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The production and microbiological status of skin-on sheep carcasses

Alan Fisher [a,*], Carol-Ann Wilkin [a], Graham Purnell [b]

[a] Division of Farm Animal Science, Department of Clinical Veterinary Science, University of Bristol, Langford, Somerset BS40 5DU, United Kingdom
[b] Food Refrigeration and Process Engineering Research Centre, Faculty of Engineering, University of Bristol, Langford, Somerset BS40 5DU, United Kingdom

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Abstract

There is a demand by certain ethnic consumer groups in the United Kingdom for skin-on, singed carcasses, primarily from older sheep, but their production is illegal under current EU legislation. The aim of this study was to devise a protocol to produce carcasses having the desired 'smoked' colour and odour and an acceptable microbiology. A successful result could form the basis of a case to revise the legislation. Three key steps in the selected procedure were carcass singeing using specially designed gas burner equipment, pressure washing to clean the carcass and then evisceration. It was shown that a second heat application, termed 'toasting', if applied after evisceration, significantly ($P < 0.001$) reduced *Enterobacteriaceae* and TVC counts on carcasses before chilling. Microbiological quality was also improved when toasting was the final step, following carcass splitting and inspection. Carcasses produced in this way had significantly ($P < 0.001$) lower *Enterobacteriaceae* and TVC counts before chilling than conventionally dressed sheep carcasses produced in the same abattoir.

Keywords: Sheep; Skin-on carcass; Singeing; Microbiology

1. Introduction

In some regions of the world, such as parts of West Africa, it is common practice to place a carcass of a food animal directly on, or over, a fire to burn off the hair and singe the skin. In addition to removing unwanted hair, this burning imparts a smoked flavour to the meat and browns the surface, these being regarded as desirable qualities. Several mammalian species are prepared in this way but the most commonly used is probably the goat (*Capra hircus*). Demand for these skin-on, singed products by several ethnic groups resident in the United Kingdom is evident and may well occur in other European countries. However, current EU legislation prohibits the production of ruminant carcasses with the skin left on and flaying during the dressing procedure is a statutory requirement (EC, 2004). This conflict, between demand and legality, has resulted in a black market for these products and it is sheep, predominantly, that have been used as the source material. Slaughter normally takes place in remote farm outbuildings and anecdotal and media reports indicate that the carcasses are singed with gas blowtorches to burn off the wool and brown the skin. The buildings used probably lack the necessary facilities for hygienic meat preparation and the personnel are unaware of hygiene requirements (Food Standards Agency, www.food.gov.uk/multimedia/pdfs/scotsmokies-guidance.pdf). Thus, there are concerns that some animals may be diseased, that there is no meat inspection and that spinal cord is not removed from older sheep as required. In addition to hygiene concerns there are welfare issues, particularly with regard to the stunning and slaughter of animals on-farm.

The fleece of a sheep is a primary vehicle for the introduction of contamination to the slaughterhouse (Koohmaraie et al., 2005) and 27 species of bacteria have been identified as colonising the fleece (Meyer, Neurand, &

* Corresponding author. Tel.: +44 0117 9289271; fax: +44 0117 9289324.
E-mail address: alan.fisher@bristol.ac.uk (A. Fisher).

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Tanyolac, 2001). Shearing, which may be done immediately after bleeding-out the carcass, significantly lowers carcass contamination (Schroder & Ring, 1998). The number of microorganisms remaining on the skin of a sheep carcass after wool removal is likely to be dependent on the method employed and may be dramatically influenced if a technique such as singeing is used. However, there is very little information on the microbiology of skin-on sheep carcasses after such interventions have been made. A study of goat carcasses in Australia (Vanderlinde, Duffy, & Barlow, 2003) concluded that differences between skin-off and skin-on carcasses, in the numbers of *E. coli* and *Salmonella* present, were of negligible biological significance and there was no greater risk to human health posed by skin-on than skin-off carcasses. Some other information of likely relevance does exist for pig carcasses for which singeing or flaming is a commonly practised procedure in carcass dressing. The pig carcass has already been scalded and largely dehaired by the time it reaches the singeing stage so may not be directly comparable to that of sheep whose wool is removed by burning. However, singeing *per se* has been shown to reduce pathogenic bacteria on pigs by two orders of magnitude (Gill & Bryant, 1993).

