Technological barriers against biofilms in the food processing sector

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***Abstract*—Biofilms are a significant and ongoing challenge in the food sector. Biofilms can be congregations of one or more species that occur in a single layer or three-dimensional structure with a complicated level of arrangement. As a matter of fact, the presence of biofilms has serious negative effects on the food sector, including monetary losses. It is necessary to make improvements to the cleaning and sanitising system used to squelch microorganisms and prevent the production of biofilms in order to guarantee the quality and safety of food products. On food matrixes and along food industrial infrastructures, a variety of microorganisms can flourish. Biofilms might develop as a result of this growth. Lower concentrations of a resilient organisms were present on equipment surfaces, and they were difficult to eradicate. We investigated the relative contributions and interactions of chemical mechanical and thermal activities in agricultural sectors. In order to include more effective ways for the mitigation and eradication of biofilm formation, it is generally important to do research on the interactions between surfaces in a specific food processing environment and bacteria. Our review's primary objective is to be more diverse, and it emphasises using physical and chemical methods for combating biofilms in areas where food is being processed. In addition, we briefly discuss techniques like electrical procedures, disinfectants, non-thermal plasma, nanotechnology, and equipment design in our assessment.**

***Index Terms*—Biofilm, food sector, electrical strategy, physical technique, nanotechnology and disinfectant**

I. INTRODUCTION

Food protection is a significant problem for health authorities and businesses because of the health consequences and economic losses caused by food contamination (Galié *et al*.,2018). In 2014 the European Food Safety Authority (EFSA) announced a total of 5,251 foodborne outbreaks resulting in 6,438 hospitalizations, following the introduction of Good Manufacturing Practices (GMP) and Hazard Identification Critical Control Points (HACCP) in the food industries. In addition to the surfaces of the atmosphere, biofilms are frequently generated on the food itself, generating probabilities for cross-contamination and degradation during preparation (Galié *et al*.,2018, Scandorieiro *et al*.,2023). In general, extracellular polymeric substances (EPS), also known as biofilms, are the substances that bacteria use to attach to surfaces to form spatially organised populations within a self-produced matrix. Because bacteria can attach to a variety of surfaces, including rubber, polypropylene, plastic, glass, stainless steel, and even food products, in just a few minutes, followed by the development of mature biofilms in a matter of days (or even hours), biofilms pose significant challenges for the food industry. (Scandorieiro *et al*.,2023)

In plenty of diverse food industries, including the processing of meat and poultry, dairy products, crustaceans, and the brew, biofilms have become more resistant to disinfectants. It is possible to manage biofilm by either preventing bacteria from secreting the EPS matrix or by utilising cleaning solutions to remove any existing biofilm (De Oliveira *et al*.,2020). Although several biofilm management strategies have been proposed, the issue has not been resolved, partly because these systems are so complicated and contain both cells and extracellular

materials (Young *et al*.,2022). A biofilm removal system should ideally have the capacity to efficiently remove both matrix components and bacteria by penetrating the biofilm structure. Given the protective barrier created and the physiological changes made by the biofilm matrix, this sessile life form has been used as an excellent survival technique for microorganisms since ancient times. It combats the unfavourable environmental conditions that bacteria typically encounter in man-made and natural settings, including in food-processing facilities (Alamiri *et al*.,2020). Therefore, biofilms are thought to be to blame for ruined equipment, higher energy expenditures, epidemics, and food spoiling. Additionally, approaches to eradication, including chemical and physical therapies, antimicrobial and photodynamic therapy, have been examined (Alamiri *et al*.,2020, Young *et al*.,2022).

