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MICROBIOLOGICAL CONTROL IN THE MEAT PROCESSING INDUSTRY[1/]

E. J. Dyett*

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* Former Chief Microbiologist, The Wall's Meat Company, England

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Summary

MICROBIOLOGICAL CONTROL IN THE MEAT PROCESSING INDUSTRY[1/]

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RESUME

CONTROLE MICROBIOLOGIQUE DANS L'INDUSTRIE DU TRAITEMENT DE LA VIANDE[1/]

par
T.J. Dyett*

Les conditions requises pour atteindre des normes bactériologiques élevées sont les suivantes :

A. Inspection préalable des matières premières, notamment celle du Service d'inspection des viandes, exécutée dans les abattoirs par un personnel dûment habilité.

B. Contrôle de la température et de la durée de stockage. Au-dessus du point de congélation les bactéries prolifèrent, leur rythme de reproduction étant fonction de la température. Il importe donc de préciser la durée ainsi que la température lorsque l'on définit les conditions de stockage.

1/ Les vues et opinions exprimées dans le présent document sont celles de l'auteur et ne reflètent pas nécessairement les vues du Secrétariat de l'ONUDI. Le présent document est la traduction d'un texte anglais qui n'a pas fait l'objet d'une mise au point rédactionnelle.

* Ancien microbiologiste en chef de la Wall's Meat Company (Angleterre).

The essentials for the achievement of high bacteriological standards are:

A. Initial screening of raw materials, including the Meat Inspection Service carried out by authorised personnel in the slaughterhouse.

B. Control of temperature and time. Above freezing point bacteria will multiply, the rate depending on the temperature. It is necessary to stipulate time as well as temperature when defining storage conditions.

C. Control of equipment and persons. A plentiful and clean supply of warm water is essential for cleaning equipment and if necessary chlorination should be applied to the water. Materials more suitable than wood should be used for boning boards etc.

Food handlers should be given elementary instruction in hygiene using simple language and aided by pictures showing good habits and bad habits. Bacteriological testing of food handlers should be made when there is a positive indication of risk, e.g. history of diarrhoea.

C. Control of processes which include salting, smoking, use of preservatives as well as cooking.

Food poisoning

At one time emphasis was placed on prevention of contamination of meat from extraneous sources, but it is now realised that the incriminating organisms are often present in the live animal and so may be present in dead meat. The best preventive measures therefore are those that control multiplication of bacteria that are assumed to be already there.

Standards

There are at present no national numerical bacteriological standards for meat products, and difficulties being largely due to variations in technique. However, a number of bodies are working towards such standards. The International Committee on Microbiological Standards for Foods does not favour a simple limit for a particular food, but suggests normal and outside limits and a proportion of samples which must achieve the normal limit. For factory standards a four grade system is recommended.

Tests

Tests available include Total Viable Counts, Microscopical Counts and tests for particular families of bacteria. Two types that have interest to developing countries because of simplicity and speed are "Extract Release Volume" and dye reduction tests.

[illegible]

[illegible] Contrôle [illegible] matériel [illegible] Il est important, pour le nettoyage [illegible] matériel, d'être bien pourvu en eau chaude et propre qu'il faudra la [illegible] et [illegible]. D'autres matériaux que le bois seraient mieux indiqués pour les étal[illegible], etc.

Il faut inculquer [illegible] manipuler la viande des notions d'hygiène, à l'aide [illegible] textes [illegible] affiches montrant les bonnes et les mauvaises habitudes. Les employés devraient être soumis à des contrôles bactériologiques lorsqu'il existe un risque [illegible] infection, cas de diarrhée, etc.

b. Contrôle des procédés de traitement : salaison, fumage, emploi d'agents de conservation, cuisson.

Intoxication alimentaire

Il fut un temps où l'on insistait sur les mesures préventives à prendre pour empêcher la viande d'être contaminée par des sources extérieures mais on sait maintenant que les organismes incriminés existent souvent dans les animaux vivants et qu'ils peuvent donc se trouver dans la viande de l'animal abattu. Les mesures de prévention les plus efficaces sont donc celles qui visent à empêcher la multiplication des bactéries dont la présence est probable.

Normes

Il n'existe pas actuellement sur le plan national de normes de numération bactériologique concernant les produits à base de viande et les difficultés proviennent en grande partie des différences dans les techniques appliquées. Toutefois, plusieurs organismes travaillent à l'établissement de ces normes. Le Comité international sur les normes microbiologiques pour les produits alimentaires ne recommande pas de limite uniforme pour un aliment donné mais propose des limites normales et maximales, une certaine proportion d'échantillons devant atteindre la limite normale. En ce qui concerne les normes applicables aux usines, on recommande l'application d'un système à quatre qualités.

Essais

Les essais auxquels on peut procéder sont notamment les suivants : compte total des germes viables, comptes microscopiques et essais sur des familles particulières de bactéries. Deux types d'essais qui présentent un intérêt certain pour les pays en voie de développement, en raison de leur simplicité et de leur rapidité, sont le "Extract Release Volume" et l'essai de réduction par la méthode des colorants.

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CONTENTS

INTRODUCTION

There are a number of animal diseases that can affect the microbiological quality of the meat produced, but which are more appropriate to the attentions of the animal doctor than the food microbiologist. This paper therefore will pay little attention to such aspects although undoubtedly they are of fundamental importance. There is a tacit assumption made that a good meat inspection service at time of slaughter exists and has been applied. Thus concern with the many possible parasitic infections (e.g. flukes, cysticercus) and bacterial complaints (e.g. tuberculosis) will not be expressed although clearly they can affect the safety and quality of the meat. The paper will be concerned with the hygienic handling of meat and meat products and with the possible tests and standards that can be applied.

Meat is cooked and consumed in very different ways in different countries by the indigenous populations and the treatment given can considerably affect its safety. In Nigeria, for example, typically beef is well boiled with peppers and consumed hot. Many Europeans will prefer a "rare" steak with the inside hardly showing evidence of cooking at all. It would be ideal for the meats used in these two different ways to have the same microbiological standards, but clearly it is not necessary and there is much to be said for having differing standards depending on usage, if such a scheme is practicable. When meat crosses national and continental frontiers such a scheme would be most impracticable and quite rightly the microbiological standards at present being proposed by various international bodies are all high standards.

