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CONVENTIONAL HIGH-POWER PULSED LIGHT SOURCE FOR DECONTAMINATION OF MEAT FROM FOOD PATHOGENS AT NON-THERMAL CONDITIONS

V. Gudelis and Ž. Lukšienė

Institute of Applied Research, Vilnius University, Saulėtekio 10, LT-10223 Vilnius, Lithuania
E-mail: zivile.luksiene@tmi.vu.lt

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The aim of this study was to evaluate the optimal algorithm of high-power pulsed light technique constructed for decontamination of meat surface from pathogenic microorganisms. Our experimental data indicate that the high-power pulsed light is fast and effective chicken surface decontamination tool and can decrease food pathogens *Salmonella* and *Listeria* by 2.0 orders of magnitude in non-thermal conditions. The constructed equipment and obtained data may serve in the future for advanced development of high-power pulsed light technique which could be used for decontamination of food matrixes or food related surfaces in non-thermal conditions.

Keywords: pulsed light technique, decontamination, chicken, *Salmonella*, *Listeria*

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1. Introduction

The Centers of Disease Control and Prevention (CDC) estimates that 1.4 million cases of salmonellosis occur annually in the USA [1] and cost 2.3 billlion dollars per year [2].The main vehicle of this disease is meat. As the consumption of chicken has increased and is estimated to be around 27% of the world's total meat consumption, effective decontamination of chicken from pathogens is a global problem. Many chemical meat safety technologies, including organic/inorganic acids, chlorine, bacteriocins, oxidizers, inorganic phosphates exist. Meanwhile, most of them have various shortcomings, for example invoked effects which usually induce different physical, chemical, or sensorial changes in the food [3].

High-power pulsed light technology is a food preservation technique that proposes decontamination of surfaces by intense and short duration pulses of a broad spectrum light and has been approved for food surface decontamination by FDA in 1999 [4].

The present work focuses on the evaluation of possibility to decontaminate chicken meat from such pathogens under non-thermal conditions by newly constructed high-power pulsed light technique.

2. Materials and methods

2.1. Bacterial strain

The target bacterium, *Salmonella enterica* was kindly provided by Prof. D.H. Bamford (University of Helsinki, Finland).

2.2. Inoculation of pathogens on the surface of chicken breast

Chicken meats (breast) were purchased from Lithuanian market. The frozen meat was defrosted at 6 °C for 24 h and cut into 4×3 cm^2 pieces (7.5 g weight). One of the chicken meat sides was inoculated by spreading 100 μl *Salm.* Typhimurium or *L. monocytogenes* suspension ($\sim1\cdot10^7$ CFU ml^{-1}). The inoculated chicken meat was kept in thermostat at 37 °C for 15 min for further attachment of the bacterial cells.

2.3. Construction of the device

The most efficient UV light source is xenon flash lamp, which creates the UV radiation generated in the low pressure gas (xenon) by a powerful electric discharge. While constructing the high power pulsed light device, we made our choice on xenon flash lamp FL-75.

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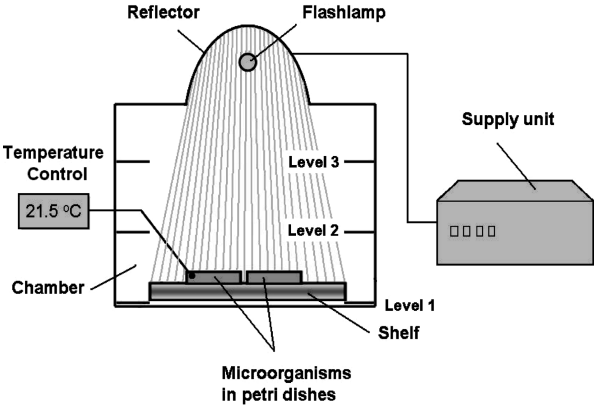

Fig. 1. Schematic presentation of high power pulsed UV light generating device to decontaminate foods.