A. Why biofilm formation

There are situations that are referred to as harsh when only a small number of microorganism species are capable of reproducing and, as a result, can only persist for a significant amount of time. Extremophiles, on the other hand, are microbes that can endure any of these environmental extremes. Bacteria in low-nutrient environments are some examples of how microorganisms can adapt to their environment. Biofilms make up the majority of the microbial growth in these conditions. Biofilms are typically formed by microbes in response to many circumstances, (O'Toole and Kolter, 1998) b cellular recognition of specific or general affixing sites on a surface, nutritional cues, or exposure of planktonic cells to antibiotics at concentrations below those that are inhibiting (Karatan and Watnick 2009; Hoffman et al., 2005). A change in behaviour known as a phenotypic shift typically occurs when a cell switches from the normal mode of development to the biofilm mode. This behaviour results in a specific regulation of a large number of genes (An and Parsek, 2007). Low nutrition availability, a stressor on the environment, also alters the phenotypic shape of planktonic cells, causing them to take on an attached (sessile) form (Carpentier and Cerf, 1993). Additionally influencing the production of biofilms are the topography, surface chemistry, and fluid movement of the substrate (Mittelman, 1998a). Cohabitation of microbes as a biofilm gives certain benefits since "Communities of microbes are usually more resilient to stress." (Van Houdt and Michiels, 2010). It is well recognised that natural ecosystems frequently lack access to nutrients, hence the development of biofilm is a crucial adaptation strategy for survival in these circumstances. (Mittelman, 1998). Autotrophic and heterotrophic microorganisms have been seen to coexist in biofilms and gain from their diverse community members. In contrast to heterotrophs, which are unable to produce their own food and hence require external carbon sources, producers known as autotrophs, such as algae or photosynthetic bacteria, produce their own food organic components in this form. It has been noted that these multi-organism groups frequently crossfeed.(Vidyasagar, 2016). Some microbe species can directly attach to the first colonies or to the matrix even when they are unable to adhere to a surface. This establishment or colonisation is caused by small signalling molecules working in conjunction with cell-cell communication systems; this phenomenon is known as quorum sensing. (Fuqua et al., 1994), hence formation of biofilm is a very significant quorum-sensing controlled phenotype (Huber et al., 2003). Biofilm development has been observed in a variety of natural phenomena: They are typically found growing on metals and minerals, on plant and animal tissues, underground and above ground, underwater, on medical devices like pacemakers and catheters, on food contact surfaces, food industry infrastructures, and on food matrixes. Dental plaque is a slimy bacteria buildup that forms on the outside of pond scum and teeth.

B. Development of biofilms

Some situations are referred to as harsh where a restricted number of species of microorganisms possess the capacity of multiplying and, as an instance, can only persist for a short period of time (Chen *et al*.,2020). However, extremophiles are microorganisms that can endure in any of these environmental extremes. Bacteria in low-nutrient environments are an example of several environmental and adaptation traits possessed by microorganisms. Microbial development in these situations occurs mostly in biofilms. In response to multiple instances, microbes typically develop a biofilm such as the exposure of planktonic cells to sub-inhibitory antibiotic doses, dietary cues, the cellular realisation of non-specific or specific affixing sites on a surface etc (Isaka *et al*.,2021). A change in

behaviour characterised as a "phenotypic shift" occurs when a cell switches from the normal mode of development to the biofilm mode. This behaviour results in a specific regulation of a large number of genes. The phenotypic appearance of planktonic cells shifts to a sessile form as a result of an environmental stressor, low nutrition availability. Additionally influencing the production of biofilms are topography, substrate composition, surface chemistry, and fluid movement (Vijayakumar *et al*.,2020). Communities of microorganisms are more often tolerant to stress, thus when they co-exist as a member of a biofilm, it confers some advantages. Since it is well recognised that natural ecosystems frequently lack nutrient resources, the development of biofilm is a crucial adaptation strategy for survival in these kinds of situations. Some microbe species can attach themselves directly to first-growth colonies or to the matrix even when they are unable to adhere to a surface (Whitfield *et al*.,2022). This establishment or colonisation is caused by small signalling molecules which function in tandem with cell-cell communication systems. This phenomenon is known as quorum sensing, and the development of biofilms is an important quorum-sensing regulated phenotype (Whitfield *et al*.,2022, Vijayakumar *et al*.,2020).

