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DAIRY INDUSTRIAL HYGIENE: A REVIEW ON BIOFILM CHALLENGES AND CONTROL

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Abstract

The development of biofilms and the microbial biofilm adherence into the production equipment and facilities used in the dairy industry is a critical issue that needs to be addressed. Biofilms lead to the contamination of food by pathogenic and spoilage m/os. The microbes cause both company loses due to unsafe spoilt products, equipment depreciation and death of consumers under severe pathogenic out breaks. Biofilms may also lead to a failure of anti- microbial therapy hence major threats to modern medicine. Biofilm formation however is a dynamic process with different mechanisms involved in the biofilm growth. Raw milk provides an ideal medium for the formation of a biofilm as it contains bacteria and is nutrient-rich. This paper gives highlights regarding microbial sources, challenges, biofilm control strategies that include but not limited to physical, mechanical, enzymatic and chemical methods for the effective control of formation and or eradicate biofilm in the dairy industry.

Keywords: Dairy Industry; Biofilm; Contamination; Challenges; Control.

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1. Introduction

Biofilms are broad aggregation of microorganism on surfaces and are essential in many industrial activities [1-3]. Biofilms are regarded as a biopolymer matrix-enclosed bacterial population adherent to each other and/or surfaces or interfaces [1, 4]. During manufacturing, bacteria cells have a tendency to live and attach themself to surfaces forming a complex structure called a biofilm [5]. Once biofilms are formed on a contact surface, they become quite resistant to antimicrobial agents because of the slimy layer formed by bacteria [6].

The formation of biofilms is a complex process influenced by factors such as; specific bacteria strain, material surface properties, pH, nutrient levels and temperature [3, 7, 8]. Bacteria are renowned for their ability to tolerate and adapt to a wide range of adverse environmental

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conditions [4, 9] become more problematic in a wide range of food industries including the dairy industry [3, 10].

Biofilm persistence on food contact surfaces and equipment leads to a continuous contamination [11]. Several reports show that bacterial cells in biofilms are considered difficult or even impossible to eradicate [12, 13] leading to a serious hygiene problem [14]. Moreover, biofilm formation on dairy equipment can lead to economic loss due the deterioration of food and equipment impairment [5, 15].

Studies have shown that some foodborne pathogens persist on food production equipment [1, 16, 17], surfaces forming biofilms that severely affect the quality, quantity and safety of the food products. The sessile populations of bacteria are responsible for bacterial population to persist [4, 18] [19]. Some biofilms-associated bacteria exhibit antibiotic resistance [19, 20].

Several studies show that biofilms cause dairy product spoilage through contamination. For example, the heat resistant spore forming Bacillus species can cause spoilage even in sterilized milk due to their production of lipolytic and proteolytic enzymes or recontamination during packaging of sterilized milk making it difficult to produce sterile dairy products [21]. Biofilms formed by coagulase-negative staphylococci (CNS) species may cause intramammary infections [18] and other severe infectious fatal diseases if no care isn't given [9].

Biofilms are also known to be a frequent source for infections [3] with over 80% of persistent bacterial infections in the United States [22]. Biofilm also enables gene transfer among bacteria which can lead to increase in the number of virulent strains. There are few studies regarding biofilms formation [23]. Microbial biofilms cause metal corrosion in pipelines and tanks by catalyzing chemical and biological re actions, and they can reduce the heat transfer efficacy if biofilms become sufficiently thick at plate heat exchangers and in the pipelines. Health wise, biofilms can lead to medical concerns such as catheters, artificial hips and research shows that biofilms are associated with about 65% of nosocomial infections and with their treatment approximated to be over 4 $1 billion annually in the U.S [2].

It's against the above critical issues that this review paper is focused on the challenges caused by biofilm in the dairy industry giving recommendation for management and control methods based on the most recent studies available.

2. Common Process for Biofilms Control

2.1. Physical Control

Use of ultrasound treatment, Super-high magnetic fields, high pulsed electrical on their own, low electrical fields both on their own help to control biofilm. Low currents of 200 and 400 mA, using silver, carbon and platinum electrodes killed planktonic cells of Gram-positive and Gram-negative bacteria and Candida albicans are important in regulating biofilm formation. Hurdle application in combination with antibiotics and low electrical currents is effective in biofilm control [2]. Electrolyzed water has an antimicrobial activity especially when it is slightly acidified helps to inactivate Salmonella enteritidis [24]. Use of stainless steel or hydrophilic

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surfaces coated with Nano-plasma trim ethyl silane (TMS) helped to prevent S. epidermis biofilms [25, 26]. An antimicrobial lock technique (ALT) is used to inhibit biofilm formation in catheters [9].

