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Effects of hygienic treatments during slaughtering on microbial dynamics and contamination of sheep meat

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ABSTRACT

The aims of this study were to investigate bacterial dynamics in the sheep meat chain, from fleece to meat trimmings, using both quantitative and qualitative analyses, and to study the effects on microbial load associated with the hygienic interventions of: i) shearing sheep immediately before slaughter, ii) manual steam vacuum pasteurisation, iii) hot water pasteurisation of carcasses, followed by iv) chilling. A further aim was to provide evidence to determine whether or not unshorn sheep should be handled in a processing line separate from that of shorn sheep in Norwegian abattoirs. A total of 176 surface swab samples were collected from three sites along the value chain: i) on fleeces, ii) on carcasses at the end of the slaughter line, and iii) on carcasses after chilling for 24 h, and 32 samples were collected from meat trimmings. The results showed that Aerobic Plate Counts (APC) were lower for the shorn group compared to the unshorn group, both on carcasses before chilling and after chilling (difference of 0.8 and 0.9 log CFU/1000 cm^2 ($p \leq 0.05$), respectively) and in meat trimmings (difference of 0.5 log CFU/g ($p \leq 0.05$)). Hygienic treatments were used on carcasses derived from unshorn sheep, and steam vacuum treatment reduced *Escherichia coli*, *Enterobacteriaceae*, and APC before chilling by 1.2, 1.0, and 0.6 log CFU/1000 cm^2 ($p \leq 0.05$), respectively, and hot water pasteurisation, in addition to chilling, reduced *E. coli*, *Enterobacteriaceae*, and APC by 0.7, 1.0, and 0.9 log CFU/1000 cm^2 ($p \leq 0.05$), respectively, compared with untreated carcasses. The effect of chilling was shown by the significant reduction of number of carcasses where *E. coli* were detected; from 65% (13/20) of the shorn group before chilling to 35% (7/20) after chilling, and from 90% (36/40) to 45% (9/20) of the unshorn group. Sequencing of the 16S rRNA gene derived from 316 colonies of *Enterobacteriaceae* showed a tendency for the relative proportion of the genus *Escherichia/Shigella*, compared with other genera within *Enterobacteriaceae*, to be greater for unshorn, untreated sheep than from the other groups at the sampling locations along the meat chain. The study showed that steam vacuum and hot water pasteurisation reduced the contamination of carcasses derived from unshorn sheep, down to the level of the shorn group, and thus can replace the separate processing line for unshorn sheep. Indeed, the low microbial contamination in meat trimmings for all groups indicates that the separate processing line is unnecessary.

1. Introduction

Various hygienic treatments and procedures are often applied during slaughtering, dressing and storage, in order to minimise sheep carcass contamination. Mandatory shearing before slaughtering, to ensure that clean sheep are presented for slaughter, has been implemented in Ireland (Byrne et al., 2007), UK (Food Standards Agency, 2007), New Zealand (Biss and Hathaway, 1995), and Norway (Hauge et al., 2011a). Hauge et al. (2011a) reported that lambs with visually clean fleeces had lower levels of Aerobic Plate Counts (APC) on carcass surfaces after skinning than those categorised as dirty. The Norwegian national guidelines for good hygienic slaughter practices, based on article 8 of European Commission (EC) regulation No. 852 (2004), include categorisation of fleece cleanliness and shearing of sheep at the abattoir. Dirty and unshorn sheep are regarded as constituting a higher risk to food safety and are channelled into a separate processing stream that includes heating of sensitive meat products and restricted product application; in addition farmers are paid less for such animals (Animalia, 2012). It is important to evaluate the effects of these self-inflicted constraints for Norwegian meat industry and search for the preventive measures with the most favourable cost–benefit ratio.

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The microbiological effect of using decontamination interventions on skinned carcasses, such as hot water pasteurisation (with or without acids), steam pasteurisation, and handheld steam vacuum pasteurisation, has been described in some studies (Dinçer and Baysal, 2004; Dorsa, 1997; Kalchayanand et al., 2007; Steenberg et al., 2006). Most decontamination studies are based on beef carcasses, as referred to in EFSA (2013a), and some studies have investigated sheep carcasses (EFSA, 2013b). However, the effects of decontamination processes on carcasses presented unshorn at slaughter and on meat trimmings have not been investigated. The normal procedure for verifying the hygienic status of sheep carcasses is, according to EC No 2073 (2005), sampling from carcasses before chilling. In the Norwegian national guidelines for Good Hygiene Practices, the hygienic quality of batches of trimmings has been emphasised. Hygienic status during slaughtering and dressing of sheep has been well described (Berends et al., 1997; Biss and Hathaway, 1996a; Biss and Hathaway, 1998; Bolton et al., 2005; Salmela et al., 2013; Steenberg et al., 2006), but there is a lack of studies covering the whole meat value chain, including chilling, deboning and processing.

