# The effects of treating bovine hide with steam at subatmospheric pressure on bacterial numbers and leather quality

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## ABSTRACT

J.M. MCEVOY, A.M. DOHERTY, J.J. SHERIDAN, D.G. BAILEY, I.S. BLAIR AND D.A. MCDOWELL. 2003.

**Aims:** To examine the effect of subatmospheric steam treatment on total viable counts (TVCs) on bovine hide and on the quality of derived leather.

**Methods and Results:** Pieces of bovine hide were heated to 75°C (±2°C) ($n = 3$) or 80°C (±2°C) ($n = 3$) for periods of 1, 10 or 20 s by the application of steam at subatmospheric pressure in a laboratory scale apparatus. Treated hide pieces and untreated controls were tanned and the quality of leather was assessed. Treatment at 80°C (T80) reduced the TVC on hide pieces by 2·95 (1 s), 3·33 (10 s) and 3·99 (20 s) $\log_{10}$ CFU cm$^{-2}$ ($P > 0.05$). Treatment at 75°C (T75) reduced the TVC on hide pieces by 1·87 (1 s), 2·51 (10 s) and 2·56 (20 s) $\log_{10}$ CFU cm$^{-2}$ ($P > 0.05$). The grain on all treated hides was damaged resulting in sueding on derived leather. Sueding was observed on 100% of surfaces from T80-treated samples and on 18 (1 s) to 84% (20 s) of the surfaces of T75 samples.

**Conclusions:** The magnitude of TVC reductions achieved using T75 and T80 could limit the impact and scale of contamination transfer to the carcass during dehiding. However, because of the sueding observed on derived leather, it is unlikely that either T75 or T80 would be a commercially valid operation during routine slaughter operations.

**Significance and Impact of the Study:** Hide decontamination would provide an important critical control point for beef processing, however there are currently no commercially available treatments.

**Keywords:** beef, contamination, hide, leather, steam.

## INTRODUCTION

Current beef carcass decontamination treatments cannot guarantee the elimination of pathogens (Smith 1992; Phebus *et al.* 1997; Cutter and Dorsa 1999). Thus, efforts to improve food safety during slaughter and processing activities focus on the use of 'multiple hurdle' technology (Bacon *et al.* 2000) to reduce the incidence of pathogens to acceptable levels. The

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hide is a major source of contamination (Empey and Scott 1939; Bell 1997; Reid *et al.* 2002), hence a reduction of the initial bacterial loading on the hides of animals entering the slaughter process would limit the impact and scale of pathogen transfer from the hide to the carcass during hide removal.

Previously described methods to reduce pathogen numbers on bovine hide include chemical dehairing (Castillo *et al.* 1998) and washing (Byrne *et al.* 2000). More recently, a laboratory scale study found that steam condensing at subatmospheric pressure significantly reduced *Escherichia coli* O157:H7 numbers on bovine hide (McEvoy *et al.* 2001).

The effect of this treatment on the resident microflora and hide quality was not investigated.

Leather, produced by tanning of hide, is an important and economically valuable by-product of the slaughter process (Food and Agriculture Organization 2001). Thus any interventions designed to reduce or eliminate hide contamination must not adversely affect the commercial value or utility of the derived leather. However, heat treatments can damage elements of the bovine hide such as the (internal) corium and (external) grain layer (D.G. Bailey, personal observations). The corium of the hide provides structure and physical strength to leather. Damage to this layer, particularly heat damage, will result in weak and brittle leather. The grain layer is important in the surface appearance of leather products. Thus damage or removal of the grain layer will result in undesirable sueding on the surface of derived leather.

This study examined the effect of steam at subatmospheric pressures on bacterial numbers on bovine hide and on leather quality.

## MATERIALS AND METHODS

### Steam treatment equipment

The steam treatment equipment used in this study has been described previously (McEvoy *et al.* 2001). Briefly, it consisted of a process chamber to which a vacuum was applied to provide conditions under which steam, introduced from an external boiler, condensed at temperatures below 100°C. During treatment, the internal chamber pressure can be maintained between preselected values, enabling temperature control at ±2°C. Following treatment, evaporative cooling in the chamber was achieved at pressures of 1·2–2·0 kPa.

### Selection of hide

A section of approx. 1 m$^2$ including the area on either side of the backbone was taken from a bovine hide immediately after hide removal, transported to the laboratory, and stored at 2°C for up to 24 h. For each treatment, duplicate samples (18 × 10 cm) of hide were removed from matching positions on opposite sides of the backbone line.