An approved procedure for the production of skin-on sheep carcasses that have acceptable microbiological status would be beneficial to the sheep industry and would be welcomed by specific consumer groups. The specific aim of this study was to devise a sequence of procedures (protocol) necessary to produce a carcass having the required microbiological status and desired appearance.

2. Material and methods

2.1. Animals

All the animals used in the carcass production trials were supplied by the same producer and were females, over 12 months of age and were from the Shetland breed, either purebred or crossbred. This breeding gave rise to a range of coat colour, from all white, through white/grey, to black. All sheep were shorn within a week of slaughter so that the wool length was approximately 5 mm.

Animals were conventionally stunned electrically and slaughtered. The hind feet were removed at the tarsus to prevent surface contamination from the feet being transferred to the more proximal limb and trunk regions of the carcass during washing.

2.2. Carcass processing

Preliminary trials showed that singeing with a naked-flame gas (propane) burner was the best method for removing wool (compared with hot water scalding or hot air singeing) and it also produced the required 'smoked' appearance and aroma.

In order to achieve consistent singeing, a purpose-built, automated, experimental singeing equipment was constructed (Fig. 1). Briefly, this consisted of a ring of eight inwardly directed gas burners attached to a supporting octagonal ring that moved up and down around a suspended carcass. The burner ring was chain driven by a DC motor controlled by a small programmable logic controller. Adjustable microswitches on the support structure controlled the stroke end positions. A single skinned hood was built above the rig to collect rising heat and fumes and was connected to a large displacement extractor fan (600 mm diameter) using flexible ducting.

A satisfactory degree of wool singeing was achieved by three complete cycles of burner ring travel, i.e. three down-up passes (the parked, home position of the ring is at the top of its travel). Following singeing, charred wool remains were removed from the carcass surface using a pressure washer (Karcher HDS 895DB coupled to an Alto short lance). The water temperature was a nominal 50 °C.

It was decided, *a priori*, that singeing should precede evisceration of the carcass for two reasons: evisceration requires the release of the bung end and splitting of the belly and breast, thus exposing meat in the anal and ventral regions (exposed meat undergoes some cooking during singeing as it is not protected by skin); washing an eviscerated carcass introduces the risk of contamination of internal carcass surfaces. The three pillars of the dressing procedure, and their order of execution, had therefore been defined on the basis of preliminary trials and considerations of practicality: singe, wash, eviscerate. This is referred to as the *basic protocol*. Using this as a starting point, the aim was to see how other procedures, some of them necessary to comply with current slaughter and dressing regulations, affected the microbiological status of the carcass and to recommend, on the basis of these results, the optimum sequence of interventions.

2.3. Treatment comparisons

2.3.1. 'Toast' versus 'no toast'

Carcasses emerging from the basic protocol were wet and had been handled after singeing in order to perform evisceration. Although quite well browned overall, carcasses occasionally had some areas that required further heat treatment. Exposure of the carcass to a further, single

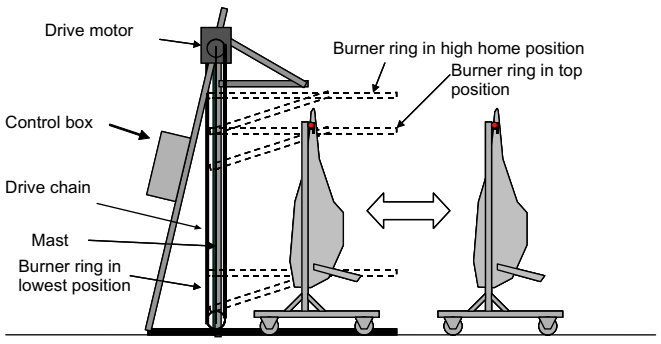

Fig. 1. A schematic diagram of the singeing equipment, viewed from the side.

cycle of the burner ring travel was therefore examined, the aim being to dry the carcass, impart an additional degree of browning and, possibly, improve its microbiological status. This additional exposure to the gas flame post-evisceration was termed 'toasting' to distinguish it from the previous singeing. Twenty carcasses were prepared according to the basic protocol, with 10 of these receiving an additional toasting. Skin samples were excised from each carcass for microbiological analysis.

