Survival of Listeria monocytogenes on a conveyor belt material with or without antimicrobial additives

Chaitiemwong, N., Hazeleger, W. C., & Beumer, R. R.

Chaitiemwong, N., Hazeleger, W. C., & Beumer, R. R. (2010). Survival of Listeria monocytogenes on a conveyor belt material with or without antimicrobial additives. International Journal of Food Microbiology, 142(1-2), 260-263. https://doi.org/10.1016/j.ijfoodmicro.2010.06.021

Survival of *Listeria monocytogenes* on conveyor belt material with/without antimicrobial additives

N. Chaitiemwong, W. C. Hazeleger, R. R. Beumer*

Laboratory of Food Microbiology, Wageningen University

P.O. Box 8129, 6700 EV Wageningen, the Netherlands

Running title: Survival of *Listeria monocytogenes* on conveyor belt

Keywords: *Listeria monocytogenes*, survival, conveyor belt, antimicrobial additives

* Corresponding author: Laboratory of Food Microbiology, Wageningen University

P.O. Box 8129, 6700EV Wageningen, the Netherlands. Phone: +31-317-483213; Fax: +31-317-484978. E-mail: rijkelt.beumer@wur.nl

ABSTRACT

Survival of *L. monocytogenes* on conveyor belt material with and without antimicrobial additives was investigated. In these experiments, also the effect of food debris (meat, fish and vegetables) and temperature (10, 25 and 37^{o}C) was evaluated. The pathogen survived best at 10^{o}C, followed by 25^{o}C and 37^{o}C on both conveyor belt materials. The reduction rate of the pathogen on conveyor belts with antimicrobial additives in the first six hours at 10^{o}C (0.6 log unit) was significantly higher than that on the surfaces without the additives, or in presence of food residue (0.2-0.3 log unit). At high temperature (37^{o}C) and low humidity (20%), a rapid decrease in numbers of the pathogen on both conveyor belt surfaces was observed. Under these conditions, an effect of antimicrobial substances could not be noticed. However, at ambient (25^{o}C) and low (10^{o}C) temperature and high humidity (60-75%), a rapid decrease in cell counts was observed. These results demonstrated that temperature and relative humidity play an important role in the reduction of the bacteria on the surfaces. Antimicrobial conveyor belts reduced numbers of *L. monocytogenes* faster than normal conveyor belts. However, this effect is limited on dry surfaces, where a reduction took place at lower rate than that in the first six hours when the surfaces were still wet. Moreover, the presence of food debris neutralized the effect of antimicrobials. The results suggested that the antimicrobial additives in the conveyor belt could help to reduce numbers of microorganism in particular at low temperature and in an absence of food residues.

1. Introduction

Contamination of *Listeria monocytogenes* on ready-to-eat cooked meat products most likely occurs after thermal processing. Many studies report that *L. monocytogenes* attaches to various types of surfaces in food processing plants (Beresford et al., 2001; Lunden et al., 2002) such as stainless steel, glass, polypropylene and rubber (Mafu et al., 1990; Wong, 1998). The bacteria survive and grow on spots that are difficult to clean and disinfect due to their poor designs, such as slicing machines, conveyor belts (Lin et al., 2006), and narrow openings between surfaces and apparatus (Tompkin et al., 1992). Of the many processing surfaces, conveyor belts are of great concern in food processing because during transfer of food products the belts are often contaminated with high numbers of microorganisms including foodborne pathogens such as *L. monocytogenes* (Thévanot et al., 2005) and *Escherichia coli* O157:H7 (Keeratipibul et al., 2009). Inadequate cleaning and disinfection procedures can cause accumulation of bacteria on surfaces and formation of biofilms, which are difficult to control or remove by conventional cleaning methods (Chmielewski and Frank, 2003; Smoot and Pierson, 1998). However, recontamination from contaminated surfaces to food products can be prevented by hygienically designed apparatus, cleaning and disinfection and zoning (Anonymous, 1991). At present, it is possible to add antimicrobial additives (e.g. triclosan, silver) to surface materials to control the survival or growth of microorganisms on the surfaces. Triclosan and silver are GRAS (generally recognized as safe) and approved by the U.S. Food and Drug Administration for their safety (Jones et al. 2000) and are currently used in medical devices, food processing, and building materials (Feng et al., 2000). Several studies have been published about the effect of antimicrobial additives in surface materials used in the food processing industry against microorganisms, e.g. antimicrobials incorporated in cutting boards, food containers (Wijnhoven et al., 2009) and the inner liner in refrigerators (Kampmann et al., 2008). However, few studies have investigated survival of microorganisms

on antimicrobial surfaces in comparison to normal surfaces in practical situations of low and ambient temperatures or with food residues.

