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Surface UV-C light treatments to prolong the shelf-life of Fiordilatte cheese

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ABSTRACT

The possibility to apply UV-C light technology to control surface contamination and extend the shelf-life of Fiordilatte was investigated. First, cheese was inoculated with *Pseudomonas* spp., exposed to UV-C light for increasing time up to 750 s to estimate the antimicrobial efficacy of the treatments. UV-C light penetration depth in Fiordilatte was also evaluated. Then, a shelf-life test was carried out on samples exposed to 0.1, 0.6, 1.2 and 6.0 kJ/m^2 UV-C light, compared to untreated control cheese. The samples were packaged with brine, stored at 9 °C and analyzed for microbial growth, sensory quality and pH. A germicidal effect of about 1–2 log cycles on *Pseudomonas* spp. and Enterobacteriaceae was observed during storage. UV-C light did not promote changes in terms of color, texture and surface appearance. With a minimum transmittance inside the product, this treatment showed an interesting surface microbial decontamination that prolonged cheese shelf-life.

Industrial relevance: Considering that dairy industry represents one of the most important components of the Italian food system, the present work focused on the utilization of UV-C light to preserve one of the most important milk-derived Italian fresh cheese, Fiordilatte, which totalized a consumption of about 20 kg per capita per year in the world. Interesting results were recorded on treated samples, above all at specific UV-C light fluence values (6 kJ/m^2). The control of microbial proliferation in these treated samples allowed prolonging shelf-life by 80% compared to untreated cheese. The technique is very rapid and simple to be scaled up; after proper optimization of light parameters, it could be applied at industrial level to prevent surface post-process contamination of Fiordilatte that generally represents the main factor responsible for product deterioration and its short shelf-life.

1. Introduction

Fiordilatte is a fresh product with spun soft dough, high moisture content (50–60%), usually packaged in trays or bags with brine to preserve the soft-springy texture during storage at 4 °C (Gammariello, Conte, Buonocore, & Del Nobile, 2011). During stretching, the curd of this cheese is heat-treated, substantially reducing the microbial load. Post-processing surface contamination by microorganisms may occur, causing quality decay, shelf-life reduction and possible risk for consumers' health (Spano, Goffredo, Beneduce, & Tarantino, 2003). Enterobacteriaceae, coliforms, *Pseudomonas* spp. and other bacteria can become the dominant microbial population (De Jonghe et al., 2011; Franciosi, Settanni, Cologna, Cavazza, & Poznanski, 2011; Martin, Murphy, Ralyea, Wiedmann, & Boor, 2011; Morales, Garcia, & Nunez, 2005). During storage, spoilage microorganisms can hydrolyze different casein fractions, releasing lipases and proteases (Baruzzi, Lagonigro, Quintieri, Morea, & Caputo, 2012). This leads to defects in textural properties, appearance, color, odor and taste, leading to product unacceptability (Cantoni, Stella, Cozzi, Iacumin, & Comi, 2003; Oommen, McMahon, Oberg, Broadbent, & Strickland, 2002).

The extension of Fiordilatte cheese shelf-life is an important consideration for the dairy industry, because there is a high interest in expanding the distribution of this traditional product beyond the local market.

Several strategies to prolong the shelf-life of mozzarella and Fiordilatte cheese have been proposed. For example, Sinigaglia, Bevilacqua, Corbo, Pati, and Del Nobile (2008) evaluated the effectiveness of lysozyme/Na_2-EDTA on spoilage microorganisms of mozzarella cheese. Various studies have been also conducted on the use of coatings and modified atmosphere packaging to control microbial proliferation and sensory changes (Conte, Gammariello, Di Giulio, Attanasio, & Del Nobile, 2009; Del Nobile, Gammariello, Conte, & Attanasio, 2009; Gammariello et al., 2011). The adoption of non-thermal technologies