### Preheating of the treatment chamber

The surfaces of the treatment chamber were preheated before insertion of hide samples. During preheating, the internal chamber temperature was continuously monitored using T-type thermocouples, fixed to the surface of the chamber base plate, and linked to a data logger (Squirrel wise Grant, Cambridge, UK). Steam was introduced into the process vessel through the steam inlet solenoid valve to raise the chamber surface temperature to 100°C. After 1 min at 100°C the steam inlet solenoid valve was closed and the chamber evacuated to a pressure of 1·2–2·0 kPa. The vacuum generated within the treatment chamber was then broken by flooding with air from the external atmosphere. Sample treatments were commenced within 3 min of the completion of preheating.

### Treatment definitions and parameters

Hide samples were subjected to treatments at 80°C (T80) or 75°C (T75), for 1, 10 or 20 s. For clarity, the notation used to describe individual treatments is 'treatment type/treatment duration', thus treatment at 80°C for 10 s is reported as T80/10 and treatment at 75°C for 1 s is reported as T75/1. The target cool-down temperature was set at 60°C.

### Treatment

One of each pair of hide samples was suspended from a support bar in the process vessel using bulldog clips. The condensed vapour temperature in the chamber was monitored using three T-type thermocouples attached to the surface of a PTFE block placed beside the hide sample. Vacuum was applied to reduce the internal pressure in the chamber to 1·2–2·0 kPa. Steam was introduced to raise the temperature to the target, i.e. 80 ± 2°C (T80) or 75 ± 2°C (T75). The time taken to reach the target temperature was approx. 10 and 6 s for T80 and T75 treatments, respectively. Treatment intervals (1, 10 or 20 s) were measured from the point at which the target temperature was reached. The target temperature was maintained (±2°C) for the duration of the treatment interval. After each treatment interval, the vessel was cooled by evacuation as previously described. The time taken to cool the samples to 60°C was approx. 10 and 5 s for T80 and T75 treatments, respectively. Hide samples were removed aseptically and examined as described below. All T80 treatments were replicated three times. All T75 treatments were replicated three times, in duplicate.

### Microbiological analysis

Before and after treatment, the entire surface of hide samples were swabbed with cotton=tipped swabs by the wet and dry swab technique (Anon. 1993). Swabs were suspended in 9 ml of maximum recovery diluent (MRD) (Oxoid Ltd, Basingstoke, UK) and stored at 2°C for up to 4 h. Total viable counts (TVC) were obtained by duplicate spread plating of 0·1 ml of MRD suspensions, or derived 1 : 10 dilutions in MRD, onto standard plate count agar (Oxoid). Plates were examined following incubation at 25°C for 72 h.

## Hide tanning

Steam-treated hide samples and untreated control samples were vacuum packed with approximately half their weight of sodium chloride, and transported to the United States Department of Agriculture, Agricultural Research Service (Eastern Regional Research Service, Wyndmoor, PA, USA). The hide samples were processed in accordance with normal tanning practices, visually inspected and graded by experts in leather production.

## Statistical analysis

ANOVA was performed on TVCs using Instat Version 3, Graph Pad (Instat Biostatistics, San Diego, CA, USA). Significant differences were determined at the 5% level of significance ($P < 0.05$).

## RESULTS

The results for T80- and T75-treated samples are presented in Table 1. For T80-treated samples, the time taken to raise the chamber temperature to 80°C, treat the hide for 1, 10 or 20 s and reduce the temperature to 60°C resulted in overall process durations of 19, 26 and 41 s, respectively. For T75-treated samples, the overall process durations to raise the chamber temperature to 75°C, treat the hide for 1, 10 or 20 s, and reduce the temperature to 60°C were 12, 21 and 31 s, respectively.

Treatments at 80°C resulted in significant TVC reductions of 2·95 (1 s), 3·33 (10 s) and 3·99 (20 s) $\log_{10}$ CFU cm$^{-2}$ from initial levels of 4·83–5·39 $\log_{10}$ CFU cm$^{-2}$ ($P < 0.05$) (Table 1). There were no significant differences among the reductions in TVCs obtained during the different treatment durations.

Treatments at 75°C resulted in significant TVC reductions of 1·87 (1 s), 2·51 (10 s) and 2·56 (20 s) $\log_{10}$CFU cm$^{-2}$ from initial levels of 4·72–4·93 $\log_{10}$ CFU cm$^{-2}$ ($P < 0.05$) (Table 1). There were no significant differences among the reductions in TVCs obtained during the different treatment durations.

T80/10 resulted in significantly greater TVC reduction than T75/1 ($P < 0.05$). TVC reductions achieved using T80/20 were significantly greater than those using T75/1, T75/10 and T75/20 ($P < 0.05$).

Visual inspection of leather derived from treated samples revealed no damage to the corium layer, and the leather appeared superficially similar to leather from untreated hide. However, damage to the grain was observed, which resulted in sueding. This effect was noted over 100% of the surfaces of all T80-treated samples. Sueding was observed over 18, 83 and 84% of the surfaces of T75 samples treated for 1, 10 and 20 s, respectively (Table 1).

