**Bacteria in Food**

**M.K. CHATTOPADHYAY**

A thorough knowledge of the type of bacteria commonly occurring in food materials and the level of their tolerance to various stress factors is necessary to ensure the quality of food.

**Bacterial** contamination of food materials is a major cause of health problems. The contaminating bacteria gain entry into the body of the consumers and infect them. In some cases they produce toxins, which cause severe illness to the consumers even in absence of the bacteria.

Campylobacter jejuni, Clostridium perfringens, Salmonella spp, Escherichia coli 0157: H7, Bacillus cereus, Shigella spp, Staphylococcus aureus, Streptococcus spp, Listeria monocytogenes, Vibrio cholerae, and Yersinia pseudotuberculosis are some of the bacterial pathogens that are commonly found in food.

Bacterial infection through food is characterized by several symptoms—nausea, vomiting, diarrhea, fever, headache, and fatigue. Consumption of food containing Listeria monocytogenes by pregnant women may culminate in abortion, stillbirth, premature birth or septicemia in the newborn. Neurotoxin produced by Clostridium botulinum may lead to disturbances of vision, weakness or paralysis of muscles and in severe cases respiratory failure and death. Infection by food-borne Campylobacter jejuni in rare cases may cause peripheral neuropathy.

**Sturdy Bacteria**

To prevent growth of contaminating bacteria, food is preserved at low temperature and/or in presence of salts. For quite some time, it was believed that these two factors could completely arrest bacterial growth by inflicting severe stress on the cellular machinery and thus ensure safety to the consumers. However, there are some bacterial strains that adapt themselves to stressful environments.

Occurrence of live bacteria in glaciers and seawater reveals that low temperature and high salt do not necessarily render the environment free from bacteria. A vast body of information is available in literature on cold-loving (psychrophiles) and salt-loving (halophiles) bacteria. The phenomenon is not confined to a particular genus or species. The same bacterium might occur as a cold-susceptible and salt-susceptible strain in temperate environments and as a cold-tolerant and salt-tolerant strain in stressful environments.

**Mechanism of Survival**

In natural environment, bacteria are evolved not only to tolerate low temperature and high salt but also some other stress factors (e.g., high temperature, high pressure, high pH, low pH, high oxidative stress, desiccation, radiation). The genetic and biochemical basis of stress adaptation offers a highly challenging field for scientific investigations. The knowledge generated out of this research promises insight into the intricacies of the machinery of a living cell. It helps us predict the possibility of occurrence of life on distant planets and their satellites with similar environments. It also suggests various ways by which we could control the growth of pathogenic bacteria in food during storage.

What makes bacteria cold tolerant and salt tolerant remains an incompletely understood phenomenon despite several clues emerging out of research in various laboratories throughout the world. It is known that there are some commonalities in the damaging effects of various stress factors on cellular proteins and cell membranes. They distort cellular proteins to render them non-functional. Besides inflicting structural damages, they also suppress the activity of enzymes, the workhorses of the cellular machinery. Hence, it is obvious that in order to survive in a stressful environment a living organism must possess some enzymes that can work under environmental stress.

Apart from having stress-resistant enzymes, an organism in a harsh environment also requires some molecules that prevent the stress-induced distortion of cellular proteins. These molecules are called molecular chaperones. They are also protein in nature. Some non-protein molecules called chemical chaperones (glycine, betaine, proline, trehalose) perform the same task. They are obtained by synthesis inside the cell or recruited from the environment by specific transport systems.

The boundary of a living cell or the cell membrane is a mosaic of various lipid and protein molecules. Besides covering the cell and protecting the delicate cellular components from injury, it selectively allows some materials (e.g., food) to enter the cells and some other materials (e.g., toxic byproducts of metabolism) to come out of the cells. It can perform its function only within a finite range of fluidity. Some of the environmental stress factors (i.e., high temperature, low temperature, high salinity, high pressure etc) adversely affect the fluidity of the cell membrane, which as a consequence, ceases to perform its function.

Hence, in order to survive in the extreme environments an organism must also be able to alter the fatty acid composition of the membrane so as to retain an optimum fluidity required for proper functioning of the membrane. The mechanism is called homeoviscous adaptation of membrane fluidity.