C. Biofilm development in the food industry

Microorganisms that can form biofilms typically adhere to surfaces and equipment in the food industry that come into contact with both non-food and food items. During the formation of a biofilm, polysaccharides, mostly exogenous DNA or proteins, and cellulose are the main types of extracellular matrix that are developed (Yan *et al*.,2021). This matrix has an important role in adhering to components with hard surfaces (such as flesh, bones, other food-related products and fruits). The extracellular matrix plays a structural role in the production of complex gradients with respect to vital nutrients and oxygen diffusion, and it contains extracellular enzymes that are used for the purpose of nutrition. This explains why these biofilms in the food industry are so tenacious and substantial (Ye *et al*.,2022). This shields the underlying cells from toxic materials and enables the absorption of chemicals involved in cell communication. It is pertinent to emphasise that in multiple and dual-species biofilm models, the primary foodborne pathogenic bacteria interact with the resident members of the flora that cling to and colonise food processing sites. Foodborne bacterial pathogens, which are poor biofilm makers, have generated confirmation of symbiotic interactions in an array of instances (Carrascosa *et al*.,2022). These bacteria take advantage of their connections to highly effective biofilm producers to adhere to or attach to items and machinery that come into contact with food. Although biofilm formation offers the cells of bacteria in conditions related to the food business a number of benefits, these include mechanical resistance, such as, chemical and physical protection (against antimicrobials, chemicals, and disinfectants frequently utilised in the industry) against desiccation and liquid streams in pipes (Iñiguez *et al*.,2022). However, in most instances, this presents a challenge that is extremely concerning because biofilms developed by spoilage or pathogenic microorganisms may be the source of food cross-contamination, reducing the effectiveness of food processing procedures and ultimately compromising the quality of the food and its nutritional competency (Carrascosa *et al*.,2022, Ye *et al*.,2022).

D. Ramifications of biofilm progress for the food industry

Foodborne pathogens and spoilage bacteria in biofilms

The existence of biofilms in the processing plant may be responsible for an assortment of these contaminations; a few instances are briefly discussed here (Yuan *et al*.,2021).

1. *Bacillus species*:

Bacillus species can be found in all of the industries that prepare dairy products. As a result of their capacity to produce spores, these species are known to accumulate on pipelines and joints in the processing environment, where they are thought to survive heat processing (Yuan *et al*.,2021). *Bacillus* and other heat-resistant bacteria would likely build a biofilm in a condition where hot fluid flows continuously over a surface for more than 16 hours. *B. cereus* biofilm production has raised severe concerns about food safety in the food industry because of its potential to act as a source of product recontamination and contamination (Kütük *et al*.,2021). They permeate food processing facilities and final food products, such as vegetables, dairy products, meat, and rice, through the environment. *B.*

cereus is known to cause the growth of biofilm on materials such as pipes, stainless steel, storage tanks, and conveyor belts with food contact (Di Ciccio *et al*.,2022).

2. *Pseudomonas species.*

Pseudomonas species are exceptionally prevalent and play a big role in food spoiling. Pseudomonads thrive in environments where food is processed, such as on the surfaces of dairy products (with low acidity), meat, vegetables, and fruits, as well as in floors. *Pseudomonas* spp. produce large quantities of EPS, which is known to adhere and form to develop biofilms on stainless steel surfaces (Panebianco *et al*.,2022, Zarei *et al*.,2022).

3. *Staphylococcus aureus.*

Foodborne disease outbreaks associated with the consumption of products like other dairy-based foods and milk are caused by *Staphylococcus aureus*, a significant foodborne bacterium with the potential to develop biofilms. In the dairy business, biofilms frequently grow on almost all types of technological system surfaces (Avila *et al*.,2022).

