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Number and Distribution of Bacteria on Some Beef Carcasses at Selected Abattoirs in some Member States of the European Communities

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SUMMARY

In seven member countries of the European Communities, three abattoirs were visited on three occasions in each of two surveys and at each visit ten beef carcasses were sampled, before chilling, at defined sites on the neck, brisket, forerib and medially on the round. In Survey I, samples were plated for total viable count (TVC) at 30° (ISO 2293) and Enterobacteriaceae *at 37° (ISO 5552); in Survey II only TVCs were made. This paper is confined to analyses of the TVCs in the two surveys.*

Data from each country were analysed separately as sampling methodology may not have been sufficiently reproducible by different workers to allow between-countries comparison.

Variations among visits to particular abattoirs and abattoir × site interactions made comparisons among abattoirs invalid within five of the seven countries. To effectively monitor differences between abattoirs within most countries it would be necessary to make more than three visits to each abattoir.

Despite abattoir × site interactions in three countries in Survey I and four countries in Survey II, comparisons between sites were generally valid because of the consistent high contamination of the brisket. In the remainder of countries the abattoir × site interaction was too large to allow valid comparisons between sites.

It is recommended that at least three or four sites are sampled in future surveys as only one site per carcass would underestimate the number of more heavily contaminated carcasses.

INTRODUCTION

Traditionally, 'hygienic slaughter' has been implemented through visual inspection and supervision of skilled operatives by suitably qualified personnel such as veterinarians. In principle, enormous numbers of bacteria, some able to cause spoilage and others potentially able to cause food-borne illness, can be transferred to the carcass if it becomes contaminated by faecal material, by the contents of the animal's alimentary tract, or by contact with the hide or fleece, the cleanliness of which is impossible to assure. Hence hygiene has included strenuous efforts to prevent 'visible dirt' reaching the surface of the meat carcass and to avoid the carcass coming into contact with materials and surfaces likely to transfer microbes to it. The vast quantities of meat consumed without ill-effect bear witness to the general success of this protocol, but the

occasional association of meat with illness and the need for longer shelf-life of both carcasses and cuts have increased interest in the bacteriological status of beef carcasses.

The bacteriological problems of slaughter were reviewed by Ingram & Roberts (1976) and Roberts (1980). Advantages and disadvantages of different sampling techniques were reviewed by Kitchell *et al.* (1973). Aspects of microbial contamination during slaughtering were studied by Fournaud *et al.* (1978) and by Nortjé & Naudé (1981) and the problems of adequate sampling for bacteriological purposes have been discussed by Roberts *et al.* (1980). Following those publications, and others where adequate numbers of carcasses were sampled (Johanson *et al.*, 1983), it is evident that the variation in microbial load at different sites on a carcass, the variation between carcasses and the variation between visits to the same abattoir, should be taken into account in any statistical analysis of bacteriological data attempting to detect differences between abattoirs or to monitor slaughter hygiene.

Within the European Communities the volume of intra-Community trade in fresh meat prompted interested parties to suggest a programme of sampling of beef carcasses for bacteriological purposes in representative abattoirs to test the usefulness of bacteriological assessments and to survey the situation in member states. Having agreed, by discussion, on standardized methodologies, the intention was to compare trends in numbers of bacteria and their distribution on carcasses within a country. If a highly reproducible sampling method could have been employed, comparisons of numbers of bacteria between countries could also have been made. However, there is no internationally agreed method of sampling carcasses and, for economic reasons, the majority of participants chose a swabbing method rather than excision. The method adopted may not have been sufficiently reproducible in the hands of different workers to permit valid comparisons between countries so the data were evaluated only within countries, i.e. each national survey was analysed separately.

MATERIALS AND METHODS

Bacteriological assessment

From previous experience in the United Kingdom, it was appropriate to visit three abattoirs on three occasions, and on each visit to sample ten

carcasses at four defined sites on the neck, the brisket, the forerib and medially on the round (Sites 1, 2, 3 and 9 in Roberts *et al.*, 1980). Each 50 cm^2 site was sampled first with a cottonwool swab moistened in peptone–saline diluent and then with a dry swab, both swabs being taken into a single bottle of peptone–saline diluent and stored chilled until examined. Decimal dilutions from this were made in the same diluent and duplicate samples from each dilution plated to estimate numbers of viable bacteria on Standard Plate Count Agar (APHA) (Oxoid CM463) incubated for 3 days at 30 °C. Each participating country received dehydrated media from the same production batch, thereby eliminating possible differences due to medium.

