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Far infrared and ultraviolet radiation as a combined method for surface pasteurization of black pepper seeds

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ABSTRACT

This study presented the potential of far infrared (FIR) and ultraviolet (UVC) radiation for surface pasteurization of black pepper seeds. FIR treatment at different exposure times and temperatures was applied followed by constant UVC treatment with an intensity of 10.5 mW/cm^2 for 2 h. Then, the reduction on total mesophilic aerobic bacteria (TMAB) and mold-yeast contents were determined, and quality changes of the seeds were evaluated. TMAB of the seeds decreased to the target level of 10^4 CFU/g after 4.7 and 3.5 min FIR treatment at 300 and 350 °C, respectively. Under given conditions, complete elimination for other microorganisms (*TMY*, *Escherichia coli* and *Bacillus cereus*) was also obtained while there were no significant changes in volatile oil and color. UVC however, alone or in combination with FIR, did not exhibit a significant reduction in TMAB content. Consequently, FIR treatment was suggested to be a promising method for the surface pasteurization of black pepper seeds.

1. Introduction

Black pepper (*Piper nigrum* L.) is a widely used ingredient and valuable for its distinctive odor and flavor (Nisha et al., 2009). It is exposed to a wide range of environmental microbial contamination with contacts of soil, dust, excrement and insects during growing, collecting, processing, storage and transport. Contamination levels of 10^{6-8} CFU/g are unsatisfactory leading to significant problems in export (Al-Jassir, 1992; Plessi et al., 2002; Little et al., 2003; Jalili et al., 2010). Microorganisms such as *Salmonella*, *Escherichia coli*, *Bacillus cereus* and toxigenic molds and yeasts might also be present in black pepper, and their presence potentially creates a public health risk (Ristori et al., 2007). With their low moisture contents, they are non-perishable, and microorganisms cannot grow or multiply. However, if the spice commodities get in contact with water-rich food products, microorganisms might find a suitable environment to germinate and multiply to effective and toxic levels (Tainter and Grenis, 2001; Banerjee and Sarkar, 2003). Because of these, spices should be decontaminated to prevent further food spoilage and food borne diseases.

Fumigation with ethylene oxide, irradiation with ionizing radiation and treatment with super-heated steam are possible decontamination processes (Tainter and Grenis, 2001; Schweiggert et al., 2007). Use of ethylene oxide, a carcinogen, is restricted and even prohibited in the European Union (Hayashi, 1998; Esa-spices, 2004) while irradiation has not found acceptance by consumers. Irradiation at high doses could cause oxidation and degradation in aromatic components of spices with significant reductions in volatile compounds during storage (Variyar et al., 1997; Hayashi, 1998; Sádecká, 2007; Yamaoki et al., 2011). Treatment with super-heated steam might cause color and aroma alterations besides losses in volatile compounds. In addition, moisture condensed on the surface of the seeds must be removed to prevent undesirable mold growth (Tainter and Grenis, 2001; Schweiggert et al., 2007). Hence, there is a need to use innovative methods for spice decontamination while maintaining the quality. Microorganisms contaminating the spices reside on the surface, and the inner parts are generally free from microorganisms (Hayashi, 1991; Hamanaka et al., 2000; Baba et al., 2004; Erdoğdu and Ekiz, 2011). Surface pasteurization might then help keep the original quality of the spices. Therefore, ultraviolet (UVC) and far infrared (FIR) treatments with their low penetration power might be preferable for surface decontamination of spices without excessive quality damages.

When spices are exposed to an infrared heating source, their surface temperatures increase rapidly, and rapid surface heating can improve sealing moisture, flavor and aroma compounds keeping the sensory characteristics (Erdoğdu and Ekiz, 2011). With their lower thermal conductivity, rate of heat transfer through their interior is slower. If the infrared exposure time is properly controlled, surface temperature can be preferentially raised to a level that a target microorganism can be inactivated without substantially increasing the interior temperature (Fasina and Thomas,

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2001; Huang, 2004; Erdoğdu et al., 2010). UVC treatment, however, is a non-thermal method approved for surface treatment of food products (FDA, 2012). UVC radiation effectively and rapidly inactivates microorganisms through a photochemical reaction within their nucleic acids (Koutchma et al., 2009). Using FIR energy and UVC might offer a pasteurization process for black pepper seeds while reducing the microbial load and maintaining the quality attributes. Therefore, the objective of this study was to determine the potential of FIR and UVC radiation as an alternative technique for surface pasteurization of black pepper seeds.

2. Material and method

2.1. Far infrared equipment

A custom designed infrared heating unit with flat electrically operated ceramic emitters (650 W in power with maximum surface temperature of 553 °C installed within aluminum reflectors) was used in this study (Erdoğdu and Ekiz, 2011). Since the infrared heaters radiate in all directions, they were placed within aluminum reflectors to focus as much of the radiation as possible uniformly onto the process line. To obtain a uniform temperature distribution inside the tunnel, the experiments were started after the temperature distribution inside the tunnel was uniform, and this was continuously checked with the located thermocouples in the tunnel. This unit consisted of 48 ceramic infrared heaters located on the side walls of a tunnel enabling the product on the belt to be heated from both top and bottom surfaces (Erdoğdu et al., 2010; Erdoğdu and Ekiz, 2011).

