Food Control 24 (2012) 154–159

Contents lists available at SciVerse ScienceDirect

Food Control

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

The potential of the combined application of hot water sprays and steam condensation at subatmospheric pressure for decontaminating inoculated pig skin and muscle surfaces

Frans J.M. Smulders, Gabriele Wellm, Johann Hiesberger[1], Alexandra Bauer, Peter Paulsen*

Institute of Meat Hygiene, Meat Technology and Food Science, Department for Farm Animals and Veterinary Public Health, University of Veterinary Medicine, Vienna, Veterinärplatz 1, A 1210 Vienna, Austria

ARTICLE INFO

Article history:
Received 8 March 2011
Received in revised form
1 September 2011
Accepted 10 September 2011

Keywords:
Pork
Hot water sprays
Steam condensation
Pseudomonas fragi
Yersinia enterocolitica

ABSTRACT

We investigated the reductions of numbers of *Pseudomonas fragi* and *Yersinia enterocolitica* artificially inoculated (6–7 log CFU/cm^2) onto pork skin and belly samples when subjected to either steam condensation at subatmospheric pressure alone, or to such treatment after a hot water spray of 55 °C (15 s). Steam condensation alone (10 min/55 °C, 18 s/65 °C, 10 s/70 °C and 10 s/75 °C) afforded 2–3 log reductions of both test organisms ($P < 0.05$). The combination hot water plus steam treatment 18 s/65 °C and 10 s/75 °C effectuated reductions of ca. 3 and 4 log, respectively. Hot water/steam treatment (10 s/75 °C) removed organisms significantly better from skin samples (reductions of 4.4 and 4.2 log units for *Ps. fragi* and *Y. enterocolitica*, respectively) than from bellies with muscle surfaces (1.2 and 1.3 log units). Per sample treatment (dimensions 20 × 10 × 1 cm; ca. 200 g), an average of 100 mL waste water were produced containing ca. 160 mg fat and 43 mg protein per skin sample and 10 mg and 163 mg for bellies. The described decontamination principle may be useful for pork processing operations.

1. Introduction

Treatment of carcasses with hot water of around 80 °C, either by immersion (lamb; Smith & Graham, 1978) or by deluging (beef; Smith & Davey, 1990) for 10–20 s has been found to yield reductions of *Escherichia coli* counts around 2 to 3 log units. Similar reductions have been achieved after a 10–20 s treatment with 80 °C water of beef brisket inoculated with *Salmonella*, generic and enteropathogenic *E. coli, Aeromonas hydrophila, Yersinia enterocolitica, Pseudomonas fragi* and *Listeria monocytogenes* (Smith, 1992). A prototype carcass washer (80 °C water spray) for veal slaughtering plants afforded modest (ca. 1 log unit aerobic flora), but statistically significant reductions in bacterial contaminants (Smulders, 1995). More pronounced effects (ca. 2.5 log reduction) of hot water washes (85 °C, 20 s) have been reported for hog carcasses (Gill, Bedard, & Jones, 1997; Gill, McGinnis, Bryant, & Chabot, 1995).

Compared with hot/warm water, steam has a higher heat capacity (James et al., 2007) and can penetrate easier into crevices and hair follicles (Logue, Sheridan, & Harrington, 2005). Steam can be applied at superatmospheric (Morgan, Goldberg, Radewonuk, & Scullen, 1996) or atmospheric pressure (Dorsa, Cutter, Siragusa, & Koohmaraie, 1996; James, Thornton, Ketteringham, & James, 2000; Whyte, McGill, & Collins, 2003), either in cabinets or by hand-held steam-vacuum devices (Gill, 2009; Huffman, 2002), effectuating microbial reductions of 1–3 log CFU/cm^2, depending on the micro-organism studied. While steam-vacuum devices are used to sanitise freshly contaminated, but small areas of the carcass, cabinets can be integrated in slaughterlines to treat whole carcasses (James et al., 2007; Retzlaff, Phebus, Kastner, & Marshden, 2005).

To allow a better control of the surface temperature of steam-treated meat (and thus to minimise discolouration and other adverse effects), steam can be applied at subatmospheric pressure. If steam is admitted to a previously evacuated chamber (constant volume) its condensing temperature is proportionate to the pressure in the chamber (Gay-Lussac's second law), which in turn means that condensing steam temperature in such a chamber can be controlled by pressure.

A combination of both techniques may be successfully applied to eliminate the microbial contaminants that have ended up on pig (sub)primals in the course of dressing, boning and portioning. As the attachment of bacteria to - and the microtopography of subprimals with or without skin differs, response to antimicrobial

* Corresponding author. Tel.: +43 1 25077 3318; fax: +43 1 25077 3390.
E-mail address: peter.paulsen@vetmeduni.ac.at (P. Paulsen).
[1] deceased.

0956-7135/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodcont.2011.09.019

treatments is likely to vary (Butler, Stewart, Vanderzant, Carpenter, & Smith, 1979; Firstenberg-Eden, 1981).

Purpose of the present study was therefore to determine whether a combination of hot water sprays and steam condensation in a prototype evacuation chamber: a) would function in principle ("proof of concept"), b) synergistic effects can be achieved, and c) effects on skin and muscle surfaces are comparable. Further objectives were to assess volume, fat and protein content of waste water, and the energy requirements for this decontamination concept.

2. Materials and methods

2.1. Decontamination chamber

Design and operation of the decontamination unit used in this study have already been described (Anonymous, 1999; Logue et al., 2005). In brief, the prototype consisted of a reaction chamber (glass bell jar on a steel base), with openings in the base for the inlet of steam and decontaminating fluids and an exhaust with a pressure-sensor controlled valve attached to a vacuum pump.