4. *Listeria monocytogenes*

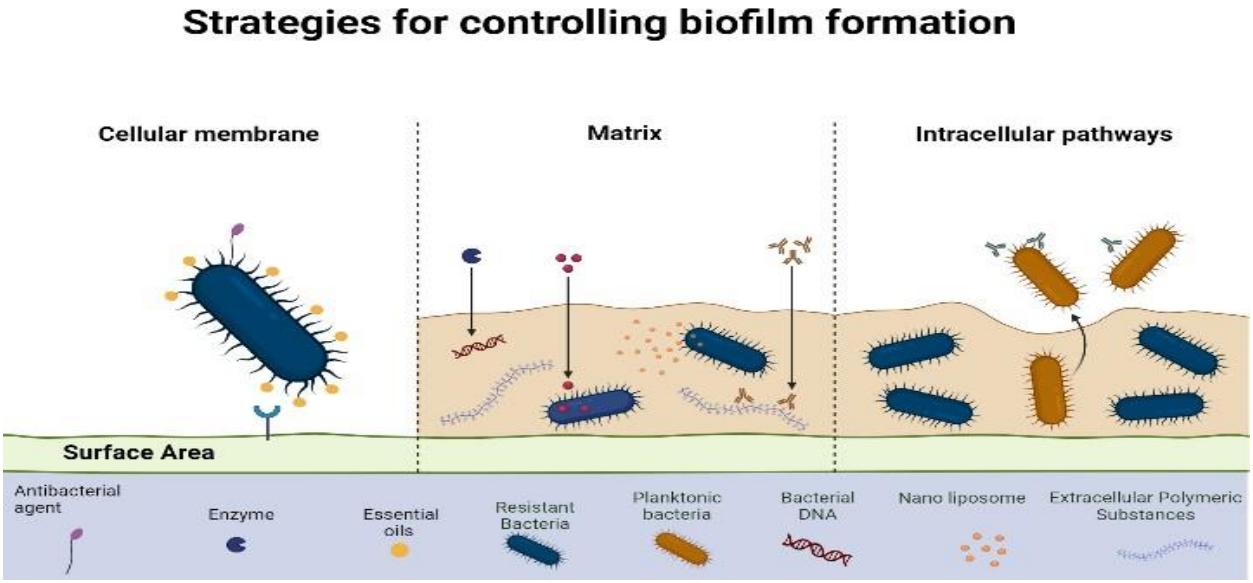
Listeria monocytogenes, one of the most prevalent food-borne infections, can form biofilms on a variety of surfaces, including those made of plastic, polycarbonate, stainless steel, and aluminium. Listeria species can therefore thrive and remain viable in many different types of microenvironments that are typically seen in food manufacturing environments (Papaioannou *et al*.,2022).

5. *Salmonella species*

Salmonella has been identified in locales used for evisceration and removal from the carcass including poultry processing equipment. It is particularly optimal for facilitating the development of biofilms when the environment is typically damp. *Salmonella* can attach to and from biofilms on surfaces like those found in plastic, stainless steel and cement, in food processing industries, even though little is known about the incidence of these biofilms occurring in circumstances like these (Bhardwaj *et al*.,2022).

E. Impact on the food industry

As it has been noted, there is limited knowledge of the beneficial effects or roles of biofilm formation; nonetheless, certain roles are described in this review. Seixas et al. (2015), "positive uses of biofilm depend on the flexibility and strength of biofilm solubility in water, and biofilm permeability against water vapour," the statement reads. It is important to be aware that biofilm may shield food from lipid oxidation, gas, water, and stink. (Kim et al., 2012). Biofilms can be used to treat wastewater and drinking water. They improve plant health and productivity, act as a water and wastewater treatment agent in the food industry, and aid in lowering the wastewater's excess sludge content. One of its advantageous functions in the food sector is the creation of edible biofilms and biodegradable food packaging.



F. PHYSICIAL Strategies

Physical therapies are currently being investigated as potential replacements for the use of alchemical disinfectants in the food processing process, especially for the cleaning of soil particles (Pereira *et al*.,2022). The researchers showed that ionising radiations had an identical, if not greater, impact on *Salmonella species*. Biofilm cells, as contrasted with planktonic cells, may be a useful tool for sanitising a variety of foods and related fields. In order to successfully remove *E. coli* biofilm from milk on stainless steel plates, researchers combined ultrasound with an enzyme preparation process. Even biocides like ozone, which is a biocide, can be improved using ultrasound. Since the cleaning method leaves minimal residue behind, the food sector frequently uses physical therapies such shear pressure, ultrasound and heat shock therapy (Wagner *et al*.,2020).

Heat shock therapy (70°C for 30 min.) was shown to be insufficient in a test to remove *Legionella* from biofilm because *Legionella* became thermo-acclimated during the second heat shock, showing that thermal disinfection was not adequately capable of eliminating Legionella and their biofilm (Sadiq *et al*.,2023). When it comes to sterilisation in the food industry, ultrasonic therapy is frequently needed for specific tools and things that cannot be pressured or heated. Additionally, studies have demonstrated that Low Frequency Ultrasound (LFU) biofilms can be entirely eliminated from the substrate in 5 minutes at 0.4 MHz and 37°C. Biofilms can be successfully removed using ultra sonication in conjunction with other antibiofilm treatments such antibiotics, ozone, and the chelating chemical ethylene-diamine-tetra acetic acid (EDTA) (Raghupathi *et al*.,2018).