There is considerable potential in many developing countries for the building up of an export trade in meat and these countries must be aware of the conditions and standards that will be required by the importing countries.

1. ACHIEVEMENT OF HIGH STANDARDS

The basic essentials for the achievement of consistent high microbiological standards in foods are few in number and quite simple of appreciation; the author would put them under four headings:

A. Initial screening of raw material to eliminate obvious contamination;
B. Control of temperature and time so as to control the growth of any micro organisms that may be present;
C. Ensuring the necessary standards of cleanliness of machines and persons that come into contact with the food during its processing;
D. Control of those aspects of process and formulation that have a bearing on the keepability and safety of the final product.

These four points will be considered in relation to meat and meat products.

A. Initial Screening

Veterinary inspectors from the indigenous populations are now appearing in many developing countries, but in some localities there are not enough, particularly to cover illnesses, vacations and so on. Hopefully this situation will improve. It is probably true that the European meat inspector has an easier, but more boring job than his African counterpart. This is because many animal diseases still common in the developing countries are now rare in the Western world.

The meat inspector applies the first screening process. When meat is moved a distance from the slaughterhouse to a processing unit, or is sold to another party, then a second screening may be necessary. A trained person using his eyes and nose can tell much about the condition of meat, but some defects may be obscured if the meat is frozen. When frozen meat requires to have a quality inspection a representative sample should be defrosted for examination, care of course being necessary to ensure that the defrosting conditions do not themselves lead to deterioration of the sample. As well as visual inspection laboratory techniques are also available if required and will be discussed later.

B. Control of Temperature with Time

The relationship of temperature with time must be understood in considering the growth of undesirable bacteria on meat and its products.

Figure 1. Growth rate of Bacteria

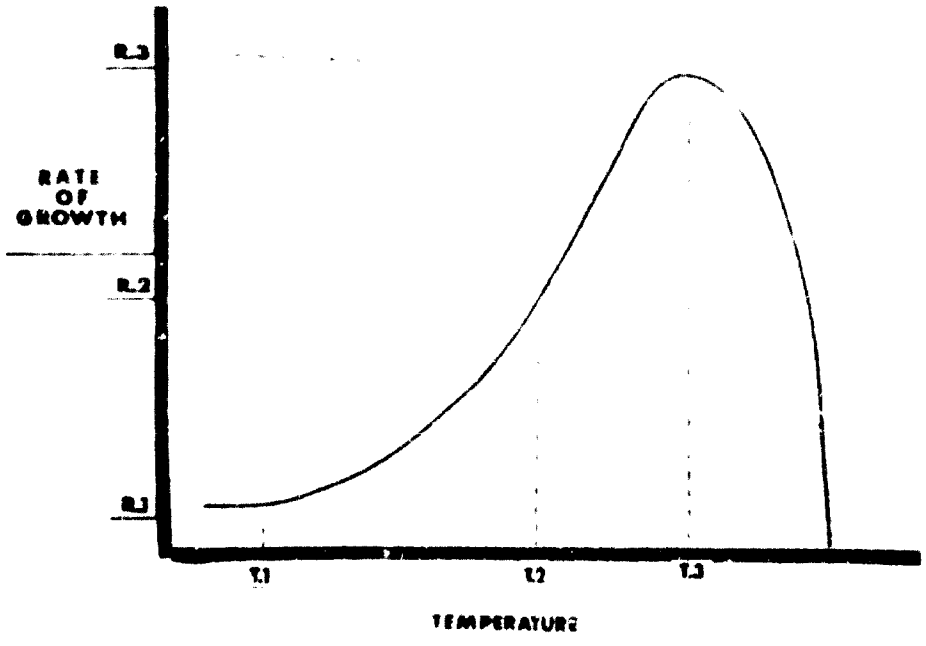


Figure 1 represents the growth curve of a typical bacterium present on meat. Below temperature T1 the organism will be incapable of multiplication and so the growth rate, R1 will be zero. At temperature T2 the organism will be multiplying steadily at a rate R2; let it be assumed to be one multiplication every hour. This means that every hour the number of bacterial cells will double and after six hours, for example, one original cell will have become 64. At temperature T3 the rate of multiplication will be at its maximum and in the example it can be seen that R3 is about double R2. This means that R3 will be a multiplication every half hour and in 6 hours one original cell will have produced 4096. If the degree of spoilage is assumed to be directly related to the population of bacteria then temperature T3 is far more dangerous than temperature T2 for the storage of meat. However, after 12 hours the number of bacteria present at T2 will equal the number of bacteria present after 6 hours at T3. Lowering of temperature enables time to be bought, but at any temperature above T1 bacteria will eventually grow to such numbers as to cause spoilage.

In practice, of course, the situation is more complicated because many different bacteria with their own characteristic growth rates will be present on a single piece of meat. Growth rates will also be influenced by other factors like water content and pH. Most organisms will not grow in frozen meat, but "refrigerated" meat that is not frozen will eventually spoil or become dangerous and it is important to stipulate both temperatures and times at which materials may be stored.

fresh

At one time the transport of meat over very long distances invariably required it to be frozen. With very tight control of temperatures it is now possible, for example, to ship lamb from New Zealand to Britain in a chilled state, but very tight control is necessary. At the present state of development of many countries where meat has to travel long distances freezing would seem to be the best solution, particularly when there are high and fluctuating ambient temperatures.

C. Control of Equipment and Persons

In the more developed countries a continuous supply of good potable water is usually taken for granted and a variety of cheap detergents are readily available. In many developing countries, particularly away from the large towns, these two commodities may be in very short supply. Chloride of lime can be used for the comparatively cheap sterilisation of a dubious water supply for washing purposes and a residual excess of chlorine in the water will have a beneficial effect in the plant sanitization. A figure of 5 to 10 p.p.m. free chlorine should be sufficient for sterilisation of the water without being strong enough to cause corrosion of equipment. The chemical and water should be in contact for at least 20 minutes to ensure sterility so it is recommended to have a two tank system, one being used while the other holds standing water and sterilant.

There are combined detergent-antiseptic mixtures commercially available and the use of these is probably the best recommendation when water is in short supply, but they are relatively expensive. The author knows of no detergent that is efficient unless used in hot water when the fatty proteinaceous debris of meat has to be removed from equipment. A hot water supply is essential. On the other hand cold water can be used for removing faeces etc., from lairages and yards where the live animals have been stored.

