

Bacterial contamination of food

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Man is a creature of his environment. He shares its hazards with many other living organisms and for most of the time achieves a measure of peaceful coexistence with them. But the balance is a delicate one, and very minor changes, such as an imperceptible rise in humidity or fall in temperature, may upset it surprisingly (Christie, 1971-2). Man is also a great manipulator of his environment and this manipulation may be simple or complicated. Farming, for example, is a grossly unnatural process. No environment could be less natural for a cow than life on a dairy farm (Christie, 1971). Modern man is, of course, still a beast of prey but, instead of hunting animals, he herds them within fences, grossly exploits their natural functions, especially those of lactation and procreation, carts them off to markets and abattoirs, and transforms their carcasses into cutlets, sausages and meat pies. Meanwhile he converts their milk into processed cheese or cream cake-fillings, and he then distributes all these products to households, restaurants, Pullman cars and jet airlines. This is environmental manipulation on the grand scale, a considerable technological achievement. But there are dangers on the way, natural dangers such as time and temperature, and accidental dangers such as contamination and adulteration and, unfortunately, though his beasts are slain, man is not the only organism alive at the end of it all (Christie, 1971).

Micro-organisms are very much smaller than men, but they are great opportunists. Give them the opportunity and they will flourish on man's food. They need time, they need warmth and moisture, and one or two other environmental factors such as a tolerable pH range and an acceptable gaseous atmosphere. The cave-man, in his hand-to-mouth existence, gave such micro-organisms few chances, but with civilization came sophistication and the modern food-handler seems almost to go out of his way to make life smooth for food-poisoning germs (Christie & Christie, 1971).

Time

Most food-poisoning organisms need time to multiply, time to infect and, of course, time to die. There are exceptions. *Salmonella typhi*, the organism of typhoid fever, and *Shigella sonnei*—a dysentery germ, are both highly specialized parasites and infect only man. They can infect him when they are present in very small numbers: they do not need time to multiply in his food. Thus Sonne dysentery can spread rapidly in a nursery by the passage of the germs from hand to hand and then to the mouth of infants, without any interval for multiplication; typhoid fever has often been spread by drinking-water, although the organism survives with

difficulty in water and is usually present only in very small numbers in contaminated water. Outbreaks of water-borne disease due to other *Salmonellae* are, by contrast, very uncommon indeed, and this may be because these other *Salmonellae* are not highly adapted to man and in small dosage cannot infect him. *Salmonella typhi-murium* for example, is a highly unselective parasite, at home in many hosts, snakes, elephants, mice and men, to name a few, but the penalty of its promiscuity is that it must be present in enormous numbers before it can establish itself. Multiplication takes time. It takes a man 40 years to grow, reproduce and bring his offspring to maturity, but a germ can do all this in 20 min (Christie & Christie, 1971). In 24 h, one organism can produce millions of offspring. This time-interval is of great importance in considering the bacterial contamination of food. A man may eat with impunity a portion of food contaminated with a few food-poisoning germs: we almost certainly do this nearly every day. But a portion of the same food eaten 12 h later may cause a severe attack of food-poisoning.

I have mentioned *Salmonellae*, but the time-factor is important for the other two common food-poisoning organisms as well, staphylococci and *Clostridium welchii* (*Cl. perfringens*). Both these organisms form toxins and unless they do so they do not cause food poisoning. To form their toxins, they need time and other suitable environmental conditions that will be mentioned later. Another food-poisoning organism which depends on the production of toxin for its effect is *Cl. botulinum*, the organism of botulism. So long as it remains in its sporing state, *Cl. botulinum* is harmless, but as soon as it germinates and the resulting vegetative forms start to multiply, a toxin is produced and this is one of the most lethal toxins to affect mankind. *Cl. botulinum* can, of course, remain in its harmless, sporing state almost indefinitely. It may be jolted into activity by heat shock, or by a change in its environment from aerobic to anaerobic conditions. Time is obviously a vital factor to food-poisoning germs, yet are all of them, *Salmonellae*, staphylococci and clostridia, may remain alive for days, weeks, months or years, not multiplying until suitable conditions occur. This is an important point, because once a site becomes contaminated with food-poisoning germs it may remain contaminated indefinitely. The site may be a farmstead, an abattoir, a meat factory or a kitchen: it might be a pat of cow-dung in a field, for *Salmonellae* can live there for at least 9 months: or it might be a can of pasteurized meat. In such a can, an organism can survive for months in the oil-phase of the product, though it cannot multiply in it, but agitation in transport may shake it from the oil-phase into the water-phase, and there it may start to multiply. *Sal. typhi*, of course, unfortunately, if it gets into a can of sterilized meat, can flourish exceedingly, without revealing its presence for, unlike most other intestinal germs, it does not produce gas and so does not blow cans. I need hardly remind you of what such a can did in Aberdeen in 1964.