In this study, the survival of three strains of *L. monocytogenes* was studied on conveyor belt materials with and without antimicrobial additives at different temperatures and in the presence and absence of food residues.

2. Materials and methods

2.1 Bacterial strains

L. monocytogenes LF 38 (serotype 1/2a isolated from cooked ham), LF 36 (serotype 1/2b isolated from cooked sausage) and LF 29 (serotype 4e isolated from cooked sliced sausage) obtained from the Food and Consumer Product Safety Authority (Zutphen, the Netherlands) were used in this study. Stationary-phase cultures of all strains were stored in 1 ml cryo vials (Greiner Bio-one, Frickenhausen, Germany) with 25% (v/v) glycerol (Fluka-Chemica, Buchs, Switzerland) and glass beads (2 mm, Emergo, Landsmeer, the Netherlands) at -20^{o}C. For each experiment, one glass bead of each strain was transferred to tryptone soy agar plates (TSA, Oxoid, UK), which were incubated at 30^{o}C for 24 h. A single colony was picked, inoculated into 10 ml brain heart infusion broth (BHI; Difco, Becton Dickinson, Maryland, USA) and incubated for 72 h at 10^{o}C or for 24 h at 25^{o}C and 37^{o}C.

2.2 Conveyor belt material (US Patent 6994209)

Two types of food grade conveyor belt materials were used in this study. The control conveyor belt material without antimicrobial additives (CM-) (FNB-6EZCT, Habasit Netherlands BV, Nijkerk, the Netherlands) was composed of polyester fabric impregnated with thermoplastic polyurethane (TPU). The conveyor belt material with antimicrobial additives (CM+) (FNB-6EZCT+H14, Habasit Netherlands BV, Nijkerk, the Netherlands) had

100 the same composition and was impregnated with thermoplastic polyurethane (TPU) and the
101 antimicrobial compound HyGUARD®. According to the US patent 6994209 (Cediel et al.,
102 2006), antimicrobial substances used are silver zeolite, aluminum oxide, calcium oxide,
103 magnesium oxide, zinc pyrithione, oxybisphenoxarsine or a combination of those. The
104 conveyor belt surfaces were cut from the roll in sheets of 10 x 10 cm.
105
106 *2.3 Food debris*
107 Raw food (minced meat, smoked salmon and chopped lettuce) were bought from a local
108 supermarket, kept in a refrigerator (< 7°C) and used within 24 h. To prepare a 10% suspension
109 of the food debris, 10 g of each selected food was aseptically placed in Stomacher® bags and
110 90 ml peptone saline solution (PSS: 8.5 g/l NaCl (Merck, Darmstadt, Germany) and 1 g/l
111 Neutralised Bacteriological Peptone (Oxoid, Basingstoke, England)) was added. The food was
112 then homogenized in a stomacher (Stomacher® 400 Circulator, England) for 1 min at 260 rpm.
113
114 *2.4 Artificial contamination of the surfaces*
115 The conveyor belt sheets were washed with anionic-active detergent, rinsed with hot
116 water (70-80°C) and air dried. Before each experiment, the belt surfaces were disinfected with
117 70% ethanol for 15 min and air dried for 15 min in a laminar flow cabinet.
118 Appropriate serial dilutions of the overnight cultures were prepared in PSS. For the
119 selected final dilutions (approximately 10^6 CFU/ml), PSS containing 0.1% Tween 80 (Merck,
120 Hohenbrunn, Germany) was used to lower the surface tension in order to obtain an even
121 spread of bacteria on the surfaces. The influence of food debris on the antimicrobial action
122 was investigated by preparing the final dilution of the test cultures in a 10% suspension of the
123 food products (with 0.1% Tween 80). From these tubes with and without food debris, 250 µl
124 was spread over 100 cm^2 of the belt surfaces by using a cotton swab (Sterile wooden/cotton

swab, LP Italiana SPA, Milano, Italy). The conveyor belt sheets were then placed at 10°C, 25°C and 37°C for 72 h. Relative humidity (Rh) was measured at each storage temperature with a digital hygro-thermometer (VWR International BV, Amsterdam, the Netherlands).

