Decontamination of pork carcasses by steam and lactic acid

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Abstract

The efficiency of a new apparatus for surface decontamination of pork carcasses was evaluated under industrial conditions. The combination of steaming by a special nozzle, followed by treatment with lactic acid (spraying with 2% solution), was applied on the surface of carcasses at the end of the slaughter process (30 min p.m.). Total counts of psychrophilic and mesophilic microorganisms were evaluated immediately after treatment and during cold storage up to five days. The treatment was effective in reducing the surface microflora by one to three decimal orders of CFU during the time of cold storage.

Keywords: Steam; Lactic acid; Pork; Carcasses; Decontamination

1. Introduction

The surface contamination of pork carcasses can negatively reduce their shelf-life. The microorganisms get to the surface of pigs during processing on the slaughter line, mostly during scalding and evisceration. First, the microorganisms reach on carcass surface from where they penetrate into deeper layers of the meat. Reducing this primal surface contamination and avoiding or limiting the microbial growth would improve food safety and extend shelf-life (James, Thornton, Ketteringham, & James, 2000).

External surfaces of the carcass become exposed to potential sources of contamination in the slaughter process. Decontamination techniques for carcasses are targeted at reducing or eliminating bacteria that may be human pathogens as well as those that may cause meat spoilage. Generally condition created by decontamination methods that lead to the reduction of overall levels of bacteria as measured by total aerobic plate count or total coliforms, provide some indication of the potential effects on pathogens. However, since this does not hold true in all cases, validation studies conducted in laboratory settings have specifically measured reductions of artificially inoculated bacterial pathogens (Huffman, 2002).

Different methods of heat treatment of surface layers were suggested and evaluated. They involved hot water, steam and hot air and were tested on different carcasses. Steam has been shown to be effective in reducing the number of microorganisms on meat surfaces (James et al., 1998; Morgan, Radewonuk, & Scullen, 1996). Gill and Bryant (1997) found that vacuum–hot water cleaning (water and steam temperature >82 °C), pasteurizing treatments (105 °C for 6.5 s) and subsequent spray-cooling of cattle carcasses can be operated in commercial practice to reduce log mean numbers of coliforms and Escherichia coli by >2 and log mean numbers of total aerobic bacteria by >1.

Castelo, Kang, Siragusa, Koohmaraie, and Berry (2001) evaluated different treatments on pork trim. They...
used different combinations of water (cold and hot 82.5 °C), hot air (510 °C) and lactic acid. On both surfaces, lean pork trim tissue and fat-covered trim tissue the lower microbial populations were observed at samples treated by water and lactic acid. Treatment of pork trim affected colour of meat. Pork mince prepared from trim treated with any of the treatment processes had lower initial microbial populations compared to the untreated samples. The water plus lactic-acid treatment provided the greatest microbial reduction and inhibition without large negative effects on quality attributes of the pork mince (Castelo, Koohmaraie, & Berry, 2001a).

Even though decontamination of meat may reduce the number of pathogens, higher growth of pathogens may occur during storage due to removal of competing non-pathogenic bacteria. Nissen, Maugesten, and Lea (2001) investigated the effect of meat decontamination (steaming and spraying with 0.2 M lactic acid) on growth and survival of pathogens in meats. Both decontaminated and untreated samples of pork were inoculated with Salmonella enteritidis, Yersinia enterocolitica and E. coli O157:H7, respectively, and stored at 10°C. For pork, no significant differences between decontaminated and untreated samples were observed (see Table 1).

Table 1
The effect of the decontamination by the steaming and/or by the lactic-acid treatment on the counts of mesophiles.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>106 ± 30.8ab</td>
<td>108,200 ± 35,510</td>
<td>8800 ± 2048d</td>
</tr>
<tr>
<td>Steaming</td>
<td>39.8 ± 10.4c</td>
<td>4496 ± 1341c</td>
<td>76.0 ± 36.8c</td>
</tr>
<tr>
<td>Steaming + LA spraying</td>
<td>26.1 ± 15.5b</td>
<td>4496 ± 1341c</td>
<td>76.0 ± 36.8c</td>
</tr>
</tbody>
</table>

a,b,c,d statistically significant differences between values within column and time.

