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Reliability and practicability of bacteriological monitoring of beef carcass contamination and their rating within a hygiene quality control programme of abattoirs

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Abstract

A total of 9600 swab samples from 900 carcasses originating from ten different abattoirs were subjected to bacteriological examination. Two sampling sites, brisket and forearm, consistently showed the highest contamination rates. The following sites are recommended for sampling: on the lateral side of the carcass neck, forearm, shoulder, brisket and abdomen. The neck is recommended for the medial side. Compared to the large variance of contamination either on individual carcasses or between different carcasses, the differences in the variance of results between double swab and incision sampling techniques should be of minor importance. Considering this big variance of colony counts, it is suggested to take five to six swab samples from each of at least ten to 15 carcasses once a month. With a view to a more differentiated and evident evaluation the results should be recorded in 'box plots' and not in the form of mean values and standard deviations. The data confirms bacteriological monitoring of beef carcasses as a useful tool for the verification of slaughter hygiene.

Keywords: Bacteriological monitoring; Beef carcasses; Hygiene quality control programme

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1. Introduction

As with all other food, microbiological hygiene measures in meat production and processing, aim at protecting the consumer against pathogenic agents and at preventing rapid spoilage of the meat. Therefore, these measures serve the purposes of health protection as well as quality assurance in general.

The initial contamination of meat occurs during slaughtering. Already at this stage hygiene deficiencies can lead to considerable contamination. Highly contaminated raw meat is a main source of bacterial contamination and cross-contamination in meat processing plants. Hence, carcass contamination during slaughtering results in hygiene deficiencies which cannot be compensated for even by the most rigorous hygiene measures during later processing stages of the raw material. This underlines the great significance of slaughter hygiene. Therefore, verification of the efficiency of slaughter hygiene by microbiological examination of carcasses is desirable.

Thus, it has been suggested by various authors as well as by the European Commission (EC-document: VI/5938/87, PVET/2140) to use the determination of bacterial counts on carcass surfaces for slaughter hygiene monitoring. The present study was undertaken to evaluate the feasibility and diagnostic value of microbiological monitoring of carcasses in routine hygiene surveillance programmes of slaughterhouses. It has to be emphasized that the word 'monitoring' is not used in the very specific meaning in context with the HACCP concept. We apply it in the extended usage of customary language as it is applied e.g. in monitoring programmes on environmental pollutants.

2. Materials and methods

The study is based on three investigation series which were carried out within three and a half years in ten different slaughterhouses in Switzerland of which four (abattoir A,F,G,H) were EU approved. In all abattoirs mechanized line slaughtering has been used. At each sampling 30 beef carcasses were included. Ten sampling sites per carcass were examined in the first series and 11 in the following two series. The sampling sites are shown in Fig. 1. In total, 9600 swab samples were examined.

In addition, the study includes data from an EU approved abattoir in which routine bacteriological monitoring has been performed for more than two years where once a month, six swab samples were taken from each of 15 carcasses.

The sampling was performed within 2 h after the carcass had left the slaughter line. All samples were taken from the left half of the carcass.

The wet-dry double swab technique (Commission of the European Communities, 1987) was used. Marking of the 40 cm^2 sampling areas was performed with a sterile disposable paper template. Each area was sampled first with a cottonwool swab moistened in peptone-saline and then with a dry swab. Both swabs were collected in a test tube containing 20 ml peptone-saline and chilled at 4°C. Bacteriological examination of the swabs was generally performed within 2–4 h after sampling. In

exceptional cases, when the samples had been taken in the late afternoon, they were stored until the following morning.

The test tubes with the swabs were rotated on a whirlmix (Vortex) for 20–30 s. Then, the undiluted sample and two decimal dilutions were plated with the spiral-plater (Spiral Systems, 6740 Clough Pike, Cincinnati, Ohio 45244, USA) on Plate Count Agar (Oxoid CM 325) and Violet Red Bile Glucose Agar (BBL

