AERAPY
UV DISINFECTION TECHNOLOGY

UVGI for Extending Food Shelf Life: Opportunities and Best Practices

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January 2023

Executive Summary

This executive summary describes the fundamentals of using ultraviolet germicidal irradiation (UVGI) mechanism in the food industry, mainly to inactivate the spread of pathogenic microbes in food products such as milk and dairy products, meat products, fruit and vegetable, and seafood. The effectiveness and advantage of existing food decontamination methods is addressed.

Introduction

The application of ultraviolet (UV-C) light in the food industry presents a practical and long-term solution for decontamination. UV-C light (200-280 nm) is shown to inactivate a wide range of microbial pathogens, namely bacteria, viruses, fungi, yeast, and molds, that can degrade the safety of food items. UV-C technology solves many of the issues that other food decontamination methods have. For instance, thermal processing is a typical method to ensure food safety, but it can affect the texture, appearance, and overall quality of food. UV-C technology solves the issue of preventing foodborne illnesses without compromising food quality (Delorme, et. al., 2020).

The food industry is continuously evolving and producing high-quality products that are safe for consumers. To remain competitive in this changing landscape, the importance of food safety has become a top priority and should remain as such within the production and storage departments of a company. With increasing competition and dynamic new products and offerings, food manufacturers are continuously developing processes that will preserve food quality and freshness.

Apart from the thermal processing technique, there are conventional technologies that have become reliable features in food production and processing. Cold plasma processing, high-pressure processing, pasteurization, ultrasound, and pulsed electric fields are among these widely used processes in the food industry.

While these techniques work to ensure that food products are decontaminated, they can negatively affect food quality. From physical changes (e.g., **shrinkage**, oxidation, changes in texture, odor, taste, and color), to nutritional value (i.e., loss of nutrients, vitamins, and denaturation of proteins) (Singh, et. al., 2021), these can affect consumer satisfaction and quality control. Having a better option in terms of food decontamination will alleviate such results and create a more optimal condition in keeping the quality of food intact and preventing food **waste**.

UVGI is one innovative solution for food safety. It is a non-toxic and non-damaging food processing method that does not result in adverse physical and nutritional changes to the food product. UV-C light is proven to have germicidal properties. The light can damage the DNA of pathogens, rendering them unable to multiply and thrive on any given surface. UVGI process has been used to disinfect water and air, recycle wastewater, and decontaminate surfaces. Now, the food industry can also apply UVGI to different types of food products (Singh, et. al., 2021).

While relatively new, UVGI is seen as an advantageous choice due to its non-thermal approach. Advances in engineering have pushed for UV-C light-based disinfection systems with optimal food penetration and impact. The technology has proven to be more effective in microbial inactivation and food quality retention than heating methods (George, et. al., 2021).

At the same time, it offers a more economical approach for industries. UVGI contributes to a reduction in processing time compared to conventional food decontamination methods, resulting in food safety, lower energy costs, and overall consistent results for the industry.

Food Sanitization: Thermal and Non-Thermal Processing

There are several ways in which food sanitization is done, but there are two main categories for each method: by heating (thermal processing) and without heating (non-thermal processing).

Thermal processing techniques could be applied for liquids such as dairy, sauces, some egg products, and other foods that lend well to heat, being able to sterilize and keep the food quality safe. However, there are problems with reducing the nutritional value or deteriorating the quality of foods. Meat products, or vegetables, for example, can be dried or treated under solar heat to reduce water content and the likelihood of spoilage substantially. But in doing so, there will be potential loss of heat-sensitive vitamins and nutrients, changes in texture and overall sensory characteristics of the food, and lastly, its inherent flavor. In addition, certain types of bacteria have proven immune to thermal processing.

The gaps that exist in thermal processing concerning food quality and safety may be addressed by using non-thermal processing techniques. Non-thermal processing involves exposing foods to ambient temperature for a minimal period (i.e., a minute or less) to decontaminate the food product. The elimination of heat enables the production sector to create longer shelf life for food while maintaining its ideal sensory qualities.

Like thermal processing, there are various non-thermal food processing treatments that have been developed in the last few decades. These methods include cold plasma, microwave, pulsed electric field, and UVGI technology. These non-thermal methods expose food to treatment conditions for a brief period, resulting in reduced microbial load, a lessened likelihood of spoilage, increased shelf-life, and intact textural and nutrient characteristics (Jadhav, 2021).

