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RESEARCH CONDUCTED WORLDWIDE IN THE FIELD OF BERRIES' DECONTAMINATION USING NON-IONIZING RADIATION UV -C

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Abstract: *Given the need of an acceptable shelf life of berries intended mainly for fresh consumption, it is necessary that their microbiological load to be kept at a lower level. Non-ionizing UV-C ultraviolet radiation can be used to decrease the microbial population from the surface of the food, as an alternative to chemical decontamination. This paper presents research conducted worldwide in berries' decontamination using UV-C radiation.*

Key words: *berries, decontamination, food safety, microorganisms.*

1. Introduction

Starting with the Earth Summit of the United Nations in 1992, the sustainable development has received worldwide recognition, and consumers began to concern themselves with increasingly environmental sustainability of agriculture. Willingness to know where food comes from, how it was produced and if the agricultural practices were environmentally friendly are just some of today's consumer demands. [7]

The quality and food safety have become a right of consumers with direct effects on the quality of life, and the issue focused on this aspect is in the spotlight of the established bodies in order to protect the interests of consumers.

The quality of the berries is a complex notion, being characterized by specific indicators such as species, variety and the growing season. Given the physical-chemical and morphological structure and physiological berries fall into the category of perishable fruits. The berries's higher water content (about 86%) and sugar (12%) is a favorable nutrient medium for the propagation of microorganisms, during growth and maturation and also, during storage [2].

The ultimate goal of treatment berries with UV-C is the decontamination of their surface. The pathogens that exist on the product's surface are divided into two main groups:

- Germs that cause the spoilage of the fruit in time; their destruction by irradiation increases the fruit's shelf life;
- Germs which can affect the health of the consumer; their partial or total removal by using UV-C increases the consumer's food safety.

2. Materials and methods

2.1. General notions about UVC

UV light is the range of light just below

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the visible spectrum of light. The range between 200 - 300 nanometers is know to be germicidal, lethal to microorganisms, Figure 1.

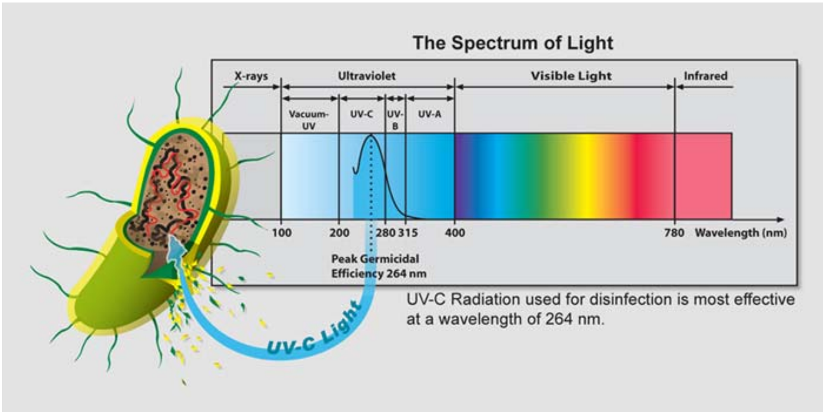

Fig. 1. *The Spectrum of Light* [7]

By disrupting the reproductive mechanism (DNA) of bacteria, virus, yeast or molds, the organisms are inactivated thereby eliminating them as agents of disease, spoilage, and biological growth.

When a cell is subjected to UV-C radiation, these processes occur in order:

- Absorption of a quantum of energy;
- Excitation of the molecule which absorbs it;
- Photo chemical reaction of the excited molecule;
- Biological effect.

Biological effects include breakdown of some of the key amino acids in proteins causing metabolic disruption.

The permanent inactivation of cells is the breakdown of DNA, the reproductive material, where incorrect linkages form.

The errors in the chain then prevent both transcription in order to produce proteins, and reproduction [2].

