Bacterial spore inactivation by ultraviolet C radiation for liquid food hygiene

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Introduction

Traditionally, the food industry used thermal treatments as the main disinfection and sterilization method. Nevertheless, it produces changes in the organoleptic properties and losses in the nutritional components like vitamins or antioxidants[1]. Furthermore, spores have been shown to survive such heat treatments[2]. Therefore, non-thermal emerging techniques like UVC radiation are of special interest in the food industry to treat liquid foods, and especially to inactivate bacterial spores.

The aims of this review are to provide up-to-date information about:

- UVC mechanism of **spore damage**
- Spores **resistance to UVC light**
- **Evaluate UVC efficiency to inactivate** bacterial spores

Spore structure

Spores are 1 to 2 orders of magnitude more resistant to UVC than vegetative cells[3] due to its particular structure (Fig. 1).

DPA – Dipicolinic acid
SASP – Small acid-soluble spore proteins
→ Alteration of DNA into an A-form
→ **Spore resistance**[4]

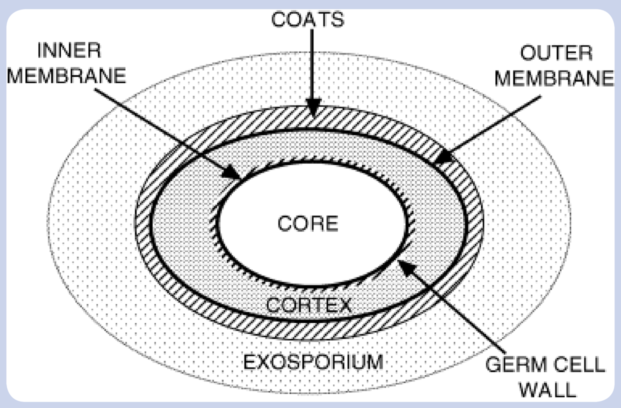

Fig. 1 Spore structure[4].

UVC spore damage

UVC light, the most germicidal UV range, has more impact in pyrimidines, than purines; therefore photoproducts derived from pyrimidines are the most common. In bacterial spores, spore photoproducts (**SP**s) are the major DNA lesions produced by UVC radiation[5]. SP is the addition of a methyl group of thymine residue to the C5 position of and adjacent thymine[6].

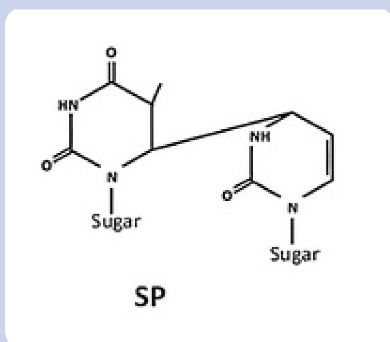

Fig. 2 Spore photoproduct[5].

DNA repair

DNA repair mechanisms

- **SP lyase**: The most relevant system for UV spore resistance[7]
- **NER**: Nucleotide excision repair system
- **HR**: Homologous recombination

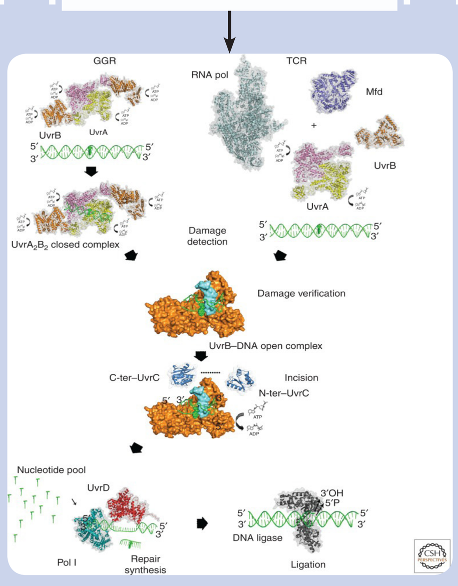

Fig. 3 Schematic representation of the prokaryotic NER pathway[8].