Statistical analyses

The counts were analysed after transformation to logarithms which made the counts normally distributed (Roberts *et al.*, 1980). Analysis of variance was then applicable.

The analysis of variance carried out was of a split-plot design with the visits to each abattoir forming the whole-plots and the ten carcasses sampled at each visit forming sub-plots. Thus, to test for significant overall abattoir differences, the mean square due the abattoir variation was compared with the whole-plot residual mean square (visit within abattoir variation). Significant overall site differences were tested for by comparing the mean square due to site variation with the sub-plot residual mean square and, if significant, with the abattoir × site interaction mean square.

This analysis takes into account variation among carcasses on each visit and among replicate visits to test whether the bacterial numbers at different abattoirs differ significantly. Large variation among carcasses on a particular visit, or among visits to a particular abattoir, makes differentiation between abattoirs impossible.

RESULTS AND DISCUSSION

Differences in the accompanying tables are tested for using the SED (Standard Error of Difference) given within each table, multiplied by the appropriate value of the *t* distribution. (Five per cent significance is used throughout and significant differences are denoted by different subscripts.)

TABLE 1

Comparison of Bacterial Numbers on Beef Carcasses at Three Abattoirs in Each of Seven Countries

a. Survey I

Abattoir	*Country*						
	*A**	*B*	*C**	*D**	*E**	*F**	*G**
A	**3·64^a	3·01	2·31	2·74	2·29	3·07^b	3·24
B	3·72^a	2·57	2·33	3·54	2·49	2·66^a	3·48
C	4·20^b	2·72	2·24	—	2·57	2·54^a	2·95
SED	0·13	0·25	0·26	0·28	0·31	0·13	0·23
Grand mean	3·85	2·77	2·29	3·14	2·45	2·75	3·23
SD	0·79	0·83	0·88	1·09	0·83	0·70	0·91

b. Survey II

Abattoir	*Country*						
	*A**	*B*	*C**	*D**	*E**	*F**	*G**
A	**3·54^a	3·21	2·67	3·65	2·56	3·37^b	3·50
B	3·60^a	3·01	2·24	3·38	2·48	2·85^a	3·49
C	4·19^b	3·23	2·13	—	2·40	—	3·00
SED	0·22	0·26	0·23	0·20	0·15	0·07	0·20
Grand mean	3·78	3·15	2·35	3·50	2·48	3·11	3·33
SD	0·79	0·83	0·92	0·91	0·90	0·71	0·92

Superscripts: Significant differences within a column.

* Abattoir × site interactions.

** Tabulated values are bacteria $(\log_{10})/cm^2$.

Within each country abattoir means are tabulated for Survey I (Table 1*a*), and Survey II (Table 1*b*). In many countries the variation among visits within abattoirs and the abattoir × site interaction was too large, making overall comparisons between abattoir means invalid. In both surveys overall differences between abattoirs were evident only in countries A and F, and these are denoted by different subscripts.

Site means within each country are tabulated for Survey I (Table 2*a*) and Survey II (Table 2*b*). No overall site comparisons can be made when the abattoir × site interaction corresponding to that country was too large. When overall site comparisons are valid, usually due to the consistent dirtiness of Site 2, significant differences are indicated by different subscripts.

