Food Microbiology 57 (2016) 172–177

Contents lists available at ScienceDirect

Food Microbiology

journal homepage: www.elsevier.com/locate/fm

Short communication

Efficacy of UV-C irradiation for inactivation of food-borne pathogens on sliced cheese packaged with different types and thicknesses of plastic films

Jae-Won Ha [a], Kyeong-Hwan Back [a], Yoon-Hee Kim [a], Dong-Hyun Kang [a, b, *]

[a] Department of Food and Animal Biotechnology, Department of Agricultural Biotechnology, Center for Food and Bioconvergence, Research Institute for Agricultural and Life Sciences, Seoul National University, Seoul 08826, Republic of Korea
[b] Institutes of Green Bio Science & Technology, Seoul National University, Pyeongchang-gun, Gangwon-do 25354, Republic of Korea

ARTICLE INFO

Article history:
Received 4 September 2015
Received in revised form
11 February 2016
Accepted 19 February 2016
Available online 22 February 2016

Keywords:
Ultraviolet light
Plastic packaging film
Sliced cheese
Foodborne pathogen
Inactivation

ABSTRACT

In this study, the efficacy of using UV-C light to inactivate sliced cheese inoculated with *Escherichia coli* O157:H7, *Salmonella* Typhimurium, and *Listeria monocytogenes* and, packaged with 0.07 mm films of polyethylene terephthalate (PET), polyvinylchloride (PVC), polypropylene (PP), and polyethylene (PE) was investigated. The results show that compared with PET and PVC, PP and PE films showed significantly reduced levels of the three pathogens compared to inoculated but non-treated controls. Therefore, PP and PE films of different thicknesses (0.07 mm, 0.10 mm, and 0.13 mm) were then evaluated for pathogen reduction of inoculated sliced cheese samples. Compared with 0.10 and 0.13 mm, 0.07 mm thick PP and PE films did not show statistically significant reductions compared to non-packaged treated samples. Moreover, there were no statistically significant differences between the efficacy of PP and PE films. These results suggest that adjusted PP or PE film packaging in conjunction with UV-C radiation can be applied to control foodborne pathogens in the dairy industry.

1. Introduction

Non-thermal decontamination technologies are increasingly being applied in food processing as a practical alternative to thermal processing (Guerrero-Beltrán and Barbosa-Cánovas, 2004). Non thermal processing can preserve food products from hazardous microorganisms while maintaining the nutritional and sensory characteristics of foods, which are often changed when thermal treatments are applied (Butz and Tauscher, 2002). There is a growing interest in the use of ultraviolet radiation as an alternate and inexpensive method for food preservation to reduce the number of microorganisms on food surfaces (Allende and Artes, 2003; Bintsis et al., 2000; Fonseca and Rushing, 2006; Guerrero-Beltrán and Barbosa-Cánovas, 2004; Shama, 2006; Yaun et al., 2004).

UV light at wavelengths shorter than 280 nm (termed UV-C) is considered germicidal on most types of microorganisms (Bintsis et al., 2000; Morgan, 1989; Sizer and Balasubramaniam, 1999). The highest germicidal effect is obtained between 250 and 270 nm, but it may decrease as the wavelength is increased (Bachmann, 1975). For this reason, a wavelength of 254 nm has been used for disinfection of surfaces, water, and some food products. UV-C radiation can be absorbed by nucleic acids and proteins, which can cause photo-damage and conformational changes, and subsequently interrupt vital metabolic functions such as DNA replication, transcription, and translation (Buma et al., 2003, 1995; Karentz et al., 1991; Lao and Glazer, 1996). More specifically, a cross-linking between adjacent thymine and cytosine (pyrimidine nucleoside bases) in the same DNA strand is caused by UV-C radiation. Due to this mutation, formation of the hydrogen bonds to the purine bases on the complimentary strand is impaired. Finally, DNA transcription and replication are inhibited, thereby rendering the microorganism unable to reproduce and eventually leading to cell death (Bintsis et al., 2000; Guerrero-Beltrán and Barbosa-Cánovas, 2004; Shama, 2006). UV-C radiation is a U.S. Food and Drug Administration (FDA) approved technology that can be used to inactivate pathogenic bacteria in liquid foods and water, and food contact surfaces (U.S. FDA, 2000).

* Corresponding author. Department of Food and Animal Biotechnology, Department of Agricultural Biotechnology, Center for Food and Bioconvergence, Research Institute for Agricultural and Life Sciences, Seoul National University, Seoul 08826, Republic of Korea.
E-mail address: Kang7820@snu.ac.kr (D.-H. Kang).

http://dx.doi.org/10.1016/j.fm.2016.02.007
0740-0020/

Post-processing contamination is the most frequent contributing factor to foodborne illness outbreaks. Generally recognized after-processing control points for access of pathogens to food products include human handling, transport containers, processing line, pumps or tanks, and sorting, packaging, cutting, and further processing equipment (Beuchat and Ryu, 1997; Reij and Den Aantrekker, 2004; Zottola and Smith, 1991). Thus, protective measures are needed to inactivate hazardous microorganisms on food surfaces after the packaging step. Currently, petrochemical-based plastics such as polyethylene terephthalate (PET), polyvinylchloride (PVC), polypropylene (PP), and polyethylene (PE) have been increasingly used as packaging materials for foodstuffs. This popularity is due to their ready availability, low cost, light weight, and good mechanical performance such as tensile and tear strength, good barrier to oxygen, carbon dioxide, anhydride and aromatic compounds, heat sealability, and so on (Lange and Wyser, 2003; Marsh and Bugusu, 2007; Siracusa et al., 2008). However, to date, there is a paucity of information in the literature on the effect of UV-C radiation to eliminate or control growth of foodborne pathogens on food surfaces packaged with plastic films.