2.5 Enumeration of test strains from the conveyor belt sheets

The conveyor belt surfaces were sampled after 0, 6, 24, 48 and 72 h by rubbing 10 x 10 cm areas with sterile cotton swabs (EUROTUBO® collection swab, Delta lab, Rubi, Spain) stored in 5 ml of buffered peptone water (BPW) according to ISO 18593:2004 (Anonymous, 2004). The swabs were reinserted in the BPW, vortexed and resuscitated for one hour. After that, 2 x 1 ml of the swab solution was added to 2 tubes with 2 ml peptone saline solution (PSS). The contents of these tubes (3 ml) were plated onto two Petrifilm™ Environmental *Listeria* plates (3M Company, St.Paul, MN, USA.). All plates were incubated at 37°C for 24-30 h, and the numbers of recovered *L. monocytogenes* were determined and transformed into log CFU per 100 cm^2.

Reduction rates of *L. monocytogenes* (log CFU/100 cm^2/h) were calculated by dividing the reduction in cells counts on the surfaces in times by lapse times (h), which were 6 h from the first six hours and 66 h from 6 to 72 h.

2.6 Statistical analysis

The results of triplicate experiments were combined. The significance of difference in survival of *L. monocytogenes* ($P < 0.05$) on types of the surfaces, *Listeria* strains, food residues, and temperatures was determined with ANOVA and a general linear model using SPSS for Windows 98/NT/2000 release 15. A balance of input (initial concentration of inoculum) and output (number of bacteria on the tested surfaces before and after sampling) was calculated.

3. Results and discussion

As can be seen in Fig. 1 (A, B and C), a rapid decrease of 2.5 - 4 log CFU/100 cm^2 of the test strains on the test surfaces was observed during the first six hours. Thereafter, the reduction was only 0.1 log unit in 6 h. These results were similar with those of Kusumaningrum et al. (2003) and may be attributed to the stress conditions during the rapidly decreasing water activity. Despite the rather high standard deviations found in our experiments, it becomes clear from Fig. 1 (A-B) that at lower temperatures (25 and 10^{o}C), the cells were significantly faster inactivated on the antimicrobial belt surfaces compared to the normal belt surfaces (P<0.05). The high reduction rate during the first 6 h demonstrated that the antimicrobial additives in the test surfaces were more active in wet than dry conditions. From the moment the surface was dry, the remaining cells were protected by the low water activity (McEldowney and Fletcher, 1988). Another explanation could be the fact that in a broth culture, a fracture of the population might be resistant against detrimental influences such as low pH, low water activity, and low concentration of preservatives or biocides (Wesche et al., 2009). A temperature close to the optimum growth temperature of the microorganism gave a more rapid inactivation and no extra effect of the antimicrobial belt could be demonstrated (Fig.1C). At 37^{o}C, the surfaces were dry within one hour, whereas these took 2 and 4 hours to dry at 25 and 10^{o}C, respectively. This emphasizes the benefit of thorough drying of surfaces directly after cleaning and disinfection.

The ability of bacteria to survive on food contact surfaces has been reported previously (Bremer et al., 2001; Wilks et al., 2006; Wong, 1998) and is influenced by bacterial strain, temperature, time, humidity, availability of nutrients, pH, presence of inhibitors and surface materials (Allan et al., 2004; Beumer and Hazeleger, 2003). All three *L. monocytogenes* strains used in this study showed the same pattern in survival on the two surfaces. The recovery of the test organisms from the surfaces was approximately 70-75%, whereas 15%

was lost during spreading of the test organism and a small proportion of the cells (10%) remained on the surfaces after sampling (data not shown).