2.2. Chemical Control

Biofilms can be control by the use of biocides, antibiotics, and ion coatings. Studies show that use of aminoglycosides in combination with iron-chelating compounds is important in the disruption of Pseudomonas aeruginosa biofilms [27]. Application of sodium citrate can also inhibit biofilm formation of Staphylococci species in vitro [28].

Antimicrobial agent such as N-alkylpyridinium bromide attaches to a poly (4-vinyl-N-hexylpyridine) is capable of inactivating about 99% of E. coli, S. epidermidis, and P. aeruginosa bacteria [2]. Peroxyacetic acid (PAA) is a sanitizer with high oxidizing potential is effective against bacteria, fungi and spores in the dairy industry [15] because it is not inactivated by catalase or peroxidase [23] . Studies show that use of ozone in Europe was effective in disinfecting drinking water and it is also a better oxidizer than chlorine and hence effective in inactivating Pseudomonas fluorescents on glass slides [29].

2.3. Mechanical Control

The mechanical biofilm control methods aim at the disturblization of bacteria from surface attachment, surface charge and hydrophobicity through the application of compounds that can prevent the biofilm formation and their spread on surface [30-32]. The use of smooth surfaces equipment is more preferred as they are less susceptible to biofilm adhesion [33]. Modification of the surface charge of polymers also enables the prevention of biofilm. Positively-charged polycationic chains enable the molecule to stretch out and generate bactericidal activity [2].

For proper and easy CIP, equipment must be connected to the cleaning and drainage systems. Detergents must reach all washable surfaces. Machines and pipes must be laid in order for easy drainage and all residual water connected to a drainage system to avoid contamination [34, 35]. All dairy-handling materials such as stainless steel, plastics or elastomers, must be of high quality food grade to avoid material product reaction leaving no trace, smell or taste to the product. They must also be resistant to contact with detergents and disinfectants at the cleaning temperature. Stainless steel is a universal material for use in the modern dairies [34].

2.4. Bacteriophages Control of Biofilms

Bacteriophages are a numerous group of viruses which are easily manipulated, and they have various functions in biotechnology, bacterial control, and therapeutics [36].

Bacteriophages are ubiquitous in nature that infects bacteria naturally and may provide a natural, highly specific, non-toxic, feasible approach for controlling biofilm formation. They may either coexist with their host by inserting themselves into the bacterial genome (lysogenic bacteriophages) or destroy them. Phage T4 and E27 help in the control of E. coli and Pseudomonas aeruginosa biofilms. Enterobacter agglomerans type of biofilms can be destroyed

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through cell lysed by bacteriophage [37]. Many studies show that phages alone disrupt Staphylococcus epidermidis growing biofilm colonies on silicon catheters [38]. Phages are also effective in the removal of biofilms in their early stages of development about 5 days old biofilms of P.fluorescens [39]. A bacteriophage such as L. monocytogenes phage ATCC 23074-B1 helps to inactivate L. monocytogenes [40].

2.5. Enzymatic Control of Biofilm

Biofilm in the dairy industry are formed by; Lactobacillus bulgaricus, Lactobacillus lactis, Streptococcus thermophiles are the most common microorganism that form biofilms [2, 41]. Enzymes like α-amylase, β-glucanase and protease were proved effective in the cleaning of adhered industrial biofilm formed during paper pulp production. Exopolysaccharide degrading enzymes more so the colanic acid degrading enzymes derived from a Streptomyces isolate was reported for the removal and prevention of biofilm formation [2]. Biofilms control with proteases such as Proteinase K and Trypsin, ensuresass the destruction of biofilm formation and biofilm removal [42] [43] and can disrupt biofilms formed by S. aureus [44]. Synergistic action of enzymes in combination with surfactants and phenolic antimicrobials are important in the control of biofilms although the application of enzymes in biofilm control is still limited.

Enzymes like lipases and proteases are often selected as complementary cleaning agents when simple chemicals such as alkaline and acid are not enough for cleaning and recovering the membrane capacity. However, most of the studies using enzyme cleaners focus on the removal of protein fouling, but did not aren't effective on biofilms [23].