UV-C Light Technology

UV-C light technology works to eliminate airborne or surface pathogens where they are released. UV-C light induces photodimers on adjacent DNA or RNA base pairs, interfering with the replication process. Photodimerization is a common form of DNA damage induced by UV radiation—this results in the organism being unable to reproduce or thrive in a given setting (Gršković, et. al., 2013). What proves effective is the UV light in the C band, from wavelengths of 200-280 nm, with the wavelength of 253.7 nm being specifically germicidal to most microorganisms.

UV-C light can reduce the microbial load on the surface of food materials that are indirectly exposed to the radiation, as the light is still absorbed by aerosolized microbial cell nucleic acids and will inhibit further replication and cell growth on foods.

UV-C light technology has shown tremendous potential as the most economical and effective non-thermal processing method in the food sector. Studies suggest that it can inactivate microorganisms in fruit juices such as apple juice, orange juice, and cantaloupe juice. Pathogenic bacteria, namely *Lactobacillus plantarum, E. coli*, and *cerevisiae* have been significantly inactivated (Fenoglio, et al., as cited in Jadhav, et al., 2021).

Ultraviolet processing is also applicable for milk and dairy product sterilization. Recent studies have shown that UV-C exposure not only inactivated microbes in fresh fruits and vegetables after harvest, but the light increased the antioxidant content of the produce.

There are still considerations with UVGI. Some studies showed high-dose UV food treatment can decrease color and adversely affect the texture of solid foods. For example, undergoing higher-than-ideal UV intensity results in physical changes in food, such as oxidation, loss of color, and changes in the fresh flavor. Hence, proper balance in decontaminating while maintaining food quality is crucial in maximizing UV light technology (Jadhav, et. al., 2021).

Modern low-pressure (LP) lamps are built to produce UV-C light at this wavelength, to combat pathogen formation. Upper air fixtures utilizing LP UV-C lamps must be designed, certified safe for occupants, and properly installed to prevent UV exposure.

Ultraviolet technology is among the most economical, non-thermal processing options. It proves to be a reliable mechanism for disinfection that many companies in the food industry can easily and readily adopt.

Aerapy UV-C Systems for Extending Food Shelf Life

Recent advances in UV technology have developed UV-C light fixtures and devices with optimized intensity, for better disinfection of aerosolized pathogens extending the shelf life of perishable foods without compromising the physical qualities and nutritional content of edible products. Aerapy offers a variety of custom UV-C systems that are certified and safety-tested for use in occupied spaces by Intertek ETL certification to Underwriters Laboratories (UL) standards.

An independent third-party laboratory in Baltimore, MD, was commissioned by Everidge, a leading innovator of commercial cold storage solutions, walk-in coolers/freezers, and cook-chill specialty solutions, to examine the efficacy of Aerapy's upper air UV-C device inside their coolers. The study included testing the microbiology on green-leafy vegetables (spinach and lettuce), legumes (kidney beans), and meat (beef and chicken). Microbes that were pertinent to the experiment included: Lactic Acid, Yeast, and Mold.

Results from lab tests suggest that Aerapy's UVGI technology has a significant effect on reducing several types of microbes across all food samples. The formation of Lactic Acid, Yeast, and Mold were predominantly hindered by the UV-C processing—with a reduction of Lactic Acid from >30,000 colony forming units/gram (cfu/g) in untreated samples, down to 20 cfu/g in treated beef and chicken samples, and a reduction of Mold from >30,000 cfu/g in untreated samples, down to 270 cfu/g in treated lettuce and spinach. See Table 1 for detailed results.

TABLE 1: Independent Third-Party Laboratory Microbiological Disinfecting Device Study Commissioned by Everidge, Inc.