UVC features

Advantages

- Efficient **microbiological inactivation**
- **Minimal loss** of nutritional and organoleptic components
- **Not toxic** residues
- Low energy[1,5]

Disadvantages

- **Lower penetration** of UVC radiation in liquids with **higher absorption coefficient**[1,5]

Factors affecting UVC germicidal efficiency[5]

Process parameters	Product parameters
Dose	Absorption coefficient
Wavelength	Turbidity

Microbial characteristics

Growth face	Type
Growing conditions	Species
Stress	Strain
Recovery conditions	

Depends on the microorganism and the sensitivy of the assay

Exponential decrease of population

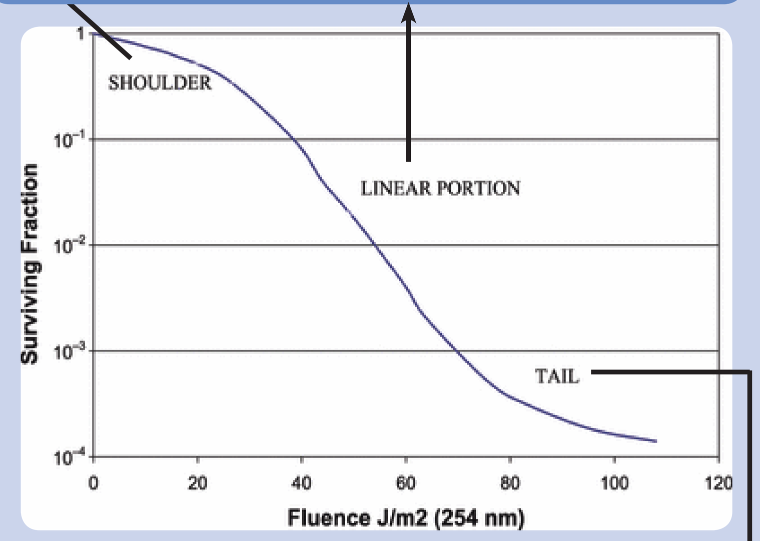

Fig. 4 Typical bacterial survival curve in response to UVC exposure[9].

- Not always present
- Due to cell clumping, a resistant subpopulation of cells or suspended solids

UVC application for bacterial spore inactivation

Table 1 UVC-resistance parameter 4D. Treatments were carried out at room temperature[10].

Spore	4D (J/mL)
Alicyclobacillus acidocaldarius	31.25
Geobacillus stearothermophilus	24.53
Bacillus cereus	30.74
Bacillus licheniformis	25.69
Bacillus coagulans	35.30

The **most heat-resistant** is the **most UVC-sensitive**.

Unlike heat treatments, UVC resitance of the **most sensitive**, was only **30% lower** than that of the **most resistance**.

Variation in UVC resistance of Bacilli spores in several articles[9]

- Variations in the strains
- Lack of common exposure techniques
- Quality and state of the spores
- Different spore concentration
- Proportion of vegetative bacteria

The use of values from **different studies** to make **comparisons** of **spore resistance to UVC** between different species **is not valid**.

Combination of UVC with other technologies

UVC and TiO_2: **Synergistic effect**; TiO_2 is responsible for an advanced oxidation process in which highly reactive radicals are produced by photolysis[11]

UVC and heat: **Synergistic effect** when UVC is applied simultaneously or prior to heat treatment[10]

UVC and O_3: **Synergistic effect** due to OH radicals produced as an intermediate in the combined O_3-UVC process[12]

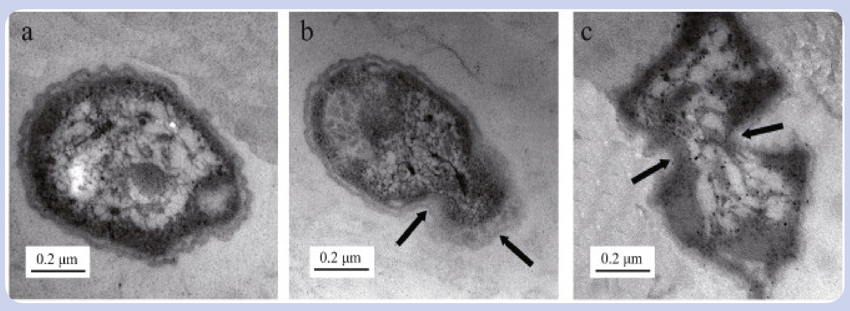

Fig. 5 TEM images of (a) untreated (b) UVC-treated and (c) UVC–TiO2-treated B. subtilis spores. UVC irradiance of 0.10 mW/cm2 and TiO2 concentration of 10 mg/L for 600 sec [11].

Conclusions

- **UVC** is a **promising method** for the inactivation of bacterial spores in the **food industry**.
- The **stability** ensured by UVC treatments is **similar** even if the **bacterial spore changes**.
- The **efficacy** of UVC light can be **enhanced** when **combined with other cited methods** to sterilize liquid foods with high absorption coefficients.
- To **improve and unify future researches** the reviewer recommends to follow the **guideline** provided by Coohill & Sagripanti 2008[9].

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