Between valve and vacuum pump a condensate collector filled with crushed ice, was situated to avoid the intrusion of water or steam into the pump.

With a peristaltic pump the decontaminating fluid (in this case: hot water) was transported to pipelines located in the reaction chamber. Pipelines were equipped with two nozzles for spraying samples and also served as a frame for the sample's suspension.

Temperature was measured within the chamber as well as on a sample surrogate (a PTFE cylinder placed near to the sample in lieu of the tissue sample's surface the reproducible temperature measurement of which proved to be unachievable).

2.2. Waste water collection

Waste water was sampled by incorporating a T-piece in the vacuum pump exhaust tube, allowing the collection of drainage water into a 250 ml "drainage-flask". The volume of waste water produced during a test run was determined by assessing the weight difference between condensate collector vessel before, and after a decontamination sequence. Water temperature was measured with a calibrated thermometer.

2.3. Collection of pig tissue samples for inoculation

Within 18–24 h *post mortem* 1 cm thick pieces of pig skin of 20 × 10 cm size were taken from chilled pig carcasses at a commercial abattoir ensuring excision under hygienic conditions. Subsequently, these were packaged in sterile polyethylene bags and transported to the laboratory at temperatures ≤ 4 °C. Also, 1 cm thick slices were cut from pig bellies, including (epi)dermis, subcutis, subcutaneous fat, and abdominal musculature.

2.4. Test micro-organisms and sample inoculation procedures

Pseudomonas (Ps.) fragi NCIMB 8542 NA was chosen to represent psychrotrophic pork spoilage bacteria (Holt, 1994), and *Yersinia (Y.) enterocolitica* GER O:3 NAS as a representative of the cold tolerant pathogenic microflora typically occurring in pork (Neubauer, 2002).

Both organisms were made available by Teagasc National Food Centre in Dublin, Ireland. The plasmid-bearing virulent *Yersinia* strain was a clinical isolate (Bhaduri, Conway, & Lachica, 1987).

For production of the bacterial suspension to be inoculated on pork tissue samples, both organisms were cultivated separately on Plate Count Agar (PCA; Merck No. 1.05462, Darmstadt, Germany) and incubated overnight at 30 °C. From these, overnight cultures in buffered peptone water were prepared. Both liquid cultures were mixed to ultimately yield a microbial concentration of > 8 log CFU/ml per organism. Samples were inoculated by 3 min immersion in the bacterial suspension, where after samples were allowed to drain for 30 s before being placed on a sterile plastic film for 30 min with the skin surface upside. This procedure resulted in surface contaminations of 6–7 log CFU/cm^2 for each *Ps. fragi* and *Y. enterocolitica* (assessed on selective media, see Section 2.6.).

2.5. Description of treatments

2.5.1. Mode of operation

For steam condensation alone, the unit was preheated by introducing steam to allow the glass bell and base plate to reach the desired temperature. Then, the glass jar was removed; samples were suspended from two clamps, whereupon the chamber was closed by placing the bell jar on the base plate. The chamber was exhausted to 2 kPa. Then the steam supply valve was opened and a constant supply of steam ensured for the desired period. When the pressure exceeded the desired range, the pressure-sensor opened a solenoid valve and pressure dropped due to the activity of the vacuum pump. This allowed keeping steam temperature fairly constant (see Logue et al., 2005). After expiration of the sample residence time the chamber was exhausted to 2 kPa, the resulting evaporation causing a temperature drop on the sample surface and removal of any remaining fluid. Equalisation to atmospheric pressure and removing the bell jar was done manually.

For combined hot water spray/steam condensation treatment, hot water (55 °C) was sprayed for 15 s into the reaction chamber via two nozzles driven by a peristaltic pump at a flow rate of 250 mL/min; then steam condensation was initiated.

2.5.2. Experiments

A total of 142 skin samples and 13 pork bellies were treated in three trials. In trial "A", steam condensation on pig skin was studied, whereas in trial "B", a combination of hot water sprays followed by steam condensation on skin was examined (see Table 1). In trial "C", skin and belly samples were treated with hot water sprays followed by steam condensation (see Table 2). Different numbers of replicates per trial were caused by difficulties in standardisation of time–temperature profiles.

Table 1
The effects of various steam condensation regimens combined with hot water sprays (55 °C) on the microbial reduction of *Pseudomonas fragi* (P) and *Yersinia enterocolitica* (Y) inoculated on pig skin; mean values ± standard deviation and range of values.

Organism	Steam condensation (trial "A")				Water spray (15 s; 55 °C), followed by steam condensation (trial "B")	
	°C	*s*	Reduction (log)	*n*=	Total reduction (log)	*n*=
P	55	600	2.0 ± 0.8 (1.0–3.2)	11	nt	
P	65	18	2.2 ± 0.8^a (0.7–3.7)	15	3.1 ± 1.2^a (2.0–4.8)	5
P	70	10	2.9 ± 0.5 (2.1–3.3)	4	nt	
P	75	10	2.7 ± 1.0^b (0.7–4.1)	21	4.4 ± 0.4^b (3.1–5.4)	25
Y	55	600	2.4 ± 0.7 (1.2–3.3)	11	nt	
Y	65	18	2.2 ± 0.7^c (0.7–4.0)	15	3.4 ± 0.9^c (2.5–4.7)	5
Y	70	10	3.1 ± 0.6 (2.40–3.6)	4	nt	
Y	75	10	2.6 ± 1.0^d (0.9–4.6)	21	4.2 ± 0.4^d (2.4–5.0)	25

nt … not tested.
a,b,c,d within rows, common superscript letters indicate that results differ significantly ($P < 0.05$).