Temperature

Temperature is perhaps the most important element in a micro-organism's environment, for the appropriate temperature can help an organism to grow, or to

produce its toxin, it can stop it multiplying or, of course, it can kill it. Most food-poisoning germs multiply freely between 20° and 50°, and staphylococci and clostridia produce toxin between these temperatures. It is important to realize that this temperature-range is commonly found in kitchens and other places where food is prepared. A joint of meat, a stew or a custard takes a long time, in cooling, to pass through this range, and a stew or a custard, which may have only a few staphylococci or clostridia in it at 50° can be teeming with organisms and full of toxin before it reaches 20°. Placing the food thereafter in a refrigerator overnight at 5° will do nothing to reduce either the organism or their toxins; reheating the food next day will not destroy the toxin, and only if it is very thorough will reheating cut down the number of organisms. Slow cooling of food is, then, one of the main hazards with food-poisoning organisms, and though it is easy to recommend quick cooling, it is not so easy to carry this out in the domestic kitchen or small catering establishment. Some device to ensure rapid cooling of food on a small scale would be of great value in the control of food poisoning. Large establishments have proper cooling rooms or even blast freezing.

The temperature required to destroy germs or their toxins varies for different organisms. Salmonellae and staphylococci are killed at 60° in 20–30 min, well below cooking temperatures: egg, for example, does not coagulate below 72°, so that sponges, baked custards and cakes are safe to eat, provided they are not re-contaminated after baking—a far from theoretical hazard in dusty bakeries or kitchens. An important factor is, of course, heat penetration: gentle frying may fail to produce a temperature of 60° in the centre of a sausage and, because of a cool spot in an oven, the centre of a pie may also be below that temperature. *Cl. welchii* is a sporing organism: in its vegetative form it is readily destroyed by ordinary cooking temperature, but its spores survive boiling for 30 min. Although staphylococci and vegetative *Cl. welchii* are readily killed by cooking, it is not so with their toxins which are very resistant to heat and, once formed in food, are very unlikely to be destroyed by cooking. It is very different with the toxin of *Cl. botulinum*. A mere taste of food containing botulinum toxin, a mere licking of the fingers is enough to kill a person, yet the toxin is very easily destroyed by heat, the most heat-resistant of botulinum toxins being destroyed in 6 min at 80°. If canned or cured food were always brought to boiling point before being eaten, botulism could never occur, for it is only the toxin which is harmful. The spores of *Cl. botulinum* are, by contrast, extremely heat-resistant. Boiling will not destroy them, and most home-canning procedures are therefore not safe, since spores surviving such heat treatment can begin to germinate and produce toxin inside the can. A temperature of 121° is required to destroy the spores and this can be obtained only in an autoclave. This temperature will destroy spores in around 2.5 min and the heat sterilization requirements of commercially canned foods is based on the heat resistance of *Cl. botulinum*. As a result, botulism from commercially canned food in the last 40 years has been an extremely rare occurrence.