Around ten years ago papers (1, 2) were published showing that wooden boning boards could harbour many bacteria and the boards were difficult to clean and sterilise. A number of alternative materials have been used. Cooper and Dyett (3) recommended a synthetic rubber material and fairly recently Gilbert and Watson (4) carried out a number of tests on different materials, including wood. The latter workers always recovered the greatest numbers of bacteria from the wooden surfaces and moreover, in 4.3% of 235 scrapings from

wooden surfaces used for preparing raw meats they recovered salmonellae.

The Directive of the Council of the European Community on health problems concerning intra Community trade in fresh meat stipulates that working equipment "shall be made of corrosion resistant material, not liable to taint meat, easy to clean and disinfect". A similar requirement is in the code of practice of Codex Alimentarius now in course of formulation. Although not specifically named in these rules the usual interpretation is that wood is an unsuitable material. At one time in Britain it was common practice to sprinkle sawdust on the floors of butchering departments to help the prevention of slipping. There was the risk that small pieces of this material might be blown or in some way be carried to the meat being processed and this practice has now ceased. Dry salt is sometimes used as an anti slip agent, but the best solution undoubtedly is to use flooring material that cannot easily be slipped on, even when small pieces of fat or water fall on to the floor.

European legislation calls for the sterilisation of knives etc., in water at at least 82°C. Certainly in Britain the veterinary authorities responsible for the licensing of slaughterhouses for export trade have insisted on a liberal supply of such sterilisers strategically placed in the appropriate departments. It has not been so easy to persuade the butchers to use the equipment as frequently as is considered necessary.

Controlling the habits of the people handling meat is more difficult than installing equipment and is largely a matter of education. Instruction should be simple and to the point, using words, even vulger words, that the worker can understand. In the author's last Company it was the custom to supplement the instruction by showing slides depicting good habits and bad habits. These slides were made in the factories concerned with actual members of the staff acting the parts; in this way it was hoped that those receiving instruction would more easily identify themselves with the messages being given. It is important that management sets a good example.

There is still considerable controversy over the merits of regular medical inspections for people handling meat and meat products for sale, but E.E.C. legislation requires this where intra Community trade is concerned. It is not

clear at present just what is meant by medical examination and not everyone interprets this as including the bacteriological examination of stool specimens. Symptomless carriers of Typhoid and other enteric diseases may not be regular excreters of the offending organisms and a negative report cannot guarantee that the person concerned is truly free of the diseases. It is certainly desirable that bacteriological testing be carried out on meat handlers who have just recovered from gastro intestinal symptoms or who have had contact with people known to have been suffering from such complaints.

Boils, septic cuts and other lesions due to Staphylococci can usually be noticed and affected workers should be removed from product handling until they have been cured.

D. Control of Processes

The manner in which a product performs regarding shelf life and safety will depend on the processing it has received in the factory. Temperature effects have already been discussed and product specifications should state minimum or maximum times at which materials being processed should be held at particular temperatures. Jellies and gravies are usually excellent media for the growth of bacteria and some meat products incorporate them as ingredients. A minimum temperature (usually boiling) must be stipulated in the preparation of the jelly and a maximum time stipulated during which the jelly may be used before discarding or reboiling. The product that has been jelled must not be allowed to remain at warm or ambient temperatures and so the production specification must lay down the maximum time allowed between jellying and placing in chill.

The other area of process control that plays a large part in the stability of meat products is that involving the use of preserving agents. One of the oldest food preservatives known to man is salt. A food with the water content completely saturated with salt would have an indefinite bacteriological life, but the European palate would require that much of this salt should be leached away before it could be consumed. Nevertheless there are food items that are stored and transported while packed on solid salt, e.g. sausage skins derived from the intestines of pigs and sheep. Most foods given a preserving treatment with salt have an intermediate salt level that while giving some degree of microbiological stability yet also require no diluting of the salt before consumption.

The "curing" of meats with salt is usually made the occasion for the addition of another preserving agent, nitrite. Traditionally bacon was treated with potassium nitrate. Under controlled conditions of temperature and salt content the potassium nitrate was converted to potassium nitrite. This chemical would then react with constituents of the meat to form the characteristic pink pigments of bacon. It also exerted a strong antibacterial effect. In modern times the traditional use of nitrate has tended to be replaced by the direct addition of nitrite, either as the sodium or potassium salt. A typical curing salt therefore consists of a mixture of common salt (sodium chloride) with either sodium nitrite or potassium nitrite, or potassium nitrate. The curing ingredients are usually added in solution with water by a combination of injection (forcing the brine under pressure through needles into the meat) and covering, in which the injected meat is left in a tank for a while with addition of extra brine. Clearly the monitoring of the constituents of curing brines and the control of the adjustments of the injection mechanisms are important areas of process control.

Smoking is another traditional means of extending the life of meat products. The meat is subjected to the hot smoke of certain woods. This treatment not only leads to a partial drying of the meat surface, but also implants chemicals present in the smoke which have anti bacterial properties. These include phenols, aldehydes and acids. Smoking treatments also affect the flavours of products. Obviously control of the temperature and time of smoking, density of the smoke and the type of wood used are important factors in the eventual life and safety of the product.

In recent years there has been some substitution of the use of traditional smokes by incorporation of "liquid smokes" in the curing brines. These materials are distillations from woods, often with incorporation of other flavouring agents. They may give products the required flavours and may have some bactericidal activities, but it would be dangerous to assume that a substitution of smoke by "liquid smoke" would not have some effect on the microbiological stability of the product.

The preserving agents so far mentioned directly influence the taste or appearance of the meat product. There remains another class of preservative that has only a microbiological effect. Sulphur dioxide is the best known example of this class of preservative in Britain since it is in general use

as an ingredient of the British Fresh Sausage. This product is popular in Britain and the Commonwealth, but has no exact counterpart in other countries being a mixture of meat (50-70%) with cereal, added water and spices, traditionally packed in a skin derived from sheep or hog gut although artificial casings are now available. The product is distributed uncooked, it being left to the consumer to fry, grill or bake in pastry and given suitable conditions it will spoil very quickly. The preservative is usually added in the form of potassium metabisulphite to the equivalent of 450 p.p.m. SO_2. The microbiology of the British Fresh Sausage has been described by Dyett & Shelley (5,6) and Dowdell & Board (7,8) and there is no doubt that the preservative not only has a general effect on the bacteria present, but has a selective action that influences the eventual spoilage pattern that will occur. This is of a harmless souring nature and the proteolytic or dangerous members of the Enterobacteria group do not appear to significantly multiply at all. Although sulphites in food appear to present minimal toxicity problems (9) their use in meat products is banned in many countries, mainly because they are unnecessary in the salted, smoked, dry or acid sausages found in these countries and because there is a laudable desire to keep the total intake of sulphites down. (They are also used in wines, vegetables and other foods).