Additional samples for microbiology were also removed from these carcasses after a storage period under refrigeration to establish if the procedure for skin-on processing affected the skin, such that it had enduring properties that suppressed (or encouraged) microbial growth. The carcasses were stored in a chiller at 2–4 °C for a period of 5 days. After this time, additional skin samples were removed from sites adjacent to those sampled prior to chilling.

2.3.2. Splitting the carcass before or after the toasting intervention

For economic, cultural and, indeed, organoleptic reasons, the animals of choice for the production of skin-on carcasses are likely to be older than those used for prime lamb, cull ewes being an obvious category. TSE control measures require that following the slaughter of sheep with one or more permanent incisors present, either the vertebral column has to be removed or the carcass has to be split and the spinal cord removed. Cord removal may take place in the slaughter hall and the additional handling and contact with equipment may introduce contamination. This trial was conducted to determine whether measurably greater microbial contamination occurred on carcasses toasted before splitting compared with carcass sides toasted after splitting. Ten carcasses, produced according to the basic protocol, were split and then toasted; another 10 were similarly produced, toasted and then split. Skin samples were excised from each carcass for microbiological determination.

2.3.3. Carcass inspection before or after toasting

Although current thinking on meat inspection is tending to favour a risk-based approach, this is not applicable to older animals where there is a greater likelihood of them carrying particular diseases. Carcasses destined for a (putative) skin-on trade will continue to be inspected individually and such inspection will entail at least some palpation (to locate inoculation lesions). This trial was conducted to determine whether the handling necessary to conduct a carcass inspection using current procedures results in a measurably different microbial contamination when performed before or after toasting. Twenty carcasses were processed in three separate lots. Two meat inspectors, working for the UK Meat Hygiene Service, were used to perform the carcass inspections in their customary ways. Lot 1 (eight carcasses) was inspected by Inspector A who confined the inspection to a visual and palpatory examination. Inspector B examined Lots 2 (eight carcasses) and 3 (four carcasses) and, as well as performing some palpation, incised the joints of the hind limbs. Within each lot, half the carcasses were produced according to the basic protocol, toasted and then inspected; the other half were similarly processed but inspection preceded the toasting step. Skin samples were excised from each carcass for microbiological determination.

2.3.4. Comparison of skin-on and conventionally dressed carcasses

The results of the three comparisons described above were used to formulate a *best practice* protocol. The microbiology of carcasses produced according to this protocol was compared with that of carcasses produced according to conventional dressing practice (skin removed) in the same abattoir, on the same day. Ten carcasses were produced according to each method; skin samples excised from the singed carcasses and matching samples of superficial tissues excised from the conventional carcasses were subjected to microbiological analysis.

Additional microbiological measurements were made on the carcasses after chilling them at 2–4 °C for a period of 5 days. Sites sampled were adjacent to those sampled prior to chilling.

2.3.5. Microbiological sampling and measurement

The approach to quantifying microbiological contamination of the carcasses in this study was based on European Commission Directive EU/471/2001 (EC, 2001) which specifies methods for quantifying aerobic colony counts and *Enterobacteriaceae*. Sites on the carcass, additional to those specified in the Directive, were sampled and a total of six per carcass were identified as those most likely to be contaminated (e.g. close to cuts made to open body cavities) and which also were widely distributed over the carcass surface. These were the rump, belly, flank, brisket, shoulder and neck. Sites were randomly allocated to the carcass left/right sides. Each site was sampled using the excision method, as previous studies had identified a better recovery using this method (Hutchison et al., 2005). Each sample was defined by cutting a 5 cm^2 circle in the skin using a cork borer that had been disinfected with an azowipe (Jencons, UK), and removal completed using a sterile scalpel and forceps to lift the piece of circumscribed skin. The skin samples were transferred aseptically to a labelled, sterile stomacher bag and stored on ice during transportation to the laboratory, with the sample from each site being kept separate. In the comparison with conventionally prepared carcasses, corresponding samples from the latter comprised subcutaneous fat and/or the thin, superficial muscle *cutaneous trunci* and were treated in the same way as the skin samples. All samples were kept chilled prior to microbiological testing for *Enterobacteriaceae* (faecal contamination), and total viable counts (TVC, general contamination).