3. Conclusion

Dairy products are highly contaminated mainly through the release of bacteria from biofilms to dairy product from contaminated milk handling equipment, raw material and personnel. Biofilm contamination of dairy products results to out-break of diseases, reduced product value, products lose and in advance cases closure of business. The dairy industrial hygiene is a crucial aspect to be monitored by following a strict sanitation routine. Recent studies on dairy biofilms should provide detailed information on how dairy biofilms develop and suggest more effective alternative control measures to delay biofilm growth and reduced product contamination to improve quality and safety of dairy products.

References

[1] Wang, W., et al., Prevalence, serotype diversity, biofilm-forming ability and eradication of Listeria monocytogenes isolated from diverse foods in Shanghai, China. Food Control, 2017. 73: p. 1068-1073.
[2] Satpathy, S., et al., Review on bacterial biofilm: an universal cause of contamination. Biocatalysis and Agricultural Biotechnology, 2016. 7: p. 56-66.
[3] Srey, S., I.K. Jahid, and S.-D. Ha, Biofilm formation in food industries: a food safety concern. Food control, 2013. 31(2): p. 572-585.
[4] Clutterbuck, A., et al., Biofilms and their relevance to veterinary medicine. Veterinary microbiology, 2007. 121(1-2): p. 1-17.

[5] Lee, S., et al., Effect of peracetic acid on biofilms formed by Staphylococcus aureus and Listeria monocytogenes isolated from dairy plants. Journal of dairy science, 2016. 99(3): p. 2384-2390.
[6] Martins, E.A. and P.M.L. Germano, Listeria monocytogenes in ready-to-eat, sliced, cooked ham and salami products, marketed in the city of São Paulo, Brazil: Occurrence, quantification, and serotyping. Food Control, 2011. 22(2): p. 297-302.
[7] Nilsson, R.E., T. Ross, and J.P. Bowman, Variability in biofilm production by Listeria monocytogenes correlated to strain origin and growth conditions. International Journal of Food Microbiology, 2011. 150(1): p. 14-24.
[8] Farizoglu, B. and S. Uzuner, The investigation of dairy industry wastewater treatment in a biological high performance membrane system. Biochemical Engineering Journal, 2011. 57: p. 46-54.
[9] Bordi, C. and S. de Bentzmann, Hacking into bacterial biofilms: a new therapeutic challenge. Annals of intensive care, 2011. 1(1): p. 19.
[10] Flemming, H.-C. and H. Ridgway, Biofilm control: conventional and alternative approaches. 2008.
[11] Abdallah, M., et al., Biofilm formation and persistence on abiotic surfaces in the context of food and medical environments. Archives of microbiology, 2014. 196(7): p. 453-472.
[12] Cos, P., et al., Biofilms: an extra hurdle for effective antimicrobial therapy. Current pharmaceutical design, 2010. 16(20): p. 2279-2295.
[13] Römling, U. and C. Balsalobre, Biofilm infections, their resilience to therapy and innovative treatment strategies. Journal of internal medicine, 2012. 272(6): p. 541-561.
[14] Sosnowski, A., et al., Remote regions, remote data: A spatial investigation of precipitation, dynamic land covers, and conflict in the Sudd wetland of South Sudan. Applied Geography, 2016. 69: p. 51-64.
[15] Bremer, P.J., S. Fillery, and A.J. McQuillan, Laboratory scale Clean-In-Place (CIP) studies on the effectiveness of different caustic and acid wash steps on the removal of dairy biofilms. International journal of food microbiology, 2006. 106(3): p. 254-262.
[16] Nam, H., et al., Efficacy of gaseous chlorine dioxide in inactivating Bacillus cereus spores attached to and in a biofilm on stainless steel. International journal of food microbiology, 2014. 188: p. 122-127.
[17] Raza, A., et al., Biofilm producing Staphylococcus aureus and bovine mastitis: a review. Molecular microbiology research, 2013. 3(1).
[18] Vanderhaeghen, W., et al., Invited review: Effect, persistence, and virulence of coagulase-negative Staphylococcus species associated with ruminant udder health. Journal of dairy science, 2014. 97(9): p. 5275-5293.
[19] Jahid, I.K. and S.-D. Ha, A review of microbial biofilms of produce: future challenge to food safety. Food Science and Biotechnology, 2012. 21(2): p. 299-316.
[20] Vasudevan, R., Biofilms: microbial cities of scientific significance. J Microbiol Exp, 2014. 1(3): p. 00014.
[21] Flint, S., et al., Bacillus thermoamylovorans–A new threat to the dairy industry–A review. International Dairy Journal, 2017. 65: p. 38-43.
[22] Janssens, J.C., et al., Brominated furanones inhibit biofilm formation by Salmonella enterica serovar Typhimurium. Applied and Environmental Microbiology, 2008. 74(21): p. 6639-6648.
[23] Tang, X., et al., The efficacy of different cleaners and sanitisers in cleaning biofilms on UF membranes used in the dairy industry. Journal of Membrane Science, 2010. 352(1-2): p. 71-75.
[24] Cao, W., et al., Efficiency of slightly acidic electrolyzed water for inactivation of Salmonella enteritidis and its contaminated shell eggs. International Journal of Food Microbiology, 2009. 130(2): p. 88-93.
[25] Augustin, M., et al., Towards a more sustainable dairy industry: Integration across the farm–factory interface and the dairy factory of the future. International Dairy Journal, 2013. 31(1): p. 2-11.

