ESTRATEGIAS PARA LA ERRADICACIÓN DE BIOPELÍCULAS DE *Listeria monocytogenes* FORMADAS EN ACERO INOXIDABLE

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Antecedentes: *Listeria monocytogenes* es un microorganismo que ha ganado importancia en la industria alimentaria debido a su amplia distribución y capacidad para contaminar una variedad de productos alimenticios. Esta bacteria es causante de listeriosis, una infección grave que afecta a aproximadamente 1600 personas al año, con una tasa de mortalidad de alrededor del 24% (1). La enfermedad puede manifestarse de forma no invasiva, con síntomas como náuseas, vómitos, fiebre, dolor de cabeza y diarrea (2). También puede manifestarse de forma invasiva, afectando a grupos de alto riesgo como embarazadas, pacientes en tratamiento por cáncer, personas con VIH/SIDA o trasplantes de órganos, ancianos y lactantes (3). En el contexto internacional, se han registrado brotes de *L. monocytogenes* en varios países asociados a productos como embutidos y quesos (4). La formación de biopelículas en *L. monocytogenes* es un proceso multifacético que involucra diversas etapas, como la adhesión a una superficie (9). La formación de biopelículas en superficies de acero inoxidable es un fenómeno de interés en el ámbito científico, ya que estas biopelículas muestran resistencia a diversos desinfectantes (10).

Objetivo: Evaluar y comparar la eficacia de diversas estrategias para la erradicación de biopelículas de *L. monocytogenes* en superficies de acero inoxidable.

Materiales y Métodos: Se realizó una revisión bibliográfica que incluyó estudios entre 2013 y 2023 en la base de datos científica Web of Science. Las palabras de búsqueda empleadas fueron: (*Listeria monocytogenes* biofilm) AND (Stainless steel) AND (Control OR disinfection OR eradication OR elimination).

Se seleccionaron los artículos de investigación correspondientes a la aplicación de estrategias de erradicación de biopelículas de *Listeria monocytogenes* en acero inoxidable. Es así como de un total de 309 artículos, se seleccionaron 42 artículos. Posteriormente, se realizó el análisis de cada artículo, extrayendo información relacionada al serotipo, estrategia aplicada, condiciones de tratamiento y reducciones logarítmicas obtenidas; la cual se organizó en una base de datos en Excel. Adicionalmente, se tuvieron en cuenta aspectos relevantes sobre la evaluación del control de las biopelículas por otros métodos de estudio.

Resultados: Al presentar los resultados de las estrategias químicas, se destaca que el agua electrolizada exhibe la mayor eficacia con reducciones significativas de 4.75 log, seguido por el ácido peracético con 4.5 log bajo condiciones de 200 ppm durante 5 minutos. En contraste, el hipoclorito de sodio (NaOCl) muestra reducciones inferiores a 2.2 log en presencia de materia orgánica. Por otro lado, los amonios cuaternarios presentan un desempeño más limitado, con reducciones de 1.89 y 1.82 log UFC/cm^2 en biopelículas muy maduras. En relación con el ozono, a 10 ppm se evidenció una reducción inferior a 1 log, mientras que a 45 ppm mostró una mayor efectividad, logrando una reducción significativa de 3.46 log UFC/mL. Dentro de las estrategias físicas el tratamiento combinado de UV-C e hipoclorito de sodio obtuvo una mayor efectividad aumentando la reducción de bacterias en un 90%.

Las estrategias biológicas para la erradicación de las biopelículas cuentan con métodos y técnicas para disminuir, prevenir o eliminar las biopelículas formadas por comunidades microbianas. En este estudio, las estrategias más utilizadas por su alta eficacia fueron: Los bacteriófagos, DNasa I y Proteinasa K. Los bacteriófagos son virus que infectan y se reproducen especialmente en las bacterias, el tratamiento de cóctel de fagos fue el más eficaz, mostrando reducciones de 3.8–4.5 y 4.6–5.4 log10 CFU/cm^2. La DNasa I indujo una dispersión incompleta de las biopelículas con un 25%, en comparación con la proteinasa K la cual inhibió completamente las biopelículas y se dispersaron en un tiempo estipulado de 5 min.