As presented in Fig. 1, the device consisted of a chamber, a reflector with a flash lamp, and a power supply unit. The chamber had three shelves with different distances from the flash lamp. Every shelf was 16×16 cm^2 square with the identical exposure conditions [5].

2.4. Light dose estimation

In order to estimate the dose of total light energy delivered to the biological object, several mathematical calculations have to be performed. The pulse power density is a pulse energy (J) delivered per cm^2 of the treated surface during pulse duration ($\tau = 112$ μs), so it is a ratio of the pulse energy to the pulse duration (J cm^{-2}s^{-1}). Traditionally photo-biological processes depend on the total light energy dose delivered to the object and are expressed as J cm^{-2}. In the case of pulsed light delivery, the total dose (D) is the energy of one pulse e_1 (J cm^{-2}) multiplied by a number of pulses during the whole treatment (t):

$$D = e_1[\mathrm{J\,cm^{-2}}] \cdot t[\mathrm{s}] \cdot f[\mathrm{Hz}]\,, \qquad (1)$$

where f is a pulse repetition rate.

2.5. Light power density measurements

Light power density measurements were performed with a light energy measure by 3sigma meter (Coherent, Santa Clara, CA, USA) equipped with pyroelectrical detector J25LP04.

2.6. Measurements of temperature dynamics on the surface of chicken

The LM35 precision Celsius temperature sensors (Delta Ohm, Padua, Italy) were used for temperature measurements as they have an advantage over linear temperature sensors calibrated in Kelvin; the user is not required to subtract a large constant voltage from its output to obtain convenient temperature scaling. Moreover, the sensor does not require any external calibration or trimming to provide typical accuracies of $\pm1/4\,^\circ$C at room temperature.

2.7. Decontamination of chicken surface by pulsed light treatment

Chicken samples inoculated with *Salmonella* or *Listeria* were placed in the treatment chamber in a sterile Petri dishes. Light doses delivered to the sample varied between 0.78 and 5.4 J cm^{-2}.

2.8. Statistical analysis

For statistical analysis bacterial populations in CFU ml^{-1} were transformed into log scale. Analysis of variance (Anova) was performed ($P < 0.05$). In addition, Bonferroni tests were performed between means. Each experimental point is an average of 3–5 experiments. A standard error was estimated for every experimental point and marked in a figure as an error bar. The data were analysed with Origin 7.5 software (OriginLab Corporation, Northampton, MA, USA).

3. Results and discussion

3.1. Decontamination of chicken from pathogens by high-power pulsed light treatment

In our previous work we tried to identify the main light region – ultraviolet (UV), visible (VIS), infrared (IR) – which was responsible for bacterial inactivation under non-thermal conditions. Data clearly indicated that both *Listeria* and *Salmonella* are susceptible to pulsed light treatment and can be inactivated by 6.5–7 orders respectively. So far, when UV light was shut down by filter, treatment exhibited no antibacterial action on *Listeria* and *Salmonella*. It means that antibacterial action of UV light is general, and no additional IR or VIS light influence on bacterial survival is present under certain experimental algorithm [5].

Data depicted in Fig. 2 indicated that inactivation of *Salmonella* or *Listeria* cells on chicken surface using high-power UV pulsed light technique was rather significant. The UV light dose of 0.78–1.08 J cm^{-2} delivered to the surface of chicken reduced the bacterial viability N/N_0 by 0.76–0.88 orders of magnitude in