In this study, we evaluated the transmission efficiency of UV-C radiation through various types of plastic packaging film, and also investigated its efficacy for inactivation of foodborne pathogens, including *Escherichia coli* O157:H7, *Salmonella* Typhimurium, and *Listeria monocytogenes*, on sliced cheese packaged with different types and thicknesses of plastic films.

2. Materials and methods

2.1. Bacterial strains

All bacterial strains, namely, *E. coli* O157:H7 (ATCC 35150, ATCC 43889, and ATCC 43890), *S.* Typhimurium (ATCC 19586, ATCC 43174, and ATCC 700408), and *L. monocytogenes* (ATCC 7644, ATCC 19114, and ATCC 19115) were obtained from the Bacterial Culture Collection at Seoul National University (Seoul, Korea) and used for all experiments. Stock cultures were stored at −80 °C in 0.7 ml of Tryptic Soy Broth (TSB; Difco, Becton Dickinson, Sparks, MD, USA) and 0.3 ml of 50% glycerol. Working cultures were streaked onto Tryptic Soy Agar (TSA; Difco), incubated at 37 °C for 24 h, and stored at 4 °C.

2.2. Culture preparation

Each strain of *E. coli* O157:H7, *S.* Typhimurium, and *L. monocytogenes* was cultured in 5 ml TSB at 37 °C for 24 h, harvested by centrifugation at 4000 × g for 20 min at 4 °C and washed three times with Buffered Peptone Water (BPW; Difco). The final pellets were resuspended in BPW, corresponding to approximately 10^7 ~ 10^8 CFU/ml. Mixed culture cocktails were prepared by blending together equal volumes of each test strain.

2.3. Sample preparation

Sliced cheddar cheese was purchased from a local grocery store (Seoul, Korea). Sliced cheese (25 g) was placed on aluminum foil in a biosafety hood for inoculation, and cut into square pieces approximately 5by 5 cm. Then, 0.1 ml of previously described culture cocktail was applied onto the surface of each cheese piece by depositing droplets at 15 to 20 locations with a micropipette. This inoculation level was much higher than would normally be encountered in commerce. A high-inoculum concentration was used to make enumeration of surviving bacteria easier. The samples were air-dried for 2 h in the hood with the fan running at room temperature (22 ± 2 °C).

2.4. UV-C treatment system

The UV-C radiation device consisted of one bank of 5 germicidal emitting lamps (G6T5, Sankyodenki, Japan) located in the ceiling of the radiation vessel (Fig. 1). The UV-C lamps and treatment area were enclosed in an incubator to reflect UV-C radiation effectively and maintain room temperature (25 °C). The distance between lamps and tray was 10 cm and treatment time was 1 min. The tray was 50 cm long and 50 cm wide for UV-C treatments; the lamps had a 0.01 mm filament size and 1 cm spacing, and the light intensity at the sample location was 3.04 mW/cm^2. Prior to use, the UV lamps were allowed to stabilize by turning them on for at least 15 min.

2.5. Plastic packaging films and UV light transmission analysis

Four types of food packaging films (Polyethylene terephthalate; PET, Polyvinyl chloride; PVC, Polypropylene; PP, and Polyethylene; PE) were used and the thickness of each of the films was 0.07 mm. These films are widely used in food packaging applications. Each film was purchased from a local store (Seoul, Korea). Specular light transmission properties of packaging films were analyzed using a UV spectrophotometer (UV-2450, Shimadzu CO., Tokyo, Japan) in the range of 200–500 nm.

2.6. UV-C light treatment on film packaged media

For preliminary experiments performed on surfaces of a microbiological medium, the cocktail suspension was 10-fold serially diluted two times with 0.2% sterile peptone water (PW) resulting in a final concentration of approximately 10^5–10^6 CFU/ml. One-tenth ml of culture suspension was spread-plated onto non-selective medium (TSA). After inoculation, the medium was dried for approximately 30 min prior to treatment. Each inoculated and film-covered sample of medium was treated with UV-C radiation for 1and 5 min at 25 °C. Following UV treatment, treated medium samples were immediately incubated at 37 °C for 24 h.

2.7. UV-C light inactivation of pathogens on film packaged cheese

To evaluate UV light inactivation of pathogenic bacteria on packaged cheese, inoculated samples were vacuum-sealed with each film using a vacuum packager (AZ-450-E, INTRISE CO., Ansan, Korea). Packaged samples were treated for 1 min at 25 °C to evaluate quantitatively the efficacy of UV light.

2.8. Effect of film thickness on UV-C light inactivation of pathogens

Packaging materials which allow penetration of UV light (PP and PE films) were tested at different film thicknesses. Before treatment, the inoculated samples were packaged with UV-C transparent films at thicknesses of 0.07, 0.10, and 0.13 mm. Then, packaged cheese samples were treated as described previously.

2.9. Bacterial enumeration

For enumeration of pathogens, 25 g treated samples were immediately transferred into sterile stomacher bags (Lab Plas Inc., Sainte-Julie, Quebec, Canada) containing 225 ml of BPW and homogenized for 2 min with a stomacher (EASY MIX, AES Chemunex, Rennes, France). One ml aliquots of homogenized samples were tenfold serially diluted in 9 ml of BPW, and 0.1 ml of sample or diluent was spread-plated onto each selective medium. Sorbitol MacConkey agar (Difco), Xylose Lysine Desoxycholate agar (Difco) and Oxford Agar Base (Difco) with antimicrobic supplement