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Wirtanen, Gun

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Microbial Surface Hygiene

Gun Wirtanen

University of Helsinki Ruralia Institute, Finland

Introduction

Pathogenic microbes have been reported to form biofilms on equipment surfaces and in pipelines. Outbreaks with pathogens have seriously damaged the consumers' trust in safe production. In European Union (EU) in 2014 there was a total of 5,251 food- and waterborne outbreaks reported. Most outbreaks were caused by viruses, followed by *Salmonella*, bacterial toxins and *Campylobacter* sp. In the EU there has been an increase in confirmed human cases of campylobacteriosis, mostly from broiler meat, since 2008. The number of human listeriosis cases has also increased, despite that *Listeria monocytogenes* in ready-to-eat foods seldom exceeded the safety limit (≤ 100 CFU/g) in EU. The number of verocytotoxigenic *Escherichia coli* infections in humans was at the same level as in 2013. These facts show that there is a need of development of optimal pathogen management strategies in the above-mentioned processes.

Therefore, it is important to prevent biofilm formation in processes through good design and manufacturing practices e.g. hygienic design, choice of surface materials, building of equipment and process lines, cleaning as well as disinfection procedures in processes. The maintenance of cold processing conditions is also important in reducing the microbial growth both on surfaces and in moist products. Furthermore, training is needed to keep process hygiene and product safety at a high level and diminish process based microbial deterioration of products. The accessibility, cleanability and drainability are important tools in combating biofilms in the food, pharma and biotech industry.

Biofilm formation on process surfaces

A biofilm consists of microbial cell clusters with internal channels or voids, which allows nutrients and oxygen to be transported from the liquid to the cells in the matrix of extracellular polymeric substance (EPS). The microbes tend to form protective EPS of polysaccharides and glycoproteins to be able to survive hostile environmental factors, e.g. heat and chemicals. The microcolony formation or microbial adhesion is the first stage in both reversible and irreversible biofilm formation. The reversible phase involves the association of cells close but not attached to surfaces. Cells associated within the EPS formation bind the cells irreversibly to the surface. When the biofilm build-up is described more thoroughly phases like transportation of cells to a wetted surface, absorption of the cells into a conditioning film, adhesion of microbial cells to the wetted surface, cell replication and detachment of biofilm from the surface are included. It is also important to remember that up to 96 % of a biofilm consists of water, which means that less than 5 % of the total biofilm volume is detectable on dry process surfaces. Contamination of persistent microbes means that microbes for long periods has caused contamination in the process. Once a biofilm is formed on either the contact or environmental surfaces, it can be a contamination source for products processed in the process line(s).

The microbes can form biofilms on any commonly used process surface material, where either moisture or water is available. Harmful microbes may enter the manufacturing process through/with e.g. raw materials, air in the manufacturing area, process waters, additives, equipment, and/or the factory personnel and reach the end-product. Microbes prefer attaching on solid surfaces rather than swimming in the liquid and therefore microbial process contamination is often related to biofilm formation. Several microbes e.g. *Pseudomonas* sp. produce sticky and/or slimy biofilm structures with microbial cells embedded on the surfaces. The attachment of microbes on both abiotic and biotic surfaces is also affected by presence of organic material e.g. organic residues as well as by temperature, acidity and cell-to-cell communication. Physical parameters e.g. fluid flow rate, surface hydrophobicity, roughness and charge as well as other material properties affect the attachment of cells to the surfaces.

General principles and requirements

Development of optimal biofilm management strategies in processes requires knowledge of contaminants and their routes and how various foods e.g. salads, deli meat or stews becomes a vehicle for disease transmission. General principles and requirements in the European law on food safety in the whole chain from farm to fork are specified in the EC Regulation No 178/2002. The European process hygiene criteria are given in the EC Regulations 852/2004, 853/2004, 854/2004, and the Machinery Directive 2006/42/EC. The hygiene rules in the EC regulations 852/2004 on the hygiene of foodstuffs, 853/2004 on specific hygiene rules for food of animal origin and 854/20014 on specific rules for the

organisation of official controls on products of animal origin intended for human consumption were all adopted in April 2004 and they became applicable from beginning of 2006. The food contact materials must be safe to use in food processing and should thus fulfil the EC Regulation No. 1935/2004.

More specific information can be found in the hygiene standard EN 1672-2+A1:2009 "Food processing machinery standard - Basic concepts - Part 2: Hygiene requirements" and the European Hygienic Equipment & Design Group (EHEDG) guidelines with both basic and specific design rules for process equipment, lines and facilities. The most fundamental EHEDG guidelines are: Document 8 'Hygienic equipment design criteria', Document 10 'Hygienic design of closed equipment for the processing of liquid food', Document 13 'Hygienic design of equipment for open processing', Document 22 'General hygienic design criteria for the safe processing of dry particulate materials', Document 26 'Hygienic engineering of plants for the processing of dry particulate materials' and Document 44 'Hygienic Design Principles for Food Factories'. Best practices in civil engineering is the base for the Document No. 44. In the quality management standards, e.g. ISO 22000 and British Retail Consortium Standard there is information how to produce safe products. The hygiene rules, which evolve with time, state that the primary responsibility in food safety is by the business operator and that the food safety shall be implemented based on the Hazard Analysis and Critical Control Points (HACCP) principles.

Prevention of biofilm formation

The aim of microbial control in a process line is two-fold to reduce/limit the number of microbes in liquids and products and their activity as well as to prevent/control the biofilm formation on surfaces. In the food, pharma and biotech industry, equipment design plays an important role in combating biofilm formations. The adherence of microbes to both contact and non-contact surfaces can be due to the complexity of process equipment, in which residues are collected and which are hard to clean. In preventing biofilms on surfaces through hygienic design attention should be drawn to dead spaces, corners, crevices, cracks, fasteners, screw heads, threads, seals, gaskets, and valves. Other hygienic design features like weldings and joints should be designed to prevent the accumulation of soil and allow easy cleaning thus prevent biofilm build up. Surface materials and their roughness treatments e.g. grinding and polishing can take part in active rejection or passive removal of biofilms. If the design is not improved poor designs can lead to persistent organisms in the process equipment, lines or even premises through adaptation to disinfectants in improper structures i.e. in places where disinfectants in sub-lethal concentrations can be harboured subsequently affecting the microbes. Improper cleaning and disinfection procedures of contact surfaces contribute to formation of biofilms.

The key to effective cleaning in a food, pharma or biotech factory is that the personnel understands the nature and type of soil, e.g. fat, proteins, carbohydrates, sugar and salts, including microbes they must remove from the surfaces. An efficient cleaning procedure consists of a sequence of detergent and disinfectant applications at effective concentra-

tions and correct temperatures as well as water rinses. Prolonged exposure to cleaning chemicals of surfaces in the process equipment/lines improves the soil removal. The cleaned equipment and process lines should be left to dry in well ventilated areas, because microbes do not grow on dry, clean surfaces. Equipment that commonly causes problems in process hygiene are conveyors, plate heat exchangers, tanks with pipelines, slicing and cutting equipment, as well as filling and packing machines. These types of equipment can cause safety problems due to biofilms of spoilage microbes e.g. lactic acid bacteria and/or pathogens e.g. L. monocytogenes and B. cereus. More about biofilm control measures in the latter articles in this series.

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