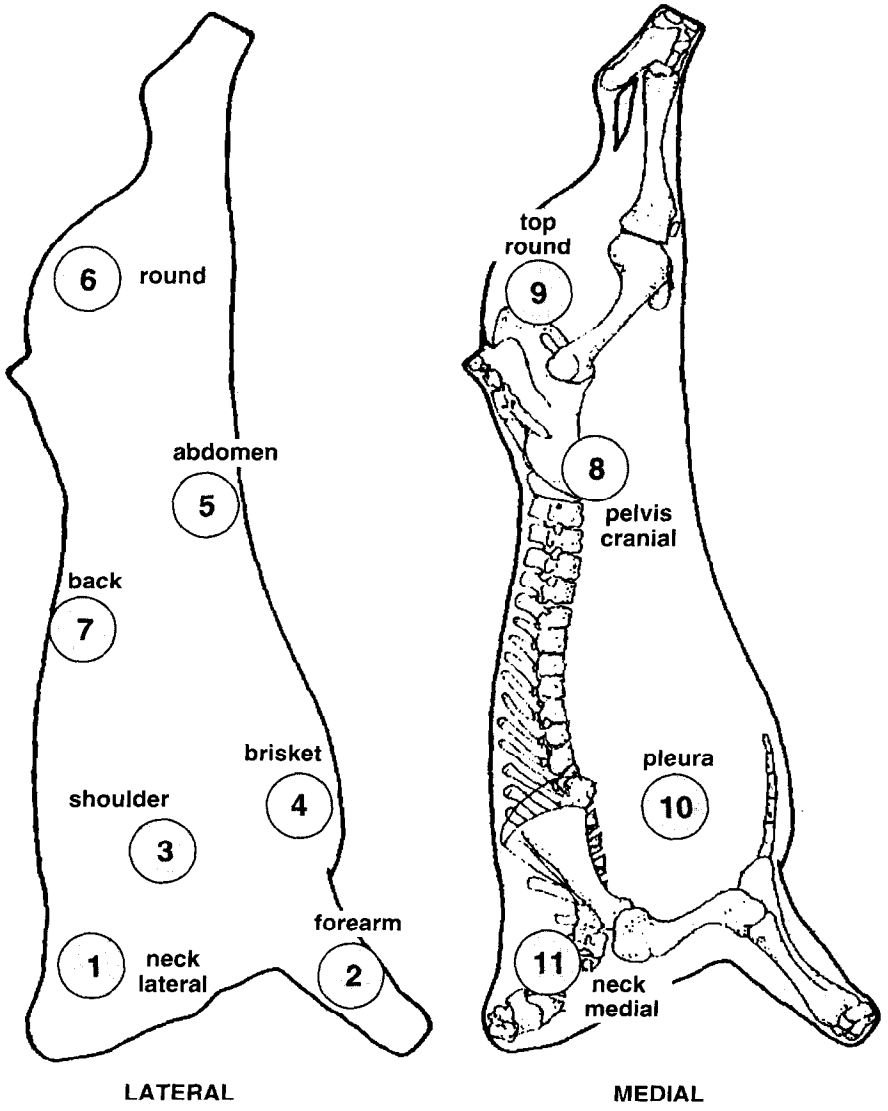

Fig. 1. Location of sampling sites on beef carcasses in the present investigation.

4311807). Plate count agar was incubated for 48 h at 30°C (aerobically) and VRBG Agar for 48 h at 37°C (anaerobically).

Colony counts were transformed to $\log_{10}$ values and depicted in box plots. By illustrating results in such a way, median values, 50%, 75%, 80% and 90% ranges and extreme values can be analysed more conveniently (Eggenberger and Thun, 1984).

3. Results and discussion

The compiled data of colony counts from the 900 carcasses are shown in Fig. 2. The data are split according to sampling sites. This figure facilitates the assessment of the highest and lowest contamination rates compared with the average of all investigation series. Mean value and standard deviation are represented in black, while the box plots are indicated in grey. The latter provide a good indication of the relatively high amount of extreme values and that the colony counts cover a wide range. Considering the 80% and 50% ranges and the median values, it can be concluded that colony counts on the medial side are significantly lower than those on the lateral carcass side. Out of the four investigated medial sampling sites only the inclusion of the neck site seems to be justified. Laterally, the highest contamination rates were found on forearm and brisket.

The two sampling sites with the highest and lowest colony counts of all abattoirs and investigation series are listed in Table 1. Among the 30 sampling series, forearm and brisket showed the highest bacterial counts in 21 series.

The abdomen showed the highest count in six series, the lateral neck and round in four series and the back in one series. These data confirm that forearm and brisket belong to the highest contaminated parts of the carcass.

Among the sampling sites of the inner side of the carcass the lowest bacterial counts were recorded for pelvis cranial in 21 out of 30 sampling series, for pleura in 22 and for top round in ten out of the 30 sampling series. Thus, these more differentiated data give the same results as the box plots in Fig. 2 where all data from all abattoirs and sampling series are compiled.

