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Effects of Ultraviolet Radiation on Microbes

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Ultraviolet (UV) radiation falls between visible light and X-rays (100–400 nm) in the electromagnetic spectrum. UVA, UVB, and UVC are the three sub-regions of the ultraviolet spectrum., with UVC reported most effective against microorganisms. Depending on the microorganism's form, UV has a different effect on microbes, having a greater effect on vegetative cells possessing short contact time, while spore-forming organisms are more resistant to UV. Yeast has also been reported to survive UV radiation better than other organisms. UV light makes microorganisms dormant by forming pyrimidine dimers in RNA and DNA, which prevent replication and transcription. Impact of UV light on microorganisms is dependent on microbial exposure and the environment the organisms exist in. Evaluating the impacts of ultraviolet radiation on different species of microbes can help in the prevention of contamination and spread of infectious organisms. There are limited reviews on the effects of ultraviolet radiation on microbes. This review will therefore analyse the effects of UV on viruses, bacteria and fungi which are the most common types of microbes.

Introduction

Johann Wilhelm Ritter discovered the ultraviolet radiation in 1801 when he observed that energy from the visible solar spectrum beyond the violet end may dissolve silver chloride (Shin *et al.,* 2016). A few decades after the discovery by Johann it was further observed that UV radiation could inhibit the growth of microbes (Downes, 1877). In recent times, Raeiszadeh and Adeli (2020) have also reported the high efficiency of UV radiation in limiting microbe's growth in medium like air and water, and on any surface. UV light is grouped according to wavelengths into UVC (having 200–280 nm), UVB (having 280–320 nm) and UVA (having 320–400 nm), with UVC being reported as the highest active radiation, making it more effective to inactivate microorganisms at lower doses (Vanhaelewyn *et al.*, 2020). UV radiation is highly successful at immobilizing Gram-negative bacteria over Gram-positive ones, based on several studies. This has been attributed to the difference in peptidoglycan structure in their cell walls, which affects the penetration of radiation Gram-positive resisting penetration of UV light than Gram-negative (Kim *et al.,* 2017). Eukaryotes demonstrate a higher resistance to UV over bacteria owing to genetic redundancy, larger size of cell and complication(Soler *et al.,* 2021). Lower DNA pyrimidine contents have also been associated to better resistance in yeast than in bacteria, which is possible of increasing the chances of photons being absorbed by different molecules (Gayan *et al.,* 2013).

Although commercially available UV sources can be found in light-emitting diodes, mercury lamps and pulsed light (Natarajan *et al.,* 2011), a long-established use of UV light is seen in biosafety cabinets in laboratories. Reports have also shown that UV irradiation has been used to neutralise microorganisms in wastewater and food-processing industry (Gomez-Lopez *et al.,* 2007).

Ultraviolet light disrupts transcription and replication by the production of pyrimidine dimers in RNA and DNA, which leads to the inactivation of the microorganisms(Cutler and Zimmerman, 2011). Microbial exposure determines the germicidal impact of UV radiation treatment.

UV irradiation technology can be used for varied purposes, which includes the disinfection of surfaces that enable aseptic procedures or packaging, disinfection of fluids since 1909 which has been applied to pasteurization of juice. It also has use in air disinfection and has been reported to be able to inactivate the human SARS coronavirus. It can also trap insects and facilitate the degradation of unwanted molecules (Darré *et al.,* 2022). Limited reviews on the effects of ultraviolet radiation on microbes exist. This review will therefore bridge the gap and analyse the impacts of UV on viruses, bacteria and fungi which are the most common types of microbes. Effects of Ultraviolet Radiation on Viruses.

Viruses are composed of nucleic acid which can be double-stranded deoxyribonucleic acid(DNA) or ribonucleic acid (RNA) and single-stranded DNA or RNA (Kowalkski, 2009). Single-stranded viruses exhibit high susceptibility to UV since they lack the genetic information redundancy present in the second strand, enabling double-stranded viruses to repair the UV damages (Tseng and Li, 2005). Non-enveloped viruses are mostly highly resistant to UV than enveloped viruses as the envelope's proteins and lipids are susceptible to other viral parts (Pinon and Vialette, 2018). Factors like the presence of a repair mechanism, physical size, surface hydrophilicity and weight of molecules determines the susceptibility of virus to UV radiation (Raeiszadeh and Adeli, 2020).