Dehydration is a means of preservation that has particular attractions for countries with warm dry climates. Natural conditions can be utilised to carry out the process, e.g. the preparation of desiccated coconut, the main problem being to protect the product from contamination during the process.

II. FOOD POISONING

England and Wales can claim to possess what is probably the most comprehensive reporting of food poisoning in the World. For many years the Public Health Laboratory Service has issued periodic report (10) that contain a wealth of detail concerning types of organisms responsible, types of food responsible, seasonal differences and so on. Some caution must be observed in the extrapolation of such national figures into a continental or world-wide setting since even between countries of apparently similar eating habits some significant differences in food poisoning statistics can be observed. Thus, while it is true to say that Botulism is never seen, but always remembered in England it still causes occasional deaths in Continental Europe and the United States. There are subtle differences in eating habits, methods of food preparation and climatic conditions. However, the bacteria commonly responsible for food poisoning in England can cause food poisoning anywhere and these will now be considered in relation to meat and meat products.

At one time much of the emphasis on food hygiene was directed towards the prevention of extraneous contamination reaching products being handled, particularly from the handlers themselves. Prevention of contamination is, of course, important, but a wider knowledge of the subject has resulted in more attention being given to the prevention of the multiplication of bacteria presumed to be already present. Certainly as far as meat is concerned there is a realistic attitude for the animals that provide the meat are liable to be infected with those organisms that cause food poisoning incidents in man. A problem that will now be discussed is that the animal may show no obvious symptoms of disease and will therefore be accepted at the meat inspection point.

A. Salmonellae

Salmonellae are responsible for most incidents of food poisoning in England and Wales and most of the incidents that can be attributed to a specific food are due to the consumption of meat and meat products (11). There are well over 1,000 different members of the salmonella family, identified by serological techniques and usually named after the district where they were first isolated. Despite this large number the serotypes actually identified with most of the illness in man were few. The "top twenty" salmonellae account for 90% of the isolations from man (10), most of these isolations being made in the diagnosis of actual illness or during epidemiological investigations. Most fortunately

there have been reported by Sojka et al (12) corresponding figures of salmonella isolations from "incidents" involving domesticated food animals in England and Wales. Four different serotypes accounted for 91% of all animal incidents. Although two of these four also appear among the 'top twenty' salmonellae of man it is clear that many of the relatively common animal isolates were uncommon man isolates while many of the common man isolates seldom caused trouble to animals. An example was Salmonella agona, fourth in the table of isolations from man and accounting for 5.8% of isolations during the years. The same organism accounted for only 0.7% of the animal isolations during the period. This did not mean that S. agona was not associated in some way with food animals, in fact all the evidence was to the contrary and Hobbs (11) has described the case history of the emergence of this particular salmonella as an important pathogen to man with Peruvian fish meal, an animal feed, being the vehicle of infection to animals and hence to man. What all the published literature indicates is that S. agona was present in feeding stuffs, caused few incidents in domestic animals, but many incidents in man. In other words the animal played the role of a symptomless carrier. This is true of many salmonella serotypes.

The eventual solution would seem to be the elimination of contaminated feeding stuffs and Denmark, for example, already legislates for the resterilisation of imported meat and bonemeal. The time is probably ar in the future when such legislation will be world-wide, meanwhile handlers and processors of meat products are wise to assume that their raw materials are probably contaminated and to act accordingly.

B. Staphylococci

Certain strains of staphylococci can cause gastroenteritis because they produce a toxin in the food in which they may grow. The staphylococci are also the common cause of sepsis, e.g. septic cuts, boils and styes. For this reason food hygiene regulations include rules concerning the banning of food handlers suffering from certain septic lesions. What is not always remembered is that food animals may also suffer septic conditions due to staphylococci and the organisms may therefore be passed on to dead meat and meat products. Frank sepsis normally will be identified by the meat inspectors in the slaughter-

horse and the animal will be rejected or the offending tissue removed. Unfortunately small lesions may not be discovered by the meat inspectors and they may come to light at some later stage. The author has experience of small abscesses in the shoulder and leg muscles of pigs that could not be discovered until the meat was being cut. A special procedure involving the isolation of equipment concerned and the liberal use of a mixed antiseptic has much reduced the risk of contamination in such circumstances, but there still remains the fact that the staphyloccus is a common organism and its presence, even only in small numbers, must be assumed to be present. The staphylococci are relatively salt resistant and can grow readily in cured products such as bacon.

C. Clostridium perfringens

Although the number of outbreaks attributed to C. perfringens was relatively small some of the outbreaks involved large numbers of people. They were nearly all due to consumption of meat products. The clostridia are strict anaerobes and so will not multiply readily in many products. They are also fairly strongly influenced by salt so food poisoning outbreaks due to consumption of bacon and similar products are comparatively rare. Unlike the other pathogens mentioned the clostridia form spores and so may require severe heat treatments to destroy them. Most outbreaks involve situations where meats are cooked, cooled and then reheated at later stages.

Clostridium perfringens is a ubiquitous organism and should be assumed to be present in raw meats.

III. BACTERIOLOGICAL STANDARDS

Specific bacteriological standards for certain products have been in existance for very many years in several countries. Ice Cream is a good example. Most standards for this material are based on the numbers of viable bacteria present and on the presence of particular families of bacteria, e.g. the coliform group or E. coli. In England and Wales there has for a very long time been a "provisional test", the Methylene Blue Test, that measures bacterial activity by the time taken to decolourise the blue dye when the dye and ice cream are incubated together under defined conditions. There are also tests of long standing for milk and of course, water. The author knows of no similar standards for meat or meat products although currently there is considerable discussion in a number of national and international bodies on the topic and it seems most probable that standards will soon be laid down, at least for carcase meats.