Pasteurization

In the pasteurization of milk, the time and temperature to which the milk is subjected is sufficient to kill all the pathogens likely to be present in milk, but this is not true in the so-called pasteurization of canned meats. Some forms of meat cannot be given the full sterilization heat process, for this causes changes in the texture of the meat which make it commercially unacceptable. These meats, mainly hams, although subjected to shorter heat treatment, have curing salts added to them, and the combination of heat and salts appears to be more effective than either alone. But the process still does not amount to sterilization. Vegetative food-poisoning and spoilage germs are probably destroyed, but spores are not, especially in the oily phase of the contents. There is usually a notice on the cans that they should be stored at a low temperature, advice which is often overlooked: it is meant to avoid the chance that spores shaken from the oily to the watery phase of the contents might germinate and start to multiply in a warm atmosphere. We are perhaps dealing in these pasteurized meats with a novel biological situation and in the interests of food hygiene it must be carefully watched.

Drying and curing

The multicellular body of a man consists largely of water, both in its extra-cellular and intracellular compartments. The unicellular body of a micro-organism has only one compartment, but it too has a high water-content. Man deprived of water will die, but micro-organisms are tougher. They do not die, but they stop multiplying. This is the rationale of drying as a method of food preservation: it may be applied in a vast modern factory as in the drying of milk, eggs and a multitude of other foodstuffs, but the same process, with the sun as the only source of heat, could be seen in the olden days outside some Scottish fisherman's cottage, or today on the plains of Achaia where the Greek sun dries the grapes, and the nearby city of Corinth gives its name to the resultant currants. It is important to remember that drying does not kill micro-organisms: one must also be aware that drying increases their heat-resistance, and that heat applied after drying may be much less effective than the same heat applied before. Liquid egg is therefore now required to be pasteurized before being dried, and it is a well-known fact that many varieties of *Salmonellae* have in the past been introduced into this country in dried egg not so treated (Ministry of Health, 1959). Dried coconut has often been contaminated with *Salmonellae*; the organisms lie dormant in the dried coconut, but when it is sprinkled on a moist cream cake they come to life and multiply on this ideal medium—outbreaks of paratyphoid fever have been caused in this way (Anderson, 1960; Semple, Parry & Graham, 1961). Curing with salt or sugar is, in effect, a form of drying, for their action depends largely on drawing fluid by osmotic pressure from the micro-organismal cells. Salt does indeed have a direct damaging effect on *Salmonellae*, which varies with the temperature, the pH, the presence of nitrites and the type of food. *Staphylococci*, on the other hand, can survive, and even produce enterotoxin in 9% brine at pH 5.3 (Riemann, 1969).

Nitrite certainly has an inhibiting effect on micro-organisms, which has nothing to do with drying, but its action is not understood. Its efficacy, and that of other curing salts, varies with temperature, pH, type of food and other factors. Nitrites seem to increase the sensitivity of some organisms, such as *Cl. botulinum*, to heat and it may be that nitrite is converted into some other substance which inhibits bacterial life—we do not know. It is probably true to say that in curing, smoking, pickling and similar methods of preserving food much of the practice is based on custom and something approaching folklore rather than on science. This is not necessarily to decry these methods for, after all, man learnt that cooking improved the keeping qualities of his food long before he knew anything about micro-organisms or autoclaves.

Irradiation

I have said nothing about irradiation, although a good deal is already known about it. It can kill micro-organisms by direct hits, or by creating reactive compounds in the food or in the bacterial cell. Its effect varies with temperature, pH, the presence of salts and other environmental factors. Spores are much more resistant than vegetative organisms, and botulinum and staphylococcal toxins are highly resistant. So, irradiation does not herald the end of food poisoning, though I am sure it will have an increasing part to play in the preservation of our foodstuffs. In 1970 two official documents were published; one was on the wholesomeness of irradiated foods (WHO, 1970), a highly technical document; the other was the new 1970 Food Hygiene Regulations (Statutory Instrument, 1970) and these were more ingenuous. They introduced, for example, a new rule that any person handling open food must wear clean and washable overclothing except in specified cases such as 'the carrying of unskinned rabbits or hares or unplucked game or poultry'. It would seem, from these two publications that in the area of food production 'our environment reflects in some areas the excitement of the space age, but retains in other aspects many features of the mediaeval village' (Christie, 1971-2).

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