G. Disinfect and infection-resistant.

A microorganism will be more susceptible to the disinfecting agents after it has been detached from the adhering layer. Few disinfectants, like mercury acid, peracetate acid and formaldehyde, have been identified by researchers to be the least successful in removing biofilms (Ciolacu *et al*.,2022). In contrast, non-chlorinated and chlorinated alkaline detergent is said to be more effective in separating biofilms. Mechanical actions, such as high-medium pressure jets and brushing, are the prevalent methods for eliminating biofilm. Formulated non-ionic wetting agents perform well as foam controllers and emulsifiers. In order to effectively clean surfaces, superheated water (257°F for 30 minutes) can eliminate biofilm. Pulse laser beams, an alternate technique, have the power to lower the proliferation of surface microbes. The main goal of cleaning in the food business is to remove product remnants that indirectly affect the management and removal of biofilm and should be able to remove the biofilm matrix from the substrate (Ciolacu *et al*.,2022, Fernández *et al*.,2023). Because reattachment and the development of biofilms might result from incomplete separation. According to Risk Assessment, Good Manufacturing Practise, and Critical Regulation Point, a food handling plant system is necessary to ensure that the product volume, safety, and quality meet high requirements. In the food handling and cleaning cycle as well as in the production plant, the cleaning protocol that takes place and is legally required by the administrative authorities typically consists of six main components such as Detergents (washing), Physical brushing (pre-cleaning), Cleaning, Rinsing, Final rinsing, and Drying (Alonso *et al*.,2023). Dairy manufacturing plants (DMPs) and several other food production industries use a controlled technique called Cleaning-In-Place (CIP) to reduce the build-up of biofilm. CIP is frequently a semi-automatic procedure used at the rinse and cleaning point with the intent of more thoroughly cleaning the instrument. Additionally, this method will allow grease layers to wash and remove substances that are helpful in the food industry for the growth of germs. This will lessen the need for hand protein cleaning. Detergent is sprayed into the process with an adequate amount of concentration and timing in the form of foam, which typically allows for effective action. Alkaline and acidic substances are also employed as detergent in the food industry for all cleaning procedures. Alkaline materials are useful for removing *Pseudomonas putida* biofilm from stainless steel (Sharan *et al*.,2022). Disinfectants are applied directly or sprayed to the field in the form of water to eliminate the airborne microorganisms. The following describes how biofilm disinfection is widely employed in the food industry.

A) It has been demonstrated that hydrogen peroxide and sodium hypochlorite are more effective at removing a biofilm developed by

Staphylococcus aureus and *Pseudomonas aeruginosa*.

B) Ozone and hydrogen peroxide (H_2O_2) in a *vibrio* biofilm that is more active L-peracetate acid species.

C) Sodium hypochlorite (NaClO) and quaternary ammonium compounds are excessively effective against *Bacillus cereus* biofilm and the biofilm of monocytogenes.

Although approach is much more effective on bacteria before binding to a surface and forming biofilm, none of the cleaning techniques are very effective in removing mature biofilm. Others are quite aware of the phenomenon, which is thought to be an incomplete understanding of the mechanism for increasing the tolerance of biofilm bacteria (Sharan *et al*.,2022, Alonso *et al*.,2023).

H. Materials and Equipment Design

In general, the equipment should be built to avoid soil acclamation and the formation of biofilm. Utilising the appropriate components, the manufactured equipment should be accorded in tandem (Pang *et al*.,2022). To expedite cleaning and uphold proper hygiene, CIP (Clean-In-Place) must be installed. According to the researcher, a general CIP with alkali or acid has the ability to eliminate biofilm. However, this method should be followed during cleaning with a chemical that has suitable dose, duration, mechanical power, and temperature to avoid destroying equipment seals, among other things. The primary difficulty facing the food business is preventing cross-contamination (Ciofu *et al*.,2022). Plant designs used in food processing and equipment designs were chosen based on the following factors:

- It might prevent chemical corrosion, be simple to clean, and the smooth surface should have some gaps and blemishes since these things help germs build up because they can't get rid of them (Ciofu *et al*.,2022).
- Prosecution should be pursued for the use of inert goods with chromium coatings, such as aluminium and stainless steel, to prevent corrosion (Ciofu *et al*.,2022).

Use of naturally occurring flexible materials with synthetic rubbers like Nitrile rubber, Ethylene Propylene Diene Monomer (EPDM), also called silicone rubber, Nitrile Butyl Rubber, and plastics like polycarbonate, polytetrafluoroethylene (PTFE), polyvinyl chloride (PVC), and Teflon may be used as tubes, tyres, caps, and gaskets in the food industry (Ciofu *et al*.,2022, Sauer *et al*.,2022).