Germicidal lamps and some special manufacturing LEDs that generate UV-C radiation. This type of radiation induces the dimerization of a pair nitrogenous base of DNA, eg thymine dimerization, as shown in Figure 2 with the welding of DNA chains on that site. As a result, the gene transcription, which means copying the information from DNA to RNA, is blocked. The cell division is stopped and finally the death of cell is produced (bactericidal effect).

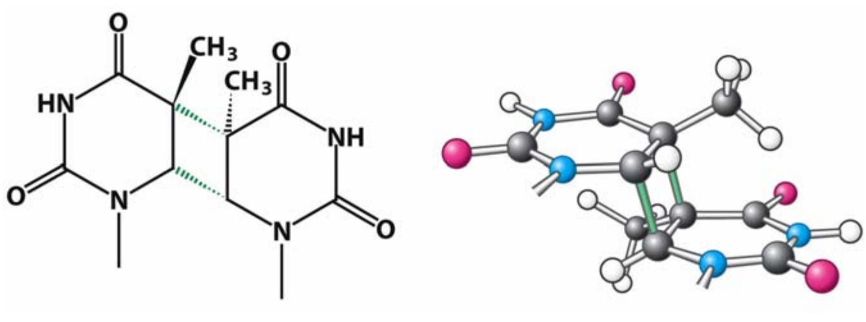

Fig. 2. *Thymine dimer* [1]

2.2. Germicidal UV generated by a mercury-vapor lamp.

Germicidal UV-C for disinfection (Figure 3) is most typically generated by a mercury-vapor lamp. Low pressure mercury vapor has a strong emission line at 254 nm, which is within the range of wavelengths that demonstrate strong disinfection effect. The optimal wavelengths for disinfection are close to 260 nm.

Fig. 3. *UV-C lamp* [8]

Lamps are either amalgam or medium pressure lamps. Low-pressure UV lamps offer high efficiencies (approx 35% UV-C) but lower power, typically 1 W/cm power density (power per unit of arc length). Amalgam UV lamps are a higher power version of low-pressure lamps. They operate at higher temperatures and have a lifetime of up to 16,000 hours. Their efficiency is slightly lower than that of traditional low-pressure lamps (circa 33% UV-C output) and power density is approximately 2–3 W/cm. Medium-pressure UV lamps have a broad and pronounced peak-line spectrum and a high radiation output but lower UVC efficiency of 10% or less. Typical power density is 30 W/cm or greater.

Depending on the quartz glass used for the lamp body, low-pressure and amalgam UV emit radiation at 254 nm and also at 185 nm, which has chemical effects. UV radiation at 185 nm is used to generate ozone [6].

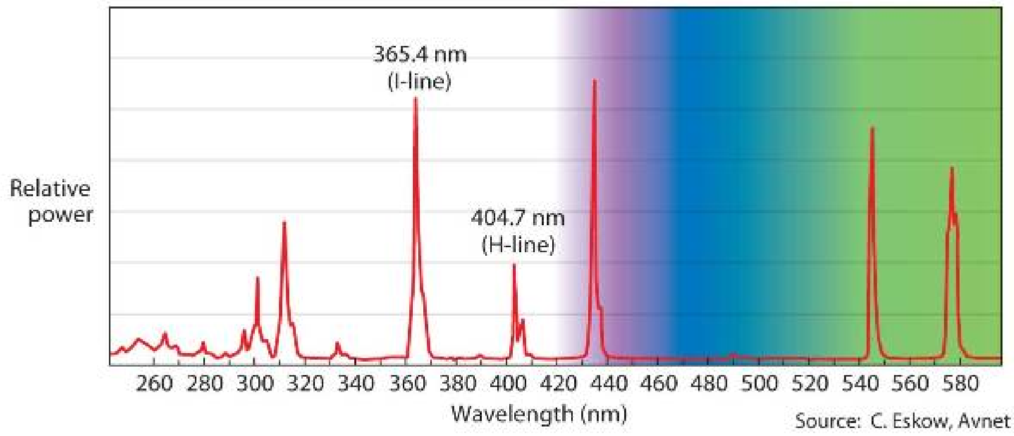

Fig. 4. *The peaks of mercury lamps* [3]

