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Short communication

Microbial contamination on beef and sheep carcases in South Australia

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Abstract

A total of 523 chilled beef and lamb carcases were sampled from four abattoirs and 13 very small plants (VSPs) in South Australia during March 2002 in order to develop a microbiological profile of meat produced for domestic consumption within the State. Aerobic viable counts (AVCs) and *Escherichia coli* counts were obtained from samples taken by sponge-sampling the muscle-adipose tissue at sites designated for each species in the Microbiological Guidelines to the Australian Standard for Hygienic Production of Meat for Human Consumption (identical with those of the USA Pathogen Reduction: hazard analysis and critical control point (HACCP) systems: final rule). On beef carcases ($n=159$) mean log AVC/cm^2 was 1.82 and *E. coli* was detected on 18.8% of carcases (area sampled 200 cm^2) for which the mean log of the positives was -0.34; for lamb carcases, on which 75 cm^2 was sampled ($n=364$), corresponding values were 2.59, 36.2% and $\log_{10}$ 0.27, respectively. There was little difference in mean log AVC/cm^2 of carcases produced at abattoirs and VSPs, 1.72 versus 1.81, respectively, for beef, and 2.80 versus 2.44, respectively, for sheep. Prevalence of *E. coli* was lower at VSPs, however, with abattoirs having 28.4% for beef and 61.5% for sheep, compared with corresponding values of 4.7% and 18.5% at VSPs. In VSPs, the range of mean log AVC/cm^2 was 0.47–3.16 for beef and 1.63–3.65 for sheep carcases, data which will allow the Controlling Authority to assist plants to improve performance of slaughter and dressing techniques. The present survey is part of an assessment by the State meat authority of the effectiveness of co-regulation of meat hygiene between government and industry.

Keywords: Meat hygiene; Survey; Australia; *Escherichia coli*; Aerobic viable count

1. Introduction

In 1993–1994, the Australian meat industry commissioned its first baseline study of the microbiological quality of Australian meat. The survey included beef and sheep carcases and manufacturing meats produced at export and domestic establishments over

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a period of at least 1 year. As well as providing criteria on general process hygiene and faecal contamination, the study determined levels of pathogens (Vanderlinde et al., 1998, 1999).

In the period immediately following the 1993–1994 survey, the domestic meat industry in Australia underwent radical change, with all slaughter and boning facilities implementing comprehensive hazard analysis and critical control point (HACCP)-based quality assurance plans. Commensurate with implementing QA systems, there were significant inputs in operator training, improved refrigeration and provision of laboratory facilities.

Also in the mid-1990s, an important stage in the evolution of meat regulation in Australia occurred when the sole, national system involving government inspectors was replaced by individual State systems. Perhaps the most extreme change in national-to-State regulation occurred in those states which permitted meat companies to employ qualified meat inspectors registered or approved by the Controlling Authority. Termed "co-regulation", companies are regulated via auditors or auditing agents, responsible to the Controlling Authority.

In 1998, the industry commissioned a second national baseline study which covered export-registered and domestic establishments, together with very small plants (VSPs), also known as slaughterhouses (Phillips et al., 2001a,b). By definition, VSPs slaughter less than 150 cattle equivalents per week (eight sheep are equivalent to one cattle beast). Located in remote areas, they undertake service kill for farmers and also for their own retail meat and smallgoods operations. One finding of the second baseline study was that VSPs had a lower prevalence of *Escherichia coli* on beef and sheep carcases than did either export or domestic plants, a finding which, given the basic construction of VSPs, seemed counter-intuitive.

Notwithstanding studies monitoring carcase hygiene at company-inspected plants (Sumner and Fabiansson, 1997; Sumner and Herd, 1999), critics claim that meat hygiene as the responsibility of the company, rather than the government, can lead to retrograde public health outcomes. In one State, South Australia, co-regulation has operated since 1995, the Controlling Authority contracting audit providers to audit the 5 abattoirs and 41 VSPs within its jurisdiction. Since 1997, all plants have been required to operate HACCP-based systems and the government wished to compare the effectiveness of its meat hygiene system with the previous system. As part of this comparison, the South Australian Meat Hygiene Unit undertook a microbiological survey of bacterial counts of beef and sheep carcases at the State's abattoirs and VSPs, the results of which are presented here. Additional objectives of the survey were to: (i) monitor any changes in meat hygiene following 5 years of operation under a co-regulatory, HACCP-based system; (ii) revisit the finding of Phillips et al. (2001a,b) that VSPs had lower prevalence of *E. coli* than did abattoirs.

