In considering the question of staphylococcus food poisoning in relation to meat there may be some temptation to feel that because the problem has been recognized for sometime somehow it must have been solved and therefore is no longer of much significance. Unfortunately, this is not the situation. In a report in 1964 by an ad hoc Food Protection Committee it was stated that "poultry and meat products have been the sources of about half of the food-borne outbreaks reported since 1956". Of the 206 outbreaks of foodborne illness recorded as caused by staphylococci in the United States between 1957-1962, 61 (approximately 30%) involving 2386 cases were attributed to meat. (Dack, 1963). It has long been recognized, and is here reiterated, that any true assessment of the microbiological hazards of meat, or any other food, based upon statistics concerning outbreaks and cases are grossly inaccurate because the reporting of incidents is known to be very incomplete. Recognizing that the above figures for the number of outbreaks of staphylococcus food poisoning incriminating meat is underestimated, perhaps in the magnitude of one-tenth the actual number of such incidents, the number of such incidents attributable to meat is still cause for concern.

As to the organism itself—the staphylococci considered to be of public health significance when found in food are those classified as pathogenic. The species is designated as Staphylococcus aureus. It is a physiologically complex organism, and certain strains produce toxins called enterotoxins, one or more of which cause emesis in man. Other characteristics of the organism which would appear to be of especial interest to persons interested in meat science include the high salt tolerance manifested by certain of the enterotoxin-producing strains and the ability under aerobic conditions of these bacteria to withstand a fairly high degree of acidity. The organism will grow in media containing a large percentage of sodium chloride and is not suppressed totally by the presence of nitrites; thus, survival and even multiplication is possible in curing solutions.

The pattern of cause and effect for staphylococcus food poisoning is well-established. A food suitable for the development of an enterotoxin-producing strain of staphylococci becomes infected, frequently through the carelessness of a food handler, responsible for some phase of the food preparation or processing. Often contamination is the result when the food handler allows secretions from nose, throat or suppurating

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wounds or burns to get into the food. Other sources of infection include unclean equipment such as grinders and slicers, and contamination by insects. Once the enterotoxin-producing strain of staphylococci is in the food, multiplication of cells may occur within the temperature range of 40\(^\circ\)-120\(^\circ\)F. Growth is most rapid when the food is held in the range of 70\(^\circ\)-100\(^\circ\)F, and under this condition of holding enterotoxin may be produced in sufficient quantity to cause human illness in approximately 4-6 hours. One characteristic of the enterotoxin which is of especial significance is its apparent heat stability in food. It has been shown to withstand boiling for one hour or more in a food substrate.

When the effect of low temperature has been studied, it has been noted that the lowest temperature at which Staphylococcus aureus appears to grow is 40-44\(^\circ\)F and that toxin production does not occur below 64\(^\circ\)F. The staphylococci have been observed to survive frozen storage at 0\(^\circ\)F for many months. Upon thawing food containing staphylococci, growth of the organism with attendant toxin formation may occur if conditions of handling or storage are improper.

Once ingested, the physiological action of the staphylococcus toxin is to produce in susceptible people, in about 2-3 hours' time, nausea, vomiting, abdominal cramps, diarrhea, sweating and prostration. Usually no fever is present. The illness is almost never fatal and the victim effects an uneventful recovery in a short time.

More recently it has been shown that there is not one but three or more enterotoxins produced by the staphylococci. All are believed to be protein in nature but whether they all induce the same physiological reaction in man is still debated. There seems to be some agreement that the enterotoxin indicated as A is one which does induce the commonly accepted syndrome.

Much effort has gone into attempting to find a means of ascertaining the presence of enterotoxin in an incriminated food. In the past feeding or injection of animals with suspensions of viable cells or with cell-free filtrates was frequently used for this purpose but never with great success because some animals were refractory. With the further elucidation of the nature of the toxin new procedures are now being tested. Chief among them are antigen-antibody reactions. Casman and Bennett (1964) have described a slide double-diffusion test which permits identification of two toxins, Enterotoxin A and B. It is based on gel-diffusion techniques. A little earlier Hall et al. (1963) published the results of a study in which they too employed the principle of gel-diffusion for detecting staphylococcal enterotoxin B. The unique effort in their work was the attempt to detect the staphylococcal enterotoxin B directly in the food. They were not successful in so-doing for all foods but their results are suggestive. As the chemical structure of the enterotoxins are elucidated, the possibility of the detection of the enterotoxin in foods by serological or other means becomes increasingly hopeful.