To achieve a more detailed picture of the bacterial dynamics by elucidating the diversity and distribution in the meat value chain from fleeces to meat trimmings, qualitative analyses are used. Results from such analyses can describe which types of bacteria are present at each step along the slaughter- and processing line where samples are collected, and hereby which types of bacteria are killed (or introduced) when using hygienic treatments. Molecular assays, such as sequencing of the 16S rRNA gene and the malate dehydrogenase (*mdh*) *Escherichia coli* housekeeping gene, have proven to be useful as an alternative means to identify and characterize bacterial populations from a wide variety of sources (Lehner et al., 2004).

The aims of the present study was to investigate the bacterial dynamics along the meat value chain using both traditional cultivation methods and molecular techniques. The various steps, from fleece to meat trimmings, were considered and also the implementation of specific control measures such as shearing in the lairage, the use of steam vacuuming, hot water surface pasteurisation and chilling.

2. Materials and methods

2.1. Carcasses

Carcasses (n = 160) were selected for inclusion in the study at the beginning of the slaughter line, just after killing (Table 1). Forty of the animals were shorn at the abattoir just before slaughter, which is the normal procedure in Norwegian abattoirs (control group), and 120 were unshorn. The shorn sheep came from 18 farms and the sheep that were slaughtered unshorn came from 11 farms. The carcasses derived from the 120 unshorn sheep at slaughter were divided into three groups, each of 40 animals, which were treated as follows and as described in Table 1: i) no decontamination treatment, ii) steam vacuum, and iii) hot water surface pasteurisation. From each group, 20 carcasses were assigned for swabbing and 20 for sampling of meat trimmings. The carcasses were derived from 132 lambs and 28 sheep. The distribution of the 28 sheep was four in the shorn group, 12 in the unshorn group, six in the steam vacuum group, and six in the hot water pasteurisation group. Average slaughter weight was 19.3 kg (range 7.6–43.1 kg).

2.2. Slaughter- and processing line

The study was conducted at an abattoir in Norway for two consecutive weeks (two days per week) during the seasonal sheep slaughter in October 2012. During both sampling weeks, the slaughter line was operated by the same group of skilled operators. The slaughter line speed was approximately 250 animals per hour. Skinning was semi-automated and the animals were skinned hanging by the forelegs. Rodding of the oesophagus using rubber bands was performed before evisceration, and bagging of the rectum with a plastic bag was performed whilst the carcass was hanging by the hind legs.

Immediately after grading, the carcasses entered a chilling tunnel for 2 h at 2–4 °C, and were stored at 4 ± 1 °C. The carcasses were hung on single-hooks which allowed the carcass surfaces to dry and chill quickly. The foreparts of the un-swabbed carcasses were cut the next day. The carcasses were deboned and cut to trimmings in the following order to minimise cross-contamination: the first group comprised of the carcasses derived from shorn lambs, followed consecutively by those pasteurised, steam vacuumed and the untreated carcasses presented unshorn for slaughter.

2.3. Steam vacuum

The steam vacuum method is a procedure for removing contamination from the surface of carcasses using hand-operated equipment (SFK System AS, Kolding, Denmark). The device consists of two main parts; a vapour unit and a vacuum unit. Steam is directed onto the carcass to decontaminate the carcass surface, and the vacuum unit removes the contamination. The treatment was carried out by one operator whilst the carcasses were hanging by the hind legs and applied to those areas of the carcasses considered to be the most contaminated: the hind legs, around the rectum, under the belly, and on the forelegs. The duration of steam vacuuming was about 10 s per carcass.

2.4. Hot water surface pasteurisation

Hot water surface pasteurisation was performed at the end of the slaughter line, after grading and before chilling (Fig. 1) as described by Hauge et al. (2011b). Three carcasses were deluged simultaneously in the cabinet for 8 s. The mean temperature of the water used to spray the carcasses was 82 °C, but varied from 72 °C to 86 °C during the first week due to technical problems.

2.5. Sampling

Four sampling locations along the meat value chain were chosen: fleeces, carcass surfaces before and after chilling, and meat trimmings (Fig. 2). A total of 208 samples were collected as shown in Table 1. Samples from fleeces were collected by swabbing 100 cm^2 areas on the groin and medial thigh. The sampling sites on the carcasses were

Table 1
Type and number of samples.

Carcass group status at slaughter (n)	Treatment	Fleece/skin swab samples	Carcass swab samples before chilling	Carcass swab samples after chilling	Meat trimmings (200 g pooled samples)[a]	Total number of samples
Shorn (40)	No treatment	8	20	20	8	56
Unshorn (40)	No treatment	8	20	20	8	56
Unshorn (40)	Steam vacuum		20	20	8	48
Unshorn (40)	Hot water pasteurisation		20[b]	20	8	48
Total (160)		16	80	80	32	208

[a] 8 pooled samples from a mix of 20 carcasses within each group.
[b] Sampling before hot water pasteurisation at this sampling location.