2. Materials and methods

2.1. Study design

To satisfy the objectives of this study, an intensive sampling regime was adopted. This comprised >500 samples, in a narrow time frame, restricted to a defined geographical area (South Australia) and included 80% of the abattoirs and 30% of the VSPs in that jurisdiction. The survey was conducted over a 1-week period in March 2002, in early autumn, during a prolonged period without rain. A total of 523 samples (159 beef and 364 sheep) were taken at 4 of the 5 medium-sized abattoirs and 13 of the 41 VSPs in South Australia. Each establishment was sampled on one occasion, when sponge samples were collected from carcasses that had been chilled for 8–48 h, the majority for 12–24 h.

2.2. Sponge-sampling of carcasses

Each carcase was sampled according to the Microbiological Guidelines to the Australian Standard for Hygienic Production of Meat for Human Consumption (AS 4461:1997) both by experienced technicians from the Controlling Authority and by QA staff at the establishment. Operators sponged designated sites on each side of the same carcase and alternated between right and left sides to eliminate bias. A sterile polyurethane sponge (Nasco Whirlpak) moistened with buffered peptone water was used to remove bacteria from carcases using 10 horizontal and 10 vertical passes across the surface. For beef, a composite sample was taken by sponging a 100-cm^2 area at the flank and brisket sites of the carcase (total area

sampled 200 cm^2) and, for sheep, a composite sample was taken by sponging 25-cm^2 areas at each of the rump, flank and brisket regions of the carcase (total area sampled 75 cm^2). The sites specified in the guideline to the Australian Standard correspond with those in the USA Pathogen Reduction: hazard analysis and critical control point (HACCP) systems: final rule (FSIS, 1996), sometimes referred to as the Mega Reg.

2.3. Transport of samples to the laboratory

After sampling, sponges in sterile bags were packed in pre-chilled insulated containers with chiller packs and transported to the laboratory for testing usually within 4 h, but never more than 24 h, after sampling. In the laboratory, samples were held in a refrigerator until analysed.

2.4. Determination of aerobic viable count (AVC) and *E. coli* biotype 1

The sponge was squeezed firmly through the plastic bag and, from the moisture expressed, serial dilutions were prepared in 0.1% buffered peptone water blanks (9 ml) using 1 ml aliquots. Aliquots (1 ml) from each dilution were spread on either Aerobic Plate Count Petrifilm (3 M) or *E. coli* Petrifilm (3 M) and incubated at 25 °C for 3 days and 37 °C for 2 days, respectively. Colonies were identified and counted as per the manufacturer's instructions.

2.5. Statistical analysis

All Petrifilm counts were converted to $\log_{10}$ cfu/cm^2. When *E. coli* was absent from Petrifilms, the result was entered as "not detected". For each establishment where *E. coli* was detected, the mean of the log counts of all positive results was calculated. For AVCs, the standard deviation was determined using Microsoft Excel software. The limit of detection for both AVC and *E. coli* for beef and sheep carcases was 0.12 and 0.3 cfu/cm^2, respectively.

3. Results and discussion

Throughput at the four abattoirs ranged from 60 to 260 cattle/day and 275 to 1600 sheep/day, while at the 13 VSPs surveyed, weekly throughputs were 1–30 and 5–110 for cattle and sheep, respectively. Processing characteristics of each abattoir and VSP involved in the present survey are presented in Table 1. Equipment at VSPs was more rudimentary than that at abattoirs, with none having a mechanised rail or undertaking inverted dressing or automatic pelt removal. For cattle, VSPs relied largely on cradle dressing, only 2/11 plants dressing bodies on a rail, and only 1/11 having a mechanical hide puller (downward removal). All 3 beef abattoirs dressed on a rail and one had a downward hide puller; at all other plants (abattoirs and VSPs), the hide was removed by knife using the hand and gravity.

The microbiological status of South Australian beef and sheep carcasses produced at 4 abattoirs and 13 VSPs is summarised in Table 2. For beef carcasses, the AVC was similar at abattoirs and very small establishments (mean log 1.72 and 1.81, respectively), as were AVCs for sheep carcases (2.80 and 2.44, respectively). *E. coli* was detected less frequently on carcases from VSPs, compared with abattoirs. For beef carcases, the prevalence of *E. coli* from 200-cm^2 areas sampled was 28.4% at abattoirs and 4.7% at VSPs, while for sheep carcases, the prevalence from 75-cm^2 areas sampled was 61.5% and 18.5% for abattoirs and VSPs, respectively.

