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Decontamination of Airborne Bacteria in Meat Processing Plants¹

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ABSTRACT

Air has been established as a source of bacterial contamination in meat processing facilities. Airborne bacteria may affect product shelf life, and have food safety implications. The effectiveness of reactive oxygen species (ROS) generating AirOcare equipment on the reduction of airborne bacteria in a meat processing environment was determined. Bacterial strains found in ground beef were used to artificially contaminate the air using a 6-jet Collison nebulizer. Airborne bacterial populations in the meat processing room were monitored every 24 h at multiple locations using a Staplex 6 stage air sampler. Total aerobic, Gram-negative, and lactic acid bacterial populations were determined by sampling on R₂A agar, MacConkey agar and Lactobacilli MRS agar, respectively. Approximately 3 log reductions of lactic acid bacteria and Gram-negative bacteria were observed after 24 hours of treatment ($P < 0.05$) compared to ~1.5 log reduction in the control treatment. Further exposure with ROS significantly reduced lactic acid bacteria and Gram-negative bacteria in the air at 48 and 96 h sampling intervals. These findings reveal that reactive oxygen species treatment using AirOcare unit significantly reduces airborne contamination in a meat processing environment.

Airborne contamination, meat processing, germicidal air cleaning unit

INTRODUCTION

Foodborne diseases are responsible for approximately 79 million illnesses, 325,000 hospitalization, and 5,000 deaths per year (Mead et al., 1999). Bacterial pathogens contribute to approximately 60 percent of the foodborne illnesses that lead to hospitalization and account for nearly two-thirds of the estimated number of foodborne pathogen-related deaths. *Salmonella* spp. caused ~26 % and 30%, *Listeria* spp. accounted for ~4% and 28%, and *Escherichia coli* (both O157 and non-O157) caused ~5% and ~4% of foodborne illness-related hospitalization and foodborne pathogen-related deaths, respectively (Mead et al., 1999). The pathogenic and spoilage microorganisms can be introduced to products by many pathways. Contamination can occur at various points during the slaughter process, cold storage, and processing of meat animals (Sofos et al., 1999). Air has long been recognized as a source of microbial contamination in a range of food processing plants, including those producing dairy (Kang and Frank, 1989), pork (Pearce et al., 2006), poultry (Burfoot et al., 2007) and beef products (Burfoot et al., 2006).

Various technologies are available to reduce microorganisms in the air. Air filtration along with electrostatic precipitation is widely used to capture airborne particles that harbor bacteria (St. Georges and Feddes, 1995). The electrostatic space charge system (ESCS) was highly effective in reducing dust and pathogens in the air and on equipment surfaces (Arnold et al., 2004). The airborne *Salmonella enteritidis* contamination was reduced by 95% in caged layer rooms using the electrostatic space charge system (Holt et al., 1999). A

patented air-cleaning system (AirOcare Inc.) utilizes a high frequency controlled pulse of electric current in a series of reaction chambers inside the unit to convert part of the oxygen in the air into various reactive oxygen species (ROS). The objective of this study was to determine the effectiveness of a wall-mounted germicidal air cleaning unit, which generates reactive oxygen species (ROS), in reducing airborne bacteria in a meat processing environment.

MATERIALS AND METHODS

ROS generating unit

Reactive oxygen species (ROS) generating equipment (Model MDS 202BS, Airocare Inc., Rockville, MD) was installed on the wall with a discharge pipe inside the meat processing room. The room (30 ft long x 16 ft wide x 10 ft high) was primarily used for further processing of meats (Figure 1). The unit is based on a system of tubular arrays and a very specific electrical field configuration to generate “steady state” cold plasma. As air circulates through the unit’s reaction chambers, part of the oxygen is electrically excited and converted to various reactive oxygen species (ROS) on a temporary basis.

Aerosol generation and air sampling

Ground beef (25 g) obtained from local retail store was transferred in 225 ml buffered peptone water, pummeled for 2 min and incubated at 37°C for 24 h. Natural beef microorganisms in the suspension were harvested by centrifugation at 5000 g for 10 min, and re-suspended in phosphate buffered saline (PBS, 50 mM). The populations of natural beef bacteria used for aerosol formation were enumerated by plating on R₂A media.

Natural beef bacterial suspension (100 ml) was transferred to a 6-jet Collison nebulizer (Model CN-25, BGI, Waltham, MA) and bacteria were aerosolized for 15 min each at three sampling sites using 20 lb/ft² air pressure. The initial population of aerosolized bacteria (0 h) was determined at three locations using a Staplex 6-stage air sampler (Staplex Inc., Brooklyn, NY) prior to turning the ROS generating unit on.

Bacterial load in the air was monitored every 24 h for up to 4 days. The R₂A agar, Lactobacilli MRS agar (MRS, Acumedia, Lansing, MI), and MacConkey agar (Difco laboratories, Detroit, MI) plates were used in the Staplex sampler for detecting total aerobic bacteria, lactic acid bacteria, and Gram-negative bacterial populations, respectively, in the airborne environment. After pulling air samples for specific time period, the plates were incubated at 35°C for 48 hours. The control experiment was carried out using the same procedure as the treatment exposure; however under the control conditions the ROS generating unit was turned off.

Statistical analysis

The bacterial populations obtained at each sampling period and each location were converted to log cfu/m³. The data obtained from three replicates were analyzed by a two-way ANOVA using a 'Proc Mixed' statement (SAS 8.2, Cary, NC) for effects of the treatment. In all cases, the level of statistical significance level was of $P < 0.05$.