Organic acids reduce bacterial counts on the meat surface layer; lactic acid is often used, as it is a natural meat compound produced during the postmortem glycolysis. Moreover, the lactate anion retards the growth of surviving microbes during storage (Siragusa, 1995). The application of lactic acid is generally known and was effective also in industrial conditions in our previous trials (Pipek & Bacˇo, 1997).

The treatment of pork carcasses by lactic acid reduced coliform counts and retarded (during five days storage at 3°C) the onset of the logarithmic phase of their growth. Salmonellae were not detected on any samples (Pipek & Bacˇo, 1997). Decontamination of pork skin suspension with 1% lactic acid was effective for Campylobacter jejuni (Netten, Huis-in’t-Veld, & Mossel, 1994). Treatment with lactic acid eliminated Salmonella typhimurium from pork carcasses (Netten, Mossel, & Huis-in’t-Veld, 1995). Pathogens found in the environment of abattoirs (Listeria monocytogenes and Y. enterocolitica) may become adapted to lactic acid used to decontaminate meat. However they did not cause an increased health hazard, although the number of Gram-negative spoilage organisms on pork skin was largely reduced by hot 2–5% lactic acid decontamination (Netten, Valentijn, Mossel, & Huis-in’t-Veld, 1997a). Lactic acid decontamination (1–5% 30–90 s) killed mainly Gram-negative bacteria. During aerobic chilled storage after lactic acid decontamination the growth of Gram-negative psychrotrophs was controlled only temporarily and these organisms became the dominant group of organisms (Netten, Mossel, & Huis-in’t-Veld, 1997b).

Lactic acid decontamination of pork carcasses by dipping in 1–2% lactic-acid solutions brought a sharp decrease in the number of cfu of pathogens occurred on the skin of chilled pork belly cuts. Acid-adapted E. coli O157:H7, S. typhimurium, Staphylococcus aureus, and C. jejuni that contaminate skin surface after lactic acid decontamination did not cause an increased health hazard (Netten, Valentijn, Mossel, & Huis-in’t-Veld, 1998).

Decontamination treatments applied during dressing of cattle carcasses were investigated for their effects on microbiological quality. Steam or hot pasteurization was shown to be consistently effective methods of reducing bacterial counts. Washing, followed by an effective pasteurization treatment, provides the maximal possible reduction in bacterial counts (Gill & Landers, 2003). James et al. (2000) compared potential methods for decontaminating lamb carcasses applied at 50 min postmortem for 8 s: steaming at 100 °C, immersion in 90 °C water and immersion in 90 °C chlorinated water. The steam system shows the best potential for industrial application due to its simplicity.

The advantage of steam is explained by Kozempel, Goldberg, and Craig (2003). The surface will appear quite rough with many pores. It is difficult to kill bacteria that get into these pores with sanitizing solutions because surface tension prevents the liquid from entering the pores. Therefore, steam should be able to enter the pores and kill the bacteria. A very thin layer of air plus the entrained moisture surrounds all solid food and steam cannot pass through these barriers to reach the bacteria. They proposed to apply vacuum to the food to remove the air and moisture; then to apply rapidly steam to kill the bacteria in the pores, and then to expose the food to vacuum again to remove the condensate and evaporatively cool the surface. A process that exposes meat to vacuum, then steam, then vacuum again leads to the reduction of different pathogens by log 1.0–2.0.

The combination of mechanical avoiding or releasing of bacteria stuck on the carcass surface followed by antimicrobial spraying or spraying with hot water induces two steps (i.e., release and inactivation) necessary for the decontamination system to be effective. The treat-
ment by hot water combines the rinse and partial heat
decontamination of the surface. Such a treatment is lim-
ited by the possible heat damaging of the appearance of
carcass surface. At the same time the water temperature
must be above 75 °C (Siragusa, 1995).

The treatment of the pig carcass with water at 85 °C
for 20 s reduced the total numbers of bacteria by an
order of 2 and these of E. coli by 2.5 as compared with
untreated carcasses (Gill, McGinnis, Bryant, & Chabot,
1995).