UVC has very destructive impacts on bacteria, as previously indicated, because their UVC photons are substantially absorbed by intercellular components (proteins, DNA and RNA) (Bolton and Cotton, 2011). The absorbed UVC photons presents severe damage to the genomic system of microbes (nucleic acid and proteins), prohibiting it from living and reproducing, since the adenine-thymine bond is broken and a pyrimidine dimer, covalent linkage is generated between two adenines(Raeiszadeh and Adeli, 2020). Increased environmental UV dose would probably result in a higher rate of viral mutation (Norval, 2006). UV's fatal effect on viral nucleic acid (RNA or DNA) is dependent on where it affects in the viral genome (Norval *et al.,* 1994). A vast number of mutations reduce virulence of viruses, while some mutations may lead to more virulent strains, because majority viral genes serve specialised purpose.

For example, as a result of UV radiation, a unique receptor-binding protein can be produced, enabling the virus to infiltrate a particular cell type different from the one it infects before being exposed to UV light.(Raeiszadeh and Adeli, 2020). Virus strains that are UV resistant can also emerge due to evolving a thicker capsid structure to prevent UVC from damaging the nucleic acid (Norval *et al.,* 1994).

UV's effects on viruses differ between a laboratory-controlled system and a real-world system. The effectiveness of the UV treatments also depends on the material the virus is attached to, viral biofilms and environmental conditions. Owing to absence of water scattering, UV resistance of microbe-containing aerosols reduces as they lose water vapour and get close to the size of an actual organism (Raeiszadeh and Adeli, 2020).

Effects of Ultraviolet Radiation on Bacteria

These are impacted at both cellular and community levels by UV radiation. Thus, affecting their diversity and damaging essential biomolecules like proteins, DNA and lipids(Pavlopoulou *et al.,* 2016). Over time, bacteria have evolved strategies that help them cope with ultraviolent radiation. They rely on active resistance to UV-induced oxidative damage, effective DNA repair pathways, and regulating their proteome (Matallana-Surget *et al.,* 2014).

Studies have also shown that bacteria, like other microorganisms, have various ways to respond to the effects of UV radiation. This suggests that UV radiation has an impact on growth efficiency, production and bacterial community composition (Pérez *et al.,* 2017). Bacteria also have varying UV susceptibility. For instance, research by Pullerits et al., (2020), shows a 4−log10 reduction of environmental isolate; Mycobacterium avium needs 128J/m2dose, while environmental isolate for same log reduction of Escherichia coli needs a higher dose of 81J/m2.

The effect of UV radiation in bacteria is majorly damaging to nucleic acids as the nucleotides interact with UV light (Jungfer *et al.,* 2007). This light absorption elicits the formation of mutagenic DNA lesions including cyclobutane pyrimidine dimers and 6–4 photoproducts (Sinha and Häder, 2002). Purines and pyrimidines can both absorb UV radiation, although pyrimidines are thought to be highly photoreactive (Rastogi et al., 2010). When UV light breaks down nucleotides, DNA replication is halted, leading to cell death (Jungfer *et al.,* 2007). The direct UV irradiation of fresh farm produce has been reported to reduce the viability of Listeria, Salmonella and *Escherichia coli* (Cheng *et al.,* 2020). By photo reactivation or dark repair, some bacteria are able to fix UV damage. (Sinha and Häder, 2002). UV-induced stress can also lead some bacteria to reach a viable state that is unculturable (Guo *et al.,* 2019).

Effect of Ultraviolet Radiation on Fungi

UV irradiation has several developmental and metabolism impacts on filamentous fungi (Tisch and Schmoll, 2010). A set of specific photo signalling pathways are responsible for the UV induced changes seen in the development of fungi. Several studies explaining the direct destruction of conidia was documented as an effect of UV radiation on fungi (Vanhaelewyn *et al.,* 2020), UV inhibition of toxin production and hyphal development (Thind and Schilder, 2018).

The known germicidal properties of UVC have sponsored research that seeks to use this technology to mitigate surface microorganisms (Charles, 2019). The death of fungi caused by UVC is linked to mutations of DNA, along with the development of pyrimidine adducts and cyclobutyl-type dimers (pyrimidine dimers) (Leung and Murray, 2021). UV light can cause an excessive build-up of reactive oxygen species (ROS), inhibit critical cellular enzymes and oxidize membrane lipids (Visser *et al.,* 2002). Microbial enzymes containing aromatic amino acids are possibly susceptible to UV radiation due to their absorption in this region.

Research on the influence of UV irradiation (single exposure) on the most frequent postharvest fungal infections and human pathogens, such as Monilinia spp, Rhizopus, Penicillum species, Fusarium spp, Botrytis cinerea and Colletrichcum spp. Have been conducted (Filho *et al.,* 2020).