The four sampling sites with the highest and lowest cell counts for the ten abattoirs are represented in Fig. 3. This figure again shows that the extreme values spread in wide ranges, even within the same abattoir.

At the sampling sites with low total colony counts the values vary on average between 2 and 2.5 $\log_{10}$ units. At the higher contaminated locations, forearm and brisket, the variations between extreme values amounted on average to between 3.5 and 4 $\log_{10}$ units.

For this reason, the use of mean values and standard deviations does not seem to be justified, especially with low numbers of samples. Box plot data allow a more detailed interpretation of results.

Also the evaluation of the hygiene status based on bacteriological mean values of pooled samples from one carcass (Hyytiäinen et al., 1975, Wyss, 1996) is unsatisfactory. This is partly because of the large variances of values between different sites

Table 1
Location of carcass sampling sites with the two highest and the two lowest contamination rates per abattoir (mean value)

Abbatoir	Series	Sampling sites[a]									
11		1	2	3	4	5	6	7	8	9	10
A	Series I		X				O			O	
	Series II		X		X					O	O
	Series III		X				X			O	O
B	Series I				X	X			O		O
	Series II		X		X					O	O
	Series III		X		X					O	O
C	Series I		X		X				O		O
	Series II		X		X				O		O
	Series III		X			X				O	O
D	Series I		X		X					O	O
	Series II		X				X			O	O
O	Series III				X		X				O
E	Series I		X		X				O		O
	Series II				X	X				O	O
	Series III		X		X					O	O
F	Series I	X							O	O	
	Series II		X				X			O	O
	Series III		X		X				O	O	
G	Series I		X		X	O				O	
	series II	X	X						O	O	
	series III	X			X					O	O
H	series I		X		X						O
	series II	X						X		O	O
	series III		X		X					O	O
I	Series I				X	X			O		O
O	series II		X			X					O
	series III				X	X				O	O
K	Series I		X		X	O					
	series II	O			X		X		O	O	
	series III		X		X				O	O	

[a]1: neck lateral; 2: forearm; 3: shoulder; 4: brisket; 5: abdomen; 6: round; 7: back; 8: top round; 9: pelvis cranial; 10: pleura; 11: neck medial.
X and O represent the 2 highest and lowest contamination rates per abbatoir (mean value), respectively.

