10

HYGIENE IN MEAT PROCESSING PLANTS

I. Importance of bacteria in meat processing plants.

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INTRODUCTION

The livestock industry in Northern Ireland is the most important part of our agricultural economy. The total output of fat cattle, cows and bulls for 1965 - 66 has been valued at approx. £ 25 m, of fat sheep and lambs £ 3.6 m, and of fat pigs £ 33.5 m. (Report, 1966). Much of this output is exported, mainly to Gr. Britain, but markets are expanding, not only to Continental countries, but also to North and South America, Africa, the Middle and Far East. Large scale production of any perishable foodstuff gives rise to marketing difficulties when markets are at a distance, and the foodstuff has to be offered fresh to the consumer. An increasing proportion of fresh meat is exported in the form of cooled carcases, and cooled or frozen meat products. It is important that these should be of high quality with the minimum of spoilage, when the point-of-sale is reached. The export of cured meat is also very important. Northern Ireland supplied 38 per cent of home produced bacon in the United Kingdom during 1965 - 66, a total of 86,265 tons, (report, 1966)

Spoilage or reduced keeping time of meat and meat products can be largely attributed to the growth of micro-organisms, especially bacteria, and the subsequent release of their metabolic products. The aim of this paper is to show how meat (particularly cattle and sheep carcases) becomes contaminated by bacteria, and how these bacteria grow on the meat. Subsequent papers will deal with methods of assessing carcase contamination, and how such contamination can be reduced. This is not a new problem. Australia and New Zealand had to face a similar one thirty years ago. They realised (Empey and Scott, 1939) that exports to Gt.Britain could only be attempted when the following conditions were fulfilled:-

(i) A very marked reduction in the average "load" of micro-organisms acquired by the beef in the meatworks.

(ii) Methods of chilling in the meatworks which would eliminate or greatly retard the growth of the acquired microflora.

(iii) Precise control of the physical conditions in the storage atmosphere during carriage shipboard.

BACTERIA OF IMPORTANCE IN THE ABATTOIR

(a) Spoilage of fresh meat.

The bacteria mainly responsible for the spoilage of fresh meat are classified in the genus Pseudomonas. Haines (1937) has pointed out that this group, together with Achromobacter and a few strains of Proteus, yeasts and moulds which are capable of comparatively rapid growth at $0^{\circ}C$ can cause spoilage of chilled products. Such spoilage is caused by slime on the surface of the meat due to bacterial growth, discolouration of the tissues due to pigment destruction or the growth of coloured colonies, and the production of odours, "cold store taint" and "souring". The time necessary for slime production is greatly influenced by the level of initial contamination. If this is high, then spoilage is rapid. Empey and Scott (1939) also found that spoilage of chilled beef held at $-_1{}^{\circ}C$ was due to growth on the surface of bacteria, yeasts and moulds.

Of the bacteria Achromobacter accounted for 90%; Micrococcus, 7%; Flavobacterium, 3%; and Pseudomonas less than 1%. Brown and Weidemann (1958), however, have shown that of 129 strains isolated by the earlier workers almost all would, in the light of present knowledge, be allocated to the genus Pseudomonas. Ayres (1960) has pointed out that not only are organisms from this genus responsible for the spoilage of chilled meat, but also with the spoilage of fresh poultry and eggs. Gardner (1965) has shown that the spoilage of minced beef held at 15°, 9° and 4°C was mainly due to bacteria of the same genus. Most workers agree that the onset of sliminess and off-odours is imminent when the numbers of bacteria per sq cm is of the order of 10^7. The reason for this type of spoilage rather than putrefaction was attributed by Ayres (1960) to the fact that though many bacteria capable of causing putrefaction do in fact come in contact with the meat, they are mesophiles which do not survive refrigeration or grow poorly at low temperatures. The pseudomonads however can survive and grow at such tempertures relatively quickly. Farrell and Barnes (1964) have reported a Pseudomonas from poultry which doubled its numbers every 36 hrs at -2°C, every 14 hrs at 0°C and every 7 hrs at 5°C and less than an hour at 25°C. Gardner (1965)found that Pseudomonas of both fluorescent (group I) and non-fluorescent (group II) kinds accounted for 96% of the flora of minced meat after 185 hrs at 4°C; 100% after 161 hrs at 9°C and 99% after 65 hrs at 15°C.