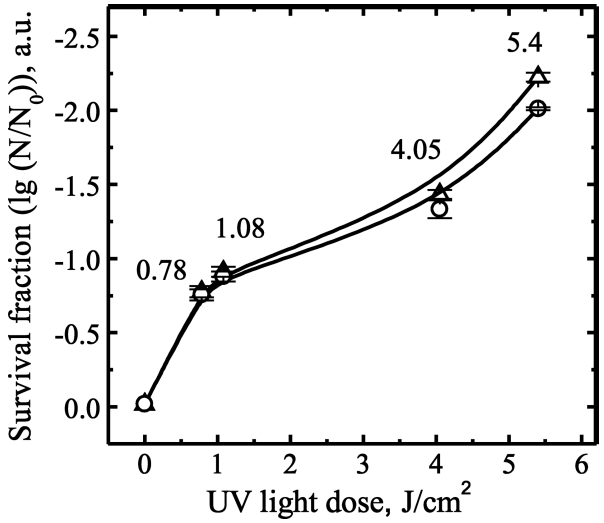

Fig. 2. Non-thermal inactivation of *Salmonella* typhimurium (○) and *Listeria monocytogenes* (△) adhered on the surface of chicken matrix as function of pulsed light dose.

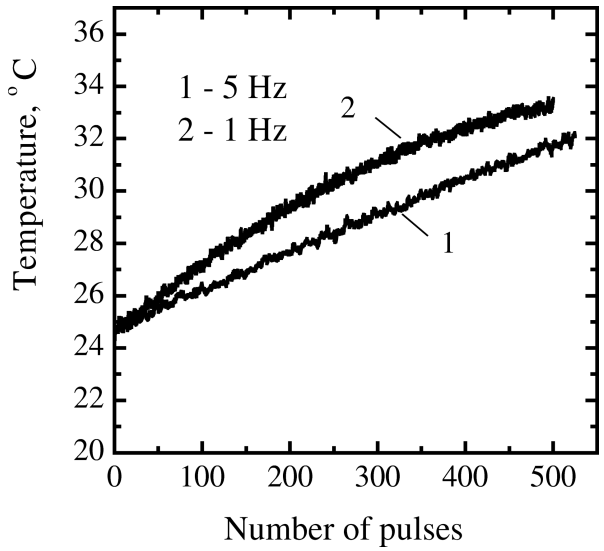

Fig. 3. Temperature dynamics on the surface of agar at 1 and 5 Hz pulse repetition rates. UV pulse energy density in the second shelf was $3.9{\cdot}10^{-3}$ J cm^{-2}.

comparison with control untreated sample. It is evident that reduction of bacterial viability on the surface of chicken is a function of light dose, when distance from the light source, exposition time, pulse repetition rate, and voltage are constant. Thus, at the highest UV light dose (5.4 J cm^{-2}) a major reduction of *Salmonella* was reached (2 orders of N/N_0 magnitude respectively).

3.2. Search for optimal high-power pulsed light treatment algorithm

The main task of this study was to inactivate pathogens on the surface of chicken under non-thermal conditions ($T < 41$ °C). As the pulse lamp heats up during irradiation, the cooling system has been necessary. However, it was not enough to maintain the non-thermal irradiation conditions. To this end, we studied the dynamics of temperature on the surface of agar at various exposure modes (Fig. 3). It was clear that the agar surface heated less than 33 °C, when the number of pulses did not exceed 500. The irradiation mode when 5 Hz pulse repetition rate was used heated the surface of agar less (up to 31.8 °C) in comparison with irradiation using 1 Hz pulse repetition rate. 5 Hz in our case is the maximum repetition rate which enables us to choose the power source. In order to choose the optimum shelf level for food matrix irradiation, we chose the two evaluation criteria: the UV energy density E and ΔT, the increment of temperature in the shelves. The ratio $E/\Delta T$ indicates the dose of UV for irradiated sample over a period of time until its surface temperature rises 1 °C. The irradiation efficiency is the main parameter to choose the optimal irradiation mode (Fig. 4). The maximal irradiation efficiency is achieved in the upper shelf. In this shelf UV energy density E is maximal and requires shortest irradiation time. The temperature in the sample did not reach the critical temperature 41 °C, when the irradiation dose was less than 2 J cm^{-2}.