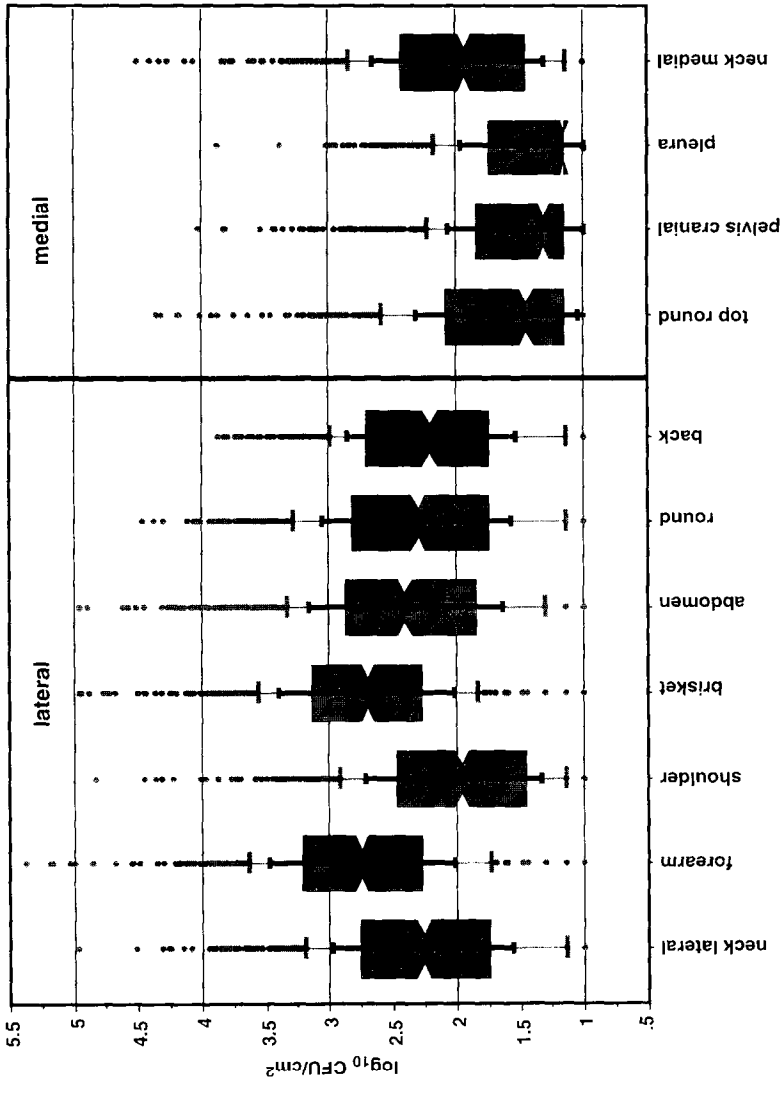

Fig. 2. Results of bacterial colony counts at 11 different sampling sites on beef carcasses; compiled data of ten abattoirs. Sample site back $n = 600$, other sites each $n = 900$, total $n = 9600$.

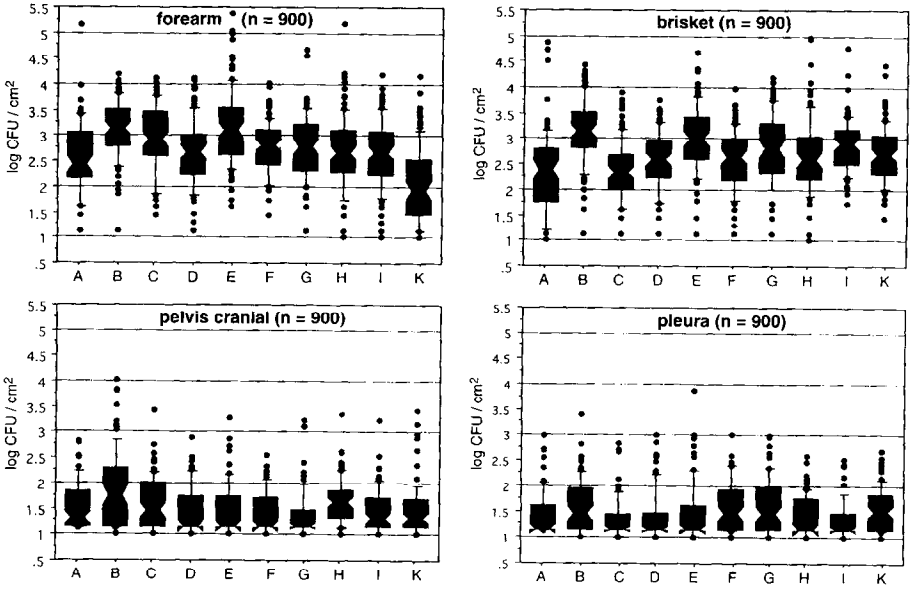

Fig. 3. Results of bacteriological investigations of the four sampling sites with the highest, respectively lowest colony counts, subdivided into the ten abattoirs.

on the same carcass which leads to distorted results and partly because direct conclusions concerning specific hygiene deficiencies in slaughter technology cannot be drawn. When examining for *Salmonella* spp, sample pooling makes sense for reasons of cost-effectiveness, because the aim is only to take a presence/absence decision.

Description and names of the sampling sites vary in the literature. More details on sampling sites which the different authors had included in their studies are given in Fig. 4. Sometimes the name for the same location differs from one author to another or it is not clear where the area had been located precisely. Therefore, the carcass region from which the samples had been taken by those authors is described in more general terms. Some or all of the following regions were included by the different authors: on the lateral forequarter neck region, pectoral region and dorsal region, on the lateral hindquarter round and ventral region, and on the medial hindquarter the top round site.

All the sampling areas mentioned above were part of our investigations. Most authors did not include the forearm in their studies. Like Stolle (1988), we found that the forearm and brisket belong to the parts with highest bacterial counts. This can be explained by the high contamination risk during the pre-dehiding process.

In two of the three series, alongside with aerobic colony counts we checked the occurrence of Enterobacteriaceae by incubating the VRBG agar anaerobically. Only 5% of 6300 swab samples revealed Enterobacteriaceae in low numbers. Values above 10^3 Enterobacteriaceae per cm^2 were only registered in four swab samples. The highest individual Enterobacteriaceae count was $5.7 \times 10^3/cm^2$. We suppose

that remarkable numbers of Enterobacteriaceae only occur on carcasses when hygiene measures are so inadequate that this can already be discovered by mere observation of the slaughtering process.