The physical treatment by hot steam followed by
spraying with lactic acid solution is another possibility
for surface decontamination; see e.g. papers of Dorsa,
Cutter, Siragusa, and Koohmaraie (1996b) or Dorsa,
Cutter, and Siragusa (1996a). In this case, acid and heat
inactivation of microorganisms follows release of micro-
organisms from the surface. The effect of combined
treatment was recently proven by Kang, Koohmaraie,
Dorsa, and Siragusa (2001). They observed that different
combinations of hot water (82 °C) and/or hot air
(510 °C) and lactic acid resulted in continuously decreas-
ing microbial populations on the beef trim.

Decontamination of swine carcasses by combination
of rinsing with water and spraying with lactic-acid solu-
tion in commercial slaughterhouses was investigated. All
treatment combinations effectively reduced microbial
contamination (Sun-Jingxin et al., 2003).

The reduction of different indicator organisms on hot
cattle carcass surfaces was obtained by a combination of
steam with subsequent sanitizing treatments by warm
(55 °C) 2% lactic acid spray (Castillo, Lucia, Goodson,
Savell, & Acuff, 1999). The effect of the steaming fol-
lowed by lactic acid was effective for the surface decon-
tamination of beef carcasses also in our experiments
(Pipek et al., 2005a). At pork, higher microbial counts
can be expected on the skin after the scalding.

However, an efficient decontamination system should
reduce bacterial numbers without any detrimental
changes of the appearance of the carcass (James et al.,
2000). From these reasons, the possible effect of the
decontamination treatment on the surface colour must
be considered. Goksoy, James, Corry, and James
(2001) reported that heat treatment (<90 °C) is capable
to cause adverse changes in the skin-on chicken meat.

The treatment with lactic acid had only a negligible
effect on the colour (Pipek, Izumimoto, & Jeleníková,
2004), but some problems may arise from the hot steam
effect. However the steaming and lactic-acid treatment
had minimal effect on the appearance of beef carcass
surface. Moreover the most of pork carcass surface is
covered by skin, where these changes are not apparent
(Pipek, Šíkulová, Jeleníková, & Izumimoto, 2005b).

The steaming and lactic-acid treatment was proven to
be effective for the surface decontamination of beef and
pork meat under laboratory conditions, and also for the
decontamination of beef carcasses under industrial con-
ditions. The goal of this study was to verify the efficiency
of combination of hot steaming and spraying with the
lactic-acid solution for decontaminating pork carcasses
under industrial conditions over the whole storage peri-
od of five days.

2. Materials and methods

A new steaming nozzle for decontamination of pork
carcasses under industrial conditions was tested. The
reduction of microbial counts induced by steaming
and lactic acid was measured immediately after each
treatment. In the next phase, the storage experiment
was carried out and microbial growth evaluated during
the cold storage of pork carcasses. The attention was fo-
cused on psychrophilic microorganisms, the growth of
which is anticipated during the cold storage. The meso-
phile counts were also evaluated because of possible
occasional breaks of the cold chain.

2.1. Materials

Pig carcasses were decontaminated immediately after
dressing at the end of the slaughter line, i.e., nearly
30 min postmortem. The decontamination treatment
comprised hot steaming followed by spraying with the
lactic-acid solution. After both decontaminating proce-
dures, the carcasses were chilled in an air tunnel and
stored at chilling temperature of about +3 °C. Experi-
ments were carried out under industrial conditions in
two large Czech meat plants.

2.2. Steam

The steam treatment was carried out with a special
rectangular nozzle with dimensions of 100 mm by
1 mm. A strong jet of steam washed the surface of the
carcass. High pressure steam at 6 bar (plant A) and
4 bar (plant B) was used. The steam jet emerging from
the nozzle expanded to atmospheric pressure at nozzle’s
mouth reaching the temperature of 100 °C at this point.
Since the mouth’s distance from the carcass surface was
constantly kept at about 20 mm, jet’s temperature at this
point could be estimated at 90-95 °C and its height at
about 3 mm. The mean time of the steam action on
one individual site can be calculated from the jet’s thick-
ness and width, and the size of the treated area, and it
equals 0.013 s.

2.3. Lactic-acid solution

The 2% solution for decontamination was prepared
by diluting L(+)-lactic acid (Purac FCC 80, 80%, PUR-
AC biochem, Gorinchem Netherlands) in water. The
temperature of solution at the moment of treatment
was 45 °C. The solution was applied on the carcass surface by a manual sprayer (plant A) or by an automatic device (plant B).