During the experiments we measured the Rh; however, it was not a set variable. At high temperature (37^{o}C), the Rh was low at around 20%. This combination of high temperature and low Rh, together with the fast drying of the surfaces, resulted in a rapid decrease in numbers on both types of the conveyor belt surfaces (Fig. 1C). This phenomenon was also described in a rapid reduction of *Pseudomonas fluorescens* at 35^{o}C on antimicrobial-containing inner liners in refrigerators (Kampmann et al. 2008). At ambient (25^{o}C) and low (10^{o}C) temperature, the Rh in our experiments showed high values (60-75%). These combinations resulted in a better survival of the target organism on the belt surfaces, probably because more time was needed to obtain a completely dry surface (2-4 h). Furthermore, it is known that *L. monocytogenes* can survive in stress conditions such as at the low temperature (2-4^{o}C) (Rocourt and Cossart, 1991) or in low water activity (0.92) (Petran and Zottlola, 1989) or in less oxygen in vacuum package (Walker et al., 1990). Regarding to survival of *L. monocytogenes* at low temperature, it is due to the fact that changes in temperature results in changes in membrane composition to maintain the optimum fluidity for growth at low temperature (Beales, 2004). This is an important aspect, since these conditions can be found in many food production areas. Similar results were found in a study of antibacterial substances in a kitchen, where the bacterial counts on antimicrobial surfaces were significantly lower than those on conventional surfaces (Sadako et al., 2001).

Presence of 10% food debris (minced meat, smoked salmon and chopped lettuce) decreased the antimicrobial effect and protected the cells. In table 1, the results obtained at 10^{o}C are presented. On the antimicrobial belt, a decrease in numbers of the test strains on the antimicrobial belts (log 0.63/100 cm^{2} per h) was faster than that on the normal belts (log 0.38/100 cm^{2} per h). In the presence of food debris, however, even in the low concentrations

200 (10%) used in this experiment, the decrease is reduced to only log 0.2-0.3/100 cm^2 per h and
201 no statistically significant difference (P>0.05) was found in the survival of *L. monocytogenes*
202 on both types of the materials.
203 In comparison to lettuce, *Listeria* survived better in the presence of meat and fish
204 residues. This may be attributed to a higher concentration of protein and fat in these products
205 (Vorst et al. 2006). Moreover, amino acids in meat and fish can bind to the antimicrobial
206 additives released from the surfaces, and in this way enhances the survival of the pathogen
207 (Liau et al., 1997). Similar results were found in several studies, where milk and chicken or
208 meat suspensions provided a protective effect on *Salmonella enteritidis* and *Campylobacter*
209 *jejuni* on stainless steel surfaces (Kusumaningrum et al., 2003), on *L. monocytogenes* and
210 *Yersinia enterocolitica* on a mortar (Allan et al., 2004) and on *L. monocytogenes* and
211 *Salmonella typhimurium* on stainless steel and buna-N rubber (Helke and Wong, 1994).
212 It is not fully clear which antimicrobial additives were present in the test surfaces in our
213 study. The US Patent (Cedeil et al., 2006) indicated that the additives used in the conveyor
214 belt might be silver zeolite, aluminum oxide, calcium oxide, magnesium oxide, zinc
215 pyrithione or oxybisphenoxarsine. Some of these substances demonstrated an antimicrobial
216 effect against *E. coli* and *L. monocytogenes* on surfaces (Cowan et al., 2003) and in
217 suspensions (Chang et al., 2008). Relevant data obtained from the literatures demonstrated the
218 effect of those antimicrobial additives in surface materials (Kampman et al. 2008, Cowan et
219 al., 2003). However, the antibacterial effect was considerably greater in suspension (Chang et
220 al., 2008) than that on surfaces (Cowan et al., 2003). Furthermore, longer contact time and
221 lower temperature also resulted in a greater reduction. Studies on the antimicrobial effect of
222 silver-containing inner liners in refrigerators demonstrated that reduction of bacterial numbers
223 on the silver-containing surfaces at 35^{o}C was one log unit faster than at 5^{o}C, when compared
224 24 h with 72 h (Kampman et al. 2008). Our results agreed with the previous study, in which