In each country where the abattoir × site interaction was significant the

TABLE 2

Comparison of Bacterial Numbers at Four Sites on Beef Carcasses in Each of Seven Countries

a. Survey I

Site	*Country*						
	*A**	*B*	*C**	*D**	*E**	*F**	*G**
2	$4{\cdot}52^{b}$	$3{\cdot}09^{c}$	2·47	3·80	2·75	2·97	$3{\cdot}83^{c}$
9	$3{\cdot}65^{a}$	$2{\cdot}83^{b}$	2·31	3·33	2·75	2·94	$3{\cdot}33^{b}$
1	$^{**}3{\cdot}59^{a}$	$2{\cdot}59^{a}$	2·59	2·78	2·13	2·52	$2{\cdot}88^{a}$
3	$3{\cdot}66^{a}$	$2{\cdot}55^{a}$	1·81	2·66	2·16	2·58	$2{\cdot}86^{a}$
SED	0·25	0·11	0·38	0·80	0·31	0·25	0·18
Grand mean	3·85	2·77	2·29	3·14	2·45	2·75	3·23
SD	0·79	0·83	0·88	1·09	0·83	0·70	0·91

b. Survey II

Site	*Country*						
	*A**	*B*	*C**	*D**	*E**	*F**	*G**
2	$4{\cdot}35^{b}$	3·42	$2{\cdot}91^{c}$	3·74	$2{\cdot}95^{b}$	3·24	$3{\cdot}87^{b}$
9	$3{\cdot}57^{a}$	3·21	$2{\cdot}18^{b}$	3·67	$2{\cdot}79^{b}$	3·23	$3{\cdot}42^{ab}$
1	$^{**}3{\cdot}47^{a}$	3·00	$2{\cdot}61^{c}$	3·21	$1{\cdot}81^{a}$	3·01	$3{\cdot}16^{a}$
3	$3{\cdot}72^{ab}$	2·98	$1{\cdot}68^{a}$	3·39	$2{\cdot}36^{ab}$	2·95	$2{\cdot}89^{a}$
SED	0·31	0·18	0·16	0·69	0·33	0·21	0·23
Grand mean	3·78	3·15	2·35	3·50	2·48	3·11	3·33
SD	0·79	0·83	0·92	0·91	0·90	0·71	0·92

Superscripts: Significant differences within a column.

* Abattoir × site interactions.

** Tabulated values are bacteria $(\log_{10})/cm^2$.

Tables of abattoir means at the different sites are shown. In Survey I (Table 3*a*), the abattoir × site interaction was significant in countries A, C, D, E, F and G. In Survey II (Table 3*b*) all countries are shown. For each country these Tables enable one to compare different sites at a given abattoir (i) or different abattoirs at a given site (ii). From them it is possible to identify particularly high or low mean bacterial counts after taking into account the effects of abattoir and site differences.

Tables 3*a* and 3*b* illustrate the problem of making overall statements about differences among abattoirs. For example, in Survey I, considering which abattoir in country C was the dirtiest, abattoir A would be chosen if only Site 3 was considered. However, abattoir A also had the lowest