It was found that irradiation has positive effects regarding reducing the incidence and severity of diseases. However, most of the research were conducted under laboratory environments and there is need for further studies on large scale application in a field environment.

The UVC sub-region has proven to be the most energetic of the UV regions, making it detrimental to microbes. The commonly known effects of UV radiation on microbes are their nucleic acids' damage. However, while UV can be used to inactivate microorganisms, they can also lead to evolution of more virulent strains. Hence, the application of UV radiation in the inactivation of microbes should be done in accordance with justifiable local guideline.

References

Charles, F. (2019). Current Challenges of Physical Treatments to Control Quality and Postharvest Diseases of Fresh Fruits and Vegetables. IOP Conference Series: Earth and Environmental Science.

Cutler, T. D., and Zimmerman, J. J. (2011). Ultraviolet irradiation and the mechanisms underlying its inactivation of infectious agents. Animal Health Research Reviews, 12(1), 15-23.

Darré, M., Vicente, A. R., Cisneros-Zevallos, L., and Artés-Hernández, F. (2022). Postharvest Ultraviolet Radiation in Fruit and Vegetables: Applications and Factors Modulating Its Efficacy on Bioactive Compounds and Microbial Growth. Foods, 11(5), 653.

Downes, A. (1877). Researches on the effect of light upon bacteria and other organisms. Proceedings of the Royal Society of London, 26, 488-500.

Filho, F. O., Silva, E. D. O., Lopes, M. M. D. A., Ribeiro, P. R. V., Oster, A. H., Guedes, J. A. C., Zampieri, D. D. S., Bordallo, P. D. N., and Zocolo, G. J. (2020). Effect of pulsed light on postharvest disease control-related metabolomic variation in melon (*Cucumis melo*) artificially inoculated with Fusarium pallidoroseum. Plos one, 15(4), e0220097.

Gayan, E., Manas, P., Alvarez, I., and Condon, S. (2013). Mechanism of the synergistic inactivation of *Escherichia coli* by UV-C light at mild temperatures. Applied and environmental microbiology, 79(14), 4465-4473.

Gomez-Lopez, V. M., Ragaert, P., Debevere, J., and Devlieghere, F. (2007). Pulsed light for food decontamination: a review. Trends in food science & technology, 18(9), 464-473.

Kim, D.-K., Kim, S.-J., and Kang, D.-H. (2017). Bactericidal effect of 266 to 279 nm wavelength UVC-LEDs for inactivation of Gram positive and Gram negative foodborne pathogenic bacteria and yeasts. Food research international, 97, 280-287.

Leung, W. Y., and Murray, V. (2021). The influence of DNA methylation on the sequence specificity of UVB-and UVC-induced DNA damage. Journal of Photochemistry and Photobiology B: Biology, 221, 112225.

Natarajan, T. S., Natarajan, K., Bajaj, H. C., and Tayade, R. J. (2011). Energy efficient UV-LED source and TiO2 nanotube array-based reactor for photocatalytic application. Industrial & engineering chemistry research, 50(13), 7753-7762. Raeiszadeh, M., and Adeli, B. (2020). A critical review on ultraviolet disinfection systems against COVID-19 outbreak: Applicability, validation, and safety considerations. Acs Photonics, 7(11), 2941-2951.

Shin, J.-Y., Kim, S.-J., Kim, D.-K., and Kang, D.-H. (2016). Fundamental characteristics of deep-UV light-emitting diodes and their application to control foodborne pathogens. Applied and environmental microbiology, 82(1), 2-10.

Soler, P., Moreno-Mesonero, L., Zornoza, A., Macián, V. J., and Moreno, Y. (2021). Characterization of eukaryotic microbiome and associated bacteria communities in a drinking water treatment plant. Science of The Total Environment, 797, 149070.

Thind, T. S., and Schilder, A. C. (2018). Understanding photoreception in fungi and its role in fungal development with focus on phytopathogenic fungi. Indian Phytopathology, 71(2), 169-182.

Tisch, D., and Schmoll, M. (2010). Light regulation of metabolic pathways in fungi. Applied microbiology and biotechnology, 85(5), 1259-1277.

Vanhaelewyn, L., Van Der Straeten, D., De Coninck, B., and Vandenbussche, F. (2020). Ultraviolet radiation from a plant perspective: The plant-microorganism context. Frontiers in plant science, 1984.

Visser, P. M., Poos, J. J., Scheper, B. B., Boelen, P., and van Duyl, F. C. (2002). Diurnal variations in depth profiles of UV-induced DNA damage and inhibition of bacterioplankton production in tropical coastal waters. Marine Ecology Progress Series, 228, 25-33.

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