In production curing operations, mercury-vapor lamps are hindered by short lifetime (2,000-10,000 hrs), slow warm-up and cool-down times, and wide spectral power distribution. In addition, over 60% of the energy that is applied to a typical mercury-vapor lamp is radiated back out as infrared energy, in other words, heat. The UV output of a mercury vapor lamp drops off rapidly over its operational life because some of its electrode material vaporizes, depositing a film on the inside of the quartz tube which the UV cannot penetrate. As a result, the user cannot easily predict the amount of UV generated at a later time; often this is a critical process parameter [3].

The mercury lamp has a main peak at 365 nm but several smaller peaks in the visible and infrared regions (Fig. 4).

2.3. Germicidal UV generated by a UV-C LED

Even though UV LED manufacturers have been working hard to improve internal quantum efficiency and optical efficiency, overall efficiency remains below 20%, meaning a great deal of heat must be dissipated from the diode's junction. To achieve the required flux densities with today's chip technologies, the multi-die emitters need to be driven at the highest current. This is only possible with a LED package capable of handling extreme power densities for the life of the product.

Fig. 5. *LED with multi-layer ceramic substrate* [6]

A thermally matched stress-free package and glass lens help eliminate common packaging failure modes associated with UV LEDs, LED Engin's patented multi-layer ceramic substrate with extremely low thermal resistance that quickly conducts heat from the die junction (Figure 5).

UVCLEAN® lamps (manufactured by Sensor Electronic Technology, Inc, USA) are multi-chip arrays of UV LEDs enclosed in metal-glass packages. Standard lamps are available in a selection of wavelengths from 255 nm to 350 nm and offer higher output powers than the UVTOP® LEDs at 1-3mW, 3-5mW, 10-15mW and 30-50mW (Fig. 6). [4]

Fig. 6. *UVCLEAN Lamps* [7]

It is important to recognize that some of the same qualities that make UV LEDs very powerful and useful – their low wavelength and high energy – are also the qualities that make them dangerous. The warning labels on UV LEDs and their products are clear but bear noting: UV-LEDs emit invisible ultraviolet radiation when in operation, which may be harmful to eyes or skin, even for brief periods [3].

2.4. The germicidal effect of the UV-C light

The following are the research conducted by a group of scientists of General

Engineering Research Institute, John Moores University, Liverpool.

The microwave plasma UV lamp (MPUVL) developed in a research project supported by the EU, is able to produce both UV light at the germicidal region (254 nm) and at the Ozone forming region (185 nm), simultaneously. The system has proven to have higher efficiency than both a conventional UV lamp and the low pressure electrical DC discharge lamp (Figure 7).

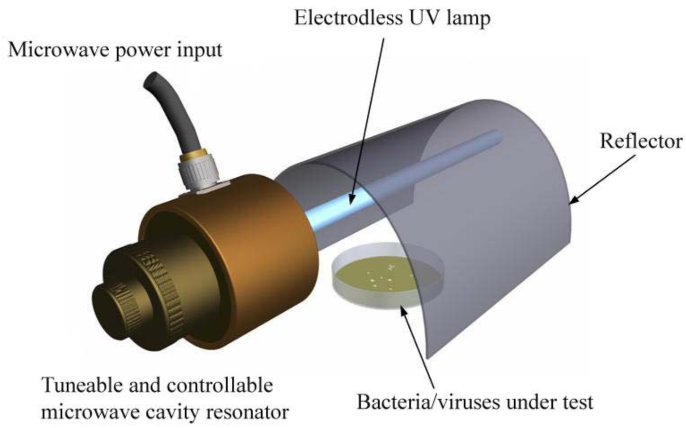

Fig. 7. *The MPUVL set-up* [5]

The germicidal effect of the UV-C light emitted by the microwave powered lamp was assessed on 4 different microorganisms. Culture plates containing from 10^5 to 10^7 cfu (colony forming units) of the bacteria were exposed to a range of doses of UV-C light. The culture plates were placed in the area directly underneath the lamp, at 10 cm distance. Plates were then exposed to the UV light for different amounts of time depending on the microorganism.