Based on our results, we recommend the following six locations for microbiological sampling: on the lateral side neck, forearm, shoulder, brisket, abdomen and medialy the neck.

Different abattoir technologies may lead to varying results. Therefore, for each abattoir, some additional sampling sites should nonetheless be included at the

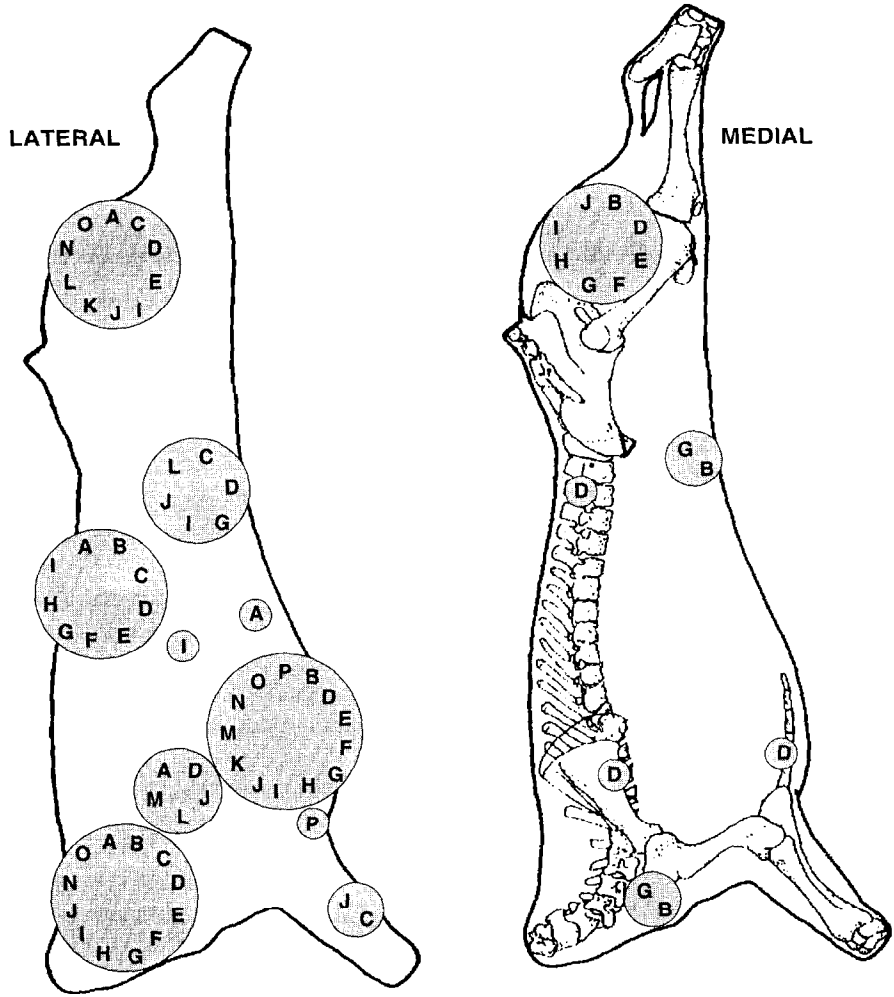

Fig. 4. Survey of sampling sites for carcass contamination monitoring, used by various authors. **A**, Catsaras et al. (1974); **B**, Nottingham et al. (1974); **C**, Hyytiäinen et al. (1975); **D**, Roberts and Ingram (1976); **E**, Snijders et al. (1984); **F**, Hudson et al. (1983); **G**, Johanson et al. (1983); **H**, Roberts et al. (1984); **I**, Whelehan et al. (1986); **J**, Stolle (1988); **K**, Lasta and Fonrouge (1988); **L**, Meermeier (1991); **M**, Ridell and Korkeála (1993); **N**, Zeleke et al. (1994); **O**, Mukartini (1995); **P**, Wyss (1996).