Twenty-five millilitres of Maximum Recovery Diluent (MRD; Oxoid, UK) were added to each stomacher bag

and each bag was stomached for 2 min to release bacteria from the surface. This was designated the original sample. Each sample was further serially diluted in MRD. All dilutions were plated onto Plate Count Agar (PCA; Oxoid, UK) and onto Violet Red Bile Glucose agar (VRBG; Oxoid, UK) using the 1 ml pour plate method, to examine for TVC and *Enterobacteriaceae*, respectively. Once set, plates were incubated at 37 °C for 24 h (VRBG) and 30 °C for 72 h (PCA).

All colonies on the PCA plates were counted, and only the dark pink/purple colonies counted on the VRBG. For each sample, the CFU/cm^2 for TVC and *Enterobacteriaceae* were calculated. The minimum detection level for each of the two groups of organisms was 5 CFU/cm^2.

2.3.6. Statistical analysis

Data points are represented by overall carcass means from four independent experiments. Microbial count data were analysed using analysis of variance (ANOVA) performed with Minitab version 14. A value of 2.5 CFU/cm^2 (half the threshold value) was used for counts below the minimum detectable level. The application of treatments (toast versus no toast, splitting before or after toasting, carcass inspection before or after toasting, conventional versus skin-on) was used as the factor.

3. Results and discussion

Results for individual carcasses and sites are not shown but comments on matters of interest are made in the text, e.g. maximum differences between treatments, proportion of total sites below the detectable level.

3.1. Effect of including a toasting step after evisceration

The microbiological results of the comparison between singed, skin-on carcasses and similar carcasses that were also toasted, are shown in Tables 1 and 2 for *Enterobacteriaceae* and TVC, respectively, for carcasses pre-chill.

The carcasses that did not have the final toasting step applied had higher site mean *Enterobacteriaceae* (up to 1.1 log units more) and TVC (up to 2.5 log units more) counts, pre-chill, than those which had undergone the final toasting step. Only one carcass (out of ten) had detectable levels of *Enterobacteriaceae* immediately after toasting, and then in just three of the six carcass sites examined, with a maximum count of 40 CFU/cm^2. This contrasts with the non-toasted carcasses of which every one had detectable levels of *Enterobacteriaceae* on at least one carcass site and just under one half (24) of the total 60 samples (10 carcasses × six sites) had detectable levels of *Enterobacteriaceae*. Toasted carcasses had detectable levels of TVC on 29 out of the total 60 sites, compared with 56 for the non-toasted carcasses.

On seven of the ten non-toasted carcasses, the sample sites which had the highest *Enterobacteriaceae* counts were either the belly or the brisket; no site had consistently the highest TVC counts on these carcasses.

Carcass chilling (data not shown) tended to reduce numbers of *Enterobacteriaceae* on the toasted carcasses and it significantly ($P < 0.001$) reduced counts on the non-toasted carcasses (by approximately 0.4 log units/cm^2). Non-toasted carcasses had significantly higher levels of TVC than toasted ones, both before and after chilling, so the extra heat treatment had a lasting effect on total bacterial numbers. Although chilling reduced site bacterial numbers overall, the TVC counts on the belly showed some increases in numbers after chilling, particularly on the toasted carcasses (eight of the ten carcasses), with increases of up to two log units.

Clearly, there is a degree of microbial re-contamination of the carcass during evisceration but the toasting step reduces this by a substantial degree. Toasting is a recommended step in the process.

3.2. Effect of splitting the carcass before or after toasting on its microbiology

The counts ($\log_{10}$ CFU/cm^2) of both *Enterobacteriaceae* (Table 1) and TVC (Table 2) were low, overall, on carcasses from both treatments. The difference between treatments in numbers of *Enterobacteriaceae* was not significant. However, differences in TVC were significant ($P = 0.003$) and counts at some sites on the carcasses that were split after toasting were up to one log unit more than on those split before toasting, with the brisket area showing the highest bacterial counts on these carcasses (Table 2).

