious foodborne pathogens transmitted by drinking water, fruits and vegetables (tomatoes, melons, parsley, cilantro, lettuce, spinach etc), raw milk or fresh meat. These products may have been contaminated at their origin or as part of the food manufacturing process.

Pathogenic E-coli strains are known as STEC and they produce Shiga toxin (STEC). This toxin produces bloody diarrhea in humans and in some cases severe kidney disease. The common 0157:H7 strain is a STEC.

In the food industry, contamination can take place during the pre-harvest period, as a result of a contaminated water supply when cultivating the vegetables. It may also take place in post-harvest environments, where it can appear after washing and processing the raw material (carcasses, vegetables, etc.), but also because of storage at temperatures which promote fast growth of bacterial contaminants.

A number of studies have shown that E. coli strains can attach to a variety of surfaces including stainless steel, Teflon, glass, polystyrene, polypropylene, PVC and biotic surfaces. The hydrophobicity of the surface material plays an important role in biofilm formation by this species. As an example, the O157:H7 strain showed strong biofilm formation on borosilicate glass and stainless steel, but little or no biofilm was observed on polypropylene, probably due to this plastic's hydrophobic nature.

E-coli survival under stress conditions and its biofilm formation abilities are strain dependent. O157:H7 displayed resistance to temperature, high pressure and common food industry disinfectants when compared to other pathogenic and non-pathogenic E. coli strains, such as O111:H-, O103:H25, O26 or O145.

Some strains of E-coli have a high resistance to acid conditions which allow them to survive in food industry processes involving acetic (commonly used in some canned vegetable products), citric (commonly used in fruit juice industry as a preservative), as well as propionic and lactic acids (commonly used in fermented dairy and meat products).

Another major problem of STEC strains, O157:H7, is that less than 50 ingested CFUs (colony forming units) are necessary for an infectious dose. This means even a low-grade biofilm contamination of a food factory installation is a serious health problem and requires that strong control measures are in place.

Listeria monocytogenes

The gram-positive bacteria L. monocytogenes (L.mc) is a ubiquitous, dangerous, foodborne pathogen. However, it is not resistant to pasteurization treatments. Some examples of foods known to transmit this pathogen are seafood, dairy products, meat, ready-to-eat products, fruits, soft cheeses, ice cream, unpasteurized milk, candied apples, frozen vegetables, and poultry.

Listeria monocytogenes biofilms are mainly composed of polyglycerol phosphate polymers (teichoic acids) which promote growth of the biofilm on polypropylene, steel, rubber, glass and concrete surfaces throughout the food industry.

Pictured above: Stock imagery of Listeria animated visualisation on produce

The acid component of L.mc promotes exceptional adhesion of the biofilm to all surfaces as well as resistance to pH changes and lysis inducing disinfectants and sanitisers. Once established on a surface this pathogen spreads to food batches, where it can replicate at refrigeration temperatures. Common contaminated foods are smoked fish, cold cuts and fresh cheese. Together with this low temperature replication ability, this pathogen enhances its hydrophilicity and induces biofilm status as a response to cold temperatures, increasing its attachment to surfaces and its resistance to cleaning procedures in many food factories.
The eradication of this pathogen in the food industry is further complicated by its resistance to treatments up to 60°C.

L.mc causes gastroenteritis in healthy individuals. In pregnant women, infants, the elderly and immunocompromised individuals, it causes listeriosis, a critical disease which also involves septicaemia and meningitis. In pregnant women, listeriosis can lead to spontaneous abortion or damage to the foetus.

All of the above factors highlight the great clinical importance of L. monocytogenes biofilm monitoring and control in all aspects of the food industry.

Salmonella enterica

This gram-negative foodborne pathogen causes gastroenteritis or septicaemia (in the case of some strains). S. enterica strain Enteritidis is the most frequent, generating nausea, vomiting, fever, diarrhoea and abdominal pain as main symptoms. Poultry meat is a common reservoir for these bacteria in processed food.
Its importance as a food pathogen is shown by the fact that S. enterica biofilm formation on food surfaces was the first ever reported. S. enterica is able to grow on stainless steel but glass surfaces are not normally suitable for S. enterica biofilm production.
Of major importance however is that under dry conditions S. enterica can survive in a biofilm on stainless steel for over a year. From there, it is possible for this pathogen to contaminate thousands of food batches.

Salmonella enterica is capable of easily attaching to meat and other food matrixes, eventually leading to cross-contamination between food batches in a manufacturing plant or supermarket. In fact, the main source of contamination by this pathogen is biofilm formation in infrastructures used during pre-cooked foods manufacturing (such as pre-cooked chicken).

In 2016, S. enterica was identified as the second most frequently agent (just after Campylobacter) of food-borne and water-borne outbreaks in the EU, with 94,625 cases.

Staphylococcus aureus

Staphylococcus aureus is a Gram-positive, non-spore forming, non-motile, facultative anaerobic bacterium. It is a human opportunistic pathogen, largely due to its characteristic production of enterotoxins at temperatures between 10 and 46°C.
This species is able to multiply on the mucous membranes and skin of food handlers, a major issue for food factories because staphylococcal enterotoxins are heat-stable and are secreted during its growth in a food matrix. Food matrixes with a low water activity, such as those with high sugar or salt content, are suitable for this pathogen.

These enterotoxins give rise to an acute toxic shock with diarrhea and vomiting. The emergence of methicillin-resistant S. aureus (MRSA) in farm animals has caused great concern because animal-derived foods are a primary contamination origin for this resistant pathogen and it is able to form biofilms on many different kinds of animal surfaces.

S. aureus can form biofilms on both biotic and abiotic surfaces along the food production chain. The growth is enhanced by various processing methods encountered in the food industry, such as suboptimal temperatures, improper disinfection or a combination of salt and glucose. Another issue is that the virulence of this pathogen can be increased in the presence of sub-lethal concentrations of various common detergents and cleaners used in the food industry.

To learn more about Biofilms, how to manage then and how AWS Group can help, you can find the full series within the testimonials & blogs section of our website.

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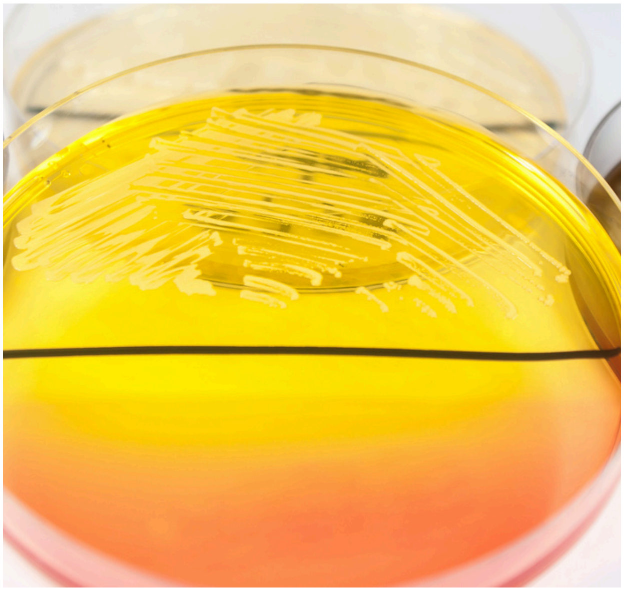

Pictured above: Stock imagery of S. aureus in petri dish