

Abstract

Milk, one of the most complete nutrition mixes for human consumption, also presents itself as the most potent nutrient medium for bacterial growth. This becomes especially pronounced for a hot country like India with highly fragmented milk production, spoiling the milk before it reaches processing plants. In recent years, the search for less expensive alternatives to cold chain preservation and heat-based shelf-life improvement has intensified. Hence, the study of the impact of Ultraviolet (UV) radiation and plasma on the physicochemical properties of various substances, including milk, has gained prominence. UV-C (200–280 nm) is also well-known for inactivating various bacteria and spores in the aqueous solution based on its DNA absorption capacity. However, the hazardous impact of conventional UV lamps on individuals and the environment due to the presence of mercury limits their usage for sterilization purposes. Far UV-C (222 nm) treatment has emerged as a potential method to replace conventional 254 nm low-pressure mercury UV-C lamps to ensure the microbiological safety of food items.

In this thesis, research focuses on utilizing dielectric barrier discharge (DBD) plasma sources and DBD based mercury-free 222 nm and 253 nm exciplex sources to investigate the microbial and physicochemical properties of milk. In the first study, we demonstrate a DBD based mercury-free 222 nm exciplex source and compare it with 253 nm and pasteurization methods. The UV dose delivered to the milk samples has been estimated using the chemical actinometry method and found to be 10.9 J/ml. The methylene blue reduction test (MBRT) of milk has been increased more than 5 h, within just 2.5 min of far UV-C treatment. Approximately 2.6 log and 2.1 log decrease in the *E. coli* and *S. aureus* have been achieved after 2.5 minutes of 222 nm treatment of whole milk. We infer that 222 nm UV light is more efficacious vis-à-vis 253 nm and pasteurization in increasing milk quality without altering its physicochemical properties, indicating its potential use as a more efficient sterilizing source for enhancing milk safety, quality, and shelf life.

In a further study, we have focused on designing a continuous milk treatment annular UV reactor. The MBRT of milk has again increased more than 5 hours, within just four passes through the UV reactor. Approximately 5 log reductions in the *Salmonella typhimurium* and *S. aureus* have been achieved in three passes of whole milk. We found that the proposed UV reactor has an identical performance in inactivating the microorganisms compared to pasteurization without altering its physicochemical properties.

In another study, an effort has been made to design a DBD based large volume surface plasma discharge system for direct treatment of milk. The developed system is optimized for operational parameters, and raw milk has been treated at different time intervals. The pH and color characteristics of raw milk samples have not been affected by the proposed cold plasma treatment. Nevertheless, the conductivity of the milk significantly increases with presence of charged ions assisting reduction of harmful bacteria in the milk. After continuous operation of the system for more than 30 minutes, there was no significant change in the raw milk temperature, which is a key requirement for milk decontamination without milk heating up using a cold plasma treatment in the developed DBD geometry.

This thesis presents a promising potential for the use of mercury-free far UV-C irradiation as a viable and non-thermal technology in the dairy industry, food sector, and overall sterilization applications. It highlights the capabilities of dielectric barrier discharge based cold plasmas to enhance milk safety, quality, and shelf-life, presenting a more efficient alternative for improving these aspects compared to traditional methods.