A. Problems of Agreeing Standards

One of the great difficulties in agreeing a bacteriological standard is that it must be accompanied by a specified and precise method of testing. There are many detail differences in techniques between laboratories, depending on personal prejudices, equipment available and sometimes the best interests of the laboratories themselves. Bacteriologists like all other humans are loath to change their habits for the sake of uniformity. Consideration of the very simple test, the"Total Viable Count" ("Colony Count", "Plate Count"), carried out in all food bacteriological laboratories everywhere, will illustrate these differences. Before it can be tested a meat sample has to be mixed with water and slurried in some way so that representative aliquots can be removed by pipette. The old fashioned method was to grind in a pestle and morter with sterile sand and water, but now there are many electrically operated blenders and macerators available that work on different principles. The degree of disintegration of the sample and the heat generated during disintegration can affect the result. In the author's laboratory a comparative test was carried out between two machines, one depending on a medium speed revolution of a top drive cutting blade, the other on part cutting, part ultra sonic action.

The maximum Total Viable Counts were obtained after about 30 seconds action in the first machine, but only 7 seconds in the second machine. Prolonged running of both machines reduced the size of the counts. Both machines gave generally similar counts, but one machine, the second, tended always to give higher values.

Having produced a suitable slurry a known quantity must be added to a suitable nutrient agar. There are a number of suitable agars but they will not necessarily produce identical numbers of colonies. The mixing of sample and sample can be done in two basically different ways, either shaking with warm liquid agar and then allowing the agar to set, or by spreading the slurry of sample over the surface of a previously poured and set agar. A recent technique, the Droplette Count (13) involves the preparation of small buttons of agar about 1 cm in diameter instead of the traditional petri dishes of the jelly. All these differences can effect the result obtained.

Finally there is the choice of incubation temperature. For a long time 37°C, the body temperature of man, was a popular incubation temperature for food samples. There was no real logical reason for this, but food microbiology often was practiced in a pathology laboratory where 37°C would be a normal incubation temperature. In more recent years it has been realised that higher colony counts on many food samples are usually obtained at lower incubation temperatures and so 30°C, 25°C and 22°C have become popular.

Within one factory or one company the differences that can arise because of technique variations can be negated by standardising on the details of the method to be used and then setting microbiological standards for the products based on that method. It does not really matter if the chosen technique in factory A gives a Total Viable Count only half of that in factory B, provided that the limit for the T.V.C. in factory A is half that of factory B. The problems arise when national and international standards are set.

Another problem is to decide at which particular point in a distribution chain from factory to consumer the standards should apply. With factory wrapped ice cream, for example, there should be no difficulty since the hard frozen product should not materially change and the number of bacteria present at the beginning will be similar to those at the end. However, perishable meat products distributed and marketed under ambient or chill conditions will continue to display bacteriological changes. A T.V.C. of 100 per g in ham

on the factory might well be 1,000 per g at the point of sale some days later without the product having exceeded a safety count; indeed a count of 10,000 per g would be considered a reasonably satisfactory figure. As any legal standards are likely to be applied at the point of sale the standards applied in the factory will usually be numerically different.

B. International Standards

A number of international organisations presently are concerning themselves with the establishment of hygiene standards or microbiological standards for a variety of foodstuffs. In addition there are national bodies that are interested in setting standards for imported foods so these too are of considerable concern to the food exporting countries.

The International Standards Organisation ('ISO') has set up expert committees that are still very involved with the minutiae of methodology. The Codex Alimentarius Commission was set up in 1962 to implement the joint F.A.O./W.H.O. Food Standards Programme. This body likewise has developed sub groups of committees, mainly based on commodities. Thus there is a Codex Sub Committee on Processed Meat Products. This latter body is composed of meat scientists from a number of different countries and is concerned with compositional standards, hygiene and codes of practice in preparation and distribution. The European Economic Community has a number of regulations and directives that are broadly in line with Codex standards. There are some E.E.C. draft directives that incorporate numerical microbiological standards, e.g. Ice Cream, but so far none of the legislation for meat or meat products, in force or in draft, has such specific requirements.

The United States Food and Drug Administration states that food is adulterated "if it bears or contains any poisonous or deleterious substances which may render it injurious to health." Adulterated food is banned in inter state commerce. The Director of the F.D.A's Division of Microbiology in discussing the interpretation of the word 'adulteration' (14) states that the presence of food poisoning pathogens, or toxins, would render the food adulterated within the meaning of the Act. This would appear to be a Council of

Perfection with the knowledge of the present state of infection of raw red meat and poultry.

A body of considerable interest to food microbiologists is the International Committee on Microbiological Specifications of Foods (I.C.M.S.F.). This is a body of experts set up in 1962, originally under the chairmanship of F.S. Thatcher who was the joint author of the Committee's first publication (15). The main aims of this Committee are to recommend methods of microbiological testing, to recommend methods of sampling and to recommend limits of tolerance for pertinent micro organisms in specific foods. Very wisely the Committee has recognised that in the present state of food production and preparation quite wide variations in types and numbers of bacteria are to be expected in similar foods.

The type of food is first categorised according to the degree of risk it represents, e.g. whether it is to be cooked before consumption or whether it will be eaten without further heating. The number of samples (n) to be taken is defined and also the number (c) that must comply with the normal microbiological limit (m). There is an outside limit (M) that no sample must exceed. Thus, the formula for T.V.C. of frozen boneless beef is n = 5, c = 3, m = 500,000/g and M = 10 million/g. This means that 5 samples are taken of which at least three must have counts not in excess of 500,000/g. No sample must have a count in excess of 10 million/g.

Similar types of standard are suggested for pathogens, e.g. n = 5, c = 1 for salmonellae in frozen beef means that one sample out of five may contain salmonellae in the sample quantity stated. Obviously with elimination of salmonellae from animal feeding stuffs and improvements in husbandry and hygiene the hope would be to eventually alter the formula to n = 5, c = 0.

In the author's opinion the I.C.M.S.F. approach is very sensible and takes due account of the variabilities in microbiological results experienced in practice.

C. Factory Standards

Whether or not there are national or international standards it is

necessary for the factory microbiologist to have some method to assess the day to day results of the product being made in the plant. It is possible that inspectors, for example, acting on behalf of the armed forces, for example, may have their own system of monitoring the goods that they purchase so it is important to know whether the factory is keeping to their specification.