the test at 10°C required a longer contact time (72 h) than at 37°C (24 h) to achieve a similar reduction after exposure to the antimicrobial surfaces. However, it becomes clear from the previous studies that even for the same antimicrobial agent results may vary considerably (Cowan et al., 2003, Chang et al., 2008). With the set up of the testing procedure, choice of test strain, concentration of the antimicrobial agent in the material, temperature, relative humidity, suspension-/carrier tests, the reducing effect of the antimicrobial agents will be influenced.

In conclusion, the presented results demonstrate that the antimicrobial additives in the conveyor belt material can help to reduce survival of microorganism on the surfaces. However, the effectiveness of the antimicrobial additives was reduced in presence of food debris. Although the additives in the surfaces are not known, the results were comparable with previous studies. Additional studies are required to examine the effectiveness of the antimicrobial conveyor belt on the other microorganisms such as *E. coli* and *Salmonella* spp.

Acknowledgements

The authors express their thanks to Habasit Netherlands BV, Nijkerk, who provided the conveyor belt materials used in this study.

References

Anonymous, 1991. *Listeria monocytogenes*. Recommendations by the National Advisory Committee on Microbiological Criteria for Foods. FSIS, Washington, adopted 17 July 1991.

Anonymous, 2004. ISO 18593. Microbiology of food and animal feeding stuffs – Horizontal methods for sampling techniques from surfaces using contact plates and swabs. International organization for Standardization, Geneva, Switzerland.

Allan, J. T., Yan, Z., Genzlinger, L. L., Kornacki, J. L., 2004. Temperature and biological soil effect on survival of selected foodborne pathogens on a mortar surface. Journal of Food Protection 67, 2661-2665.

Beales, N. 2004. Adaptation of microorganisms to cold temperatures, weak acid preservatives, low pH, and osmotic stress: A review. Comprehensive Reviews in Food Science and Food Safety 3, 1-20.

Beresford, M.R., Andrew, P.W., Shama, G., 2001. *Listeria monocytogenes* adheres to many materials found in food-processing environments. Journal of Applied Microbiology 90, 1000-1005.

Beumer, R. R., Hazeleger, W. C., 2003. *Listeria monocytogenes*; diagnostic problems. FEMS Immunology and Medical Microbiology 35, 191-197.

Bremer, P. J., Monk, I., Osborne, C. M., 2001. Survival of *Listeria monocytogenes* attached to stainless steel surfaces in the presence or absence of *Flavobacterium* spp. Journal of Food Protection 64, 1369-1376.

Cedeil, L. E., Honold, C., Broadmann, K. 2006. The US Patent 6994209. Conveyor belt with a polymer surface coating containing an antimicrobial additive. Available at http://www.patentstorm.us/patents/6994209/description.html Accessed 02 June 2009.

Chang, Q., He, H., Ma, Z., 2008. Efficient disinfection of *Escherichia coli* in water by silver loaded alumina. Journal of Inorganic Biochemistry 102, 1736-1742.

Chmielewski, R. A. N., Frank, J. F., 2003. Biofilm formation and control in food processing facilities. Comprehensive Reviews in Food Science and Food Safety 2, 22-32.

Cowan, M. M., Abshire, K. Z., Houk, S. L., Evans, S. M., 2003. Antimicrobial efficacy of a silver-zeolite matrix coating on stainless steel. Journal of Industrial Microbiology and Biotechnology 30, 102-106.

Feng, Q. L., Wu, J., Chen, G. Q., Cui, F. Z., Kim, T. N., Kim, J. O., 2000. A mechanistic study of the antibacterial effect of silver ions on *Escherichia coli* and *Staphylococcus aureus.* Journal of Biomedical Materials Research 52, 662-668.

Helke, D. M., Wong, A. C. L., 1994. Survival and growth characteristics of *Listeria monocytogenes* and *Salmonella typhymurium* on stainless steel and buna-n rubber. Journal of Food Protection 57, 963-968, 974.