3. Methods

3.1. Contamination and decontamination

For microbiological evaluation, skin samples were taken in the dishing over the shoulder where high surface contamination was anticipated. Only natural contamination was used in experiments. Only in the case of Experiment 3 the initial contamination was artificially increased by a solution prepared from the swabs from visually unclean parts of carcasses. The polyurethane foam roller was used for a homogenous increase of contamination of carcasses’ surface.

In all experiments, 10 pork carcasses were decontaminated by steaming and spraying with the solution of lactic acid and five carcasses were left untreated as control samples. Both treated and control carcasses were stored together.

The samples for microbiological analysis were taken from the same carcass before decontamination, after steaming, after treatment with lactic acid and then after 24, 48, 72, 96 and 120 h of cold storage. Control samples were taken from the opposite half of the same carcass.

3.2. Sampling of surfaces

Literature reports sampling made by swabbing or an excision. As the latter is reported to be the more effective sampling method for recovering and subsequently enumerating bacteria than sponge swabbing (Bacon, Sofos, Belk, & Smith, 2002), we preferred the method of abscission of the surface layer. We also expected the infiltration of microorganisms into the lower layers during subsequent storage experiment.

Three to 5 mm thick surface layer of the pork carcass (skin) including subcutaneous fat tissue was used for microbiological evaluation. The 40 × 40 × 5 mm samples were aseptically cut from the carcass surface, placed in plastic bags, chilled and immediately transferred to a microbiological laboratory.

The total counts of mesophilic microorganisms were determined according to the ČSN ISO 4833 standard. Each 10 g of sample were homogenised with 100 g of physiological solution and according to the expected microbial counts. One millilitre of diluted sample was placed on Petri discs and covered with 15 ml of PCA (plate count agar, temperature of 40–45 °C). After mixing, Petri discs were stored at a temperature of 37 °C. After 24 or 48 h of cultivation, the total counts were related to 1 g of the sample.

Total counts of psychrophilic microorganisms were determined the same way, only the cultivation was carried out on PCA agar for 72 h at 15 °C (ČSN ISO 560100 standard).

3.3. Statistics

Statistical analysis of the measured data was performed using Microsoft Excel, version 2002, at the significance level $P < 0.05$. The Student $t$-test between corresponding values was carried out. The values with indexes in the tables represent statistically significant differences.

4. Results and discussion

The new apparatus for steaming, a special nozzle, proved to be suitable for surface decontamination of pork carcasses. In all experiments, the decontamination treatment by steaming and lactic-acid spraying was effective in reducing the microbial counts on the surface of pork carcasses and in suppressing the microbial growth during storage. The effect of decontamination treatment on the reduction of microbial growth was affected by initial counts of microorganisms. Therefore, due to different initial contamination, there were differences in results achieved in two meat plants where the experiments took place.

4.1. Experiment 1 (plant A)

The decontamination results were affected by relatively low microbial counts due to a perfect hygiene in this factory. The treatment with steam caused a statistically significant reduction of microbial counts on the surface; the subsequent spraying with the lactic-acid solution increased (insignificantly) this reduction. The total decrease of microbial counts after the decontamination treatment can be estimated as one decimal order (see Figs. 1 and 2).

The average counts of mesophiles decreased from 200 to 40 g$^{-1}$ and those of psychrophiles from 1000 to 60 g$^{-1}$. It is evident that the microbial counts in this case were very low. During the subsequent cold storage, a microbial growth took place. It proves that the shelf-life of carcasses is prolonged and the effect of decontamination is apparent even after the five-day storage; by that time, the difference between the treated and control samples was two decimal orders for mesophiles (see Table 1) and almost three decimal orders for psychrophiles (see Table 2).

Although the immediate effect of the lactic-acid treatment was not statistically significant, the remaining lactate ions retarded the subsequent microbial growth and after 2 h of cold storage, even a reduction of
4.2. Experiment 2 (plant B)

This experiment was carried out in a plant, where the hygiene level was lower (the plant is not operating anymore), and the initial microbial counts were higher (see Figs. 3 and 4). In this case, the effects of steaming and spraying by lactic-acid solution were evaluated together. The immediate effect of the decontamination treatment was higher compared to Experiment 1. The total statistical significant differences between values within column and time.