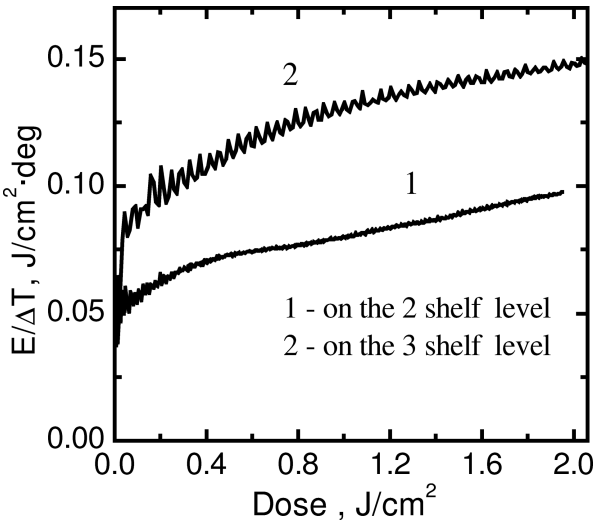

Fig. 4. Dependence of irradiation efficiency $E/\Delta T$ on the total light dose in different shelves.

4. Discussion

As presented in Fig. 2, it is possible to reduce *Salmonella* and *Listeria* by 7 orders *in vitro* using 1.95 J cm^{-2} light dose. Due to opaque and irregular chicken surface, the shadowing effect decreases antimicrobial efficiency of the treatment. So far, the efficiency of pathogen inactivation on the surface of meat is not so

significant due to more complicated light–surface interaction *6*. Thus, higher light doses (5.4 J cm^{-2}) are necessary to achieve inactivation of *Salmonella* and *Listeria* reaching 2 orders (Fig. 3).

The xenon lamp high-power pulsed light treatment therefore can be considered as a nonthermal process, but only if applied for short exposures. Our data confirm the idea that a limited number of light pulses can be delivered to the food matrix, as longer exposures of light induce thermal effects (Fig. 4). Higher antimicrobial effect of pulsed light is tailored by higher temperature on the surface of chicken (Fig. 3). Studies indicate that enhancement of light pulse power as well as incorporation of effective cooling systems in the equipment will open new possibilities to increase antimicrobial efficiency of the UV pulsed light treatment.

5. Conclusions

Obtained data indicate that a conventional xenon lamp high power pulsed light can inactivate food pathogens *Listeria* and *Salmonella*, distributed on the surface of chicken meat, by 2 orders. It is important to note that we have found an experimental algorithm allowing the treatment to be performed at non-thermal conditions. It means that laserless high-power pulsed light technique has a potential to be developed as nonthermal, fast, and inexpensive chicken decontamination technology.

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DIDELĖS GALIOS IMPULSINĖS ŠVIESOS ŠALTINIS NETERMINIAM MAISTO PATOGENŲ MIKROBIOLOGINIAM NUKENKSMINIMUI

V. Gudelis, Ž. Lukšienė

Vilniaus universiteto Taikomųjų mokslų institutas, Vilnius, Lietuva

Santrauka

Ištirtas neterminis maisto patogenų mikrobiologinio nukenksminimo metodas, pagrįstas didelės galios impulsinės UV šviesos poveikiu. Išnagrinėtas sukurto impulsinės šviesos šaltinio mikrobiologinis ir terminis poveikis mėsos paviršiui. Parinktos optimalios švitinimo sąlygos, kuriomis patogeninių organizmų nukenksminimas vyksta efektyviai esant minimaliam terminiam poveikiui. Eksperimentiniai duomenys rodo, kad aukštos galios impulsinė šviesa yra greita ir efektyvi vištienos paviršiaus nukenksminimo priemonė ir gali sumažinti maisto užkratų *Salmonella* ir *Listeria* kiekį neterminiu būdu. Sukurti įrenginiai ir gauti duomenys leidžia toliau tobulinti aukštos galios impulsinės šviesos prietaisus, kurie galėtų būti naudojami apdoroti maisto matricų ar maisto pakuočių paviršių.