In the endeavor to find means of confirming a given food as the cause of a food poisoning, an alternative approach to detecting the enterotoxin has been a search for characteristics of enterotoxin-producing
strains of staphylococci which differentiate them from other strains. These efforts have not been totally successful, either. The most commonly used criterion is the coagulase test based on the ability of the organism to coagulate citrated or oxalated blood plasma. Apparently, all enterotoxin producing staphylococci are coagulase-positive but not all coagulase-positive strains are enterotoxigenic. Another procedure in use today is phage typing. The phage pattern of a given strain has been found to be quite stable. By the use of 21 basic phages many strains of the organism can be divided into 4 groups. Additional phages are available for further typing, if necessary. Blair and Williams (1961) described the procedures for such typing in detail.

Emphasis is given to the general problem of microbial contamination of food, including meat by the recent report (1964) referred to above as published by an ad hoc sub-committee on food microbiology appointed by the National Academy of Sciences-National Research Council Food Protection Committee. The committee emphasized that "departure from time-honored practices in production, processing, preservation, distribution and serving of foods have raised new questions concerning the microbiological contamination of products now reaching large segments of the public in partially or completely prepared form." This statement of the committee was elaborated to include several additional points: (1) the effect of changes in American food-buying and eating habits to include many more frozen and pre-cooked foods and those foods which are purveyed by vending machines, (2) the possible microbiological impact of the shift in preparation of food from the home to the factory, (3) the effect, in terms of bacteriological quality, of "mildly processed" foods as contrasted with foods processed by the more traditional methods, (4) the relationship of present-day procedures for packaging, transportation and storage of foods to the microbial flora and (5) the question of establishing reasonably uniform microbiological standards for foods across the country.

Turning now to the implications of the preceding generalizations for meat. In a study bearing directly on the possibility of contamination of meat by staphylococci, Casman, McCoy and Prandly in 1963 reported that raw and cooked beef, raw and cooked pork and canned ham supported growth of the one strain of staphylococci with concurrent enterotoxin A production. They concluded that enterotoxin production and good growth were obtained in all samples. The growth appeared to be greater, but there was no significant increase in enterotoxin production, in the samples following cooking. The data presented by the authors are shown on Table I.

TABLE I. Growth and enterotoxigenicity of staphylococcal strain 234 on meat

<table>
<thead>
<tr>
<th>Meat</th>
<th>Staphylococcal count (per g)</th>
<th>Enterotoxin A (ug/10g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw beef</td>
<td>32 x 10^7</td>
<td>0.6</td>
</tr>
<tr>
<td>Cooked beef</td>
<td>220 x 10^7</td>
<td>0.64</td>
</tr>
<tr>
<td>Raw pork</td>
<td>19 x 10^7</td>
<td>1.28</td>
</tr>
<tr>
<td>Cooked pork</td>
<td>150 x 10^7</td>
<td>0.4</td>
</tr>
<tr>
<td>Canned ham</td>
<td>150 x 10^7</td>
<td>0.96</td>
</tr>
</tbody>
</table>
As suggested by the Food Protection Committee methods of marketing of food changed and in this regard meat is no exception. Recently a paper appeared (Wilkinson, et al., 1965) dealing with the effect of heat processing on the destruction of pathogenic bacteria in turkey rolls. The authors pointed out that compact rolls of meat will require alteration in cooking procedures as compared with the more traditional methods applied to whole birds, since the geometry of the product is altered. It would appear that, similarly, the now common practice of offering meat for sale in the retail market which is boned, sometimes closely trimmed, often rolled and frequently package may suggest a need for reevaluation in terms of microbiological quality of the time-temperature treatments such products receive during cookery. The results of the experiments with the turkey rolls indicated that staphylococci did not survive when the product had been heated to an internal temperature of 150°F. Allowing a safety factor, the investigators recommended that turkey rolls should be brought to an internal temperature of 160°F in a 225°F oven to insure destruction of Staphylococcus aureus.

