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Comparison of bactericidal effects of two types of pilot-scale intense-pulsed-light devices on cassia seeds and glutinous millet

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ABSTRACT

The aim of this study was to evaluate the bactericidal effect of two types of pilot-scale intense pulsed light (IPL) devices constructed in our laboratory. Cassia seeds and glutinous millet, with initial microbial loads of 2.04×10^4 and 5.03×10^3 CFU/g, respectively, were treated by cyclone-type and belt-type IPL devices at total fluences of 3.89–54.43 J/cm^2. The maximum microbial reductions of the cassia seeds and glutinous millet were 0.74, and 0.66 log/g, respectively, when using the cyclone-type IPL, and 2.63 and 0.55 log/g when using the belt-type IPL device. The geometric mean diameter of cassia seeds and glutinous millet was 0.25 and 0.13, respectively. The cassia seeds having larger particle size than glutinous millet showed a greater bactericidal effect when treated with the belt-type device. Therefore, the design of the treatment chamber can have an improved bactericidal effect on cassia seeds, demonstrating the importance of selecting a suitable IPL device according to the size of the sample to be treated.

1. Introduction

Intense pulsed light (IPL) is an innovative nonthermal processing technology involving the application of intense, short-duration pulses of light to the food surface (Dunn, Ott, & Clark, 1995; Gómez-López, Devlieghere, Bonduelle, & Debevere, 2005). IPL is attracting considerable attention because it can destroy microorganisms with less physical or chemical damage to the food than a conventional thermal process. An IPL system consists of a power supply, treatment chamber, and xenon lamp. The electrical energy accumulated in the power supply is delivered to the lamp filled with xenon gas, which generates an intense light with a wavelength range of 200 to 1100 nm that is applied to the food surface within milliseconds (Elmnasser et al., 2007; Oms-Oliu, Martín-Belloso, & Soliva-Fortuny, 2010). The microbial inactivation mechanisms of IPL have not yet been fully elucidated, but it is generally accepted that IPL induces pyrimidine dimers and other kinds of DNA lesions (Oguma et al., 2001; Rowan et al., 1999).

The disinfection performance of IPL for various types of food has been demonstrated by many studies, with the microbial inactivation being especially effective in transparent liquid foods (Oms-Oliu et al., 2010). We also previously studied the inactivation of microorganisms in liquid foods exhibiting various transmittances (Hwang, Cheigh, & Chung, 2015), and similarly found high efficacy for transparent liquid foods. In contrast, IPL was not able to penetrate opaque liquid foods, which drastically reduced the bactericidal effect. These findings indicate that factors causing shadow effects and affecting the transmittance will influence the bactericidal effect of IPL. Moreover, there have been far fewer published studies of microbial inactivation in powdery foods and seed foods. A major problem when applying IPL to such foods is the shadow effect, which makes the use of novel treatment chambers necessary.

Cassia seeds and glutinous millet are common food ingredients in Korea. Cassia seeds are mainly added to tea, and glutinous millet is usually eaten after being mixed with rice. Glutinous millet have high component of amylopectin, so it becomes sticky after cooked. Cassia seeds and glutinous millet are exposed to several microbiological contaminants during their cultivation, and so they are subjected to mild heating process prior to being distributed to consumers. However, the risk of this thermal treatment changing or damaging their sensory and nutritional quality means that an alternative decontamination process is required. Chemical treatments using chlorine and sodium hypochlorite are being used, but due to consumers' negative perception of chemical residues, new disinfection techniques are required.

The aim of this study was to determine the microbial reductions obtained when using two types of pilot-scale continuous-flow IPL systems for decontaminating cassia seeds and glutinous millet, thereby evaluating the feasibility of using IPL in commercial applications. In addition, the diverse properties of the two sample types were measured

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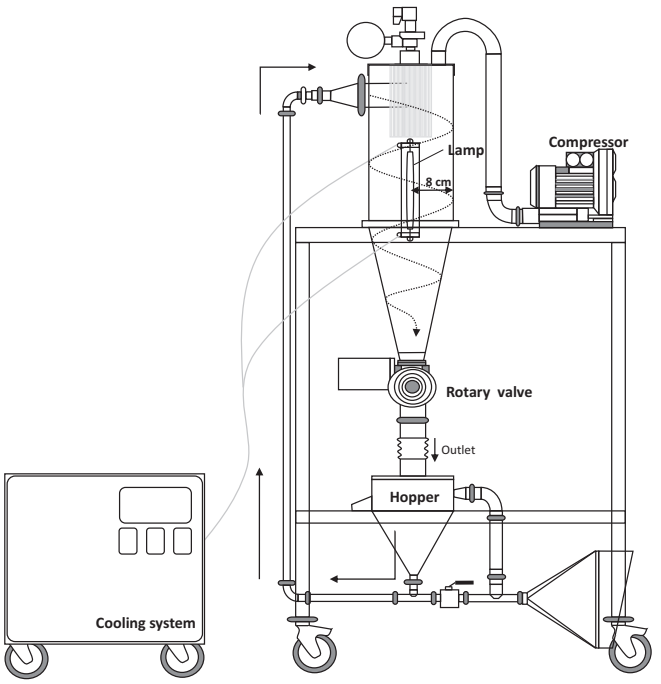

Fig. 1. Schematic diagram of the cyclone type of pilot-scale intense pulsed light (IPL) treatment system. The arrows indicate the flow of the seeds.