TABLE 3a

Bacteria on Beef Carcasses: Abattoir × Site Interactions

Survey I

Sites	*Abattoir*			*Sites*	*Abattoir*		
	A	*B*	*C*		*A*	*B*	*C*
COUNTRY A							
(i)				(ii)			
2	4·23^{b}	4·19^{b}	5·13^{c}	2	4·23^{a}	4·19^{a}	5·13^{b}
9	3·50^{a}	3·92^{b}	3·53^{a}	9	3·50^{a}	3·92^{b}	3·53^{a}
1	3·41^{a}	3·34^{a}	4·03^{b}	1	3·41^{a}	3·34^{a}	4·03^{b}
3	3·44^{a}	3·42^{a}	4·12^{b}	3	3·44^{a}	3·42^{a}	4·12^{b}
(SED 0·19)				(SED 0·19)			
COUNTRY C							
(i)				(ii)			
2	2·16^{a}	2·51^{bc}	2·74^{b}	2	2·16^{a}	2·51^{a}	2·74^{a}
9	2·23^{a}	2·03^{ab}	2·69^{b}	9	2·23^{ab}	2·03^{a}	2·69^{b}
1	2·73^{a}	3·10^{c}	1·93^{a}	1	2·73^{b}	3·10^{b}	1·93^{a}
3	2·14^{a}	1·67^{a}	1·61^{a}	3	2·14^{a}	1·67^{a}	1·61^{a}
(SED 0·30)				(SED 0·30)			
COUNTRY D							
(i)				(ii)			
2	2·62^{a}	4·99^{c}	—	2	2·62^{a}	4·99^{b}	—
9	2·92^{a}	3·73^{b}	—	9	2·92^{a}	3·73^{b}	—
1	2·63^{a}	2·93^{a}	—	1	2·63^{a}	2·93^{a}	—
3	2·80^{a}	2·52^{a}	—	3	2·80^{a}	2·52^{a}	—
(SED 0·33)				(SED 0·33)			
COUNTRY E							
(i)				(ii)			
2	2·71^{b}	3·23^{c}	2·31^{a}	2	2·71^{ab}	3·23^{b}	2·31^{a}
9	2·63^{b}	2·66^{bc}	2·97^{a}	9	2·63^{a}	2·66^{a}	2·97^{a}
1	1·89^{a}	1·88^{a}	2·62^{a}	1	1·89^{a}	1·88^{a}	2·62^{b}
3	1·92^{a}	2·18^{ab}	2·48^{a}	3	1·92^{a}	2·18^{a}	2·48^{a}
(SED 0·36)				(SED 0·36)			
COUNTRY F							
(i)				(ii)			
2	3·44^{b}	2·63^{a}	2·85^{b}	2	3·44^{b}	2·63^{a}	2·85^{a}
9	3·40^{b}	2·57^{a}	2·84^{b}	9	3·40^{b}	2·57^{a}	2·84^{a}
1	2·74^{a}	2·84^{a}	1·99^{a}	1	2·74^{b}	2·84^{b}	1·99^{a}
3	2·68^{a}	2·59^{a}	2·48^{b}	3	2·68^{a}	2·59^{a}	2·48^{a}
(SED 0·18)				(SED 0·18)			
COUNTRY G							
(i)				(ii)			
2	4·01^{b}	4·16^{b}	3·34^{b}	2	4·01^{b}	4·16^{b}	3·34^{a}
9	3·01^{a}	3·77^{b}	3·21^{b}	9	3·01^{a}	3·77^{b}	3·21^{a}
1	2·99^{a}	3·03^{a}	2·61^{a}	1	2·99^{a}	3·03^{a}	2·61^{a}
3	2·97^{a}	2·97^{a}	2·64^{a}	3	2·97^{a}	2·97^{a}	2·64^{a}
(SED 0·27)				(SED 0·27)			

(i) Superscripts: Significance within a column.

(ii) Superscripts: Significance within a row.