(b) Spoilage of cured meat.

This is somewhat different to the spoilage of fresh meat. Pseudomonads probably play a part in the spoilage of uncured pork, but sliminess of the cured product, bacon, is largely due to the growth of micrococci, which are more salt tolerant than the pseudomonads. Many of the micrococci on the sides going into the curing brine, which may have 25% of salt present, can survive the cure and grow slowly at curingcellar temperature (3-4°C). A contribution of micrococci is also

received from the brine (Patterson 1963, 1966). These bacteria are also important in the spoilage of bacon products such as vacuum-packed sliced bacon, and the closely related Staphylococcus aureus has often been responsible for outbreaks of food poisoning caused by eating contaminated meat and meat products. Internal spoilage ("taint" or "souring") of cured hams and gammons has also been attributed to such bacteria.

(c) Food poisoning bacteria.

To many people the word "hygiene" implies the control of harmful bacteria which may cause food poisoning in man. It is fortunate that many of the control measures aimed at keeping spoilage bacteria in check in food also serve to control the dangerous bacteria such as Salmonella, Staph. aureus and Cl. perfringens. Such potential pathogens will not grow much at temperatures below 10°C, so that adequate refrigation keeps them in check. This does not mean that they are of no importance on meat. Vernon (1966) has recorded that 74 out of 84 outbreaks of food poisoning in which a particular food was incriminated (in England and Wales) were associated with meat products. Of the 74, 12 cases were due to Salmonella typhimurium, 8 to other salmonellae, 15 to staphylococci, and 40 to Cl. perfringens. Processed meats were most often the cause. Salmonellae were generally the cause in "meat" and poultry, and Cl.perfringens in beef, poultry and mutton. Dixon and Peacock (1965) examined 898 samples of imported chilled meat and offal from Holland, and 67 (7.5%) of these contained salmonellae. The probable source of these bacteria will be discussed later in this paper.

GROWTH OF BACTERIA IN THE ABATTOIR.

When bacteria of any kind are added to a suitable medium, i.e. something providing the nutrients required for growth, they will grow and multiply more or less rapidly depending on the food supply, temperature, acidety and the presence or absence of O_2. First of all,

however, there is a period of readjustment (the "lag phase") before multiplication starts, and then the bacteria pass through further stages, viz. phase of rapid multiplication, stationary phase and death phase. In food preservation the aim is to lengthen the lag phase as much as possible. This is done (1) by introducing as few spoilage bacteria as possible, for the fewer the bacteria present initially the longer will be the lag phase.

(ii) by avoiding the addition of actively growing bacteria from dirty equipment, containers, hands or clothes which come in contact with the carcases, or from hides, air or water.

(iii) by making the environment unsuitable for the bacteria to multiply, e.g. by chilling or freezing the carcases as quickly as possible.

(iv) by actual physical removal of bacteria from the sides, e.g. by washing, or damage to the bacteria as in chlorination of the washing water.

As an example of this, work by Haines (1937) has shown that slime formation at $0^{\circ}C$ took about 18 days when the initial bacterial load on a carcase was 10 per sq cm, but when this was 100,000 it only took about 8 days. In an abattoir the cold-tolerant spoilage bacteria can grow rapidly on all dirty surfaces at quite low temperatures (e.g. $15^{\circ}C$), but more slowly at $4^{\circ}C$. A combination therefore of low bacterial numbers on the sides going into chill, with adequate cooling, should be effective in keeping the carcases wholesome for a period long enough to allow for transportation and marketing. Conversely highly contaminated sides, inadequately cooled, may develop sliminess and off-odours within a few days.

SOURCES OF BACTERIAL CONTAMINATION OF THE MEAT

(a) Condition of the animal on arrival and infection in the lairage.