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for food preservation could represent an alternative strategy. Pulsed electric fields, ultrasound, low-temperature plasma, irradiation, pulsed light treatment and UV-C light are interesting examples of novel non-thermal technologies able to inactivate microorganisms within short treatment times (Sharma, Bremer, Oey, & Everett, 2013; Arroyo, Cebrián, Pagán, & Condón, 2012; Innocente et al., 2014; Ignat, Manzocco, Maifreni, Bartolomeoli, & Nicoli, 2014; Fernández, Shearer, Wilson, & Thompson, 2012; Misra et al., 2014; Huo, Bai, Guo, & Zhao, 2013). The use of UV-C light has recently aroused great interest because it can improve food safety and quality with minor effects on product nutritional and sensory characteristics (Soliva-Fortuny & Martín-Belloso, 2003). UV-C light treatments exploit the radiation with wavelength from 200 to 280 nm. Due to the low penetration depth of UV-C radiation in a food matrix, this technology is particularly suitable for the inactivation of food surface microorganisms and enzymes (Choudhary & Bandla, 2012; Manzocco, Da Pieve, Bertolini, et al., 2011). The technology is easy to use and characterized by low maintenance, installation and operation cost with minimum energy usage (Bintsis, Litopoulou-Tzanetaki, & Robinson, 2000). It does not produce any chemical residue and does not form toxic by-products (Keyser, Müller, Cilliers, Nel, & Gouws, 2008). The microbial inactivation is caused by the DNA mutation of microbial cells (Guerrero-Beltrán & Barbosa-Cánovas, 2004). Studies on UV-C light treatments have been reported for minimally processed fruit and vegetables (Manzocco et al., 2015; Gómez, Alzamora, Castro, & Salvatori, 2010), raw meat, fish, shell eggs, bakery products (Bintsis et al., 2000; Siddiqui, Chakraborty, Ayala-Zavala, & Dhua, 2011) and liquids such as fruit juice, apple cider or milk (Matak et al., 2005; Franz, Specht, Cho, Graef, & Stahl, 2009; Bandla, Choudhary, Watson, & Haddock, 2012; Rossito et al., 2012; Cilliers et al., 2014).

Considering the limited studies conducted on the surface sterilization of fresh cheese with UV-light the aim of the present work was to evaluate the effectiveness of this treatment on microbiological and sensory quality of Fiordilatte cheese. The work was divided into two parts. In the first part, the inactivation efficacy of UV-C light on inoculated samples was evaluated and the UV-C light penetration depth in Fiordilatte was measured. On the second part, a shelf-life test was carried out. Untreated and UV-C treated samples were packaged and stored at 9 °C. Microbial count, pH and sensory evaluation were monitored during storage.

2. Materials and methods

2.1. Strains and samples preparation

For preliminary tests a microbial inoculum of *Pseudomonas putida* (DSM 591) and *Pseudomonas fluorescens* (DSM 50090) was prepared, being these strains responsible for anomalous discoloration in pasta filata cheese (Soncini, Marchisio, & Cantoni, 1998; Franzetti & Scarpellini, 2007; Caputo et al., 2015). All strains were grown overnight at 25 °C in Plate Count Broth (PCB Oxoid, Milano) and then subjected to serial dilutions in saline solution (NaCl 0.9% w/v in distilled water), depending on the microbial concentration to be reached.

Fiordilatte samples (30 g) were purchased in an Italian local market and maintained at 4 °C. Cheese samples were produced from pasteurized cow milk by adding lactic acid bacteria starters. The curd obtained by rennet addition was subjected to a short ripening phase until reaching a pH between 4.9 and 5.2 (fundamental for the stretching phase). Then, the drained curd was stretched in hot water (80–85 °C) to obtain Fiordilatte cheese samples. The proximate composition of cheese was: proteins 17%, carbohydrates 1%, fat 16.5%, calcium 0.36% and salt 0.8%. Samples were inoculated by dipping cheese for 5 min in the above described microbial inoculum to reach a final contamination of 10^4–10^5 cfu/g. Fiordilatte cheese samples were then stored at 9 °C overnight before UV-C light irradiation.