TABLE 3b

Survey II

Sites	*Abattoir*			*Sites*	*Abattoir*		
	A	*B*	*C*		*A*	*B*	*C*
COUNTRY A							
(i)				(ii)			
2	4·06^{b}	4·16^{c}	4·82^{c}	2	4·06^{a}	4·16^{a}	4·82^{b}
9	3·57^{b}	3·63^{b}	3·50^{a}	9	3·57^{a}	3·63^{a}	3·50^{a}
1	2·86^{a}	3·13^{a}	4·43^{bc}	1	2·86^{a}	3·13^{a}	4·43^{b}
3	3·68^{b}	3·47^{ab}	4·01^{b}	3	3·68^{ab}	3·47^{a}	4·01^{b}
(SED 0·25)				(SED 0·25)			
COUNTRY B							
(i)				(ii)			
2	3·36^{a}	3·50^{b}	3·39^{a}	2	3·36^{a}	3·50^{a}	3·39^{a}
9	3·37^{a}	2·72^{a}	3·54^{a}	9	3·37^{b}	2·72^{a}	3·54^{b}
1	3·08^{a}	2·92^{ab}	2·99^{a}	1	3·08^{a}	2·92^{a}	2·99^{a}
3	3·02^{a}	2·91^{ab}	3·02^{a}	3	3·02^{a}	2·91^{a}	3·02^{a}
(SED 0·30)				(SED 0·30)			
COUNTRY C							
(i)				(ii)			
2	3·08^{b}	2·97^{c}	2·66^{c}	2	3·08^{a}	2·97^{a}	2·66^{a}
9	2·39^{a}	2·12^{b}	2·04^{b}	9	2·39^{a}	2·12^{a}	2·04^{a}
1	2·95^{b}	2·55^{bc}	2·32^{bc}	1	2·95^{b}	2·55^{ab}	2·32^{a}
3	2·26^{a}	1·31^{a}	1·48^{a}	3	2·26^{b}	1·31^{a}	1·48^{a}
(SED 0·28)				(SED 0·28)			
COUNTRY D							
(i)				(ii)			
2	3·30^{a}	4·09^{a}	—	2	3·30^{a}	4·09^{a}	—
9	3·67^{a}	3·66^{b}	—	9	3·67^{a}	3·66^{b}	—
1	3·39^{a}	3·07^{b}	—	1	3·39^{a}	3·07^{a}	—
3	4·26^{b}	2·70^{a}	—	3	4·26^{b}	2·70^{a}	—
(SED 0·23)				(SED 0·23)			
COUNTRY E							
(i)				(ii)			
2	2·87^{b}	3·15^{c}	2·84^{c}	2	2·87^{a}	3·15^{a}	2·84^{a}
9	2·81^{b}	2·39^{b}	3·18^{c}	9	2·81^{ab}	2·39^{a}	3·18^{b}
1	2·33^{a}	1·87^{a}	1·24^{a}	1	2·33^{c}	1·87^{b}	1·24^{a}
3	2·22^{a}	2·51^{b}	2·34^{b}	3	2·22^{a}	2·51^{a}	2·34^{a}
(SED 0·22)				(SED 0·22)			
COUNTRY F							
(i)				(ii)			
2	3·66^{b}	2·83^{a}	—	2	3·66^{b}	2·83^{a}	—
9	3·60^{b}	2·86^{a}	—	9	3·60^{b}	2·86^{a}	—
1	3·13^{a}	2·88^{a}	—	1	3·13^{a}	2·88^{a}	—
3	3·09^{a}	2·82^{a}	—	3	3·09^{a}	2·82^{a}	—
(SED 0·16)				(SED 0·16)			
COUNTRY G							
(i)				(ii)			
2	3·70^{b}	4·49^{b}	3·43^{c}	2	3·70^{a}	4·49^{b}	3·43^{a}
9	3·73^{b}	3·35^{a}	3·17^{bc}	9	3·73^{b}	3·35^{ab}	3·17^{a}
1	3·50^{ab}	3·19^{a}	2·78^{ab}	1	3·50^{b}	3·19^{ab}	2·78^{a}
3	3·09^{a}	2·94^{a}	2·64^{a}	3	3·09^{a}	2·94^{a}	2·64^{a}
(SED 0·26)				(SED 0·26)			

(i) Superscripts: Significance within a column. (ii) Superscripts: Significance within a row.

bacterial numbers of the three abattoirs at Site 2. In the case of country C the variation between sites at a particular abattoir is so large as to make overall conclusions about abattoir differences virtually impossible. Hence in surveys of this nature, several sites should be sampled. The number of sites and their location should be determined experimentally, because sites with high bacterial counts are of particular interest. Because of the site-to-site variation in bacterial numbers, surveys which sample only one site would underestimate the frequency of occurrences of dirty carcasses and would fail to detect differences between abattoirs.

The abattoir × visit means are tabulated (Table 4) for all countries where the variation between visits within an abattoir is significantly larger than the residual variation and include all countries except country F in Survey II. These Tables for Survey I (Table 4*a*) and Survey II (Table 4*b*) show the large difference in visit means for a given abattoir. Analyses of variance show that the visit variation is a most important, albeit unwanted, source of variation. If the object is to pinpoint differences between abattoirs, it would be necessary to visit each abattoir on several occasions.

Considering only the accumulated bacteriological data, in both surveys the variation among visits within an abattoir was significantly larger than the residual error, with the sole exception of country F in Survey II.

In both surveys there was a significant difference between bacterial numbers at different abattoirs in country A. In that country, abattoirs were deliberately chosen to represent the extremes of hygiene assessed by visual appearance and to include a large modern abattoir with an export licence, and two others without such a licence. Carcasses at the abattoir with an export licence consistently carried larger numbers of bacteria. In mitigation, it was also by far the busiest of the three. Similarly, in both surveys there were significant differences in bacterial numbers at abattoirs in country F.

