LWT - Food Science and Technology 75 (2017) 735–741

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Investigation of the potential of dry ice blasting for cleaning and disinfection in the food production environment

Anna Kristina Witte [a], Martin Bobal [a], Roland David [b], Beat Blättler [c], Dagmar Schoder [a, d], Peter Rossmanith [a, d, *]

[a] Christian Doppler Laboratory for Monitoring of Microbial Contaminants, Department of Veterinary Public Health and Food Science, University of Veterinary Medicine, Veterinaerplatz 1, 1210, Vienna, Austria
[b] Minus80Grad, Waldmüllergasse 21, 2380, Perchtoldsdorf, Wien, Austria
[c] LEU Anlagenbau AG, Zelgstrasse 65, 3661, Uetendorf, Switzerland
[d] Institute of Milk Hygiene, Milk Technology and Food Science, Department of Veterinary Public Health and Food Science, University of Veterinary Medicine, Veterinaerplatz 1, 1210, Vienna, Austria

ARTICLE INFO

Article history:
Received 11 May 2016
Received in revised form
27 July 2016
Accepted 8 October 2016
Available online 11 October 2016

Keywords:
Dry ice blasting
Cleaning
Disinfection
Food production area
Dairy industry

ABSTRACT

Cleaning with solid CO_2 (dry ice blasting) is an environmental friendly, fast and residue-free method applied in many industrial areas. In this study the disinfection potential of dry ice blasting and parameters influencing cleaning efficacy was investigated. The method removes bacterial cells to a similar extent from several surfaces and components of dairy production equipment, occasionally with a slight abrasive effect. Efficacy is affected by the quantity of dry ice and pressure applied but neither by the pellet size nor the initial quantity of bacterial cells on the surface. Since the bacteria removal rate is less than five $\log_{10}$ units, dry ice blasting cannot be recommended as a disinfection method, but it demonstrates efficient cleaning comparable to other conventional methods. In practice, dry ice blasting of food production equipment is recommended outside the production area because there is a high risk of recontamination due to spread of the bacteria.

1. Introduction

Cleaning and disinfection of equipment are essential processes in the food industry to reduce the risk of product contamination with bacteria. Since frequent use of chemicals can damage materials, retain residues and is time-consuming to perform, alternative cleaning methods are desirable (Otto et al., 2011). Physical alternatives to chemical cleaning include conventional cleaning with brushes, radiation, vapor blasting, ultrasound or dry ice blasting.

Dry ice blasting was initially developed in the 1980s and has been finding increased relevance over the last few decades. Besides the lack of residues, cleaning with CO_2 in its solid form offers the advantage being environmentally friendly and not particularly cost-intensive. During dry ice blasting, 3 mm standardized pellets consisting of solid CO_2 (-78 °C) are generally applied to surfaces. When hitting the surface to be treated, the CO_2 sublimates and increases in volume by a factor of 800 (Spur, Uhlmann, & Elbing, 1999). In addition to the mechanical effects, the efficacy has been attributed principally to the different thermal expansion coefficients (Spur et al., 1999; Uhlmann, Hollan, & El Mernissi, 2009).

Dry ice blasting is regarded as being environmentally friendly compared with other blasting methods, such as sand blasting and water jetting, as dry ice blasting requires less energy (Millman, 2012). Nonetheless, the CO_2 pellets are applied at high pressure (1–20 bar) which is still responsible for the majority of the energy required for this technology. It is here where optimization could be performed (Máša & Kuba, 2015; Máša, Kuba, Petrilák, & Lokaj, 2014). Common applications for dry ice blasting include cleaning and paint removal (Stratford, 1999), especially in the automotive industry. Besides blasting with solid CO_2 pellets, CO_2 in liquid form and supercritical CO_2 as well as solid CO_2 with smaller particle size are used for cleaning purposes. Dry ice blasting with particles of sub-millimeter size is called CO_2 snow jetting and is used for sensitive surfaces where less abrasion is desirable (Otto et al., 2011; Sherman, 2007). This CO_2 cleaning technology can even remove molecular contaminations from surfaces. Thereby, removal efficacy correlates with the solubility of the contaminant in liquid CO_2

---

* Corresponding author.
E-mail address: peter.rossmanith@vetmeduni.ac.at (P. Rossmanith).

http://dx.doi.org/10.1016/j.lwt.2016.10.024
0023-6438/

(Hills, 1995).

Only little information is available in respect of the disinfection potential of dry ice blasting, but it has been shown that dry ice blasting can reduce bacterial counts on different surfaces in food processing areas (Millar, 2004, pp. 1–114), even though neither low temperatures nor CO_2 *per se* are lethal to bacteria. In Millar's study, bacterial reduction up to a factor 10^5 was obtained what corresponds by definition to disinfection. However, the reduction varied between different surfaces and was often lower. In an attempt to decontaminate poultry carcasses a one to two logarithmic reduction was demonstrated (Akkara & Kayaardi, 2013, pp. 1–7). In another study, dry ice blasting removed between 98% and 100% of bacteria from oak barrels used for wine aging (Costantini et al., 2015). However, dry ice blasting is not recognized in the literature as a disinfection procedure (Otto et al., 2011). Since cleaning with dry ice blasting offers advantages, it is worth investigating this method further, especially in respect of its disinfection potential.