**Biotechnological Aspects**

Bacteria that survive in extreme environments possess some sturdy enzymes that can work even in harsh conditions. These enzymes, called extremozymes, are of immense biotechnological importance. For example, Taq polymerase, a heat resistant enzyme from the thermotolerant bacterium Thermus aquaticus, is essential for polymerase chain reaction (PCR), a technique by which we can amplify very small amounts of DNA to a workable quantity.
Vent DNA polymerase, another thermophilic enzyme, is obtained from an organism (Thermococcus litoralis) isolated from the submarine thermal vent. It retains more than 90% of its activity even after incubation at 95°C for 1 hour. A thermostable alkaline phosphatase, isolated from a cold-adapted bacterium, is useful in preventing self-ligation of the vectors in recombinant DNA technology. Several other industrially important enzymes have been isolated so far from various stress-adapted bacteria.

The efficacy of the molecular chaperones could also be useful for biotechnological purpose. It was found that when genes encoding two molecular chaperones in an Antarctic bacterium were cloned and expressed in Escherichia coli, the colon bacterium, which as such grows very poorly in cold environments, it started growing significantly faster at low temperatures.

A genetically modified organism of this sort could be used to degrade the biological wastes, accumulated due to human activities in the low-temperature environments. It could also be employed to degrade polycyclic aromatic hydrocarbons (petroleum wastes) in the soil and water of Polar Regions. Bioremediation with bacteria obtained from temperate environment is not possible in these extreme environments because of the poor growth rate of the organisms.

Interlinked Stress Response
It is known that in natural environment bacteria are most often challenged with more than one stressor factor at a time. Many places that are very cold, like Antarctica, are also very dry. Obviously bacteria surviving there not only have to be cold tolerant but also desiccation tolerant.

In the same way, organisms occurring in the ocean bottom have to be pressure tolerant besides being salt tolerant. Some of these multistress tolerant organisms have been reported to possess molecules that help them withstand more than one stress factor. These molecules offer cross protection against more than one stress factor and thus interlink the mechanisms involved in adaptation of bacteria to different stress factors. These multistress-combatants might be protein or non-protein in nature.

Problems in Food Processing and Preservation
Stress tolerance of bacteria is the root cause of various problems in the food industry, such as, stress hardiness and cross protection. Bacteria present in food materials are exposed to several types of stress factors during preservation and processing of food. For example, during manufacture of cheese they are challenged with high temperature during heat treatment of the milk, exposure to hydrogen peroxide added to the milk and also acid produced during the fermentation of the starter culture. During production of sausage they are exposed to the added salt besides acid and heat. Some organic acids are used as food preservatives. Thus contaminating bacteria face acid stress.

The importance of the dosage of stress factors used for food preservation and processing is crucially important. If the amount of stress used is sublethal (not sufficient to annihilate all the bacteria present in food), the organisms may get adapted to tolerate the same stress at higher level. This is called stress hardening. In a study involving the food-borne pathogen Listeria monocytogenes, it was observed that adaptation of the bacterium to mild acidic condition was associated with tolerance of the same organism to more acidic environment. Gradual increase in acidity is observed during food fermentation.

Hence if the organism is present in the food, it is likely to survive the process and lead to health problems upon ingestion of the food. Acid tolerance resulting from acid adaptation is also observed in Salmonella typhimurium and Escherichia coli.

Exposure of bacteria to the sublethal level of a stress factor may promote emergence of strains resistant to some other stress factors, a phenomenon known as cross-protection. For example, in an investigation acid adaptation of S. typhimurium was found to result in general protection of the organism against several environmental stress factors. It was also shown that acid adaptation of a lactic acid bacterium belonging to the genus Lactobacillus led to the improved tolerance of the organism to low temperature. Needless to say, it is difficult to control bacteria that are immune to more than one factor used for preservation.

Food materials, contaminated with pathogenic organisms of this sort are extremely dangerous for consumers.

Stress adaptation might also lead to two more serious problems. In some pathogenic bacteria expression of virulence factors (molecules produced by an infecting organism, that enhance the potential of the organism to cause disease) is triggered by stress treatment. It appears that the organisms sense the environmental stress as signal for expression of the virulence factors. Thus stress-adapted cells might have increased potential for causing diseases.

Stress treatment may also contribute to the spread of antibiotic-resistance among food bacteria. An investigation performed by Professor M. C. Mahon and his colleagues from two different research institutes of Northern Ireland revealed that when two bacteria commonly present in food materials were exposed to salt, acid, high and low temperature at a sublethal level, the rate of horizontal gene transfer between them was increased. This mechanism is known to promote the spread of antibiotic-resistance among bacteria.

Dr M.K. Chattopadhyay is a Scientist at the Centre for Cellular and Molecular Biology (CCMB), CSIR, Hyderabad-500007; Email: mkc@ccmb.res.in

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