Jones, R. D., Jampani, H. B., Newman, J. L., Lee, A. S., 2000. Triclosan: A review of effectiveness and safety in health care settings. American Journal of Infection Control 28, 184-196.

Kampmann, Y., de Clerck, E., Kohn, S., Patchla, D. K., Langerock, R., Kreyenschmidt, J., 2008. Study on the antimicrobial effect of silver containing inner liners in refrigerators. Journal of Applied Microbiology 104, 1808-1814.

Keeratipibul, S., Oupaichit, T., Techaruwichit, P. 2009. Contamination profiles of Escherichia coli and Enterococci in steamed chicken meat products. Journal of Food Protection 72, 1821-1829.

Kusumaningrum, H. D., Riboldi, G., Hazeleger, W. C., Beumer, R. R., 2003. Survival of foodborne pathogens on stainless steel surfaces and cross-contamination to foods. International Journal of Food Microbiology 85, 227-236.

Liau, S. Y., Read, D. C., Pugh, W. J., Furr, J. R., Russel, A. D., 1997. Interaction of silver nitrate with readily identifiable groups: relationship to the antibacterial action of silver ions. Letters in Applied Microbiology 25, 279-283.

Lin, C. M., Takeuchi, K., Zhang, L., Dohm, C. B., Meyer, J. D., Hall, P. A., Doyle, M. P., 2006. Cross-contamination between processing equipment and deli meats by *Listeria monocytogenes*. Journal of Food Protection 69, 71-79.