Therefore, this study focused on factors influencing the efficacy of dry ice blasting. We investigated: (i) quantity of CO_2 pellets, (ii) pellet size, (iii) pressure, (iv) influence of the initial amount of contaminating bacteria, and (v) recontamination caused by aerosols. These were investigated under standardized conditions by using a fixed device constructed by our laboratory. The study was performed especially with respect to cleaning food processing areas. Consequently, different materials were compared: standardized tiles and material derived from smear robots. Moreover, the effect of temperature was investigated.

In this study, we concentrated on one surrogate in order to optimize cost and benefit based on the data of the Cold Jet Report (Millar, 2004, pp. 1–114) which showed that the three bacteria, *Listeria monocytogenes, Escherichia coli* and *Salmonella* Typhimurium responded similarly to dry ice blasting. We selected the ubiquitous Gram-positive bacterium *Micrococcus roseus* because it is non-pathogenic and its intensive red color is easily detected. Furthermore, it has been shown that it has similar physical properties to *Listeria monocytogenes* (Rossmanith, Frühwirth, Süß, Schopf, & Wagner, 2010).

2. Materials and methods

2.1. Bacterial strains and growth conditions

Micrococcus roseus (strain R4) was part of the collection of E. Schopf (Department of Veterinary Public Health and Food Science, Vetmeduni Vienna, Austria) and was cultivated for 24–96 h on plates with tryptone soya agar with 0.6% yeast extract (TSA-Y; Oxoid, Hampshire, UK) or in tryptone soya broth (TSB-Y; Oxoid, Hampshire, UK) at room temperature.

The optical density was measured at 600 nm wavelength and adjusted to 0.6 (approximately 10^6 cfu/ml). Cells were washed twice with 1 × PBS with respective centrifugation steps for five minutes at 8000 g and prepared by serial dilutions of 1:10. 100 µl of the suspensions (1:10, 1:100, 1:1000, and 1:10 000) were applied to the materials (and to control plates), distributed with a spatula and dried at room temperature for at least two hours.

2.2. Dry ice blaster

Solid CO_2 pellets (3 mm diameter) were obtained from Linde, Vienna. The pellets were further granulated immediately before use with either a coffee mill (Rosenstein & Söhne, Pearl, Buggingen, Germany) or a chopper (WMF Kult X Zerkleinerer, WMF Group GmbH, Geislingen/Steige, Germany).

As nozzle, the “SANDSTRAHLPISTOLE PROFI MIT SAUGSCHLAUCH” AGRE 400 l/min at 7.0 bar, diameter 6 mm (AGRE Kompressoren, Steyr, Austria) was utilized with compressed air from the compressor unit of AGRE Kompressoren (Steyr, Austria).

The setup is illustrated in Supplemental Fig. 1.

2.3. Materials

Test materials comprised: plain white ceramic tiles (47 mm × 47 mm) from a local construction market, materials of smear robots (PE1000 milled, PE1000 plain, polycarbonate, metal sheet coated, metal sheet plain, metal sheet polished and flat steel bright-drawn, from LEU Anlagenbau AG, Uetendorf, Switzerland) and chopping boards of wood (bamboo) and PE from a local supermarket. All materials were cut to an approximate size of 47 mm × 47 mm.

Depending on their heat stability, the materials were either baked for two hours (180 °C) or treated twice for five minutes with alcohol-based Bacillol® (Bode, Hamburg, Germany) with subsequent washing with sterile H_2O. Sterile controls were prepared and, in addition, for analysis the typical red color of *Micrococcus roseus* was used as visual marker.

2.4. Treatment with the dry ice blaster

Surfaces were fixed with a distance of 75 mm from the dry ice blaster and sprayed with a weighed quantity of dry ice (between 25 and 200 g) at a pressure between 1 and ~7.4 bar (maximum). Treatment duration and the temperatures (IR Thermometer with 1:10 lens, BASETech, Hirschau, Germany) of the surface directly after blasting were documented. The CO_2 pellets were crushed using a coffee mill (<1 mm) or a chopper (~1 mm) immediately before the application (Supplemental Fig. 2). TSA plates for detection of recontamination were placed next to the treated surface (~10 cm distance) and on the bench below the treated surface (~30 cm distance, Supplemental Fig. 1). Bacterial counts were determined after dry ice blasting using TSA contact plates (cultivation for 24–96 h at room temperature).

2.5. Cleaning with methods other than dry ice blasting

Tiles coated with bacteria were incubated for 20 s (time corresponds approximately to 100 g of dry ice blasting, see Supplemental Fig. 4) with gentle shaking in 50 ml H_2O, 1% SDS (Sigma-Aldrich, Steinheim, Germany), 1% Lutensol TO-12 (BASF, Ludwigshafen, Germany) or Bacillol® (Bode, Hamburg, Germany). After washing the liquids were rinsed, the tiles were allowed to dry and bacterial counts were determined using TSA contact plates.

2.6. Calculation

Cfu on materials was determined on TSA plates used as contact plates. Relating cfu from cleaned materials to the cfu of the respective control plates revealed the relative amount of remaining cfu (%). For the analysis of the central area of the blasting beam, exclusively a spot of ~26 mm diameter was evaluated (Fig. 4).

3. Results

3.1. Tile cleaning by varying CO_2 quantity, pressure, pellet size and bacterial concentration

As summarized by Spur et al. (1999), the parameters influencing the dry ice blasting process can be classified as machine parameters, pellet parameters and process parameters. In this study, the process parameters pressure and quantity of applied CO_2 were examined as well as the pellet size (pellet parameter). Furthermore,