It is the author's experience that production managers and similar factory personnel frequently do not wish to be bothered with details of laboratory testing although they like to be reassured that things are going right and to be quickly informed if things are going wrong. About fifteen years ago he decided that in future reports to the factory would not include columns of figures of T.V.C.'s, microscopical counts and so on, but instead a simple grading system would be used. Four grades A, B, C and D were introduced, A being the most satisfactory and D definitely unsatisfactory. The results of the normal laboratory tests were translated by the laboratory staff into gradings so that, for example, the factory would be informed that during the previous week 20 samples of a particular product were taken of which 18 were grade A and two were grade B. Such information told the management that testing was being done and the results obtained were satisfactory. Had unsatisfactory results been obtained then it is probable that management would have been informed earlier and possibly an enquiry instituted as to the reasons.

Development of a grading system implies that standards have been formulated. In the author's company these were arrived at and agreed at a meeting of appropriate laboratory personnel from the four factories then operating. At the time there was little published data to give guidance, but there was a considerable amount of internal information which enabled the standards to be agreed without a great deal of argument. It is pleasing to report that over the years there has been little evidence to suggest that the original standards were far wrong and they do fall into line with those standards which have been recently suggested.

Most of the gradings were based on the Total Viable Count test and in Table 1 are given the standards for two typical items:

Table 1. Bacteriological Standards

(T.V.C. per g. at 30°C incubation)

Product	Grade			
	A	B	C	D
Boned out Pork legs	less than 100,000	100,000 to less than 500,000	500,000 to less than 1 million	1 million or more
Cooked ham	less than 100	100 to less than 1,000	1,000 to less than 10,000	10,000 or more

Microbiological standards are not only applied to products, but also to equipment. The cleanliness of equipment can be tested in several ways, the oldest technique probably being to rub a sterile swab over a measured area and then to count the number of organisms picked up on the swab by a colony count. The contamination inside pots, pipes and churns can be estimated by rinsing the vessels with sterile water and then counting the bacteria picked up in the water.

A technique that has become very popular in food factories is to press a suitable nutrient agar on a surface requiring testing, e.g. a boning board or conveyor belt, and then to incubate the agar and count the colonies that develop. One version of this method is by use of an "Agar Sausage" (16). A rather stiff agar is sterilised inside a cylindrical casing of plastic film and allowed to set. To test the end of the "sausage" is cut with a sterile knife exposing a flat cross sectional area of the sausage. This is pressed on the surface of the equipment and then another cut is made on the sausage so that a slice about $\frac{1}{4}$" thick is produced which is aseptically placed in a Petri Dish, the pressed surface uppermost. The dish is incubated in the usual way. Suggested standards are given in Table 2.

Table 2. T.V.C. on Slices of Agar Sausage

Grade	T.V.C.
A	less than 10
B	10 to less than 50
C	50 to less than 100
D	100 or more

Another version of the method is to prepare "contact plates", small Petri Dish fillers [illegible] agar which can be directly pressed onto the surface being tested. The diameter of the Ten Cate Agar Sausage (16) is somewhat smaller so the suggested standards in Table 2 would require suitable adjustment if contact plates are used.

The technique of taking agar pressings, whether by Agar Sausage or Contact Plate, is so simple that it has been suggested that it can be carried out by any reasonably intelligent person and laboratory facilities are not required, e.g. the plates can be left on a shelf in a warm room to incubate. In fact farmers can carry out their own testing. All this is true, but there is one potential danger that must never be forgotten. Although the great majority of bacteria that grow on meat are not dangerous there is always the possibility that a pathogen may be present. The innocent looking colony growing on a slice of Agar Sausage could be of a salmonella and it would be reprehensible to allow unqualified people, through their ignorance, to handle such material and thus possibly endanger themselves or their friends or even contaminate other products. There is nevertheless an attraction for factories in developing areas where laboratory facilities may be sparse to take advantage of such techniques. In these circumstances perhaps the solution is to allow the production manager or some equally responsible person to carry out such tests with facilities for holding secure and disposing of the test media. He should of course be given training in the principles of the test and understand something of the problems of cleaning so that he can both monitor and advise.

IV. BACTERIOLOGICAL TESTS

A. Total Viable Count

In previous chapters mention has been made of the Total Viable Count in its many forms both as a means of testing products and testing equipment. The test is so well known that no attempt will be made in this paper to go into the precise details of performance. Suffice to say however that it is in the author's opinion the best single [illegible] to be performed on meat or meat product samples. The test does not distinguish between the types of bacteria that may form colonies in the test, except in a very rudimentary way in that certain types may produce rather characteristic colonies, either in shape or colour.

B. Pathogen Testing

Testing for the presence of pathogens in foodstuffs is a specialised branch of bacteriology and is best carried out by experts. There is also a safety aspect to be considered and it is not advisable to have cultures of salmonellae and other dangerous bacteria being made in close proximity to factory departments preparing food products. The best methods of test for meat products are well documented and these will not be detailed in this paper.

C. Coliform Testing

Testing for the presence of coliform organisms is often recommended for meat products. Originally the coliform test was devised for the examination of water supplies and over many years has proved to be a very satisfactory method. The coliform family, and particularly Escherichia coli, should be absent in potable waters, the presence of these organisms indicating a possible contamination of faecal origin that is potentially dangerous. Coliforms die in clean water so their presence indicates recent polution. In many foods coliforms will actively multiply so their presence does not necessarily mean recent contamination, but could mean a remote contamination of processing equipment that has not been completely eliminated during subsequent cleaning. As coliforms are present in vast numbers in the alimentary tracts of food animals it is not surprising that they should be found in raw meats. However,

[illegible] slaughterhouse procedures have [illegible] are more vital in testing for their presence [illegible].

[illegible] should not be found alive on the fillings of cooked pies, ham and a variety of cooked sausages. Their presence may indicate undercooking or recontamination after cooking.

There are a number of methods available for indicating the presence of coliforms in meat products. The author prefers a broth technique where small quantities of sample are inoculated in tubes of Lauryl Sulphite Broth or MacConkey Broth and examined for gas production. False positive results are frequently obtained with ice cream and sugared products, but it is the author's experience that they are seldom obtained in the testing of meat. Once again the details of the technique are well known.