Conclusiones: La presente revisión evidencia que se han evaluado diferentes estrategias para la erradicación de biopelículas de *Listeria monocytogenes* formadas en acero inoxidable. En el caso de las estrategias químicas, las sustancias que lograron mayores reducciones correspondieron al ácido peracético, compuestos de amonio cuaternario y aceites esenciales. En relación con las estrategias físicas la luz UV en combinación con desinfectante y luz LED fueron las más eficientes. En cuanto a las estrategias biológicas resultan prometedoras el uso las bacteriocinas y cocteles de fagos los cuales tuvieron reducciones de 3 log UFC/cm^2. A futuro se podría optar por el uso frecuente de estrategias biológicas debido a su mayor sostenibilidad o la combinación de estrategias fisicoquímicas los cuales reducen el uso de desinfectantes que comprometen la salud humana y el medio ambiente.

Palabras clave: Acero inoxidable, *Listeria monocytogenes*, biopelícula, control, desinfección, erradicación, eliminación, estrategias.

ABSTRACT

Background: *Listeria monocytogenes* is a microorganism that has gained importance in the food industry due to its wide distribution and ability to contaminate a variety of food products. This bacteria causes listeriosis, a serious infection that affects approximately 1,600 people a year, with a mortality rate of around 24% (1). The disease can manifest itself non-invasively, with symptoms such as nausea, vomiting, fever, headache and diarrhea (2). It can also manifest itself invasively, affecting high-risk groups such as pregnant women, patients undergoing cancer treatment, people with HIV/AIDS or organ transplants, the elderly and infants (3). In the international context, outbreaks of *L. monocytogenes* have been recorded in several countries associated with products such as sausages and cheeses (4). Biofilm formation in *L. monocytogenes* is a multifaceted process that involves various stages, such as adhesion to a surface (9). The formation of biofilms on stainless steel surfaces is a phenomenon of interest in the scientific field, since these biofilms show resistance to various disinfectants (10).

Objective: To evaluate and compare the effectiveness of various strategies for the eradication of *L. monocytogenes* biofilms on stainless steel surfaces.

Materials and Methods: A bibliographic review was carried out that included studies between 2013 and 2023 in the scientific database Web of Science. The search words used were: (*Listeria monocytogenes* biofilm) AND (Stainless steel) AND (Control OR disinfection OR eradication OR elimination).

The research articles corresponding to the application of *Listeria monocytogenes* biofilm

eradication strategies on stainless steel were selected. Thus, from a total of 309 articles, 42 articles were selected. Subsequently, the analysis of each article was carried out, extracting information related to the serotype, strategy applied, treatment conditions and logarithmic reductions obtained; which was organized in an Excel database. Additionally, relevant aspects regarding the evaluation of biofilm control by other study methods were taken into account.

Results: When presenting the results of the chemical strategies, it is highlighted that electrolyzed water exhibits the greatest effectiveness with significant reductions of 4.75 log, followed by peracetic acid with 4.5 log under conditions of 200 ppm for 5 minutes. In contrast, sodium hypochlorite (NaOCl) shows reductions of less than 2.2 log in the presence of organic matter. On the other hand, quaternary ammoniums present a more limited performance, with reductions of 1.89 and 1.82 log CFU/cm^2 in very mature biofilms. In relation to ozone, at 10 ppm a reduction of less than 1 log was evident, while at 45 ppm it showed greater effectiveness, achieving a significant reduction of 3.46 log CFU/mL. Within the physical strategies, the combined treatment of UV-C and sodium hypochlorite was more effective, increasing the reduction of bacteria by 90%.
Biological strategies for the eradication of biofilms have methods and techniques to reduce, prevent or eliminate biofilms formed by microbial communities. In this study, the most used strategies due to their high effectiveness were: Bacteriophages, DNase I and Proteinase K. Bacteriophages are viruses that infect and reproduce especially in bacteria, the phage cocktail treatment was the most effective, showing reductions of 3.8–4.5 and 4.6–5.4 log_{10} CFU/cm^2. DNase I induced an incomplete dispersion of the biofilms with 25%, compared to proteinase K which completely inhibited the biofilms and they dispersed in a stipulated time of 5 min.

Conclusions: The present review shows that different strategies have been evaluated for the eradication of Listeria monocytogenes biofilms formed on stainless steel. In the case of chemical strategies, the substances that achieved the greatest reductions corresponded to peracetic acid, quaternary ammonium compounds and essential oils. In relation to the physical strategies, UV light in combination with disinfectant and LED light were the most efficient. Regarding biological strategies, the use of bacteriocins and phage cocktails is

promising, which had reductions of 3 log CFU/cm^2. In the future, we could opt for the frequent use of biological strategies due to their greater sustainability or the combination of physicochemical strategies which reduce the use of disinfectants that compromise human health and the environment.

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