II. NON-THERMAL PLASMA

A low-temperature fume with high antibacterial capabilities, non-thermal plasma is a partially ionised fume. It is formed by combining UV light along with ozone, oxygen, water, nitrogen and helium under electric pardon just at atmospheric pressure. Bacterial biofilms that are Gram-positive (*Bacillus spp*.) or Gram-negative (*S. enteric, Pseudomonas spp*.) can be eliminated in just 10 minutes. Cold plasma deposition on implanted biofilm made up of the previously known Gram-negative *Salmonella typhimurium*, Gram-positive *P. fluorescens*, and Gram-negative *S. epidermidis*, as well as other devices like catheters (Sauer *et al*.,2022, Tarafdar *et al*.,2022).

According to this study's conclusion, the plasma approach might be utilised to deposit antifouling coverings on a variety of products that are used on clinical implants, in food processing equipment, and on other devices including catheters. Following a trial of oxygen glow discharge plasma therapy for PVC, the number of adherent bacteria decreased (Tarafdar *et al*.,2022). They repeatedly exposed a four-day biofilm of *Chromobacterium violaceum* to plasma, and they discovered that 10 minutes of plasma therapy killed nearly all of the cells. Confocal laser scanning microscopy (CSLM) was used to see the lethal impact of the NTP plasma rocket applied to the *Enterococcus faecalis* biofilm (Guerra *et al*.,2022).

According to their findings, the cells from a 25.5 m thick biofilm in the lowest layer became devitalized following a 5-minute NTP injection. All techniques were able to rapidly inactivate Candida biofilms, according to Sun et al.'s (2012) study on the eradication of Candida biofilm by NTP using He: (2%) O2 plasma alone or in combination with traditional antifungal medications. Sterilisation techniques Brelles-Marino (2012) discussed the limitations of NTP's contemporary antimicrobial technology and contrasted its impact on oral health with conventional techniques of sterilisation as well as fresh food (Cámara *et al*.,2022). Recent developments in the use of atmospheric pressure-induced plasma to eradicate bacteria that produce biofilms were investigated by the authors. The

deactivation of Salmonella biofilms from multi-day crops was evaluated by this author using NTP plasma jet. A decrease in 2 log 10 was seen in the 15s biofilm, which was revealed to be virtually self-sufficient at the age of culture. The procedure is still somewhat pricey when compared to other sterilisation methods. However, compared to conventional biofilm removal methods, cold air pressure plasmas are a compelling option (Pereira *et al*.,2022).

A. Electrical strategy

Electrical current has a powerful antibacterial activity that was originally demonstrated in 1919. An antibiotic's dosage needed to inactivate a biofilm species can be decreased by electrical current (Liu *et al*.,2022). currently known as the "bioelectrical effect", the efficiency of an electrical flux that is antimicrobial. Such bioelectrical effects are triggered by pH changes, the transport of antimicrobials and production *via* electrophoresis, the release of hyperoxygenation and biocide ions, of the biofilm. It has been demonstrated that a biocide's industrial effectiveness against *P. aeruginosa* can be increased by producing a sizable electrical field with low current concentration. The aggressive breakdown of the lipid layer by the bacteria or the biofilm's EPS-charged matrix represents other potential mechanisms of action (Bashir *et al*.,2022). Along with intensifying the repellent electrostatic interactions between the bacteria and the occupied substrate. More effort is being put into developing affordable electric-powered tools to treat catastrophes and stop the initial soil colonisation. Because electrostatic interactions between the bacteria and the substrate will cause the very steadily (5s) attachment of thermo-resistant Streptococci to stainless steel; This approach can be disrupted by the application of a modest voltage. The *S. thermopiles* were retained between the stainless-steel electrodes when pertinent to a suspension at a 40-mA current and 9 V voltage, with the anode being inhibited. Additionally, it captured the alleged bioelectric effect, though with varying outcomes (Aiyer *et al*.,2020). They consequently discovered that when a current is introduced, the activity of a weak field that generates a stable voltage of 3.7 mm-2 in nutrient water on a circular reactor considerably increases the amount of bacterial biofilm. The treatment did not remove the biofilm of mixed microorganisms in conjunction with pure chloride, allowing metal compounds to oxidise in conjunction with the treated material (Sonawane *et al*.,2022).