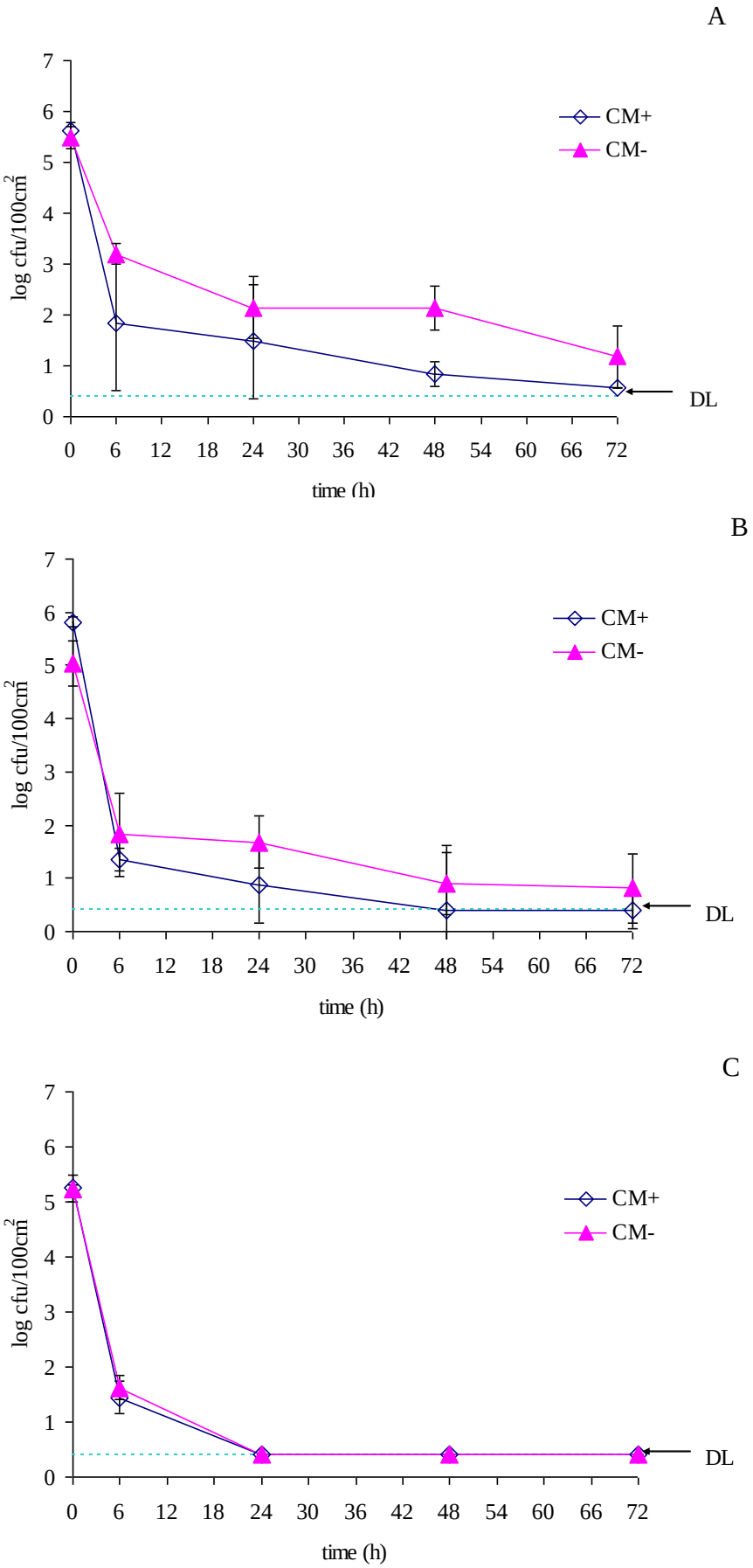
298 Lunden, J. M., Autio, T. J., Korkeala, H. J., 2002. Transfer of persistent *Listeria*
299 *monocytogenes* contamination between food-processing plants associated with a
300 dicing machine. Journal of Food Protection 65, 1129-1133.
301 Mafu, A. A., Roy, D., Goulet, J., Magny, P., 1990. Attachment of *Listeria monocytogenes* to
302 stainless steel, glass, polypropylene, and rubber surfaces after short contact times.
303 Journal of Food Protection 53, 742-746.
304 McEldowney, S., Fletcher, M., 1988. The effect of temperature and relative humidity on the
305 survival of bacteria attached to dry solid surfaces. Letters in Applied Microbiology 7,
306 83-86.
307 Petran R. L., Zottola, E. A., 1989. A study of factors affecting growth and recovery of *Listeria*
308 *monocytogenes* Scott A. *J. Food Prot*. 52:458-460.
309 Rocourt, J., Cossart, P., 1997. *Listeria monocytogenes*. In: Doyle, M.P., Buechat,
310 L.R., Montville, T.J. (Eds.), Food Microbiology - Fundamentals and Frontiers.
311 American Society for Microbiology (ASM) press, Washington DC, pp. 337–352.
312 Sadako, Y., Wataru, U., Takenori, N., 2001. Effect of using antibacterial metal on the surface-
313 environment in reducing the bacterial population in a kitchen. Journal of Antibacterial
314 and Antifungal Agents 29, 763-768.
315 Smoot, L. M., Pierson, M. D., 1998. Effect of environment stress on the ability of *Listeria*
316 *monocytogenes* Scott A to attach to food contact surfaces. Journal of Food Protection
317 61, 1293-1298.
318 Thévenot, D., Delignette-Muller, M. L., Christieans, S., Vernozy-Rozand, C. 2005.
319 Prevalence of *Listeria monocytogenes* in 13 dried sausage processing plants and their
320 products. International Journal of Food Microbiology 102, 85-94.
321 Tompkin, R. B., Christiansen, L. N., Shaparis, A. B., Baker, R. L., Schroeder, J. M., 1992.
322 Control of *Listeria monocytogenes* in processed meat. Food Australia 44, 370-376.