Leaving aside for the moment the question of dirty animals, the effects of transport, fatigue and starvation deserve some consideration.

Traditionally, fatigued or "heated" animals have been considered unfit for slaughter for four main reasons (Haines, 1937; Ingram, 1964): -

(i) Intestinal bacteria tend to leak from the gut into the tissue if an animal is fatigued.

(ii) With animals in a state of stress, bleeding tends to be imperfect, and such retention of blood in the muscles is believed to promote putrefaction.

(iii) Animals killed when fatigued produce meat which is more liable to putrefy because it is less acid.

(iv) In addition, animals which are fatigued in transport may suffer severe losses in weight.

Ingram (1964) has examined the case for feeding and resting meat animals before slaughter to get over these ill-effects. He pointed out that most of the observations which have been made deal with pigs. Adult cattle are much more resistant to the effects of fatigue, and no experiments seem to have been made with sheep. Calves may be much more susceptible to fatigue than older cattle.

The feeding of an easily assimilated carbohydrate such as sugar together with resting can to a large extent overcome the effects of fatigue with pigs, and in fact this has been done in some bacon factories. Patterson and Carson (1963) have reviewed the literature and have also shown that if a carcase of low pH is required, as in Wiltshire curing, it is essential to avoid fatigue, starvation, fighting, overheating or any other form of stress. This can be achieved by feeding sugar, preferably the night before slaughter, and resting. In the case of factory killed pigs for the roll and ham (dry salt) cure this is an essential precaution to avoid tainted hams. One other interesting side effect of sugar-feeding is the increased liver weight obtained in pigs (about 20% increase within 7 hrs after feeding 2 lb sugar, and resting). Several important points have to be borne in mind however. When meat of high pH is required, e.g. in sausage-making, where such meat has a

better water-binding capacity than meat of low pH, sugar-feeding may not be desireable. Also in certain cases, trouble has been experienced with pale, watery muscle. This condition is believed to arise when the muscle pH falls below 6.1 within 45 min of death. Sugar-feeding is liable to encourage this high acidity, but fortunately the condition is not yet common in this country. If sugar-feeding is done even a short time (3-6 hrs) before slaughter, benefits can still be obtained. One bacon factory in N.Ireland fed 2 lb of sugar to pigs and rested them 5-6 hrs before slaughter; an increase of 12-15% in liver weight (which appears to be a measure of sugar absorption) was recorded after slaughter (Patterson and Carson, 1963).

Another factor which must be taken into consideration is the possiblity of cross-infection within the lairages during the rest period. This possibility had been put forward by several workers, and Burns, Mair and Hooper (1965) have investigated the reasons for an outbreak of Salmonella brandenburg infection caused by infected pork products at Leicester. Their results show that of 63 specimens from pigs slaughtered within 24 hrs of arrival, 2 (3.2%) yielded S.brandenburg, whereas of 351 specimens from pigs kept 1-7 days in the lairages before slaughter, 32 (9.1%) harboured the organism. From 4 specimens of the latter group S. stanley was also isolated, bringing the total amount of Salmonella infection to 10.3%.
S.brandenburg was cultured from floors and walls of certain pens in the lairages, from specimens of bedding and from the intestinal contents of a rat trapped near the lairages. After a regular system of cleansing and disinfection was instituted no further isolations were made. Similar observations have been made with calves (Ingram, 1964).

(b) Sources of contamination during butchering.

One source of such contamination is the "stick-knife". Jensen

and Hess (1954) have shown that bacteria from the skin of pigs could be transferred in this way into the bloodstream, and then to all parts of the body while the pig was dying (i.e. a period of about 40 secs.) Unwashed pig skin carries large numbers of bacteria, both aerobic and anaerobic, and when these are introduced into the body they can contribute to souring of hams after cure.

Scarafondi (1957) has summarised the work of Empey and Scott (1939) who made a thorough study of sources of contamination of cattle carcases during the butchering operations. The main sources were as follows: -

(i) Dirt and skins of animals (approx. 33%).