[26] Privett, B.J., et al., Antibacterial fluorinated silica colloid superhydrophobic surfaces. Langmuir, 2011. 27(15): p. 9597-9601.
[27] Moreau-Marquis, S., G.A. O'toole, and B.A. Stanton, Tobramycin and FDA-approved iron chelators eliminate Pseudomonas aeruginosa biofilms on cystic fibrosis cells. American journal of respiratory cell and molecular biology, 2009. 41(3): p. 305-313.
[28] Shanks, R.M., et al., Catheter lock solutions influence staphylococcal biofilm formation on abiotic surfaces. Nephrology Dialysis Transplantation, 2006. 21(8): p. 2247-2255.
[29] Tachikawa, M., K. Yamanaka, and K. Nakamuro, Studies on the disinfection and removal of biofilms by ozone water using an artificial microbial biofilm system. Ozone: Science & Engineering, 2009. 31(1): p. 3-9.
[30] Yang, L., et al., Combating biofilms. Pathogens and Disease, 2012. 65(2): p. 146-157.
[31] Blackledge, M.S., R.J. Worthington, and C. Melander, Biologically inspired strategies for combating bacterial biofilms. Current opinion in pharmacology, 2013. 13(5): p. 699-706.
[32] Masák, J., et al., Pseudomonas biofilms: possibilities of their control. FEMS microbiology ecology, 2014. 89(1): p. 1-14.
[33] Meiron, T. and I. Saguy, Adhesion modeling on rough low linear density polyethylene. Journal of food science, 2007. 72(9).
[34] Memisi, N., et al., CIP cleaning processes in the dairy industry. Procedia Food Science, 2015. 5: p. 184-186.
[35] Christian, G. and P. Fryer, The effect of pulsing cleaning chemicals on the cleaning of whey protein deposits. Food and Bioproducts Processing, 2006. 84(4): p. 320-328.
[36] Merabishvili, M., et al., Quality-controlled small-scale production of a well-defined bacteriophage cocktail for use in human clinical trials. PloS one, 2009. 4(3): p. e4944.
[37] Sharma, M., J.H. Ryu, and L. Beuchat, Inactivation of Escherichia coli O157: H7 in biofilm on stainless steel by treatment with an alkaline cleaner and a bacteriophage. Journal of applied microbiology, 2005. 99(3): p. 449-459.
[38] Curtin, J.J. and R.M. Donlan, Using bacteriophages to reduce formation of catheter-associated biofilms by Staphylococcus epidermidis. Antimicrobial agents and chemotherapy, 2006. 50(4): p. 1268-1275.
[39] Sillankorva, S., et al., Bacteriophage Φ S1 infection of Pseudomonas fluorescens planktonic cells versus biofilms. Biofouling, 2004. 20(3): p. 133-138.
[40] Hibma, A.M., S.A. Jassim, and M.W. Griffiths, Infection and removal of L-forms of Listeria monocytogenes with bred bacteriophage. International journal of food microbiology, 1997. 34(3): p. 197-207.
[41] Augustin, M., T. Ali-Vehmas, and F. Atroshi, Assessment of enzymatic cleaning agents and disinfectants against bacterial biofilms. 2004.
[42] Mootz, J.M., et al., Staphopains modulate Staphylococcus aureus biofilm integrity. Infection and immunity, 2013. 81(9): p. 3227-3238.
[43] Gilan, I. and A. Sivan, Effect of proteases on biofilm formation of the plastic-degrading actinomycete Rhodococcus ruber C208. FEMS microbiology letters, 2013. 342(1): p. 18-23.
[44] Chaignon, P., et al., Susceptibility of staphylococcal biofilms to enzymatic treatments depends on their chemical composition. Applied microbiology and biotechnology, 2007. 75(1): p. 125-132.

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