Considering the overall differences among site means, in Survey I, for those countries where significant differences were observed (countries A, B and G), Site 2 gave the largest mean count. Site 2 was also significantly more contaminated at one abattoir in country D, and most contaminated at one abattoir in country C, and at two abattoirs in countries E and F.

In Survey II the high bacterial numbers at Site 2 were again apparent. Significant overall site differences were observed for countries A, C, E and G with Site 2 the highest. Site 2 was also most contaminated, although not significantly, at one abattoir in countries B, D and F.

TABLE 4a

Bacteria on Beef Carcasses: Abattoir × Visit Interactions

Visits	*Abattoir*			*Visits*	*Abattoir*		
	A	*B*	*C*		*A*	*B*	*C*
Survey I							
COUNTRY A				*COUNTRY B*			
1	$3{\cdot}69^{a}$	$3{\cdot}73^{a}$	$3{\cdot}93^{a}$	1	$2{\cdot}78^{a}$	$2{\cdot}89^{b}$	$2{\cdot}47^{a}$
2	$3{\cdot}50^{a}$	$3{\cdot}67^{a}$	$4{\cdot}21^{b}$	2	$3{\cdot}27^{b}$	$2{\cdot}24^{a}$	$3{\cdot}09^{b}$
3	$3{\cdot}74^{a}$	$3{\cdot}75^{a}$	$4{\cdot}44^{b}$	3	$2{\cdot}98\|^{ab}$	$2{\cdot}56^{ab}$	$2{\cdot}60^{a}$
(SED 0·13)				(SED 0·17)			
COUNTRY C				*COUNTRY D*			
1	$2{\cdot}29^{ab}$	$2{\cdot}65^{c}$	$1{\cdot}80^{a}$	1	$2{\cdot}47^{a}$	$3{\cdot}59^{a}$	—
2	$2{\cdot}17^{a}$	$1{\cdot}99^{a}$	$2{\cdot}59^{b}$	2	$3{\cdot}01^{b}$	$3{\cdot}49^{a}$	—
3	$2{\cdot}49^{b}$	$2{\cdot}33^{b}$	$2{\cdot}33^{b}$	3	—	—	—
(SED 0·16)				(SED 0·16)			
COUNTRY E				*COUNTRY F*			
1	$1{\cdot}87^{a}$	$2{\cdot}44^{b}$	$2{\cdot}50^{a}$	1	$3{\cdot}03^{a}$	$2{\cdot}47^{a}$	$2{\cdot}77^{b}$
2	$2{\cdot}48^{b}$	$3{\cdot}05^{c}$	$2{\cdot}53^{a}$	2	$3{\cdot}08^{a}$	$2{\cdot}77^{b}$	$2{\cdot}35^{a}$
3	$2{\cdot}52^{b}$	$1{\cdot}98^{a}$	$2{\cdot}68^{a}$	3	$3{\cdot}08^{a}$	$2{\cdot}73^{ab}$	$2{\cdot}50^{a}$
(SED 0·19)				(SED 0·13)			
COUNTRY G							
1	$3{\cdot}17^{a}$	$3{\cdot}32^{a}$	$3{\cdot}14^{b}$				
2	$3{\cdot}17^{a}$	$3{\cdot}97^{b}$	$2{\cdot}77^{a}$				
3	$3{\cdot}38^{a}$	$3{\cdot}16^{a}$	$2{\cdot}94^{ab}$				
(SED 0·18)							