(ii) Pollution in the abattoir atmosphere (approx. 5%)

(iii) The visceral content - in normal conditions (approx. 3%)

(iv) Transport and storage (50% or over.)

(v) Halving, quartering and packing of carcases (approx. 2%)

(vi) Miscellaneous - utensils, personnel etc. (approx. 3%)

The first and most important source appears to be the animal itself, and other sources are the result of this initial contamination building up. These workers found the hides of cattle before slaughter to be heavily contaminated by bacteria. When dry areas of the hide were moistened bacterial contamination increased 5 to 10-fold. The transfer of large numbers of these bacteria to the carcase began as soon as the first incision was made and continued with direct contact of the hide with underlying tissues, or by direct transfer via the hands, arms and clothing of the men who were handling the carcases with the hide still attached.

After skinning they found 10^4 - 10^5 organisms per sq cm. on the tissues, the contamination being greatest at the point of incision and lowest in the regions farthest from it. Blades of knives carried 8×10^4 - 4×10^7 bacteria per blade; leggings of men removing the

hides when scraped after skinning 100 carcases in 6 hrs carried 3×10^9 bacteria per gm. of scrapings. The hand of a worker handling the hide carried 2×10^6 bacteria. Table 1 gives some results from butchering lines studied by us.

Table 1. Contamination of hands, clothing and equipment in two abattoirs.

	Total count/swab
Abattoir 1 (killing cattle)	
Butcher's hand (skinning carcases).	4×10^6
" apron (i).	5.9×10^6
" " (ii)	1.4×10^7
Abattoir 2 (killing sheep)	
Butcher's hand (removing fleece).	1.3×10^7
" " (opening carcase).	6×10^6
" " (removing viscera)	5×10^6
" apron (opening carcase)	2×10^7
" " (removing viscera).	Ov. 5×10^7
Knife blade (opening carcase).	6.7×10^4

If the hair of the hide is heavily contaminated with faeces, the amount of transfer to the carcase by butchering operations must be considerable, unless steps can be taken to reduce it by frequent washing of hands, clothes, and equipment. Another source of contamination is from soil, which, especially in wet weather with grass finished cattle can cling in appreciable amounts to hooves and the lower parts of the leg. Field soils contain large numbers of bacteria, including Pseudomonas, and we have found total counts in soils of 10^6 - 6×10^8 organisms per g. The contents of the intestinal tract also carry very large numbers of bacteria, and if some part is accidentally punctured, contamination may occur. Thornton (1962) has noted that fresh bovine faeces contains 1.5×10^8 bacteria per oz, and that contamination of the surface of the carcase readily occurs during the process of dressing.

After hide removal, the carcase becomes exposed to airborne contamination, and although this may not be great, care should be taken to minimise it by keeping all surfaces, including roof supports,

as dust free as possible.

Water-borne contamination should not be great in N.I. abattoirs, where the standards laid down are similar to those for chlorinated water for human consumption. These are shown in Table 2.

Table 2. Standards for chlorinated water supllies.

Faecal coli (E.coli I)	- Absent in 100 ml of water sample.
Coli-aerogenes bacteria at 37°C	- Not exceeding 3 per 100 ml of water sample.
Cl. perfringens	- Not more than 3 per 40 ml. of water sample.
Total count at 37°C	- Not exceeding 100 per ml of water sample.
Total count at 22°C	- Not exceeding 200 per ml of water sample.

As well as a low number of organisms of public health significance it is essential to have a low 22°C count, for it is this group of bacteria which cause spoilage of fresh meat. For certain purposes in the abattoir, such as boiler feed water, slightly lower standards are applied, but it is obvious that polluted water which might contain dangerous organisms such as Salmonella should not be used.

(c) Bacterial multiplication during cooling.