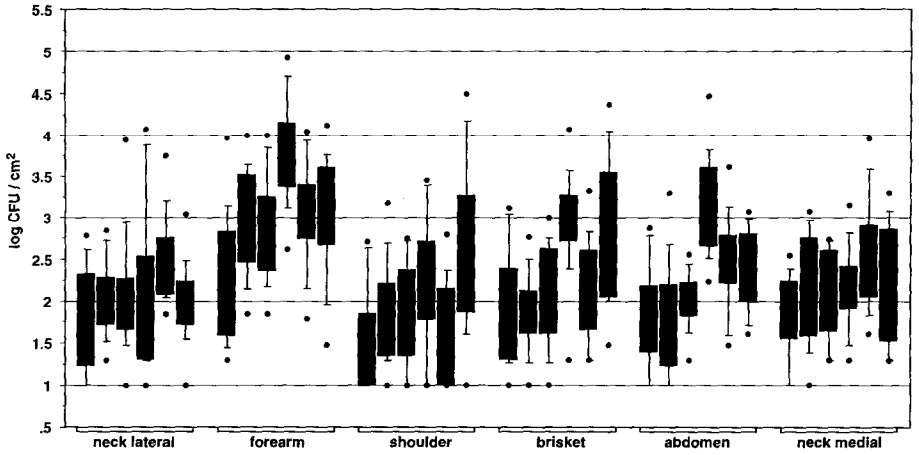

Fig. 5. Routine bacteriological monitoring of beef carcasses in abattoir A: results of 6 months (January–June 95) carcasses per month, $n = 15$.

beginning of a monitoring programme. The selection of additional areas should depend on observations during the slaughtering process that lead to the assessment of higher contamination risks at particular areas of the carcasses.

Although the excision sampling technique gives more precise results than swab sampling (Ojala, 1964; Reuter, 1984; Snijders et al., 1984; Anderson et al., 1987) we prefer the latter technique as long as sampling is performed by reliable and trained staff. The diluent fluid from swab samples can be plated directly on a nutrient medium by the spiral-plater technique. In contrast, samples from excision techniques have to be homogenized and filtered before applying the spiral-plater technique. Other surface plating techniques are more time consuming. Therefore, a considerably higher number of swab samples can be examined with the same expenditure of time and cost.

Furthermore, the methodological variance between wet-dry double swab and excision sampling techniques (Ojala, 1964; Reuter, 1984; Snijders et al., 1984; Anderson et al., 1987) is of minor importance compared to the enormous variance of colony counts that occur within carcasses from the same day of slaughtering, which is demonstrated by the wide range of extreme values shown in Fig. 3. Therefore, it seems to make sense to examine a larger number of samples with the double swab technique, instead of a lower number of samples by the excision technique.

Considering the observed variation of colony counts, we suggest the taking of five to six swab samples from each of at least 10–15 carcasses once a month. Our experience over more than two years with routine bacteriological monitoring of beef carcasses in abattoirs shows that useful information about hygiene trends can be derived from such a sampling plan. Fig. 5 shows the record of monthly investigations from January to June 1995. In April results of four sampling sites and in June results of two sampling sites are significantly higher than the results at

the same locations during the other months. This fact points to hygiene deficiencies in the slaughter process on the days of sampling. The findings from such examinations cannot provide the basis for the establishment of official standards. However, they constitute a useful tool for in-plant process controls.

It should be emphasized that bacteriological monitoring of beef carcasses is only one aspect of quality surveillance concerning abattoir hygiene. Quality assurance measures for hygiene in abattoirs can be divided into basic hygiene measures and process-orientated hygiene measures.

Basic hygiene measures include design and construction of the abbattoir according to the regulations of the EU, as well as procedures for the cleaning and disinfection of equipment during slaughtering, and finally, personnel hygiene.

For process-orientated hygiene measures, there has to be a description of specific hygiene standards for the slaughter process, including a flow chart emphasizing 'critical points' according to Council Directive 93/43/EEC.

For a surveillance programme for defined hygiene measures the following points are essential: first, it is important that quality assurance requires a continuous documentation based on surveillance investigation to guarantee traceability. A successful surveillance of basic hygienic measures depends upon daily surveillance and documentation of cleaning procedures by visual checking in the morning before slaughtering as well as upon monthly bacteriological sampling to prove the effectiveness of cleaning and disinfection.

The process-orientated hygiene standards and especially the 'critical' check points have to be surveyed daily with special attention to the behaviour of the staff. It is advisable to use check lists for documentation.

In addition, carcasses should be checked daily for visible contamination with dirt and monthly bacteriological monitoring of beef carcasses should also be carried out. These last two surveillance measures can be defined as 'verification' according to the meaning of this term within the HACCP concept and according to ISO 8402.

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