There was little difference between the treatments in the number of sites with undetectable *Enterobacteriaceae*, being 53 out of a possible 60 for those split before toasting and 50 of 60 for those split after toasting. However, for TVCs, the difference between treatments was greater, with undetectable returns being 36 and 19 out of a possible 60, for splitting before and after toasting, respectively.

It is concluded that the additional handling required to split the carcass does introduce a small amount of additional contamination to a toasted carcass that has low initial levels of contamination. It is recommended that splitting be performed prior to the toasting step. To avoid partial cooking of the carcass tissues exposed after splitting, it may be preferable to configure the gas burners so that the medial surface of the carcass is not directly flamed (this was not done in the described trials).

3.3. Effect of inspecting the carcass before or after toasting on its microbiology

As in the time of splitting comparison, the overall levels of microbial contamination were low and there was no difference in numbers of *Enterobacteriaceae* when carcasses were inspected before or after inspection ($P = 0.833$, Table 1). TVCs were clearly more prevalent on the carcasses inspected after toasting and the mean difference was highly significant ($P = 0.004$). There were 20 occurrences of counts of 2–5 log units compared with nine occur-

Table 1
The effects of toasting *per se*, toasting before or after splitting and inspection, and skin-on or conventional dressing, on the mean number ($\log_{10}$ CFU/cm^2) of *Enterobacteriaceae* at six carcass sites, and overall

Comparison	Neck	Flank	Shoulder	Belly	Brisket	Rump	Overall
No toast	1.129	0.488	0.656	1.551	1.559	0.398	0.964
Toast	0.518	0.398	0.398	0.398	0.428	0.458	0.433
Sed							0.123
Significance							<0.001
Toast before splitting	0.850	0.398	0.398	0.398	0.939	0.428	0.569
Toast after splitting	0.698	0.398	0.428	0.398	0.736	0.398	0.509
Sed							0.074
Significance							0.427
Toast before inspection	0.536	0.398	0.398	0.428	0.428	0.428	0.424
Toast after inspection	0.518	0.488	0.398	0.398	0.398	0.398	0.429
Sed							0.022
Significance							0.833
Skin-on	0.498	0.398	0.428	0.398	0.398	0.398	0.420
Conventional	0.747	0.884	0.814	1.529	1.035	0.722	0.955
Sed							0.105
Significance							<0.001

Standard errors (sed) of the means and the significance of the difference between compared means are shown for the carcasses overall.

Table 2
The effects of toasting *per se*, toasting before or after splitting and inspection, and skin-on or conventional dressing, on the number ($\log_{10}$ CFU/cm^2) of TVC at six carcass sites, and overall

Comparison	Neck	Flank	Shoulder	Belly	Brisket	Rump	Overall
No toast	2.962	2.325	2.437	3.589	3.259	1.558	2.689
Toast	1.203	0.665	1.292	1.122	0.859	0.825	0.994
Sed							0.187
Significance							<0.001
Toast before splitting	1.567	1.545	0.639	1.574	2.715	1.230	1.545
Toast after splitting	1.434	0.785	0.637	0.566	1.910	0.398	0.955
Sed							0.191
Significance							0.003
Toast before inspection	2.133	1.187	1.211	1.836	1.548	1.381	1.524
Toast after inspection	1.931	0.858	0.704	0.679	0.910	0.766	0.959
Sed							0.192
Significance							0.004
Skin-on	1.120	0.876	1.055	0.686	0.693	0.666	0.850
Conventional	3.119	3.415	2.717	3.549	2.764	2.100	2.944
Sed							0.135
Significance							<0.001

Standard errors (sed) of the means and the significance of the difference between compared means are shown for the carcasses overall.

rences of counts of 2–3 log units on carcasses inspected before toasting.

The highest levels of contamination were seen on the neck region, for both *Enterobacteriaceae* and TVC and in both treatments. This probably reflects the inclusion of some larger (longer) carcasses in this comparison whose neck region was not completely singed nor toasted because the lower limit of burner travel in the rig was set too high.

There was no appreciable difference between the treatments in the number of sites with undetectable *Enterobacteriaceae*, being 56 out of a possible 60 for those inspected before toasting and 54 of 60 for those inspected after toasting. For TVC, the difference between treatments was greater, with undetectable returns being 32 and 21 out of a possible 60, for inspection before and after toasting, respectively.