After butchering, carcases should be cooled as quickly as possible to prevent bacterial multiplication, and once cooled, kept in this state. The bacteria which cause deterioration of the cooled meat can multiply slowly even at chillroom temperature, and if this is allowed to rise even several degrees for some hours, e.g. when freshly killed sides are placed in the chill, bacterial growth may accelerate considerably. The work of Farrell and Barnes (1964) on chilled poultry which had already been noted is of interest in this connection, and is relevant in that the spoilage bacteria of poultry carcases are much the same as that of red meat.

Some sides have been sampled which had been in the chillroom for periods of 0 - 7 days. The results are summarised in Table 3.

Table 3. Bacterial numbers on cooled cattle carcases during storage (mean values).

	No. of carcases	Total count per g. of surface scrapings.
Freshly killed	5	3.6×10^3
3 days in chill.	3	5.1×10^6
5 " " "	2	1.3×10^8
6 " " "	3	2×10^7
7 " " "	3	1.9×10^8

Unfortunately no record was made of temperature changes in the chillroom over the period, but it is probable that fresh sides were being placed in the chillroom on successive days, probably causing temperature fluctuations. Where there is enough refrigerated capacity to allow chillrooms to be cleaned thoroughly before putting in freshly killed carcases, and they are properly operated, there should be very little bacterial multiplication for several days.

Apart from those bacteria on the carcases from butchering, others may be added in the chillroom. Doors, uprights, walls, are often heavily contaminated and the sides may make contact with these. The continuous circulation of air will distribute dust, moulds from fittings, ceilings and floors, and open doors allow contaminated air in from the slaughter floor and outside the abattoir. Sawdust, if used on the floor can become highly contaminated,and gets on the sides in various ways. 24×10^6 bacteria per g. of sawdust on a chillroom floor has been recorded in an abattoir before its use was discontinued.

(d) Subsequent operations.

Cutting, quartering, wrapping, and transfer to containers for transportation all add bacteria to the sides. Sometimes the hands and clothes of the men carrying sides are far from clean. However one of the most important part of the production of high quality carcases is the effect of transportation of these to the point of sale. The same factors affecting bacterial multiplication apply during

transportation and if the temperature rises in the container and storage is more than a few hours, sliminess and off-odours will develop. This is particularly true of meat already carrying a large load of bacteria leaving the abattoir. Probably the best answer is to have well cooled, clean carcases transported in mechanically refrigerated containers.

If the meat is to be used for further processing into various cuts, or into steakburgers, sausages and other meat products, and has a high bacterial count, the product will also have a high count and short keeping time. Cutting tables, knives, saws, containers, hands and clothes all become heavily contaminated and need to be often cleaned. A build-up of meat on the tables either awaiting cutting, or further processing, may lead to further bacterial multiplication. Personal hygiene is particularly important, and unless frequent hand washing is carried out undesirable organisms may be transferred to the meat.

CONCLUSIONS

It is of great importance that meat sides should carry as little bacterial contamination as possible. The results given in Tables 1 and 3 are probably not untypical of many similar abattoirs. However, there is not a great deal of published work dealing with this problem on which to base standards. It is not feasible, in view of the condition of the animals on arrival at the abattoir with large numbers of bacteria on the feet, hides and fleeces and in the intestines, to completely prevent such contamination. However steps can be taken to minimise the transfer of bacteria to the meat. This involves frequent washing of the carcases during butchering operations and also frequent cleansing of equipment, hands andclothing which may come in contact with the meat. It is necessary for the bacteriologist to be able to assess the hygenic condition of the meat after butchering, cooling and

transportation and also of the equipment, hands and clothing which come in contact with the carcases. He must also be in a position to give advice on how to reduce bacterial contamination of the meat at the different stages during butchering and processing. In addition, bacteriological standards are required not only for the whole carcase, but also for any processed meats derived from such a carcase.

S U M M A R Y

The importance of bacteria in the spoilage of fresh and cured meat is discussed. Food poisoning bacteria on meat are considered. The sources of spoilage and food poisoning bacteria on the meat are dealt with viz. the animal itself, contamination due to butchering and subsequent operations, and from air and water. Factors affecting the growth of bacteria on the meat are examined and bacterial numbers are shown to increase rapidly on cooled cattle carcases during storage.

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