TABLE 4b

Survey II							
COUNTRY A				*COUNTRY B*			
1	$3{\cdot}42^{a}$	$3{\cdot}81^{b}$	$4{\cdot}14^{a}$	1	$3{\cdot}09^{a}$	$3{\cdot}02^{ab}$	$2{\cdot}83^{a}$
2	$3{\cdot}76^{b}$	$3{\cdot}10^{a}$	$4{\cdot}21^{a}$	2	$3{\cdot}16^{a}$	$2{\cdot}78^{a}$	$3{\cdot}13^{a}$
3	$3{\cdot}45^{a}$	$3{\cdot}89^{b}$	$4{\cdot}22^{a}$	3	$3{\cdot}37^{a}$	$3{\cdot}24^{b}$	$3{\cdot}75^{b}$
(SED 0·12)				(SED 0·17)			
COUNTRY C				*COUNTRY D*			
1	$2{\cdot}64^{a}$	$1{\cdot}74^{a}$	$1{\cdot}93^{a}$	1	$3{\cdot}40^{ab}$	$3{\cdot}48^{ab}$	
2	$2{\cdot}76^{a}$	$2{\cdot}38^{b}$	$2{\cdot}17^{ab}$	2	$3{\cdot}34^{a}$	$3{\cdot}39^{ab}$	
3	$2{\cdot}62^{a}$	$2{\cdot}60^{b}$	$2{\cdot}28^{b}$	3	$3{\cdot}69^{b}$	$3{\cdot}23^{a}$	
				4	$4{\cdot}18^{c}$	$3{\cdot}68^{b}$	
(SED 0·16)				(SED 0·16)			
COUNTRY E				*COUNTRY G*			
1	$2{\cdot}39^{a}$	$2{\cdot}54^{b}$	$2{\cdot}58^{b}$	1	$3{\cdot}66^{b}$	$3{\cdot}16^{a}$	$3{\cdot}04^{a}$
2	$2{\cdot}61^{a}$	$2{\cdot}22^{a}$	$2{\cdot}37^{ab}$	2	$3{\cdot}56^{ab}$	$3{\cdot}48^{a}$	$2{\cdot}83^{a}$
3	$2{\cdot}66^{a}$	$2{\cdot}67^{b}$	$2{\cdot}25^{a}$	3	$3{\cdot}29^{a}$	$3{\cdot}83^{b}$	$3{\cdot}14^{a}$
(SED 0·16)				(SED 0·17)			

Superscripts: Significance within a column.

A superficial judgement from visually scanning the bulked data was that Site 2 frequently carried largest bacterial numbers. Consequently, we considered how much information would be lost if only Site 2 were sampled, thereby reducing fourfold the amount of work.

Table 5 shows the distribution of maximum counts with site at each abattoir for both surveys, i.e. in Survey I at abattoir A in country A, Site 2 was most heavily contaminated on 40% of the carcasses examined, at abattoir B on 57% and at abattoir C on 83%. Unfortunately, the distribution of bacteria is not sufficiently systematic to warrant sampling only Site 2, although it was often the dirtiest site than any other.

An alternative approach to testing whether Site 2 is the most appropriate single site for sampling would be to take an arbitrary contamination level and to record the numbers of occasions that a count on Site 2 was below that level, yet a count on one of the other three sites was above it, i.e. the number of times that a 'dirty' carcass would *not* have been rejected if Site 2 only had been sampled. Table 6 summarises the data so evaluated at an arbitrary level of $10^4/cm^2$ and shows that, in Survey I, 56 of 580 'dirty' carcasses, and in Survey II, 106 of 590 carcasses, would not have been identified.

An attempt was made to relate the bacterial numbers recorded to expert observations and abattoir practices, including cleanliness of animals slaughtered that day (scored 'exceptionally clean', 'average' or 'very dirty'), position of carcasses on de-hiding (manual or mechanical de-hiding, the hides being pulled up or down), the way the carcasses were pushed, the evisceration procedure (careful or careless), splitting by hand or mechanically, water usage (temperature and volume), number of animals slaughtered per hour, number of persons from stunning to entry of chill room, other species being slaughtered and whether the abattoir held an export licence. However, none of the variations in bacterial numbers was obviously related to any of the above factors.

In this survey of commercial carcasses, the first of its type, the magnitude of the problems in bacteriological monitoring have been identified, particularly the need for adequate numbers of visits to abattoirs before judgments of differences between them are made. It is also clearly beneficial to sample several sites per carcass, rather than only one, although the samples from one carcass may be bulked before bacteriological analysis (Roberts *et al.*, 1980). The appearance of an abattoir was not a good guide to the bacteriology of the carcasses it produces.