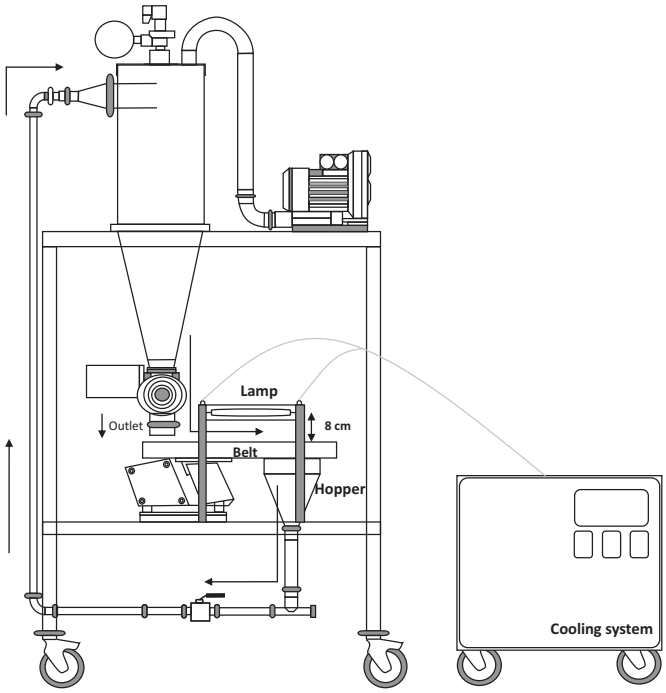

Fig. 2. Schematic diagram of the belt type of pilot-scale IPL treatment system. The arrows indicate the flow of the seeds.

to identify the factors affecting microbial reduction level.

2. Materials and methods

2.1. Sample preparation

Cassia seeds and glutinous millet from China were purchased from a market because such imported agricultural products are generally used in Korea based on their good cultivation condition and low price. The samples were stored at 25 °C. The initial microbial load of the cassia seeds and glutinous millet was in the order of 2.04×10^4 and 5.03×10^3 CFU/g, respectively.

2.2. IPL devices and treatment conditions

Two types of pilot-scale IPL devices constructed in our laboratory were used in this study. One of them is a continuous IPL device that applies a cyclonic flow (Fig. 1). The samples are fed into the hopper, and turning on the power switch will result in the samples traveling up the pipe due to the inner part of the treatment chamber beings kept in a vacuum state by the compressor. The raised samples then fall down along the chamber surface of the wall in the form of a cyclone. Then, the samples are transferred to the hopper through a rotary valve having a diameter of 80 mm and a rotation speed of 60 rpm. The xenon lamp (type NL9553, XAP series, Heraeus Noblelight, Cambridge, UK) installed in the middle of the treatment chamber is in a quartz pipe filled with distilled water. The distilled water is continuously circulated by the cooling system consisting of the water tank and the motor. The temperature can be adjusted from 10 °C to 25 °C. In this study, the temperature of distilled water was set at 14 °C and it was checked with a digital thermometer inside the cooling device. The temperature of the sample before and after the IPL treatment was also measured by a digital thermometer (TP101, Shanghai Automation Instrument Factory, Shanghai, China). It was confirmed that the temperature of the sample was increased by no > 5 °C regardless of treatment condition. This device was used to treat 150 g of samples with IPL at pulse fluence from 64.83 to 226.8 mJ/cm^2/pulse, as achieved using voltages of 1200–2400 V, pulse durations of 0.5–3.0 ms, a frequency of 2 Hz, treatment times of 30–120 s (number of pulses; 60–240), and total fluences of 3.89–54.43 J/cm^2.

The second IPL device is shown in Fig. 2. It comprises a chamber with a conveyor belt, and the bottom of the device is made of stainless steel-mesh so the samples can be rolled on the mesh ground. Adjusting the current applied to the motor that drives the belt will control the intensity of its vibration. The xenon lamp is installed above the belt, and sterilized samples fall down and circulate along the pipe. The seeds move on the belt for about 30 s in one cycle of processing. As with the cyclone-type IPL device, 150 g were treated with IPL at total fluences of 7.42–53.58 J/cm^2, as achieved using a voltage of 1800 V, a frequency of 2 Hz, treatment times of 30–120 s (1–4 cycle), and pulse durations of 0.5–3.0 ms. All of the experiments using both IPL devices were conducted in triplicate.

2.3. Measurement of total IPL fluence

The total IPL fluence was measured by a spectroradiometer (ILT-900, International Light Technologies, Peabody, MA, USA). The distance between the lamp and the measurement sensor of spectroradiometer was about 8 cm for both IPL devices.

2.4. Microbiological analysis

In this study, the count of overall microorganisms before and after the IPL treatment was determined. Samples (10 g) were diluted in 90 mL of 0.85% NaCl solution and the solution was shaken using a shaking incubator for 2 min (HB-201SF, HANBAEK SCIENTIFIC CO., Bucheon, Korea). Then, the solution was serially diluted in 0.85% NaCl solution and 0.1 mL of the solution was spread on a plate count agar (Difco™, Sparks, MD, USA), which was then incubated at 37°C for 24–48 h. Plates on which 15–300 colonies formed were counted, and the surviving fraction was expressed as the ratio of the surviving number of microorganisms (N) to the initial number (N_0) using Microsoft Excel (version 2007, Microsoft, Redmond, WA, USA).