For the shelf-life test, untreated and UV-C light treated Fiordilatte cheese were packaged in 14 × 14 cm polyethylene pouches (2 samples per pouch) with 50 mL brine (0.6% NaCl solution) and stored at 9 °C.

2.2. UV-C light treatments

UV-C light treatments were carried out at 8 °C into a thermostated cell (Climacell 222, Sylvania, SLI lighting, Raunheim, Germany) equipped with 4 UV-C lamps with emission in the range 200–280 nm (15 W, OF, OSRAM, GmbH HNS, Munich Germany, maximum emission: 253.7 nm). The lamps were positioned at 2 cm from the surface of the samples (Fig. 1). The irradiance on the cheese surface was 20 W/m^2 and samples were treated for increasing time up to 750 s. Irradiance (W/m^2) was multiplied by treatment time (s) to obtain the total fluence (J/m^2) of the treatment. In the first step, inoculated Fiordilatte samples were treated by UV-C light at 20 W/m^2 for 5, 30, 60, 150, 300, 450 and 750 s corresponding to specific fluence values: Ctrl, A (0.1 kJ/m^2), B (0.6 kJ/m^2), C (1.2 kJ/m^2), D (3.0 kJ/m^2), E (6.0 kJ/m^2), F (9.0 kJ/m^2), and G (15 kJ/m^2). After treatments, samples were immediately analyzed for microbiological counts.

For the shelf-life test Fiordilatte cheeses were treated by UV-C light at the selected fluence values: Ctrl (no treatment), H (0.1 kJ/m^2), I (0.6 kJ/m^2), L (1.2 kJ/m^2) and M (6.0 kJ/m^2), on the basis of the preliminary tests.

2.3. UV-C light transmittance

UV-C penetration depth in Fiordilatte cheese was determined photometrically using a luminometer (HD-2102.2 Delta Ohm, Padova, Italy) equipped with UV-C light probe (LP471 UVC, Padova, Italy) as described by Manzocco, Da Pieve, Bertolini, Bartolomeoli, Maifreni, Vianello and Nicoli (2011). Sections of Fiordilatte cheese tissues of increasing thickness up to 1 mm were manually cut by a sharp blade. Sample thickness was measured by a digital caliper (ABS Digimatic, Mitutoyo Corporation, Kawasaki, Japan). Fiordilatte cheese sections were positioned on the luminometer sensor and exposed to 20 W/m^2 UV-C light. The irradiance of the light transmitted through Fiordilatte tissues was measured. The ratio between transmitted light (I_0) and incident light (I) was measured and fitted by the Beere-Lambert law:

$$I/I_0 = e^{-\alpha x} \quad (1)$$

where x is the Fiordilatte thickness and α is an experimental parameter.

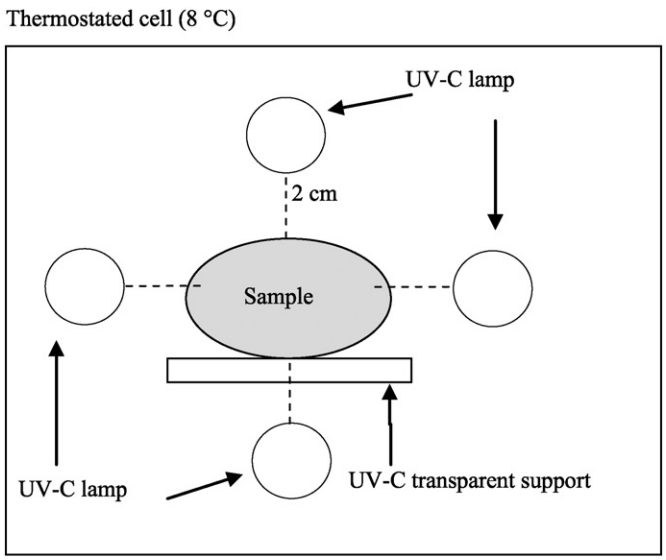

Fig. 1. Schematic representation of UV-C light treatment of Fiordilatte cheese.