TABLE 5
Percentage* of Carcasses with Maximum Bacterial Counts for Each Site

	Abattoir	*Sites*			
		1	*2*	*3*	*9*
Survey I					
Country A	A	23	40	20	17
	B	7	57	10	27
	C	10	83	7	0
Country B	A	13	35	33	18
	B	13	40	13	33
	C	23	37	7	33
Country C	A	57	13	10	20
	B	63	20	7	10
	C	7	58	0	35
Country D	A	16	16	32	37
	B	5	90	0	5
Country E	A	10	43	7	40
	B	7	67	7	20
	C	40	27	17	17
Country F	A	7	57	3	33
	B	45	23	13	18
	C	0	37	20	43
Country G	A	20	70	7	3
	B	3	67	7	23
	C	13	33	20	33
Survey II					
Country A	A	7	48	35	10
	B	7	57	17	20
	C	30	60	7	3
Country B	A	17	37	13	33
	B	20	53	17	10
	C	13	37	10	40
Country C	A	30	50	7	13
	B	30	60	0	10
	C	37	47	7	10
Country D	A	3	10	65	23
	B	10	54	4	32
Country E	A	13	42	2	43
	B	10	63	13	13
	C	0	37	13	50
Country F	A	13	45	8	33
	B	17	43	10	30
Country G	A	30	30	20	20
	B	10	77	3	10
	C	17	50	10	23

* Percentages have been rounded to the nearest 1%.

TABLE 6
The Number of Carcasses with Counts Exceeding 10^4 at Sites 1, 3 or 9 when the Count on Site 2 was $< 10^4$

Country	*Visit*	*Survey I Abattoir*			*Visit*	*Survey II Abattoir*		
		A	*B*	*C*		*A*	*B*	*C*
A	1	4*	1	0	1	1	0	1
	2	2	3	1	2	1	0	0
	3	2	2	1	3	3	0	1
B	1	2	0	1	1	1	3	2
	2	2	0	3	2	6	0	3
	3	0	0	0	3	1	2	3
C	1	0	2	0	1	0	0	1
	2	0	0	0	2	1	1	0
	3	1	0	0	3	0	1	1
D	1	1	0	—	1	7	1	—
	2	1	1	—	2	7	3	—
	3	—	—	—	3	6	1	—
					4	3	1	—
E	1	0	0	1	1	0	0	1
	2	0	2	2	2	1	0	0
	3	2	0	4	3	2	3	0
F	1	2	0	0	1	5	4	—
	2	1	1	0	2	1	0	—
	3	2	3	0	3	0	1	—
G	1	1	0	1	1	6	1	3
	2	0	0	0	2	4	2	2
	3	0	2	2	3	3	1	4

* Number out of 10.

Considering the differences in animals and slaughter practices, the numbers of bacteria detected in different countries do not suggest that beef of initially poor bacteriological quality is being produced. Sampling schemes of this type could serve as a useful purpose in monitoring meat production or, if applied later in the distribution chain, the same basic scheme could also monitor the effects of distribution.

These data relate to actual manufacturing practices in the abattoirs visited. The facts that (a) there are differences between visits to the same abattoir and (b) the variation in the numbers was obviously unrelated to the data collected on the actual manufacturing practices, indicate that

there are still factors not properly evaluated or understood. This leads to the conclusion that our present understanding of 'good' or 'bad' manufacturing practices clearly is not related to bacterial numbers or hazards. It emphasizes the need for further studies of manufacturing practices to identify the critical points, e.g. dehiding and evisceration, in relation to microbial numbers. This type of study should be extended to determine the effects of further treatments, including chilling at the abattoir and during distribution.

Internationally agreed methods of sampling, bacteriological analysis and data analysis could serve a useful purpose in facilitating international and intra-Community trade with increased assurance that the product is of satisfactory bacteriological quality. However, bacteriological specifications should always be based on surveys of adequate numbers of producers to determine what can be achieved with good commercial practice over a range of production conditions.

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