9. Dye Reduction Tests

Dye reduction tests for milk, ice cream and dairy cream have been used for a long time and are well known. The basis of the technique is that the sample under test is mixed with a dye stuff, Methylene Blue, and incubated under specified conditions. The dye is coloured in its normal oxidized state, but becomes colourless in a chemically reduced state. Reducing chemicals may be naturally present in the sample, but these are reinforced by the activities of bacteria present. Thus the speed in which the colour change occurs bears a relationship with the number of bacteria originally present and their state of activity. By standardising the details of the procedures and noting the time when the colour change occurs, a grading system has been devised with four grades, ranging from very satisfactory to unsatisfactory.

There have been many attempts to devise dye reduction tests for meat and meat products (17,18). The popular dyes used have been resazurin and tetrazolium salts rather than methylene blue. A big problem has been that the natural reducing systems of meats vary with age since death, anatomical origins and treatments received. However, in certain limited applications the principle has been found to be very useful, e.g. the actual location of areas of contamination on a slice of bacon or ham can be identified by spraying with a

tetrazolium salt and incubating for a short time (1½). A technique for identifying beef slices with heavy bacterial contamination consists of simply rinsing the slice in a glass petri dish with a solution of resazurin and then tipping the solution into a bottle and storing for a few minutes at room temperature. The solution will turn from blue to red or even to a colourless form if the T.V.C. is large. (20)

E. Extract Release Volume

If fresh meat is homogenized with water and then placed over a filter paper a volume of liquid will pass through it. If meat of an unsound bacteriological condition is similarly treated then less liquid will pass. This phenomenon called Extract Release Volume has been utilised by Jay (21) and others (22) to produce a rapid test for the detection of spoilage in beef and other meats. Like the dye reduction tests this test is not directly counting bacteria, but is measuring an aspect of bacterial activity and can be carried out by relatively unskilled people without elaborate laboratory facilities. Moreover it gives a quick answer.

F. Microscopic Counts

If a known volume of milk is evenly distributed over a known area of microscope slide, dried and stained and if the preparation is viewed through a microscope with known optical dimensions, then the average numbers of bacteria seen in a microscopic field can be directly related by a known factor to the number of organisms per ml in the milk. This is the basis of the Breed Count (23) and the technique has been suitably modified for the examination of meats (24) using a 10% aqueous slurry of sample. This technique of course is capable of giving a quick answer; the whole test from weighing sample to counting bacteria through the microscope can be done in about half an hour. However, a certain amount of expertise is required in fixing the film of sample on the microscope slide and in distinguishing bacteria from miscellaneous sample debris when viewing through the microscope.

G. Non destructive Sampling

The tests listed above assume that samples of meat and meat products can be removed from larger units before testing. It is not always convenient to do this; for example the larger unit may be significantly devalued if pieces are

cut off. This could apply to a large cooked ham. In these circumstances a non destructive sampling technique can be used. Surface swabbing is a popular method using a wooden stick such as a medical spatula as the swab handle with a piece of fabric such as medical bandage securely tied to the end which makes contact with the meat. A known area of surface is swabbed, the fabric removed aseptically and shaken with a known volume of diluent which is then tested by one of the standard techniques. Rinsing techniques can also be used. For example, the entire surface of a large ham can be tested by placing the ham in a polythene bag, adding a suitable quantity of weak sterile brine, shaking the contents of the bag together and then running off the brine and testing it. Brine is used rather than water so as avoid leaching salt from the surface of the ham during the rinsing process. The ham of course will be unaffected other than having received a surface wetting and can be distributed and sold in the usual manner. The bacteriological results obtained are usually expressed in terms of surface area, e.g. Total Viable Count per sq. cm of surface.

SUMMARY AND CONCLUSIONS

1. A good Meat Inspection Service at the time of slaughter is essential.

2. Microbiological control is effected by -

   (a) Screening of raw material (and the Meat Inspection Service is an important part of this screening).

   (b) Controlling temperatures in relation to time.

   (c) Controlling cleanliness of plant and persons.

   (d) Controlling processes and formulations.

3. Food poisoning organisms are liable to be present in raw meats because the responsible bacteria are commonly present in the animals during life. Moreover, the animal may be a symptomless carrier or there may be localised lesions in the animal not detectable at the time of the Meat Inspection Service.

4. Numerical bacteriological standards for meats are not yet applied in legal national or international codes but a number of agencies are interested in the subject and eventually such standards are likely to appear. There are standards in respect of hygienic operation of plants, medical inspections of staff and plant design.

5. Despite the absence of legal standards the plant bacteriologist must have standards to operate in his factory so that he can assess the microbiological quality of the products being produced and the ingredients being used. A grading system of standards is recommended.

6. A number of tests are available, some of which are of an indirect nature (e.g. Dye reduction, Extract Release Volume) and are capable of being carried out by semi-skilled staff. Such tests could be of particular use in a developing country where laboratory resources are scarce outside of the large towns.

The author has naturally reviewed his subject from the viewpoint of a large meat manufacturing company in England, a country that considers itself sophisticated. However, since the formation of the European Economic Community and the promulgation of Community rules, e.g. the Directive on health problems concerning intra-Community trade in fresh meat, the English have found it necessary to alter some of their long accepted ways of doing things in order