B. Nanomaterials

Nanotechnology is a practical tool with a sensitivity of less than 100 nm that can manipulate the scale of individual atoms and molecules. The potential role of TiO_2 nanoparticles as a novel substitute in the defence of fungal biofilms and their ability to prevent microbial adherence has only recently come to the attention of researchers (Zhao *et al*.,2023). These researchers suggested using TiO2 to coat clinical injectable products. As a result of their physical attraction to certain electrically charged surfaces, the researchers additionally developed nanoparticles that bond to microbes and eventually kill them. These researchers implemented silver nanoparticles to inhibit the growth of biofilms of *E. coli, S.aureus, P.aeruginosa, Enterococcus and C.albicans spp* (Mohanta *et al*.,2023). The biomass of adherent *C. glabrata* cells was reduced by almost 90% by adding silver nanoparticles to a culture of Candida adherent cells at a dosage of 3.3 g/mL. Comparatively, mature biofilms were effectively eliminated (by 97 %) by the treatment of 54 g/ml AgNPs; in contrast, *C. albicans* biofilm biomass was reduced by 85 % when silver nanoparticle application was made at concentrations higher than 6.7 g/mL. Superparamagnetic iron oxide nanoparticles were also applied to combat a biofilm. According to these researchers, the hydroxyl radicals generated have the power to depolymerize polysaccharides, trigger DNA breaks, and deactivate enzymes that could support the EPS structure of biofilms (Mohanta *et al*.,2023, Su *et al*.,2022).

III. PHOTODYNAMIC THERAPY

PDT is a form of treatment that used as a drug known as a photosensitizer. During PDT, photo-sensitizers are exposed to light and produce oxygen, which kills cells in the vicinity. Oscar Raab initially outlined the method of PD Treatment to inactivate microbes more than 100 years ago when he discussed the lethal effects of visible light and acridine hydrochloride on *Paramecium caudatum* (Xiu *et al*.,2022). The photodynamic methodology has emerged as an innovative replacement for antibacterial procedures and mechanical possibilities for biofilm abolition, and its application in biofilms continues to provide superior outcomes than conventional approaches.

One of the main barriers to biofilm management utilising PDT is the establishment and development of slime (Yin *et al*.,2022). Both of these biofilm properties reduce the photodynamic mitigation of an assortment of pathogenic microbes, such as *S. aureus* and *S. epidermis.* Utilising the currently being researched cationic photosensitizers based on polylysine can easily overcome this hurdle. Porphyrins, phthalocyanines, porphycenes, chlorines, and pheophorbides are examples of substances that can be used as photosensitizers. The removal of food-borne pathogenic biofilms and their spores by researchers involved the application of photosensitization (Ramakrishnan *et al*.,2022, Anju *et al*.,2022).

IV. CONCLUSION

Bacterial biofilms are prevalent in existence and the food industry is unable to avoid the hazards they may bring. Biofilm formation on food processing instruments and certain food contact sites serve as a constant source of adulteration that threatens the microbiological safety and quality of food items, resulting in food borne disease and economic loss. Hence the removal of biofilms is necessary in food industries. Using control technique at food manufacturing facilities aims to improve biofilm prevention. To eliminate more microorganisms and inhibit microbial growth on surfaces, cleaning and disinfection and the use of efficient cleaning processes with chemical disinfectants are commonly listed. Some researchers have noted that the food industry utilizes a wide variety of chemical disinfectants such as acidic chemicals, aldehyde-based biocides, caustic products; chlorine, hydrogen peroxide, iodine, isothiazolinones, phenolic, biguanides, surfactants halogens and quaternary ammonium compound etc, but none is adequate to eliminate biofilms completely. Disinfection strategies should be regarded to ensuring optimal, cost-effective outcomes without harmful effects on humans and the environment. This review describes existing physical-mechanical approaches and even chemical method. Some of the new promising techniques include surface modification, physical method and nanotechnology. Ultimately, Nano-particles provide a promising platform for more effective resolution of the biofilm problem in the near future and the development of new efficient strategies to target biofilms. Combination of novel strategies (enzymes) with physical method has also been used in successful biofilm removal. Furthermore, research should be conducted in order to develop new physical-mechanical and chemical approaches.

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