2.2. Ultraviolet equipment

UVC light treatment was carried out in a lab scale – custom designed UVC cabinet where four low pressure germicidal lamps (Slim line germicidal lamps, G24T6L, Atlantic, Ultraviolet) emitting UVC at 253.7 nm were placed on top (Erdoğdu and Ekiz, 2011). Each lamp (with 60 cm tube length and light intensity of 82 μW at 1 m distance) had a nominal power output of 25 W. The lamps were installed 4 cm apart from each other, and the UVC field area under the lamps was $0.70 \times 0.30\ m^2$. Interior of cabinet was lined with aluminum reflector to auxiliary redirect the UVC and minimize any shadowing effects on the samples. A stainless–steel sample holding tray was used to place the samples at different distances from the lamps. This also facilitated the application of various UVC doses. To carry out reproducible results and minimize the fluctuations in the intensity, the UVC lamps were switched on for about 1 h prior to the treatment of the samples. UVC irradiance during the treatments was measured at the surface of the samples using a digital radiometer (UVP-UVX UVP Inc., CA, USA) equipped with a UVX-25 254 nm sensor.

2.3. Treatment of black pepper seeds with far infrared and ultraviolet

Black pepper seed samples (*P. nigrum* L.) obtained from Kadıoğlu Spices Industry (Mersin–Turkey) were used in this study. Treatment process of the samples were performed in 2 stages: exposing the seeds to FIR at different treatment times and temperatures (2.78 to 5.88 min at 300 °C, and 1.88 to 4.33 min at 350 °C) and applying the combined effect of the FIR and UVC treatments where a 2 h of UVC treatment in a constant UVC intensity ($10.5\ mW/cm^2$) following the FIR treatments. During the combined treatment, transferring the samples from FIR tunnel to the UVC line was carried out manually, and samples for further analysis were collected before and after the seeds were treated with FIR and UVC. Triple samples were used at each treatment condition, and the results were reported with average values and the standard deviations.

During treatments, black pepper seeds were placed into 3 sterile Petri dishes (8 g sample in each), and the Petri dishes were fed into the FIR tunnel on a conveyor belt for exposure to the FIR radiation. FIR tunnel temperatures were measured by a thermocouple located between the ceramic emitters in the tunnel. Treatment times were adjusted using the conveyer belt speed. Following the FIR treatment, 9 g from the merged FIR treated seed samples were placed in a sterile Petri dish and the dish was put on an automatic stirrer (IKA, MS1 Minishaker, IKA Works, Inc. Wilmington, NC) below the collimated UVC beam. During 2 h of UVC treatment, seeds were shaken (at 250 rpm) continuously to obtain a homogeneous distribution of UVC on the thin layer of the seeds. UVC light intensity at the surface of the samples was measured to be $10.5\ mW/cm^2$.

2.4. Evaluation of the product quality

The effects of FIR and UVC treatments on the quality of black pepper seeds were evaluated in terms of microbial reduction, moisture, volatile oil and color changes and weight losses.

2.4.1. Microbiological analysis

To determine the effect of FIR and UVC treatments on the microbial reductions, total plate counts of total mesophilic aerobic bacteria (TMAB), and total mold and yeast (TMY) content of the black pepper seeds were determined. Following the FIR and UVC treatments, black pepper seeds were aseptically weighed and placed in sterile 0.1% peptone water (Peptone from casein Merck 1.07213) in Erlenmeyer flaks and agitated on an automatic stirrer at 600 rpm for 1 min. The wash solution was then sequentially diluted into a sterile 0.1% peptone water solution and surface plated (0.1 mL) on a sterile Plate Count Agar (PCA, Merck 1.05463) for TMAB and Dichloran Glycerol Agar (DG-18, Merck 1.00465) for TMY. After incubation at 35 °C for 24 h, and 30 °C for 5 days, TMAB and the TMY colonies were enumerated, respectively. TMAB and TMY content of the untreated black pepper seeds were also enumerated. Microbial enumerations were expressed as log of colony forming unit per gram sample (CFU/g).

2.4.2. Determination of moisture and volatile oil content, color changes and weight losses

Moisture content of the samples was determined by toluene distillation method and expressed as mL/100 g sample (TS 2134, 1987). This method was based on direct measurement of the amount of water removed from spices by evaporation.

Volatile oil content was, on the other hand, determined by distillation method (TS 8882, 1991). This method consisted of boiling spices in water and collecting condensed water and volatile oil. The amount of volatile oil was then measured by volume using the separation by gravity effect, and the results were reported as mL/100 g sample.

Color changes of the black pepper seeds were determined from the CIELAB parameters using the Color Quest XE colorimeter (Hunter Lab., Hunter Associates Laboratory, Reston, VA., USA) equipped with the light source D65 and observation angle of 10°. The instrument was standardized with a standard light trap and calibrated to a green reference plate ($X = 18.99$, $Y = 24.77$, $Z = 20.22$). Three measurements at the different quadrants of each sample were averaged and expressed as Hunter system 'L^*' (lightness), 'a^*' (redness) and 'b^*' (yellowness) values.

Weight losses of the samples were calculated by using the difference in the weight of the samples before and after each treatment.