EVERIDGE® Every step of the way®

CATEGORY	UNTREATED/ TREATED	SAMPLE ID	LAB ID	MICROBIOLOGY (CFU/G)		
				Lactic Acid Bacteria	Yeast	Mold
Kidney Beans	Untreated	E1-VKBU	21G2001-01	100	10	<10
	UV-C Treated	E1-VKBV	22K0789-01	10	<10	<10
			% REDUCTION	**90.0%**	**>0.0%**	**0.0%**
Chicken and Beef	Untreated	E2-MCBU	21G2001-02	>30,000	2500	510
	UV-C Treated	E2-MCBV	22K0789-02	20	410	110
			% REDUCTION	**99.9%**	**83.6%**	**78.4%**
Lettuce and Spinach	Untreated	E3-VLSU	21G2001-03	<10	21,000	>30,000
	UV-C Treated	E3-VLSV	22K0789-03	30	910	270
			% REDUCTION	**<-200%**	**95.7%**	**>99.1%**

cfu/g = Forming units per gram = Number of UV-C treated microbiology decreased

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Aerapy UV-C Technology for Reducing Food Shrinkage

Aside from its food safety benefits, UVGI has also proven to prevent excess shrinkage in perishable goods, mainly fruits and vegetables.

Another study conducted by a large-chain grocery store deli department showed positive results. Shrink numbers significantly decreased for greens, deli meats, and beans. After one week, there was a 100% reduction for the vegetables when using Aerapy's upper air UV-C device. The deli meats and the beans had a 75.75% and a 26.85% reduction in shrinkage costs, respectively. See Table 2 for detailed results.

TABLE 2: Large-Chain Grocery Store Deli Department Study

CATEGORY	AVERAGE WEEKLY SHRINK	ACTUAL SHRINK AFTER UV-C TEST	SHRINK SAVINGS	PERCENT REDUCTION
Greens	$139.79	$0.00	**$139.79**	**100.0%**
Deli Sliced Meats	$217.31	$52.69	**$164.62**	**75.75%**
Beans	$99.15	$72.53	**$26.62**	**26.85%**

Small-scale studies show a concrete reduction in food shrinkage. There is a two-fold benefit from UVGI—efficient in sanitizing food and at the same time, keeping shrinkage at a minimum for businesses in the food sector. While there are results that show food quality being affected when treated at a higher intensity, developing an optimal UV-C light processing mechanism will prevent any undesirable changes in food.

Conclusion

Ultraviolet germicidal irradiation (UVGI) is an established technology that has been proven to be a practical method for preventing foodborne illnesses while increasing the shelf life of different foods. UV-C light technology sanitizes the air and disinfects surfaces at the cellular level, inhibiting growth of common food pathogens. It is an ideal non-thermal processing technique that solves much of the food sector's issues when decontaminating foods at the manufacturing and packaging stages.

Third-party tests have shown that Aerapy upper air UVGI systems can kill microbes, minimize compromising effects on food's sensory and nutrient quality, and, most importantly, present economic advantages to businesses. By increasing the shelf life of food, there is a high possibility of minimizing shrinkage in fresh food, and therefore, fewer expenses on repurchasing produce and meat products. These key benefits make UV-C light disinfection an excellent and logical option for companies that seek to move beyond the conventional thermal processing techniques that do not address shrinkage and food quality concerns.

Development of standards for UVGI in food safety practices is currently underway, but the industry is relying on scientific data to support widespread implementation. Aerapy is among the leading brands in furthering UV-C light technology studies to make the method a forerunner in non-thermal processing in food safety.

UV-C disinfection depends on a variety of factors, and expert providers such as Aerapy are ready to work with food industry players in making the technology as accessible as possible. Parameters in UV-C equipment, microbial solutions, and standards for food exposure are among the most critical features that should be discussed with a UVGI provider.

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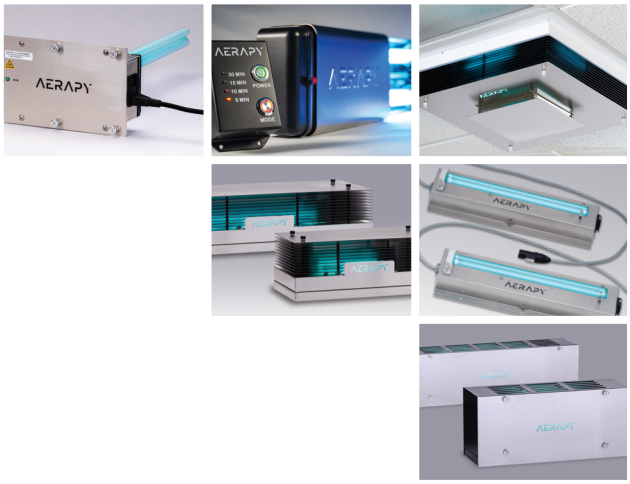

To learn more about UV-C and Aerapy UV Disinfection Technology, call:

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