RESULTS AND DISCUSSION

The effect of ROS generated using AirOcare ROS system on bacterial population is shown in Table 1. Aerobic bacterial populations varied from 3.71 to 4.70 log CFU/m³ immediately following aerosolization at different sampling locations. The initial airborne bacteria detected at site 3 (log 3.71 CFU/m³) during the ROS exposure study were lower ($P < 0.05$) compared to airborne bacteria detected at site 1 (log 4.48 CFU/m³) and 2 (log 4.03 CFU/m³). Aerobic populations recovered after 24 h in control samples were ~1.5 log lower compared to the initial aerosolized populations (0 h). Likewise, ca. 2 log reduction in aerobic bacterial population was observed after 24 h ROS exposure. The bacterial populations detected after ROS treatments were significantly lower than those of the corresponding control samples for 24 and 96 h, for Sampling site 1 and 2.

Initial lactic acid bacterial populations ranged from 3.54 at site 3 to 4.62 log CFU/m³ at site 1 (Table 1). As observed with aerobic bacterial populations, lactic acid bacteria recovered at site 3 (3.54 log CFU/m³) during the ROS exposure study were lower ($P < 0.05$) than the lactic acid bacteria recovered at site 1 (4.42 log CFU/m³). Approx. 3 log CFU/m³ reductions ($P < 0.05$) in lactic acid bacteria were observed at each location following 24 h of ROS treatment, compared to ~1.5 log reduction with control samples. Extended ROS exposure up to 96 h did not influence additional reduction in airborne lactic acid bacterial populations. Lactic acid bacteria recovered at each location following 24, 48, 72, and 96 h of ROS exposure were significantly lower than the lactic acid bacteria detected in corresponding control sampling times.

In general, recovery of Gram-negative bacteria was lower than the recovery of aerobic populations or lactic acid bacteria following aerosolization (Table 1). Again the least recovery of Gram-negative bacteria was found at site 3 (1.99 log CFU/m³). The reduction in airborne Gram-negative bacteria following 24 h ROS exposure was 3.5, 2.6, and 2.0 log CFU/m³, respectively, for site 1, 2, and 3. Gram-negative bacteria recovered at each location following 24, 48, and 96 h of ROS exposure were significantly lower than the Gram-negative bacteria detected in corresponding control sampling times.

The present study showed that ROS exposure produced 2 to 3.5 log reduction in airborne bacteria within 24 h. These reductions are superior to the reduction of airborne bacteria obtained using germicidal air cleaning console units (Cundith et al., 2002) and electrostatic precipitation (St. Georges and Feddes, 1995). Electrostatic space charge system (ESCS) reduced total aerobic bacteria in a broiler breeder facility by 76%, resulting in fewer *Salmonella enteritidis*-positive hens and chicks (Richardson et al., 2003).

Reduction of bacterial contamination of meat products during processing is of major concern among processors. The airborne microbes are a potential source of microbiological contamination in meat products. This study showed the significant effect of ROS exposure in reducing airborne microorganisms in a meat processing environment. Reactive oxygen species are moderate to strong oxidizing agents. They inactivate bacteria by rupturing the cell wall. The ROS level (monitored by an O₃ maker) of 0.0389 ppm used in this study is well below the permissible (0.1 ppm) eight-hour exposure limit for a worker. The ROS generating unit can reduce airborne contamination in meat processing

facilities. The unit has an application for controlling airborne contamination in meat processing facilities. Air with fewer bacteria in meat processing environments may help improve meat shelf life and reduce potential product recall.

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Table 1: Airborne bacterial populations in meat processing room following treatment with ROS generating system

Site ^x	Treatment	Bacterial populations				
		(log CFU/m ³) ^y				
	Time (h)	0	24	48	72	96
Aerobic Bacteria						
1	Control	4.70	2.87 a	3.24		
		3.19	3.24 a			
	ROS	4.48	2.08 b	2.82		
		2.68	2.38 b			
2	Control	4.63	3.32 a	3.24		
		3.14	3.57 a			
	ROS	4.03	2.44 b	2.66		
		2.61	2.12 b			
3	Control	4.47	3.15 a	3.37 a		
		3.25 a	3.35 a			
	ROS	3.71	2.41 b	2.41 b		
		2.36 b	2.34 b			
Lactic acid bacteria						
1	Control	4.61	2.96 a	2.69 a		
		2.51 a	2.63 a			
	ROS	4.42	1.25 b	1.64 b		
		1.41 b	1.43 b			
2	Control	4.53	3.09 a	2.65 a		
		2.71 a	2.42 a			

	ROS	3.90	1.28 b	1.38 b
	1.34 b	1.35 b		
3	Control	4.34	2.84 a	2.11 a
	2.52 a	2.51 a		
	ROS	3.54	0.81 a	0.66 b
	0.87 b	0.70 b		
Gram-negative bacteria				
1	Control	3.77	1.47 a	2.28 a
	2.25 a	2.41 a		
	ROS	3.95	0.28 b	ND b
	0.18 b	0.69 b		
2	Control	3.28	1.64 a	1.75 a
	1.22	2.40 a		ROS
	2.82	0.22 b	ND b	0.22
	0.84 b			
3	Control	2.09	2.20 a	2.11 a
	1.00	2.26 a		ROS
	1.99	ND b	ND b	ND
	0.64 b			

^x Sampling site # (1 –Mixer by the kill room entry door, 2 – Weighing scale, 3 – Cutting table)

^y For each site, means in the same column with a different letters are different (P < 0.05)

ND non-detectable

Figure 1: Meat processing room with three air sampling locations



Sampling site # (1 –Mixer by the kill room entry door, 2 – Weighing scale, 3 – Cutting table)