## DISCUSSION

This study has established that a relatively brief treatment with subatmospheric steam can achieve significant reductions in bacterial numbers on bovine hides. The TVC reduction achieved for T80/10 (3·3 $\log_{10}$ CFU cm$^{-2}$) was similar to the 3·4 $\log_{10}$ CFU cm$^{-2}$ reduction reported in a study using chemical dehairing to decontaminate bovine hide (Castillo *et al.* 1998).

The magnitude of the TVC reduction following T80/20 was approx. 4 log cycles. This is in agreement with previous findings, in which a similar steam treatment reduced the numbers of *E. coli* O157:H7 inoculated onto bovine hides by 4–6 log cycles (McEvoy *et al.* 2001). While differences between the sampling methods used in the previous study (McEvoy *et al.* 2001) and the present study prevent direct

**Table 1** Heat treatment parameters and their effects on total viable counts (TVCs) and leather quality

| Treatment target temperature (°C) | 80 | | | 75 | | |
|---|---|---|---|---|---|---|
| **Time (s)** | | | | | | |
| At target | 1 | 10 | 20 | 1 | 10 | 20 |
| Heat up | 9 | 10 | 10 | 6 | 6 | 6 |
| Cool down (to 60°C) | 9 | 6 | 11 | 5 | 5 | 5 |
| Total | 19 | 26 | 41 | 12 | 21 | 31 |
| **TVC ($\log_{10}$ CFU cm$^{-2}$) (±S.E.)** | | | | | | |
| Before | 4·83 (±0·62)[a] | 5·02 (±0·65)[a] | 5·39 (±0·56)[a] | 4·72 (±0·31)[a] | 4·93 (±0·24)[a] | 4·81 (±0·20)[a] |
| After | 1·88 (±0·61)[b] | 1·69 (±0·56)[b] | 1·40 (±0·16)[b] | 2·85 (±0·47)[b] | 2·42 (±0·25)[b] | 2·20 (±0·12)[b] |
| Difference | 2·95 (±0·17)[123] | 3·33 (±0·34)[12] | 3·99 (±0·43)[1] | 1·87 (±0·23)[3] | 2·51 (±0·14)[23] | 2·56 (±0·11)[23] |
| **Leather damage** | | | | | | |
| Corium | No damage | No damage | No damage | No damage | No damage | No damage |
| Sueding (%) | 100 | 100 | 100 | 18 | 83 | 84 |

Different superscripted letters and numbers denote significant differences.

comparison of the results obtained, it might have been expected that the resident TVC in the present study would be more resistant to the heat treatment than the *E. coli* O157:H7 culture inoculated directly onto the hide surface in the previous study. In general, environmentally adapted bacteria, e.g. bacteria surviving on the less nutrient-rich surface of beef hides are more difficult to eradicate than cultures grown in nutrient-rich conditions prior to inoculation (Rees *et al.* 1995).

Reductions in TVCs during all T75 treatments were significantly less than the reductions during T80/20 treatment. However, the TVC reductions of *ca* 2 log cycles for T75 treatments compare favourably with the *ca* 1 log cycle TVC reduction following steam treatment of dressed washed carcasses (Nutsch *et al.* 1998). While it is acknowledged that hide decontamination as reported in this study is not a direct edible tissue decontamination strategy, the magnitude of reductions reported following T75 and T80 treatments should nonetheless limit the scale of bacterial transfer to the carcass during hide removal operations. This would provide a useful hurdle in addition to those already being used as part of a multiple hurdle approach to reduce the incidence of contamination on carcasses (Dickson and Anderson 1992; Dorsa 1997; Sofos and Smith 1998).

All treated hide pieces in the present study had a damaged grain layer that resulted in sueding of leather. Leather manufacturers regard sueding as a critical defect. Therefore it is unlikely that any of the treatments reported in the present study would be commercially viable in routine slaughter operations. Given that the extent of sueding was less at 75 than 80°C and less at T75/1 than T75/10 or T75/20, further reductions in temperature or overall treatment duration may provide conditions under which the hide is not damaged and leather will not have a sueded appearance. Bacterial reductions at lower time/ temperature combinations could be augmented by the application of chemical decontaminants prior to steam treatment. In a laboratory study (Ward *et al.* 2000), a synergistic effect using 0·2 M lactic acid in combination with subatmospheric steam to decontaminate carcass meat was demonstrated.

In conclusion, this study has demonstrated that although subatmospheric steam treatment at 75 or 80°C can significantly reduce general levels of bacterial contamination on bovine hide, the current process does include disadvantages in terms of reduced quality in derived leather products. Thus, while such treatment may contribute useful reductions as an additional hurdle within a multiple hurdle approach to reduce carcass contamination, it is unlikely to become part of current routine abattoir processes.

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