Within VSPs, there was considerable in-plant disparity between the hygienic status of carcases (Table 3). For beef carcases, 9/11 plants surveyed had log mean

Table 1
Key process characteristics of the four abattoirs and 13 very small plants (VSPs) involved in the present study

Characteristic	Number of abattoirs	Number of VSPs
Sheep		
Carcase steam vacuuming	0/4	0/11
Automatic pelt removal	2/4	0/11
Inverted dressing	2/4	0/11
Operators for slaughter and dressing (range)	8–28	1–3
Beef		
Carcase hung on gravity rail	3/3	2/11
Cradle dressing	0/3	11/11
Downward hide puller	1/3	1/11
Upward hide puller	0/3	0/11
Operators for slaughter and dressing (range)	8–24	1–3

Table 2
Aerobic viable counts (AVCs) and prevalence of *E. coli* on beef and sheep carcases produced at abattoirs and VSPs in South Australia

	n	Mean log AVC	Prevalence (%) of *E. coli*[a] (mean log of positives)
Abattoirs			
Beef	95	1.72	28.4 (−0.33)
Sheep	148	2.8	61.5 (0.39)
VSPs			
Beef	64	1.81	8.4 (−0.88)
Sheep	216	2.44	18.5 (−0.01)

[a] Area sampled: 200 cm^2 for beef and 75 cm^2 for sheep carcases.

AVCs ranging from 0.47 to 2.27/cm^2 and *E. coli* was not detected on any of the 54 carcases surveyed at these plants. By contrast, 2/11 VSPs had mean log AVCs >3/cm^2, and *E. coli* was found at 16% and 50% prevalence. On sheep carcases, 7/11 plants had mean log AVCs of 1.63–2.72/cm^2, and *E. coli* was detected on carcases at 5 of these plants, prevalence ranging from 0 to 70%. At 4/11 plants, sheep carcases had mean log AVCs >3/cm^2, and *E. coli* prevalence ranged from 0 to 90%.

At the three abattoirs processing beef, mean log AVC ranged from 1.2 to 2.44/cm^2, and *E. coli* prevalence from 0 to 80%. At the four abattoirs processing sheep, the mean log AVC ranged from 2.36 to 3.16/cm^2, and *E. coli* prevalence ranged from 0 to 88% (Table 4).

The present survey examines carcases from two categories of plants with significantly different slaughter volumes, under which meat is processed domestically in South Australia. While abattoirs and VSPs vary in terms of complexity of construction and processing, all comply with Australian standards for construction and hygienic operation of abattoirs and refrigeration capacity is adequate for the slaughter volume.

In terms of processing systems, abattoirs have mechanised chains and several operators (8–24) who each perform a limited range of operations. Qualified meat inspectors, in addition to line inspection duties, are also quality assurance officers and may carry out microbiological sampling and analysis. By contrast, VSPs may have only one operator (though two is more usual) who is qualified in meat inspection and undertakes QA and microbiological testing duties in addition to slaughter and dressing. Carcases from VSPs generally had lower AVCs and prevalence of *E. coli*, compared with abattoirs, but between individual VSPs, there was a greater range in AVCs than between abattoirs.

An historical comparison is possible via the 1998 survey of Phillips et al. (2001a,b) when AVCs on 40 beef and 149 sheep carcases in South Australian VSPs were 3.17/cm^2 and 3.82/cm^2, compared with the present survey of 1.81/cm^2 and 2.44/cm^2, respectively. Prevalence of *E. coli* in 1998 was 2.5% on beef carcases and 18.1% on sheep carcases compared with 4.7% and 18.5%, respectively, in 2002.

One possible use of microbiological data is to improve process hygiene. Among VSPs, plants B–G had lower AVCs and prevalence of *E. coli* on both

Table 3
Aerobic viable counts (AVCs) and prevalence of *E. coli* on beef and sheep carcases produced at very small plants (VSPs) in South Australia

Plant	*n*	Beef		Plant	*n*	Sheep	
		Mean log AVC (S.D.)	Prevalence (%) of *E. coli*[a] (mean log of positives)			Mean log AVC (S.D.)	Prevalence (%) of *E. coli*[a] (mean log of positives)
A	4	0.47 (0.18)	0	E	16	1.63 (0.18)	20 (0.22)
B	4	0.64 (0.64)	0	G	38	1.78 (0.20)	14.5 (−0.46)
C	2	0.96 (0.64)	0	F	24	1.83 (0.56)	0
D	12	1.36 (0.26)	0	C	22	1.94 (0.75)	0
E	4	1.63 (0.10)	0	D	28	2.14 (0.38)	21.4 (−0.45)
F	10	1.80 (0.22)	0	B	46	2.33 (0.22)	2.2 (−0.48)
G	12	2.19 (0.38)	0	L	6	2.72 (0.30)	16 (−0.48)
H	2	2.26 (0)	0	H	10	3.41 (0.48)	70 (−0.32)
I	4	2.27 (0.16)	0	M	6	3.54 (0.09)	0
J	6	3.16 (0.09)	16 (0.05)	I	10	3.53 (0.19)	40 (0.32)
K	4	3.16 (0.89)	50 (−0.9)	K	10	3.65 (0.06)	92 (0.59)

[a] Area sampled: 200 cm^2 for beef and 75 cm^2 for sheep carcases.