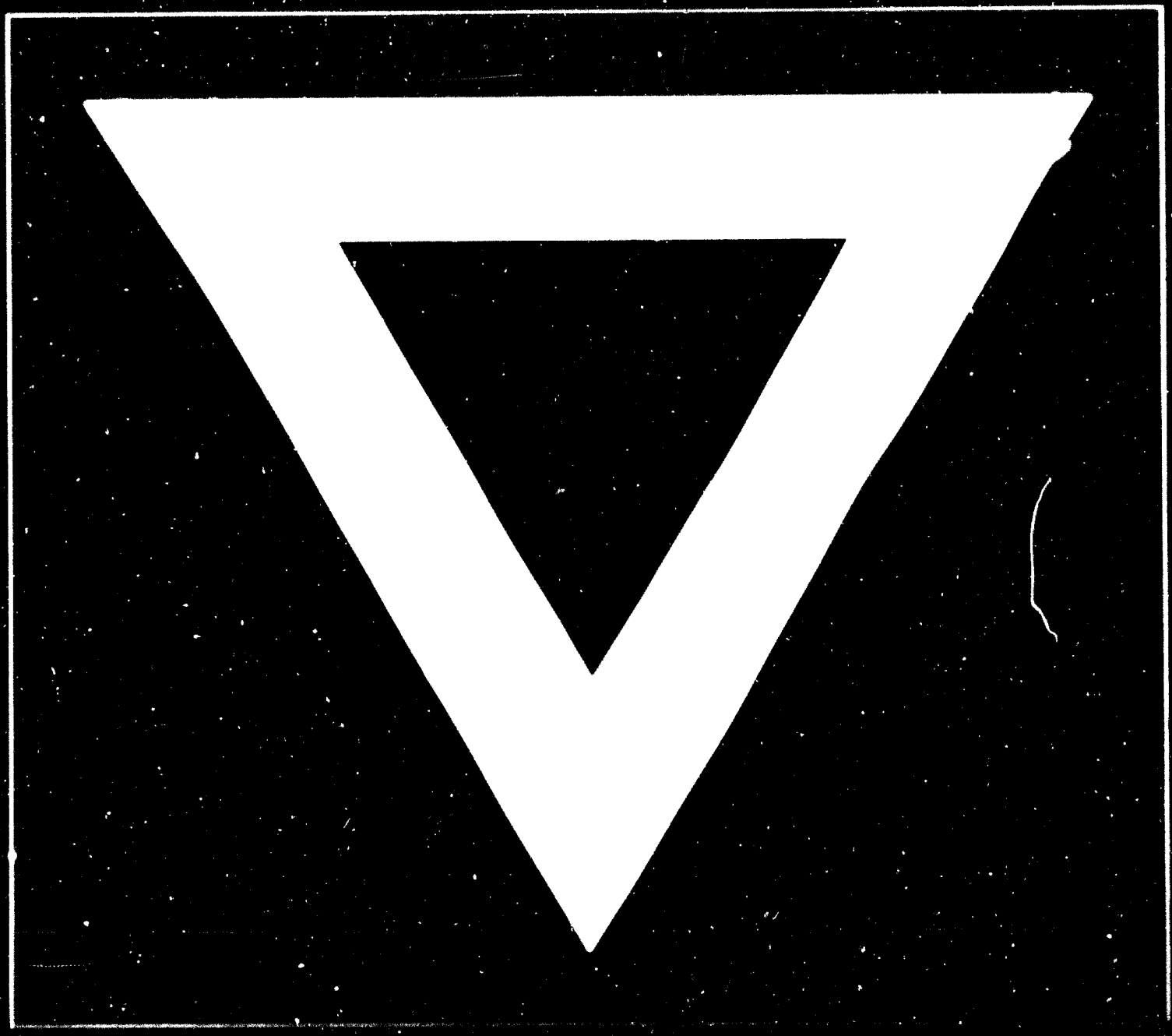
to export into the Common Market. It is interesting that while the number of British slaughterhouses presently licenced to export into Europe is an extremely small proportion of the total, the proposed new British slaughterhouse regulations now being considered do in fact very largely comply with the Community directive. This is an example of national standards following international standards and such changes are inevitable and should not be opposed if the reasons are clearly to improve the safety and attractiveness of the end product.

The road to the final goal of a universal high standard may be longer for some African countries because they have started further back. While the average Englishman is able to water his garden with an apparently unlimited supply of excellent quality water out of his kitchen tap, in some African countries there is a grave shortage of this commodity for such essential services as cleaning of food factories. The food processor may have to make his own potable water instead of buying it cheap from a water authority. Manufactured products that make the attainment of good hygiene standards comparatively easy, for example detergents, sanitizers and the equipment for applying them may have to be imported from distant countries and so will be expensive. With all these difficulties there are those additional ones due to the climate.

The author has no doubt that the final long term objective for all countries must be universally acceptable and achievable standards, but common sense must control the speed of change. Because of different ways of preparing and eating foods to be found in different countries and among different communities rapid changes are not necessarily essential for the health and well being of the indigenous populations involved.

REFERENCES

1. Gerigk, K. (1966) Die Fleischwirtschaft(11), 1215 - 1217.
2. Torry Res. Stn. An. Rpt. (1965), H.M.S.O.
3. Cooper, L.G. & Dyett, E.J. (1967). Public Health Insp. June 1967.
4. Gilbert, R.J. & Watson, H.M. (1971). Fd. Technol. 6, 163 - 170.
5. Dyett, E.J. & Shelley, D. (1962). Proc. 1st Int. Cong. Fd. Sci. & Tech., 395 - 403.
6. Dyett, E.J. & Shelley, D. (1966). J. appl. Bact. 29 (3), 439 - 446.
7. Dowdell, M.J. & Board, R.G. (1967). J. appl. Bact. 30 (3) 11.
8. Dowdell, M.J. & Board, R.G. (1968). J. appl. Bact. 31, 378 - 396.
9. Kidney, A.J. (1974). Chem. & Ind. 717 - 718.
10. Vernon, E. & Tillett, H.E. (1974). Publ. Hlth (Lond) 88, 225 - 235.
11. Hobbs, B.C. (1974). Fd Manuf. Oct. 1974, 29 - 35.
12. Sojka, W.J., Wray, C. & Hudson, E.H. (1975). Vet. Rec. 96, 280 - 284.
13. Sharpe, A.N., Dyett, E.J., Jackson, A.K. & Kilsby, D.C. (1972) Appl. Microbiol. 24 (1), 4 - 7.
14. Olson, J.C. (1969), F.D.A. Papers 1968/69 2 (10) 10.
15. Thatcher, F.S. & Clark, D.S. (1968) Microorganisms in Foods. University of Toronto Press, Canada.
16. Ten Cate, L. (1965), J. appl. Bact. 28 (2), 221 - 223.
17. Straka, R.P. & Stokes, J.L. (1957) Fd. Res. 22, 412 - 419.
18. Walker, H.W., Coffin, W.J. & Ayres, J.C. (1959), Fd. Tech. 12, 578 - 581.
19. Bradshaw, N.J. Dyett, E.J., & Herschdoerfer, S.M. (1961), J. Sci. Fd. Agric. 4, 341 - 344.
20. Austin, B.L. & Thomas, B. (1972), J. Sci. Fd. Agric. 4, 541.
21. Jay, J.M. & Kontou, K.S. (1964), Appl. Microbiol. 12, 378.
22. Lewis, M.J. (1971), Fd. Technol. 6, 413 - 422.
23. Collins, C.H. & Lyne, P.M. (1970) Microbiological Methods. Butterworths, London.
24. Dyett, E.J. (1963). Chem. & Ind. 234 - 237.



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