Examples of newer types of processing which may need further evaluation based on the possibility that the final product may support growth of enterotoxigenic staphylococci with concurrent elaboration of toxin includes irradiation and freeze-drying. Erdman, Thatcher and MacQueen (1961) reported on the effect of irradiation on a number of organisms of significance in food preservation and sanitation. In their experiments they included 6 coagulase-positive strains of S. aureus of different phage patterns. They determined percent survival of the organisms suspended in buffer, broth or in meat after varying doses of irradiation with cobalt60. All six strains of staphylococci showed close similarity in reaction and when measured in the range of 0 to 400x103 R.E.P. of irradiation they were among the most resistant of the organisms tested. The decreasing order of sensitivity was: M. tuberculosis, A. aerogenes, A. cloacae, E. coli 1, E. coli II, Salmonella, Staphylococci, S. fecalis. Comparing the effect of the various suspending media, the staphylococci were least sensitive to irradiation, under conditions of the experiments, when placed in chopped meat; they were less sensitive in broth than in buffer. Using crude staphylococcus toxin, emetic activity for cats was absent after a dosage of 2.2 million R.E.P.

Published information concerning the effect of freeze-drying on staphylococci in meat does not seem to be available although firms marketing these products have undoubtedly made such studies. Inferentially, it has been indicated that staphylococcus cultures are quite stable to freeze-drying. Steel and Ross (1963) found that 10 of 100 strains of various types of organisms showed no significant alteration after being held 10 years subsequent to freeze-drying. Of the 10 strains unaffected, three were staphylococci. It thus appears that some staphylococci are able to survive both freeze-drying and storage.

The details of the laboratory techniques for examination of food for the presence of enterotoxigenic staphylococci is without the scope of this presentation. For those interested, the subject is reviewed by F. D. Crisley (1964) in a publication Examination of Foods for Enteropathogenic and Indicator Bacteria edited by K. H. Lewis and R. Angelotti and

One other facet of the problems of staphylococcus food poisoning which should be mentioned is the observation that results of studies on staphylococci made in pure culture cannot necessarily be applied when the staphylococci are a part of a mixed flora in a food. In many situations this organism appeared not to be a strong competitor when it occurs as a part of a mixed flora. For example, growth of staphylococci was inhibited by the natural microflora in a slurry of poultry or beef pot-pies and on vacuum packed bacon held at 25°C or less (Dack and Lippitz, 1962; Eddy and Ingraham, 1962). Conversely, when pure cultures of food bacteria were tested for their effect on the growth of staphylococci some were inhibitory but others were stimulatory, (Graves and Frazier, 1963). The development of staphylococci in a food must be judged in terms of the total environment, including the competing organisms which are present.

This paper is far from all-inclusive; it does suggest certain knowledge and some of the unanswered questions relative to staphylococci as they occur in meat.

LITERATURE CITED


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DR. SULZBACHER: I think after those two very workmanlike presentations you fellows can understand why the University of Wisconsin enjoys such a high reputation in microbiology.

Now, the two organisms that we have heard about so far are ones that grow in foods and produce toxins and it is the toxins that do the damage. Now we are going to turn our attention to another organism, which is a slightly different sort. In this case, it is the organism itself that invades our systems rather than its toxins. I referred in my opening remarks to the typhoid outbreak in Aberdeen, Scotland. This outbreak was considered to have been caused by typhoid organisms which were present in a can of corned beef. The causative organism of typhoid is called Salmonella typhi and it is named for a former...I mean the genus salmonella, not the organism of typhoid fever, is named for a former Chief of the Bureau of Animal Industry, Dr. Salmon. These organisms are of great importance in animal health as well as in food poisoning. There are a tremendous number of these organisms. It is a rather confusing field and I hesitated to include any discussion of them in this program because of the fact that they are so confusing and there are so many of them. However, Dr. Galton, who has done a good bit of work on salmonella in meats has been talking to me about them. In fact, she was hoping to be on the program, but was unable to come and recommended that I call on Dr. L. P. Williams of the Minnesota State Health Department who got his D.V.M. at Colorado and later a doctor of public health at Tulane where I think he was associated with the Communicable Disease Center. Dr. Williams very kindly consented to come here although he is a stranger to most of us and here he is and we are going to hand this real hard job of covering the Salmonella to him and see what he can do with it in twenty minutes. Thank you for coming......

Dr. Williams.