Table 4
Aerobic viable counts (AVCs) and prevalence of *E. coli* on beef and sheep carcases produced at abattoirs in South Australia

Plant	*n*	Beef		Plant	*n*	Sheep	
		Mean log AVC (S.D.)	Prevalence (%) of *E. coli*[a] (mean log of positives)			Mean log AVC (S.D.)	Prevalence (%) of *E. coli*[a] (mean log of positives)
P	20	1.20 (0.56)	0	Q	50	2.36 (0.11)	88 (0.16)
Q	45	1.72 (0.30)	4 (−0.4)	S	48	2.92 (0.78)	72 (0.69)
R	30	2.44 (0.16)	80 (−0.12)	R	20	3.05 (0.18)	65 (0.26)
				P	30	3.16 (0.35)	0

[a] Area sampled: 200 cm^2 for beef and 75 cm^2 for sheep carcases.

beef and sheep carcases than did plants H, I and K, and it would be useful to be able to identify reasons for these differences in processing outcome. The present study was undertaken over a 5-day period when weather conditions were uniformly dry across the survey area, and it might be expected that livestock entered VSPs with similar contamination levels on their hides. As well, equipment and techniques used at VSPs to slaughter and dress animals were almost uniform. Gill et al. (1998a,b) have demonstrated that incision cuts through the hide and skinning operations are both critical in determining contamination levels of beef carcases. By observing and gaining information from individual operators, and by swabbing exposed surfaces immediately after each operation, these researchers were able to identify the most hygienic ways of skinning the carcase. Clearly, this approach would be the obvious first step in improving the hygienic quality of carcases on a statewide basis. A further step would be maintaining a simple time-course control chart at each operation to indicate any seasonal effects.

The present study provides a comparison between "traditional" and "modern" slaughter and dressing practices, as practiced in VSPs and abattoirs, respectively. In the former, "solo butchering" using traditional equipment and cutting lines appears more able to minimise faecal contamination compared with modern, mechanised systems manned by a team of operators. Merging data for both categories (VSPs and abattoirs), the 159 beef carcases sampled had a mean AVC of 1.82/cm^2, *E. coli* was present on 18.8% of carcases and the mean log of positive *E. coli* results was −0.33; for the 364 lamb carcases sampled, the corresponding data were 2.59/cm^2, 36.2% and $\log_{10}$ 0.2.

These levels compare favourably with those established in other surveys both nationally and internationally, where similar analytical techniques were used (swabbing or sponging of chilled carcases). For beef carcases, Phillips et al. (2001a) found that 1268 carcases processed at Australian export and domestic (including very small) plants had a mean AVC of 2.42/cm^2; *E. coli* was present on 10.3% of carcases and the mean log of positive *E. coli* results was −0.41. In USA, Siragusa et al. (1998) found that 93% of beef carcases had AVCs less than $\log_{10}$ 3/cm^2 with 62% less than $\log_{10}$ 2/cm^2; 44% of carcases were positive for *E. coli*. For sheep carcases, Phillips et al. (2001b) sampled 917 carcases from export and domestic sectors and established a mean AVC of 3.54/cm^2; *E. coli* was present on 29.1% of carcases and the mean log of positive *E. coli* results was 0.16. In New Zealand, Armitage (1995) found that 772 lamb carcases had a mean AVC of 3.35/cm^2, while in Canada, Gill and Baker (1998) found that unchilled sheep carcases had $\log_{10}$ AVC/cm^2 at the shoulder, loin and leg of 2.81, 2.80 and 2.56, respectively. In USA, Duffy et al. (2001) surveyed 2522 chilled lamb carcases at six USA plants finding mean log AVCs of 4.23/cm^2 (Spring) and 4.61/cm^2 (Winter) and overall prevalence of *E. coli* of 66.2%.

From the present survey, it may be concluded that co-regulatory responsibility between industry and government as practiced in the domestic meat sector in South Australia leads to levels of carcase contamination which are similar to those produced nationally and internationally under differing regulatory systems.

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