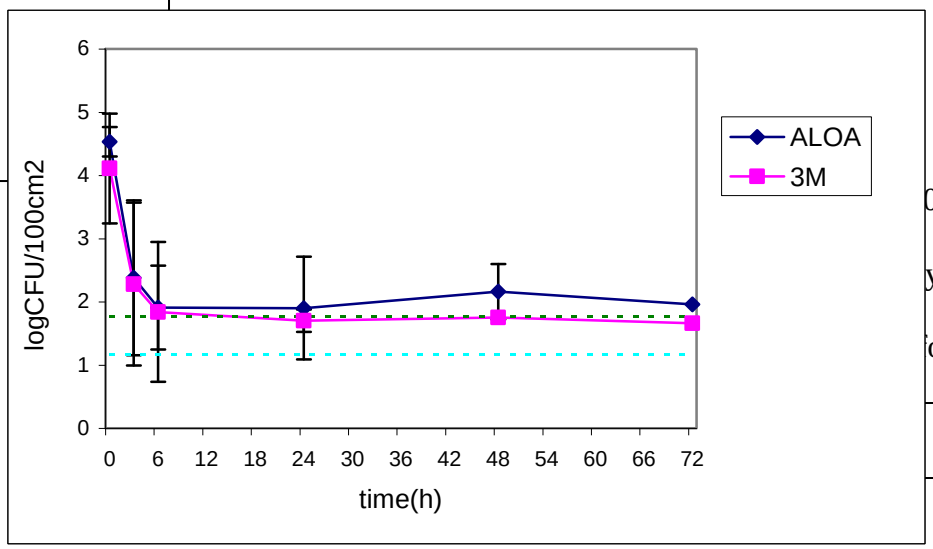
323 Vorst, K. E., Todd, C. D., Ryser, E. T., 2006. Transfer of *Listeria monocytogenes* during
324 slicing of turkey breast, bologna, and salami. Journal of Food Protection 69, 619-626.
325 Walker, S. J., Archer, P., Bangs, J. G. 1990. Growth of *Listeria monocytogenes* at
326 refrigeration temperature. Journal of Applied Bacteriology 68, 157-162.
327 Wesche, A. M., Gurtler, J. B., Marks, B. P., Ryser, E. T., 2009. Stress, sublethal injury,
328 resuscitation, and virulence of bacterial foodborne pathogens. Journal of Food
329 Protection 72, 1121-1138.
330 Wijnhoven, S. W. P., Peijnenburg, W. J. G. M., Herberts, C. A., Hagens, W. I., Oomen, A. G.,
331 Heugens, E. H. W., Roszek, B., Bisschops, J., Gosens, I., Van De Meent, D., Dekkers,
332 S., De Jong, W. H., van Zijverden, M., Sips, A. J. A. M., Geertsma, R. E. 2009. Nano-
333 silver - a review of available data and knowledge gaps in human and environmental
334 risk assessment. Nanotoxicology 3, 109-138.
335 Wilks, S. S. A., Michels, H. H. T., Keevil, C. C. W., 2006. Survival of *Listeria*
336 *monocytogenes* Scott A on metal surfaces: Implications for cross-contamination.
337 International Journal of Food Microbiology 111, 93-98.
338 Wong, A. C. L. 1998. Biofilms in food processing environments. Journal of Dairy Science 81,
339 2765-2770.
340
341
342
343
344
345
346
347

Figure captions

Fig. 1. Survival of *L. monocytogenes* on conveyor belt material with (◊: CM+) or without (▲: CM-) incorporated antimicrobial additives at 10^{o}C (A), 25^{o}C (B) and 37^{o}C (C). (Means of three *L. monocytogenes* strains ± standard deviation (n = 3), DL: detection limit).

Fig. 1.


A
CM+
CM-
log cfu/100cm2
DL
time (h)
B
CM+
CM-
log cfu/100cm2
DL
time (h)
C
CM+
CM-
log cfu/100cm2
DL
time (h)



0 cm^2/h, mean of three *L.*

yor belt material with (CM+) and

ood debris stored at 10^{o}C for 72 h.

			CM-	
			0-6 h**	6-72 h**
Control	0.63 ± 0.02[a]	0.02 ± 0.00	0.38 ± 0.06[b]	0.03 ± 0.00
Minced meat	0.22 ± 0.05[c]	0.03 ± 0.01	0.26 ± 0.03[c]	0.02 ± 0.01
Smoked salmon	0.23 ± 0.01[c]	0.03 ± 0.01	0.26 ± 0.03[c]	0.02 ± 0.01
Chopped lettuce	0.33 ± 0.04[c]	0.03 ± 0.01	0.31 ± 0.11[c]	0.03 ± 0.01

401 * Different letters in the same row or column are significantly different (P = 0.05)
402 **Reduction rates were calculated at two different time intervals (first 6 h and 6-72 h).
403