It is recommended that inspection precedes toasting.

3.4. Comparison of microbial status between conventionally produced and skin-on sheep carcasses produced according to the evolved protocol

Based on all the previous results, a best practice protocol emerged in which the sequence of individual steps was: remove feet, singe, wash, eviscerate, remove head, split carcass, inspect, toast. In order to demonstrate the microbiological quality of carcasses produced according to this protocol, comparisons were made with carcasses

dressed conventionally in the same abattoir. The comparison was between a skin sample and a 'flesh' sample and it is not known if the microbiological method used, particularly the stomaching stage, would release bacteria equally from the two types of tissue. However, it was considered that there was unlikely to be much bias as other studies in our laboratory (unpublished), examining the efficacy of different interventions to reduce bacteria on cattle hides, showed that high recovery of marker bacteria (including one 100% recovery) were obtained after stomaching skin samples.

The results of the comparison are shown in Table 1 (*Enterobacteriaceae*) and Table 2 (TVC) for carcasses immediately post-preparation (pre-chill). The conventional carcasses had higher *Enterobacteriaceae* numbers on the sites sampled, with a minimum mean value of 0.7 log unit (rump site) compared with a maximum of 0.5 log unit for the skin-on carcasses (neck site). The belly and brisket sites were the most heavily contaminated by *Enterobacteriaceae* in the conventionally dressed carcasses, a finding in agreement with Zweifel and Stephan (2003), but corresponding counts on the skin-on carcasses were not at detectable levels (Table 1). In total, there were 58 of the possible 60 counts of *Enterobacteriaceae* below detectable levels in the skin-on carcasses compared with 34 of 60 in the conventionally dressed carcasses. Corresponding ratios for TVCs were 35:60 and 5:60, respectively.

Chilling reduced counts of both groups of bacteria on conventional carcasses by approximately 0.4 log units/cm^2 ($p < 0.05$) but had no effect on the skin-on carcasses.

3.5. Overall evaluation of procedure

The overall objective of this study was to determine if skin-on sheep carcasses could be produced to an acceptable microbiological standard and comparison with conventionally dressed carcasses is one way of making that judgement. Microbiological monitoring in many studies of sheep carcass contamination have used total aerobic counts as an overall index of hygienic status and potential storage life, and either *Enterobacteriaceae* or *E. coli* as indicators of faecal contamination (and hence, indirectly, pathogens) (Biss & Hathaway, 1995, 1996; Byrne, Dunne, Lyng, & Bolton, 2007; Whyte et al., 2002). Typical levels on lamb carcasses dressed conventionally (i.e. skinned) range between 3.9–4.4 and 0.9–1.5 $\log_{10}$ CFU/cm^2 for TVC and *E.coli*, respectively (Whyte et al., 2002). However, counts are quite dependent on the cleanliness of the animals when presented for slaughter (Byrne et al., 2007; Hadley, Holder, & Hinton, 1997). The log counts of both *Enterobacteriaceae* and TVC on the conventionally dressed carcasses in the comparison with skin-on carcasses in the present study were representative of good practice, mean values lying within the 'acceptable' range specified in the EC HACCP Regulation (EC, 2005) (*Enterobacteriaceae* < 1.5, TVC < 3.5). These counts therefore set a desirable baseline that the skin-on carcass should emulate. Skin-on carcasses, produced according to the best practice protocol, surpassed these targets, having approximately 0.5 log units *Enterobacteriaceae* and 2 log units TVC CFU/cm^2 less ($p < 0.001$) overall.

Clearly the toasting step itself is an important operation and although inclusion of it as a final step, after splitting and inspection, did not further reduce the already low levels of *Enterobacteriaceae*, including it at the end of the dressing process did significantly reduce TVC and is therefore recommended. The counts after toasting in the four comparisons in this study showed a high degree of similarity, those of *Enterobacteriaceae* being around 0.4 log units and those of TVC around 0.9 log units/cm^2.

4. Conclusions

This study shows that skin-on sheep carcasses that meet consumer requirements can be produced to an acceptable hygienic status using the described methods.

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