After exposure to UV-C light, the plates were incubated overnight at 37ºC. Surviving bacteria developed a colony, which were then counted. The plates situated on the top row were inoculated with 10^5 *E. coli bacteria*, and exposed for different amounts of time to UV light. The longer the plates were exposed to UV light, the lower the amount of bacteria that were able to survive. Figure 8 shows the reduction in the numbers for the 4 different microorganisms tested. Experiments were performed in triplicate, and the average values are shown. The exposure times for the plates varied from 2 to 8 seconds for *E. coli*, *P. aeruginosa* and *S. aureus*, and from 10 to 60 for B. *cereus*. A reduction of up to 6 Log in the number of living microorganisms was observed for *E. coli* and *P. aeruginosa* in less than 2 sec exposure, which corresponds to less than 20 J/m^2 S. *aureus* was slightly more resistant, and needed between 20 and 50 J/m2 to obtain the same Log reduction. Vegetative cells of Bacillus were more resistant to UV radiation, and an exposure to 600 J/m^2 was needed to produce a 6 log reduction in the number of surviving microorganisms in the test plates. When spores of *B. cereus* were used to perform the tests, they proceed to be highly resistant to damage by UV light, and very high doses of radiation (600 J/m^2) were needed to observe a reduction of even 2 Log in the number of surviving microorganisms [5].

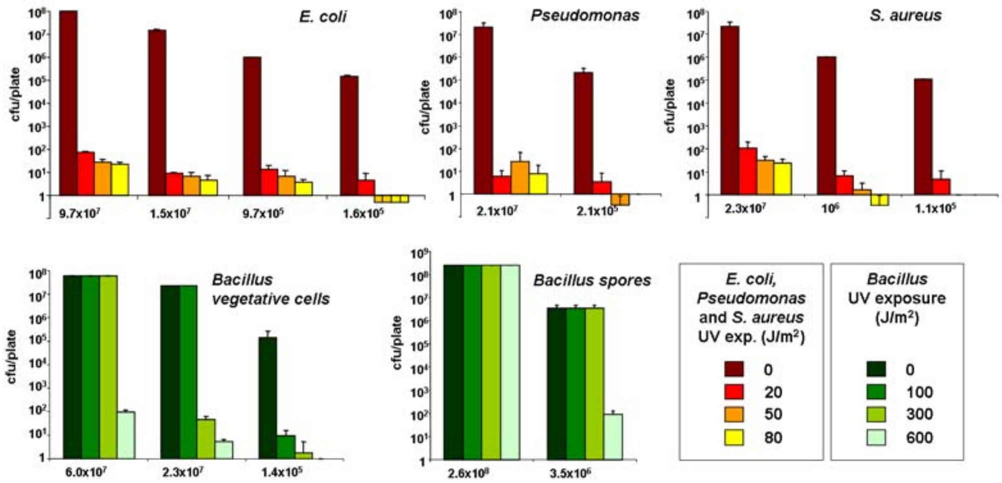

Fig. 8. *Effect of UV radiation on different bacterial species* [5]

3. Conclusions

- UV-C, by disrupting the reproductive mechanism (DNA) of bacteria, virus, yeast or molds, the organism are inactivated thereby eliminating them as agents of disease, spoilage, and biological growth;
- Even though UV LED manufacturers have been working hard to improve internal quantum efficiency and optical efficiency, overall efficiency remains below 20%;
- The effect of UV-C light emitted by the microwave powered lamp on four different microorganisms showed a significant reduction in the numbers of living microorganisms;
- Germs which can affect the health of the consumer; their partial or total removal by using UV-C increases the consumer's food safety.

Acknowledgement

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