**Table 2**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>7600 ± 371</td>
<td>37,780 ± 14,005</td>
<td>11,680 ± 3917</td>
</tr>
<tr>
<td>Steaming</td>
<td>395 ± 131</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steaming + LA spraying</td>
<td>145 ± 37.3</td>
<td>664 ± 417</td>
<td>170 ± 143</td>
</tr>
</tbody>
</table>

Microbial counts was observed (see also following experiments).

**Fig. 1.** The growth of mesophiles during storage of decontaminated pork carcasses in Experiment 1 (plant A).

**Fig. 2.** The growth of psychrophiles during storage of decontaminated pork carcasses in Experiment 1 (plant A).

**Fig. 3.** The growth of mesophiles during storage of decontaminated pork carcasses in Experiment 2 (plant B).

**Fig. 4.** The growth of psychrophiles during storage of decontaminated pork carcasses in Experiment 2 (plant B).
tically-significant decrease of microbial counts after decontamination treatment can be estimated at almost two decimal orders for both psychrophilic and mesophilic microorganisms. During the subsequent air-chilling cold storage, the microbial counts increased; at the end of the storage, the differences between the treated and control samples were higher than two decimal orders.

The differences can be found between the mesophilic and psychrophilic microorganisms. Although the effect of the decontamination treatment was similar in both microbial groups, the growth of psychrophiles during the cold storage was, as expected, steeper than that of mesophiles. The initial delay of microbial growth in treated samples can be ascribed to the effect of lactate ions from the decontaminating solution on the surface layer.

4.3. Experiment 3 (plant A)

The experiment was carried out again in the first meat plant but, unlike in Experiment 1, with artificially increased initial microbial counts on the surface of carcasses. Before the experiment, the surface contamination was intentionally increased by a solution of microorganisms.

The decontamination effect of steaming and treatment with lactic-acid solution on the surface of pork carcasses was proven also by this experiment (see Figs. 5 and 6). The statistically significant decrease in microbial counts was induced; during subsequent cold storage, the growth of both psychrophilic and mesophilic microorganisms occurred, that of psychrophiles having been faster. At the end of the monitored period, the difference between treated and control samples was more than two decimal orders.

Summarising results of all three experiments it can be concluded that the combination of both decontamination treatments, i.e., steaming and lactic-acid spraying, is effective. All four experiments proved that the action of hot steam in combination with lactic-acid solution reduced microbial counts on the surface of pork carcasses, and that this treatment retarded the microbial growth during the cold storage. In this way, the shelf-life of carcasses and meat can be significantly prolonged. As expected, the growth of psychrophiles was higher in comparison with mesophiles.

The effect is less conspicuous when the initial surface contamination is low. In other words, if the initial counts are higher, the effect of decontamination treatment is more evident. Similarly, Gill and Landers (2003) found out that when relatively high levels of bacterial contamination were present, washing reduced bacterial counts, but it had little effect at relatively low levels. Results suggest that washing, followed by an effective pasteurization treatment provides the maximal possible reduction in bacterial counts.

However, the purpose of decontamination is not to camouflage a poor hygiene. It should be regarded only as a measure to assure food (meat) safety in cases of occasional local increase of microbial counts or cooling chain breaks. But, even in good hygienic conditions, any (however small) reduction in microbial counts represents a prolongation of the shelf-life and an improvement of the food safety.

Another aspect worth considering is the risk subsequent transfer of microbes from the environment during boning, trimming and portioning of meat. Reduction of microbial counts is very important for production of packed retail meats. The lower the microbial input, the higher quality and longer shelf-life of meat packs can be expected.
The proposed decontamination process can be also used as a manual treatment of parts of carcasses visually evaluated as impure.

In comparison with beef, the surface contamination of pigs generally tends to be higher due to pollution risks during scalding and dehairing. On the other hand, surface singeing of carcasses often decreases microbial counts. In our study, pork carcasses were indeed more contaminated than carcasses of beef. Therefore the effect of surface decontamination was more conspicuous in case of pigs.

5. Conclusions

The decontamination of pork carcasses by steam and lactic acid reduced the surface microbial counts immediately after the treatment and retarded microbial growth during storage. The effect was better on more contaminated carcasses and also more conspicuous in comparison with beef carcasses. Such treatment can be used to prolong the shelf-life and to increase the safety of pork carcasses and meat.

Acknowledgement

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References


